T.C. PÎRÎ REİS UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES

A PRODUCTIVITY EVALUATION AND IMPROVEMENT METHODOLOGY FOR SHIPYARDS

Ph.D. THESIS

SAİM TURGUT KOÇAK

FEBRUARY 2024

T.C. PÎRÎ REİS UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES

A PRODUCTIVITY EVALUATION AND IMPROVEMENT METHODOLOGY FOR SHIPYARDS

Ph.D. THESIS

by
SAİM TURGUT KOÇAK
B.S., Naval Architecture, Deniz Harp Okulu, 1983
B.S.E., Naval Architecture & Marine Engineering, The University of Michigan, 1989
M.S.E., Naval Architecture & Marine Engineering, The University of Michigan, 1990

High Performance Marine Platforms Program

Thesis Advisor: Prof. Dr. İsmail Hakkı Helvacıoğlu

FEBRUARY 2024

APPROVAL of the INSTITUTE for GRADUATE STUDIES

PRU, Graduate Studies Institute's Doctoral student 188018001 Saim Turgut KOÇAK prepared his thesis titled

"A PRODUCTIVITY EVALUATION AND IMPROVEMENT METHODOLOGY FOR SHIPYARDS"

by fulfilling all the necessary conditions determined by the relevant regulations and successfully presented it to the jury whose signatures are below.

Approval of the Institute for Graduate Studies

Prof. Dr. Zehra AKDENİZ
Director

Dr. Ahmet Ziya SAYDAM
Head of Department

Examining Committee Members

Prof. Dr. İsmail Hakkı HELVACIOĞLU (Advisor) _____

Prof. Dr. Funda YERCAN _____

Prof. Dr. Rauf Nurettin NİŞEL _____

Prof. Dr. Ahmet Fahri ÖZOK _____

Assoc. Prof. Dr. Eda TURAN _____

Date of Approval: 15.02.2024

ABSTRACT

A PRODUCTIVITY EVALUATION AND IMPROVEMENT METHODOLOGY FOR SHIPYARDS

Saim Turgut KOÇAK

HIGH PERFORMANCE MARINE PLATFORMS DOCTORAL PROGRAM

Thesis Supervisor: Prof. Dr. İsmail Hakkı HELVACIOĞLU

February, 2024, 465 Pages

Shipbuilding is a highly competitive sector and shipyards are high-cost investments. Shipyards require good management, where all effort is spent to produce a unique, built-to-order, usually high-technology and big-size product as an output over long periods of time. Productivity is an important performance measure during the production of such unique output. Each shipyard in the world has its own distinctive way of building ships, conditions, and facts due to internal and external factors. Building a ship in the shortest time while delivering her at the required quality and within budget is an important indication of shipyard productivity. Therefore, continuous efficiency, performance, productivity measurements, evaluations, and improvements are necessary and critical. Research on a method to calculate a dimensionless "Productivity Number" system to overview the productivity status by a shipyard's own throughout a total shipbuilding process was deemed helpful. Developing a novel method formed the research problem; a common application during ship production helped to formulate the research problem and led to a mathematical model that is based on a common application in ship design. Sixty-two references and 21 methods on the measurement and evaluation of total shipbuilding process and shipyard productivity were found during the literature review. Only three of these methods, the Compensated Gross Tonnage (CGT), Data Envelopment Analysis (DEA), and Shipyard Productivity Prediction Equation (SPPE) based evaluations were put in use by some shipyards and by the academicians. About 500 factors were reviewed in the literature that affect shipbuilding in terms of production, infrastructure, engineering, management, and workforce. Among these factors, 185 were identified as having an important impact on the shipbuilding time schedule from the start of contracting works until the delivery of the ship. This study referenced these 185 factors as distributed among major ship production stages, shipbuilding management, and ship design works, all with unique importance, magnitude, and timing. Forty-two shipyards all around the world were applied for a comprehensive survey and surveys at two shipyards were realized. This was complemented by a survey with 26 experts with experience in shipbuilding, acting as the employees of two other hypothetical shipyards. Survey results provided shipyard-specific and generalized sector information in the utilization of the mathematical model. The model provided a reliable "Dimensionless Productivity Number" for a shipyard to evaluate the shipyard's overall productivity. Results presented a Dimensionless Productivity Number of a Shipyard (**U**), the improvement target

number, and also the same for the processes, improvement needs, and possible effects of alternative decisions on improvements. The factors to be improved on each ship production stage, ship design, and management basis became visible. The chain reaction of any improvement act on the processes, positive or negative, became recognizable. This new mathematical and visual methodology assists in shipyard's top management to numerically see the status of the shipyard's own, different than benchmarking with other shipyards; shows the priority of the factors to be improved in ship production, ship design, and shipbuilding management processes. Application of this methodology will also lead to shorter shipbuilding periods. The method developed in this study is also expected to be found interesting by the academic field for further research and by other industrial sectors, especially those that manufacture unique products over extended periods of time.

Keywords: Shipyard, shipbuilding, productivity, management, production

ÖZET

TERSANE ÜRETKENLİĞİNİN DEĞERLENDİRMESİ VE GELİŞTİRİLMESİ İÇİN BİR YÖNTEM

Saim Turgut KOÇAK

YÜKSEK PERFORMANSLI DENİZ PLATFORMLARI DOKTORA PROGRAMI

Tez Danışmanı: Prof. Dr. İsmail Hakkı HELVACIOĞLU

Şubat 2024, 465 Sayfa

Gemi inşa sektörü oldukça rekabetçi bir sektör, tersaneler de yüksek maliyetli yatırımlardır. Uzun bir sürede, müşteri isteklerine göre özgün, genellikle yüksek teknolojili ve büyük boyutlu bir ürün çıktısı üretmek için çaba harcanan tersaneler iyi bir yönetim gerektirir. Üretkenlik, bu özgün çıktıların üretiminde önemli bir performans ölçütüdür. Dünyada her bir tersanenin, iç ve dış faktörlerden dolayı kendine özgü gemi inşa etme şekli, koşulları ve gerçekleri vardır. Bir gemiyi en kısa sürede, istenilen kalitede ve bütçesi dahilinde inşa ve teslim etmek tersane üretkenliğin önemli bir göstergesidir. Bu nedenle sürekli olarak verimlilik, performans, üretkenlik ölçümleri, değerlendirme ve iyileştirmeler yapılması kritik bir gerekliliktir. Bir tersanenin kendi üretkenliğine odaklanarak, bir gemi inşa sürecinin bütünü boyunca durumunu gözden geçirmesi için boyutsuz bir "Üretkenlik Sayısı" sistemini içeren bir yöntem üzerinde araştırma yapılmasının yararlı olacağı değerlendirilmiştir. Yeni bir yöntem geliştirilmesi araştırma problemini oluşturmuştur. Gemilerin inşaatı sırasında yapılan bir uygulama araştırma probleminin formüle edilmesini, gemi tasarımında kullanılan yaygın bir uygulama da matematik modelin ortaya çıkmasını sağlamıştır. Yazın taramasında, toplam gemi inşa süreci ve tersane özelinde üretkenliği ölçme ve tanımlamaya yönelik 62 referans doküman ve 21 yöntem belirlenmiştir. Bu yöntemlerden sadece üçü, Dengelenmiş (Düzeltilmiş) Gros Tonaj (Compensated Gross Tonnage - CGT), Veri Zarfı Analizi (VZA) ve Gemi İnşa Üretkenlik Eşitliği (Shipyard Productivity Prediction Equation – SPPE) tabanlı yöntemler göreceli olarak bazı tersane ve akademisyenler tarafından uygulanmıştır. Yazın taramasında ayrıca üretim, altyapı, mühendislik, yönetim ve iş gücü açısından gemi inşaatını etkileyen 500'e yakın faktör belirlenmiştir. Bu faktörlerden 185 tanesinin, sözleşme faaliyetlerinin başlangıcından geminin teslimine kadar olan sürede gemi inşa proje zaman planını önemli ölçüde etkilediği tespit edilmiştir. Bu çalışmada, her birinin özgün ağırlığı, büyüklüğü, zamanlaması olan ve gemi inşaatı ana süreçleri, gemi inşa yönetimi ve gemi tasarım faaliyetlerine dağılmış bu 185 faktör dikkate alınmıştır. Kapsamlı bir saha çalışması için Dünya genelinde 42 tersaneye başvurulmuş ve iki tersanede saha çalışması gerçekleştirilmiştir. Saha araştırması ek olarak, iki varsayımsal tersanenin çalışanı rolünde, gemi inşaatı konusunda deneyime sahip 26 uzmanın katılımı ile tamamlanmıştır. Saha araştırması sonuçları, matematiksel modelin uygulanması için hem tersaneye özgü hem de sektör açısından bilgiler sağlamıştır.

Tersanenin bütününün üretkenliğini değerlendirmek için güvenilir bir "Boyutsuz Üretkenlik Sayısı" elde edilmiştir. Sonuçlar, nihai yönetsel kararlar verilmeden önce, süreçler için de aynısı olmak üzere tersanenin Boyutsuz Üretkenlik Sayısını (**U**), hedef iyileştirme sayısını, iyileştirme ihtiyaçlarını ve alternatif kararların iyileştirmeler üzerindeki olası etkilerini göstermiştir. Gemi inşaatı, gemi tasarımı ve yönetim süreçleri bazında iyileştirilmesi gereken faktörler görünür hale gelmiştir. Bir iyileştirme eyleminin süreçler üzerindeki olumlu veya olumsuz zincirleme etkisi belirlenebilmektedir. Bu yeni matematiksel ve görsel metodoloji, tersane üst yönetiminin, diğer tersanelerle karşılaştırmaktan farklı olarak, tersanenin kendi durumunu sayısal olarak görmesine yardımcı olup, gemi inşaatı, gemi tasarımı ve gemi inşa yönetiminde iyileştirilmesi gereken faktörlerin önceliğini ortaya koymaktadır. Bu metodolojinin uygulanması gemi inşa sürelerinin kısalmasına da yol açacaktır. Geliştirilmiş olan yöntemin, ilerideki akademik çalışmalarda dikkate alınması ve özellikle uzun süreler boyunca özgün ürünler üreten endüstriyel sektörler tarafından da ilgi çekici bulunması beklenmektedir.

Anahtar Kelimeler: Tersane, gemi inşaatı, üretkenlik, yönetim, üretim

DEDICATION

To My Wife and My Son,
they always supported me and stood by me.

ACKNOWLEDGMENTS

I thank my thesis advisor Prof. Dr. İsmail Hakkı HELVACIOĞLU and former thesis advisor Prof. Dr. R. Adm. (ret.) Nurhan KAHYAOĞLU for their guidance, support, and motivation throughout this research,

I am grateful to the members of my thesis supervisory committee, Prof. Dr. Ahmet Fahri ÖZOK and Prof. Dr. Rauf Nurettin NİŞEL for their very valuable comments and contribution,

I would like to express my gratitude and thanks to my wife Neslihan and my son Nadir Can, to my and my wife's family for their great support, motivation, and patience,

I thank the two anonym shipyards that participated in the first survey phase, the 26 anonym experts who participated in the second survey phase, and also to Turkish Shipbuilders Association (GISBIR) for their support,

I would like to extend my gratitude to Prof. Dr. Bahadır İNÖZÜ, Prof. Dr. Klaus Peter-Beier, late Prof. Dr. Raymond A. Yagle (RIP), late Prof. Dr. Howard M. Bunch (RIP) and my dear Professors, lecturers at the Turkish Naval Academy, University of Michigan, İstanbul Technical University and Piri Reis University, R.Adm. (ret.) Ersin GÜLER, R.Adm.(ret.) Nadir KINAY, Capt. (ret.) Sezai IŞIK, late R.Adm. M. Savaş ONUR (RIP), Cdr. (ret.) Mehmet ÖZCAN, Prof. Dr. Capt. (ret.) Mehmet Ali BAYKAL, Capt. (ret.) Zafer BETONER, late R.Adm. (ret.) Aydın EKEN (RIP), Dr. Ing. Stefan Harries, Mr. Bülent ŞENER, and all my colleagues in my past workplaces who helped me to gain precious experience, knowledge, and supported me during my long shipbuilding career that helped me in this research.

TABLE OF CONTENTS

ABSTRACT ..... **iii**
ÖZET ..... **v**
DEDICATION ..... **vii**
ACKNOWLEDGMENTS ..... **viii**
LIST OF TABLES ..... **xii**
LIST OF FIGURES ..... **xvi**
LIST OF ABBREVIATIONS ..... **xxii**
1. INTRODUCTION **1**
1.1. Background **1**
1.2. Statement of the Problem **3**
1.3. Rationale **4**
1.3.1. Research Objectives **6**
1.3.2. Research Questions **6**
1.3.3. Research Focus **6**
1.4. Main Assumptions and Limitations **8**
1.4.1. Assumptions at the beginning **8**
1.4.2. Assumptions made during the study **8**
1.4.3. Limitations **9**
1.5. Significance of the Thesis **10**
1.6. Thesis Outline **11**
1.7. Summary **11**
2. PRELIMINARIES AND LITERATURE REVIEW **13**
2.1. Constituents of the Shipbuilding Process **13**
2.1.1. Major and Sub-Processes **15**
2.1.2. Shipbuilding Processes in this Research **24**
2.2. Productivity and Shipbuilding **26**
2.2.1. Productivity **26**
2.2.2. Productivity in Shipbuilding **31**
2.2.3. Ships, the Output at Seas and in Waters **42**
2.3. Literature Review **56**
2.3.1. Classification **57**

2.3.2. Methodology Based Review 58
2.4. Summary 82
3. METHODOLOGY, TEST CASES, AND NUMERICAL ANALYSES 86
3.1 Mathematical Model 87
3.1.1. Factors Affecting Shipbuilding: Effects 92
3.1.2. Effects' Numerical Properties 102
3.1.3. Curves and Areas 105
3.1.4. Productivity Numbers 111
3.1.5. Improvement areas Priority Lists 115
3.2 Test Cases 116
3.2.1. Preparing for Data Collection 117
3.2.2. Shipyard Surveys 129
3.2.3. Numerical Analyses 134
3.3. Summary 174
4. RESULTS AND DISCUSSION 178
4.1. Shipyard Based Results and Discussion 178
4.1.1. Shipyard 200 179
4.1.2. Shipyard 300 193
4.1.3. Productivity Status Evaluations from Cost and Labor Basis 212
4.2. Further Results and Discussions 217
4.2.1. Additional Findings and Discussions 217
4.2.2. Reliability and Validity of the Research 222
4.2.3. Comparison to Earlier Work 227
4.3. Summary 229
5. CONCLUSION 231
5.1. Implications of the Findings on Practice 233
5.2. Recommendations for Future Research 234
REFERENCES 235
APPENDIX A. EFFECTS A-1
APPENDIX B. EFFECTS' DISTRIBUTION LIST B-1
APPENDIX C. EFFECT SUB-DETAILS AND MAGNITUDE CHOICES C-1
APPENDIX D. BASIS INFORMATION QUESTIONS D-1
APPENDIX E. SURVEY PARTICIPANTS STATISTICS E-1
APPENDIX F. PAIRWISE COMPARISON TEMPLATE F-1

APPENDIX G. EFFECT WEIGHTS RECORDING TEMPLATE G-1
APPENDIX H. EFFECT MAGNITUDE GATHERING, CURVE-AREA CALCULATION TEMPLATES H-1
APPENDIX I. CALCULATED EFFECT WEIGHTS I-1
APPENDIX J. EFFECT MAGNITUDES J-1
APPENDIX K. TIME SCHEDULES K-1
APPENDIX L. SECTOR WEIGHTS L-1
APPENDIX M. SAMPLE DESCRIPTIVE STATICS OF EFFECT M-1
APPENDIX N. MANAGEMENT:BASIS INFORMATION PAIRWISE QUESTIONS AND CALCULATED WEIGHTS N-1
APPENDIX O. SHIPYARD DASHBOARD SAMPLES O-1
CURRICULUM VITAE I

LIST OF TABLES

TABLES

Table 2.1	**:**	Technological Level (TL) classification of shipyards in a global sense	23
Table 2.2	**:**	Groups and their performance measurement focus in a shipyard	32
Table 2.3	**:**	Major Factors affecting the entire shipbuilding process	34
Table 2.4	**:**	Methods previously studied on shipyard productivity	35
Table 2.5	**:**	The A and B factors of the CGT system	37
Table 2.6	**:**	The CGT system A and B factors of motor yachts up to 1000 GT	37
Table 2.7	**:**	Commercial ships in the World and in Türkiye	42
Table 2.8	**:**	Global shipbuilding completion, approximate Average and Maximum Production Capacities of global shipyards in Million GT	45
Table 2.9	**:**	Global shipbuilding completions between 2001-2022 in Million Gross Ton	47
Table 2.10	**:**	Shipbuilding completions at some European countries in Million Gross Ton	49
Table 2.11	**:**	Several productivity metrics and their values based on CGT	52
Table 2.12	**:**	Turkish shipyards' productivity metrics based on CGT/MxY and comparison for 2007	53
Table 2.13	**:**	Example DEA results	55
Table 2.14	**:**	Methodologies and references on entire Shipyard Productivity	59
Table 2.15	**:**	References in which DEA was used to benchmark shipyards' efficiencies and productivities	71
Table 2.16	**:**	References in which DEA was used for shipyard internal processes' efficiencies and productivities	73
Table 3.1	**:**	Classification of major factors in literature and groups of Effects in this study	93
Table 3.2	**:**	Breakdown of the Effects in groups and subgroups	94
Table 3.3	**:**	Group and subgroup heading numbers of the Effects	100
Table 3.4	**:**	Distribution of the Effects into the processes	101
Table 3.5	**:**	Sub-details of an Effect (sample)	102
Table 3.6	**:**	Applied pairwise comparison scale	103
Table 3.7	**:**	Random Consistency Index values	104
Table 3.8	**:**	Process classification in this study	111
Table 3.9	**:**	Question groups and pairwise comparisons in the sections of the survey questionnaires	129
Table 3.10	**:**	Applied shipyards	130
Table 3.11	**:**	Information on Shipyard 5 and Shipyard 12, with their referenced shipbuilding projects' summary	131
Table 3.12	**:**	Specialty, frequency, and job position of the 26 second phase survey participants	132
Table 3.13	**:**	Given information on hypothetical shipyards	133

Table3.14a : Process/subprocess population, needed and actual sample sizes... 136
Table3.14b : Shipyards' and their referenced shipbuilding projects' summary.. 137
Table 3.15 : Process/subprocess time information for hypothetical shipyards... 139
Table 3.16 : Bad data and trimming in compiled sector weights data of Effects on process/subprocess basis……... 146
Table 3.17 : Process/subprocess population, needed and actual sample sizes... 154
Table 3.18 : Internal consistency measurement results……..……. 159
Table 3.19 : Descriptive statics, geometric means of compiled sector weights (JASP output) ……..……...…… 161
Table 3.20 : Normality fit statistics, geometric means of compiled sector weights (JASP output)…….……... 161
Table 3.21 : Descriptives, geometric means of compiled sector weights (JASP output)……..……...…… 165
Table 3.22 : Test for equality of variances (Levene's), geometric means of compiled sector weights (JASP output)……..…… 165
Table 3.23 : Kruskal-Wallis test result, geometric means of compiled sector weights (JASP output)…….……... 166
Table 3.24 : Dunn's Post Hoc Comparisons, geometric means of compiled sector weights (JASP output)…….. 166
Table 3.25 : Descriptive statics, geometric means of Shipbuilding Management process sector weights (JASP output)……... 169
Table 3.26 : Normality fit statistics, geometric means of Shipbuilding Management process sector weights (JASP output)…….…….. 169
Table 3.27 : Test for equality of variances (Levene's), geometric means of compiled sector weights (JASP output)……..… 170
Table 3.28 : Independent Samples T-Test (Student's T-Test), Welch's test and Mann-Whitney U test results, actual shipyards vs. hypothetical shipyards (JASP output)…….…… 171
Table 3.29 : Kruskal-Wallis test result, geometric means of Management Process sector weights, actual shipyards vs. hypothetical shipyards (JASP output)…….…… 172
Table 4.1 : Subjects of the first 24 Effects in Figure 4.11 (in Effect nr. Order)…….. 189
Table 4.2 : Proposed 6 Effects to be investigated and tested for improvement in Shipyard 200 (in priority order)…….…….…… 189
Table 4.3 : Subjects of the first 23 Effects in Figure 4.24 (in Effect nr. Order)…….. 202
Table 4.4 : Proposed 6 Effects to be investigated and tested for improvement in Shipyard 300 (in priority order)…….…….…… 203
Table 4.5 : Shipyard 200 and its Shipbuilding Management process Key Numbers at four different basis…….. 217
Table 4.6 : Comparison of improvement priorities, for Shipyard 200…….……. 218
Table 4.7 : Improvement priorities based on non-weighted Effect Magnitudes, for Shipyard 200…… 218
Table 4.8 : Common improvement needs of Shipyard 200 and Shipyard 300 (in Effect nr. Order)…… 221
Table 4.9 : Common Effect priorities of Shipyard 5 and Shipyard 12……..… 222

Table 4.10 : List of Effects' group/subgroups sector weights in priority order.. 228
Table A.1 : List of Effects based on groups and subgroups…….. A-1
Table B.1 : Effects 'distribution (repeat) to processes and subprocesses…….. B-1
Table C.1 : List of Effects, sub-details, and survey questionnaire second division Effect Magnitude (Magn.) question choices..... C-1
Table E.1 : Questions asked to survey participants in the Questionnaire for participants' statistics……..……... E-1
Table E.2 : Survey participants summary..... E-1
Table E.3 : Distribution of survey participants on process responses basis..... E-2
Table E.4 : Participants' gender distribution..... E-2
Table E.5 : Participants' age distribution…….. E-3
Table E.6 : Participants' experience in the shipbuilding sector (years)……..... E-3
Table E.7 : Participants' specialties..... E-4
Table E.8 : Participants' current job title..... E-5
Table E.9 : Participants' workplace history..... E-6
Table E.10 : Participants' education level (last completed)..... E-7
Table I.1 : Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard survey responses (raw data)..... I-1
Table I.2 : Effect weights of Design (DES) process, calculated from shipyard survey responses (raw data)..... I-5
Table I.3 : Effect weights of Contracting (CON) subprocess, calculated from shipyard survey responses (raw data)..... I-8
Table I.4 : Effect weights of Hull & Superstructure Block Construction (BLK) subprocess, calculated from shipyard survey responses (raw data)…… I-9
Table I.5 : Effect weights of Hull Erection (ASLY) subprocess, calculated from shipyard survey responses (raw data)..... I-12
Table I.6 : Effect weights of Parts Manufacturing in Shipyard (PPT) subprocess, calculated from shipyard survey responses (raw data…….. I-15
Table I.7 : Effect weights of Outfitting before Ship Launching (OUT) subprocess, calculated from shipyard survey responses (raw data)…… I-18
Table I.8 : Effect weights of Ship Launching (LCH) subprocess, calculated from shipyard survey responses (raw data)..... I-21
Table I.9 : Effect weights of Outfitting after Ship Launching (QAY) subprocess, calculated from shipyard survey responses (raw data)…… I-23
Table I.10 : Effect weights of Setting-to-Work, Harbor and Sea Trials (TEST) subprocess, calculated from shipyard survey responses (raw data)…… I-26
Table I.11 : Weights of Management:Basis information, calculated from shipyard survey responses (raw data)..... I-28
Table J.1 : Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses.. J-1

Table J.2 : Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses..... J-5
Table J.3 : Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses..... J-8
Table J.4 : Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses.. J-11
Table J.5 : Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses..... J-15
Table J.6 : Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses..... J-18
Table K.1 : Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses..... K-1
Table K.2 : Shipyard 200 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses..... K-4
Table K.3 : Shipyard 200 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses..... K-6
Table K.4 : Shipyard 300 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses..... K-8
Table K.5 : Shipyard 300 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses..... K-11
Table K.6 : Shipyard 300 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses..... K-13
Table K.7 : Shipyards 200 and 300 (hypothetical) – Master Time Schedule.... K-16
Table K.8 : Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule..... K-17
Table L.1 : List of Effects' sector weights based on groups and subgroups, with cleaned data..... L-1
Table L.2 : List of Effects' group/subgroups sector weights in the order of priority..... L-7
Table L.3 : List of Effect sector weights in the order of priority..... L-8
Table N.1 : List of pairwise questions in Management:Basis section of the survey questionnaire..... N-1
Table N.2 : List of weights based on Management:Basis Information, with cleaned data..... N-3

LIST OF FIGURES

FIGURES

Figure 1.1	**:**	Outline of the research ……..…….	7
Figure 2.1	**:**	Generic breakdown of a shipbuilding project and main focus area in this thesis …….	14
Figure 2.2	**:**	A generic shipbuilding project time frame…….……..……	16
Figure 2.3	**:**	New orders and deliveries for Bulk carriers……..……..	25
Figure 2.4	**:**	Basic performance indicators, Triple-P Model……..……..…	27
Figure 2.5	**:**	Examples of key factors influencing the shipbuilding productivity……..	40
Figure 2.6	**:**	Distribution of commercial ship types by GT in 2022...……..	43
Figure 2.7	**:**	Data and graph of active shipyards, only shipbuilding and both shipbuilding and ship repair…..…….….	44
Figure 2.8	**:**	Global shipbuilding completion, approximate Average and Maximum Production Capacities of global shipyards in Million GT……..……...…...	46
Figure 2.9	**:**	Maximum production capacities of Turkish shipyards (in million DWT)……..……	46
Figure 2.10	**:**	Global shipbuilding completions between 2001-2022 in Million GT……..…….	48
Figure 2.11	**:**	Global commercial shipbuilding activities between 2002-2020 in million CGT……..…….…..	48
Figure 2.12	**:**	Shipbuilding completions in some European countries in Million GT……...……	49
Figure 2.13	**:**	Shipbuilding completions at 29 European countries in Thousand CGT…….	50
Figure 2.14	**:**	Shipbuilding completions in Türkiye and global market share in Thousands CGT……..…….	50
Figure 2.15	**:**	Global commercial shipbuilding order forecast (approx.) and current actual orders (approx.) in Million GT……...…..	51
Figure 2.16	**:**	Turkish shipyards' productivity graph based on CGT/MxY and comparison for 2007……..……..	54
Figure 2.17	**:**	The contribution of changes in unit labor cost and employee compensation on productivity in Japanese shipbuilding…..…..	56
Figure 2.18	**:**	Yearly distribution of 62 references..……..	60
Figure 2.19	**:**	Productivity Space……..…….	63
Figure 2.20	**:**	Shipbuilding Productivity Prediction Equation (SPPE) structure	65
Figure 3.1	**:**	A simplified arrangement of ship propeller shafting…...…….	87
Figure 3.2	**:**	Sample graph of forces acting on a propeller shafting and nodal slope……..……...	88
Figure 3.3	**:**	Ideal Shipyard line and Effects' placement on the scatter plot....	90
Figure 3.4	**:**	Symbolic representation of Effects, Shipyard and Ideal Shipyard curves and shipbuilding processes & subprocesses…..	91
Figure 3.5	**:**	Distribution of Effects in groups……..……...	95
Figure 3.6	**:**	Distribution of Effects into processes and subprocesses..……...	101

Figure 3.7 : Shipbuilding Management process Effect-Time graph with cubic B-Spline; SRS1 Cubic Spline for MS Excel V2.5 add-on. 107
Figure 3.8 : Shipbuilding Management process Effect-Time graph with cubic B-Spline; MATLAB R2019……..….. 107
Figure 3.9 : Shipbuilding Management process Effect-Time graph, OneWay (monotonic) Spline test with SRS1 Cubic Spline for MS Excel V2.5 add-on……..……... 108
Figure 3.10 : MATLAB Code for Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) test……...……... 109
Figure 3.11 : Shipbuilding Management process Effect-Time graph, Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) test with MATLAB R2022b…… 110
Figure 3.12 : A sample question format to find Effect magnitude (Effect number 11PSB03 with three sub-details)……..……... 122
Figure 3.13 : A sample question format for the three sub-details of Effect number 11PSB03 in pairwise comparison style…….……. 123
Figure 3.14 : A sample question format to find effective periods of the Effects (here for Effect number 11PSB03)……..…… 124
Figure 3.15 : A sample question format to find Effects' timewise distribution type (here for Effect number 11PSB03)……..…… 125
Figure 3.16 : A sample question on comparison of Ship production subprocesses on cost basis……... 126
Figure 3.17 : A sample question on comparison of major processes on labor basis…….. 126
Figure 3.18 : A sample question on comparison of Effects……..……..... 127
Figure 3.19 : A sample question on comparison of Effect groups&subgroups. 128
Figure 3.20 : Flow chart of numerical analyses……...…….. 135
Figure 3.21 : Sample view, Table I.1. Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard surveys responses (raw data)……...…….. 138
Figure 3.22 : Sample view, Table J.1. Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses……..…….. 139
Figure 3.23 : Sample view, Table K.1. Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses…… 141
Figure 3.24 : Sample view, Table K.8. Shipyards 200 and 300 (hypothetical) -Effects' detailed time schedule for Shipbuilding Management process ……...…….. 141
Figure 3.25 : Sample view, Table L.1. List of Effects' sector weights based on groups and subgroups, with cleaned data…… 142
Figure 3.26 : Sample view, Table L.2. List of Effects' group/subgroups sector weights in the order of priority…….. 143
Figure 3.27 : Sample view, Table L.3. List of Effects' sector weights based on groups and subgroups, with cleaned data……..…….. 143

Figure 3.28 : Box plot of Shipyard 300 Design Process' five sample Effects' weights as responded by six participants (after pairwise matrix calculation)……...…… 145
Figure 3.29 : Box plot of Shipyard 300 Design Process' five sample Effect's Magnitudes as responded by six participants (as intervals after Effect subdetail weights were applied)……...…. 146
Figure 3.30 : Comparison of geometric means and medians of the compiled Sector Weights from four shipyards with raw data and on 185 Effects base……...……... 147
Figure 3.31 : Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view)……..…….. 150
Figure 3.32 : Key numerical output on the dashboard of Shipyard 200…….. 150
Figure 3.33 : Shipyard 300, Shipbuilding Management process improvement needs Pareto……. 152
Figure 3.34a : Comparison of geometric means of the compiled Sector Weights from four shipyards with raw data and on185 Effects' numerical order base…… 156
Figure 3.34b : Comparison of geometric means of the compiled Sector Weights from four shipyards with cleaned data and on 185 Effects' numerical order base…….. 157
Figure 3.35 : Comparison of geometric means of the compiled Sector Weights from four shipyards with approximately normalized data before test statistics analyses, on 133 Effects' numerical order base……. 157
Figure 3.36 : Q-Q graphs, geometric means of compiled sector weights (from JASP output)……...…. 162
Figure 3.37 : Raincloud plots, geometric means of compiled sector weights (JASP output)……...…… 163
Figure 3.38 : Boxplots, geometric means of compiled sector weights (from JASP output)…… 163
Figure 3.39 : Histogram & Density plots, geometric means of compiled sector weights (from JASP output)…….. 164
Figure 3.40 : Histogram of total data, geometric means of compiled sector weights (JASP output)……. 164
Figure 3.41 : Raincloud plots, geometric means of Shipbuilding Management process sector weights (JASP output)…… 170
Figure 3.42 : Descriptive plots, geometric means of Management Process sector weights, actual shipyards vs. hypothetical shipyards with 95% confidence intervals (from JASP Output)……..……. 171
Figure 3.43 : An excerpt from Table L.1……... 173
Figure 4.1 : Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view)……. 179
Figure 4.2 : Sample screen-view of Shipyard 200 Productivity Status Dashboard, top middle and left parts……... 180
Figure 4.3 : Key numerical output on the dashboard of Shipyard 200…… 181
Figure 4.4 : Productivity Summary graph of the dashboard of Shipyard 200. 182
Figure 4.5 : Shipyard 200 – Shipbuilding Management and Ship Design processes' graphs……. 183

Figure 4.6 : Shipyard 200 – Contracting, Hull & Superstructure Block Construction and Hull Erection subprocesses' graphs……. 184
Figure 4.7 : Shipyard 200 – Parts Manufacturing in the Shipyard, Outfitting before Launching, Ship Launching and Outfitting after Ship Launching subprocesses' graphs……. 185
Figure 4.8 : Shipyard 200 – Parts Manufacturing in the Shipyard graphs after two improvements were tested…… 186
Figure 4.9 : Key numerical output on the dashboard of Shipyard 200, revised after two improvements tested…… 186
Figure 4.10 : Shipyard 200 – Setting-to-Work, Harbor and Sea Trials subprocess graph…….. 187
Figure 4.11 : : Shipyard 200 – Proposed initial five Effects for improvement testing for processes/subprocesses (in the order of higher to lower priority)…….. 188
Figure 4.12 : Key numerical output on the dashboard of Shipyard 200, before and after six improvements were applied……. 190
Figure 4.13 : Shipyard 200 Productivity Status Dashboard graphs of Shipbuilding Management process before and after six improvements applied…….. 191
Figure 4.14 : Shipyard 200 Productivity Status Dashboard graphs of the Ship Design process before and after six improvements were applied…….. 192
Figure 4.15 : Shipyard 200 Productivity Status Dashboard graphs of the Contracting subprocess before and after six improvements applied…….. 193
Figure 4.16 : Sample screen-view of Shipyard 300 Productivity Status Dashboard (expanded view)……. 194
Figure 4.17 : Sample screen-view of Shipyard 300 Productivity Status Dashboard, top middle and left parts……... 195
Figure 4.18 : Key numerical output on the dashboard of Shipyard 300…… 196
Figure 4.19 : Productivity Summary graph of the dashboard of Shipyard 300. 198
Figure 4.20 : Shipyard 300 – Shipbuilding Management and Ship Design processes' graphs……. 198
Figure 4.21 : Shipyard 300 – Contracting, Hull & Superstructure Block Construction and Hull Erection subprocesses' graphs……. 200
Figure 4.22 : Shipyard 300 – Parts Manufacturing in the Shipyard, Outfitting before Launching, Ship Launching, and Outfitting after Ship Launching subprocesses' graphs……. 200
Figure 4.23 : Shipyard 300 – Setting-to-Work, Harbor and Sea Trials subprocess graph……. 201
Figure 4.24 : Shipyard 300 – Proposed initial five Effects for improvement testing for processes/subprocesses (in the order of higher to lower priority)…….. 202
Figure 4.25 : Key numerical output on the dashboard of Shipyard 300, before and after six improvements were applied……. 205
Figure 4.26 : Shipyard 300 Productivity Status Dashboard graphs of the Ship Design process before and after six improvements were applied……. 206

Figure 4.27 : Key numerical output on the dashboard of Shipyard 300, before and after seven improvements were applied……. 207
Figure 4.28 : Shipyard 300 Productivity Status Dashboard graphs of the Ship Design process before and after seven improvements were applied..... 208
Figure 4.29 : Shipyard 300 Productivity Status Dashboard graphs of the Shipbuilding Management process before and after seven improvements were applied...…….. 209
Figure 4.30 : Shipyard 300 Productivity Status Dashboard graphs of the Hull and Superstructure Blocks Construction subprocess before and after seven improvements were applied……...…… 210
Figure 4.31 : Shipyard 300 Productivity Status Dashboard graphs of the Contracting subprocess before and after seven improvements were applied…...…….. 211
Figure 4.32 : Key numerical outputs on the dashboard of Shipyard 200 In General and on Cost basis…… 213
Figure 4.33 : Key numerical outputs on the dashboard of Shipyard 200 on Labor and on Time basis…….. 214
Figure 4.34 : Productivity Summary graph of the dashboard of Shipyard 200 In General and on Cost basis…… 215
Figure 4.35 : Productivity Summary graph of the dashboard of Shipyard 200 on Labor and on Time basis……. 216
Figure 4.36 : Shipyard 200 Productivity Numbers Status before and after respondents' five improvements were applied……. 219
Figure 4.37 : Shipyard 200 Productivity Status Dashboard graphs of the Shipbuilding Management process before and after six and respondents' five improvements were applied…….…… 220
Figure D.1 : Questions on the Basis Information……...…….. D-1
Figure E.1 : Participants' gender distribution……..... E-2
Figure E.2 : Participants' age distribution……...…… E-3
Figure E.3 : Participants' experience in shipbuilding sector (years)……..…. E-4
Figure E.4 : Participants' specialties……..……. E-4
Figure E.5 : Participants' current job title……..……. E-5
Figure E.6 : Participants' Workplace History…….…… E-6
Figure E.7 : Participants' education level (last completed)……..….... E-7
Figure F.1 : Pairwise comparison calculation template sample for six Effects…….. F-1
Figure G.1 : Effect weights recording template sample……...… G-1
Figure H.1 : Effect magnitudes gathering template sample……..….... H-1
Figure H.2 : Curve-area calculation template sample……..…… H-2
Figure K.1 : Shipyard 5 and Shipyards 200 & 300 Master Time Schedules.. K-15
Figure M.1 : Sample descriptive statistics, confidence interval, and interquartile calculation results table of EFFECT groups' and EFFECTs' Sector Weights……...…… M-1
Figure N.1 : List of weights based on Management:Basis Information, with cleaned data and normalized as tabulated before for Shipyard 200 Dashboard data entry (screen-view)…….… N-5

Figure N.2 : List of weights based on Management:Basis Information, with cleaned data and normalized as tabulated before for Shipyard 300 Dashboard data entry (screen-view)……...…….. N-6
Figure O.1 : Sample screen-view of Shipyard 200 Productivity Status Dashboard……..…….. O-1
Figure O.2 : Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view)……...…….. O-2
Figure O.3 : Key numerical output on the dashboard of Shipyard 200…...…. O-3
Figure O.4 : Sample screen-view of Shipyard 300 Productivity Status Dashboard……..…….. O-4
Figure O.5 : Sample screen-view of Shipyard 300 Productivity Status Dashboard (expanded view)……..…….. O-5
Figure O.6 : Key numerical output on the dashboard of Shipyard 300……... O-6

LIST OF ABBREVIATIONS

A	Total area of a process/subprocess
AHP	Analytic Hierarchy Process
ASLY	Hull Erection
BLK	Hull & Superstructure Blocks Construction
CGT	Compensated Gross Tonnage System
CON	Contracting
CSD	Computational Shipyard Dynamics
DEA	Data Envelopment Analysis
DES	Ship Design
DPN	Dimensionless Productivity Number
E	Engineering, quality, and documentation
H	Labor
HVAC	Heating, Ventilation and Air-Conditioning
LCH	Ship Launching
ISY	Ideal Shipyard
M	Management capability
Magn.	Magnitude
MNG	Shipbuilding Management
n	Criteria
OUT	Outfitting before Launching
PN	Productivity Number (dimensionless)
PPT	Parts Manufacturing in the Shipyard
QAY	Outfitting after Launching
r	Survey respondent
SP and SPRD	Ship Production
SY and S.YARD	Shipyard
T	Infrastructure and technology
t	Time
TEST	Setting-to-Work, Harbor and Sea Trials
TL	Technological Level
U	Dimensionless Productivity Number of the Shipyard for the entire shipbuilding process (origin: In Turkish “Üretkenlik”)
USD	The United States dollar
w	Shipyard Weight of a process/subprocess
wb	Process basis weight (general, cost, labor, or time) of the Shipyard
wbs	Process basis weight (general, cost, labor, or time) of the Ideal Shipyard
WM$_i$	Weighted magnitude of an Effect
ws	Sector Weight of a process/subprocess

1. INTRODUCTION

This thesis covers a novel methodology to evaluate the productivity of a shipyard by a dimensionless "Productivity Number" system. It is also aimed that the methodology should provide a visual and interactive tool to identify the prioritization of required improvements for the entire shipbuilding process along with its major processes. The developed method can be used at any time, during, before, or after the production of all kinds of ships.

In this Section 1, the background, statement of the problem, rationale of the research, and significance of the thesis will be presented.

1.1. Background

Shipbuilding is a labor and technology-intensive heavy industry branch that brings many engineering and business disciplines together to work in harmony. Different than mass production, in shipbuilding all effort is spent to produce a unique, built-to-order, and usually big-size product over long periods for private or public customers. Then if required by the customer, some same or similar but improved follow-on products are produced in limited numbers. The products in shipbuilding are mainly floating structures such as commercial and naval ships, different types of vessels such as pleasure craft, offshore structures, and also subsea vessels. Some products contain high technology and require complex processes and materials. Heavy industrial products other than marine vessels may be produced by the shipbuilding industry such as battle tank bodies or mill machinery to sustain capabilities when requested or during economically hard times.

The production place for the end-product is mainly the shipyards of different sizes and capabilities. Shipyards are expensive investments for production, along with the repair and conversion/modernization activities and they are big sources of employment. Comprehensive and complex management, design, side-industry contribution, production, and quality assurance activities are held within the shipyards at different branches and out of the shipyards, under dependent and independent work stages, processes, and flows. This

is an orchestrated chain of efforts. Shipyard branches, composed of departments and sections, shops are responsible for the successful completion of their portion of the work, while management is responsible for completing the contracts within budget, on time, and at the required quality. Interim and final measurements and indicators of performance and progress must be applied continuously for the projects, for the branches of the shipyard, and for the shipyard at an overall level. Success monitoring and further improvement decisions should be based on those indicators. These measurements and indicators are applied at different levels at the shipyards throughout the world; some spend high effort, and some do not. For all shipyards, the indicators of efficiency, performance, productivity, and competitiveness are necessary and critical for profitability and sustainability, to keep the customers satisfied and good repetition to remain in the business, as it is common for all manufacturing and production facilities.

The number of shipyards, as compiled and put together was 1030 shipyards all around the world in August 2021 (GISBIR 2020b; Infomarine On-Line, n.d.; Marine Vessel Traffic, n.d; Trustteddocks.com, n.d.). Half of them, 514 in number, were concentrated on shipbuilding (143 solely on shipbuilding, 371 on both shipbuilding and ship repair) while the remaining were on ship repair and/or ship recycling.[1] The number of active shipyards with at least one order for bigger than 1,000 GT ships reached 425 (Gordon, 2023) in 2021. The global shipbuilding industry is a very competitive sector which provided an output of 346 billion USD in 2015 (Gourdon and Steidl, 2019). For 2022 value of orders was USD 124.3 billion (Gordon, 2023) and the expectation was USD 143.34 billion (Skyquest, 2023). For the 2021-2030 period, ship replacement demand for new ships forecasts show a continuous increase from 69 million gross ton[2] (mGT) of 2021 to 100 mGT in total for major commercial ship types (Daniel et al., 2022). The maximum production capacity of shipyards in 2023 is estimated as 177.5 mGT (Gourdon et al. 2023) while the order forecast for 2021-2030 is lower than existing capacity, including naval shipbuilding and offshore platforms & vessels. This shows a highly competitive environment for the next decade and the obvious requirement for better-managed shipyards.

[1] Ship recycling is scrapping an out-of-service ship.

[2] "Gross ton (GT)" is one of the major tonnage measurements for ships. It was internationally accepted in 1969 as defined in the International Maritime Organization (IMO)'s 1969 International Convention on Tonnage Measurements of Ships. It is a function of the total volume of the spaces in a ship's hull and of the enclosed spaces above the deck available for passengers, crew, stores, fuel, and cargo, converted to a numerical value.

1.2. Statement of the Problem

During the literature review, it was seen that the focus was largely either on shipyard branch or process-based efficiency measurements and improvements or, numerical methods to benchmark with other shipyards. There exist several methods to measure and evaluate the efficiency, performance, and competitiveness of shipyards. However, productivity measurement methods are still not agreed upon or applied totally for this distinctive sector. On the other hand, benchmarking with other shipyards is necessary but when the subject shipyards are comparable. Fifty-nine papers and references were obtained and reviewed which strictly mention shipyard total efficiency or productivity measurements and/or evaluations. It is noted that only three of the 21 methods were more emphasized in 53% of those papers and references, but even these methods did not become a globally applied productivity measurement evaluation method for the Shipbuilding industry yet. Further research on shipyard productivity and competitiveness assessment continues. No method is observed to simply provide an indicator for the productivity of the shipyard and the total shipbuilding process, from the contracting phase to the delivery of the ship, along with a solid numerical target for improvement and with the respective prioritization of improvement needs. There is also a need for a methodology to obtain a "dimensionless" metric compared to metrics in several units in use.

For improvement decisions in a shipyard, there exists research for different methodologies including Multi-Criteria Decision Making (MCDM) methods[3] in literature but no clear studies in the past were found on the effect of local improvements on the total shipbuilding process except one by Birmingham et al. (1997). Local improvements in shipyard branches or their processes can be either helpful or harmful through the chained but different characteristics of the ship production workflow. There is a need for a method to observe the effects of local improvements on the entire shipbuilding process.

In addition, a graphical and interactive presentation and evaluation possibility at the shipyard level is deemed useful from the practicality aspect. In only six references, three

[3] "Multi-criteria decision-making (MCDM) methods are mathematical models that help to make decisions in scenarios where the possible alternatives are evaluated over multiple conflicting criteria (Ceballos et. al., 2016)."

separate simple graphical representations were seen for productivity in shipbuilding (Kim et.al. 2018; Lamb 1986, 1998; The University of Michigan, 1995; Todd, 1980; Xue et al., 2020).

Therefore, a gap is found in the literature to meet the need for a non-dimensional, relatively easy methodology to measure shipyard productivity throughout the total shipbuilding process. This created the research problem. This problem was also evident to the student and his two consecutive advisors through their careers in shipbuilding for over 30 years. Accordingly,

"**Can we develop a new methodology, preferably with dimensionless metrics, to evaluate the shipyard productivity and can we prioritize the improvement needs that are compatible with the entire shipbuilding process?**" formed the main research question and hypothesis was put forward as follows:

Hypothesis:

A methodology can be developed to evaluate a shipyard's productivity with a dimensionless metric system for the entire shipbuilding process, which also helps to prioritize the improvement needs.

1.3. Rationale

The aim of this research is to develop a new productivity evaluation and improvement method for shipyards; a basic methodology to identify a shipyard's productivity numerically, preferably in a dimensionless structure and covering the entire shipbuilding process. A Ph.D. study should focus on a narrow focus and developing a productivity measurement method may contradict this fact as in the "volcanology" versus "the history of a volcano" sample in *"How to write a Thesis (1977)" a book by Umberto Eco*[4]. However, the student's advisor guided the student on this broad perspective based on student's background and experience in the shipbuilding sector. The second guidance was to search for compatible events in nature or to review common industrial applications or utilize student's past teachings to develop the model as a starting point. The third and final guidance was to "go out-of-boundaries,

[4] "*Coma si fa una tesi di laurea: le materie umanistich* (1977)" is a book of Italian author Umberto Eco (1932-2016). The student gives this example on Eco's suggestion that a Ph.D. thesis should be on a narrow focus.

remembering the nine dots-four lines problem"[5] which leads to more creative thinking to find new approaches than common routine applications.

Starting from the easiest point and looking from a broad window, "out-of-the-boundaries" thinking led to the question of "why do shipyards try to benchmark with other shipyards as commonly applied, compared to benchmark with their own initially?; why they don't test and try to utilize their maximum attainable capacity first?". By experience, each shipyard has its own facts, conditions, and distinctive way of building ships. So that an internal evaluation is logically necessary before benchmarking with other shipyards. Accordingly, for the method to be developed it is decided that a shipyard should be first benchmarked with its own "Ideal" version.

During further thinking on the method to be developed,

(i) the Propulsion Shafting Alignment[6], an application during ship production has seemed to provide a direct[7] analogy and,

(ii) B-Spline curves[8], an application in Naval Architecture has seemed to help formulate the mathematical model leading to the possible solution for the research question.

Both kept important places in the research question and the student's past.

As detailed in Section 3 of this thesis, a poorly aligned propeller shaft between the gear at the engine end and the ship's propeller, rotating with friction on the bearings due to vertical forces acting on it such as the shaft's weight may resemble the "shipbuilding process of a Shipyard"; and a perfectly aligned same shaft, with minimum friction on the bearings, may resemble the "Ideal shipbuilding process in that Shipyard". The flexibility of a B-Spline curve with the complete shape change property, when the curve is manipulated at one point, may resemble the effect of a change due to an improvement throughout a shipbuilding time period on the entire shipbuilding process.

[5] A simple and common thinking method in creativity that advises thinking beyond unconsciously defined boundaries and restrictions (Foster, 2009).
[6] A static condition that observed at the bearings supporting the propulsion shafts in ships (ABS, 2019).
[7] Comparing a problem with homogenous facts, information, or technology (Proctor, 2006).
[8] A piecewise polynomial curve type.

1.3.1. Research Objectives

The following research objectives helped to achieve the aim of the thesis;

(i) Analyzing components of the shipbuilding process,

(ii) Investigating the factors[9] affecting shipyard productivity,

(iii) Developing a mathematical model, leading to a simple visual tool,

(iv) Data gathering from shipyards and numerical analyses to utilize the developed method.

1.3.2. Research Questions

The main research question and research objectives led to the search for answers to further questions;

(i) What are the major and sub-processes in shipbuilding; what would be the referenced process flow in this research?

(ii) How can we develop a mathematical model based on a similar logic in Propeller Shafting Alignment and can we reach a "dimensionless" solution?

(iii) What are the Effects acting on shipyard productivity?

(iv) How can we define and obtain needed data to make numerical analyses on our methodology?

(v) How can we observe the effect of a process level improvement on the whole shipbuilding process?

1.3.3. Research Focus

In this thesis, to narrow the research focus following boundaries were set initially:

(i) This study will focus on "productivity" only. Measurements, indicators, methods on efficiency, performance and competitiveness, etc. will not be considered.

(ii) Major shipbuilding processes and their main sub-processes will be taken into consideration.

[9] The term "Factor" will not be used after Section 3 to prevent confusion with other scientific methods but instead the term "Effect" will be used for the same.

(iii) This study will focus on basic shipyards, common workflows and shipyard processes, and common steel ship types, but the model will be designed to be open to others.

(iv) Gathered project data will cover the period of 2021-2022 (cross-sectional data) but qualitative issues may refer near past.

(v) For this study, the term "Factor" will not be used to prevent confusion with other scientific methods but instead "Effect" will be used for the same. Respectively, the term "Effect" will be capitalized throughout this Thesis for distinction.

The outline of this research study is shown in Figure 1.1.

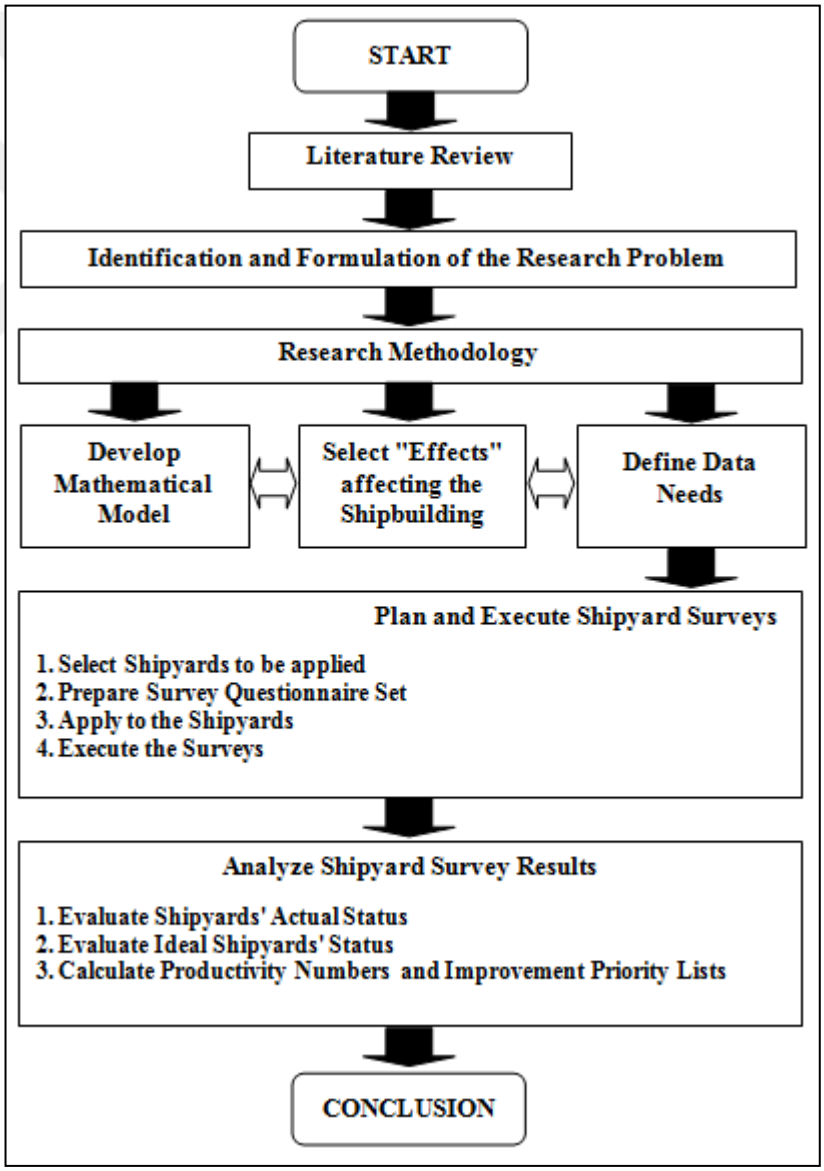


Figure 1.1: Outline of the research.

1.4. Main Assumptions and Limitations

At the beginning of the study and later on during the study following main assumptions were made and limitations occurred.

1.4.1. Assumptions at the beginning

(i) Each shipyard should be evaluated on its own; initially, its first competitor should be itself in "Ideal" status.
(ii) The new method should be applicable at any time, during, before, or after the production, for any type of ship.
(iii) The method should be designed such that sensitive data such as costs, material amount, etc. are not asked to the Shipyards.
(iv) Calculated results and suggestions should be easily visible and testable by the top management.
(v) The method should be designed as such that, decided improvements should not lead to adverse effects on other processes. If so, those improvements should not be a priority. Chain reaction should be monitored by the use of Spline-type curves.
(vi) Suppliers and Subcontractors of the shipyards are not to be surveyed at their own premises. But they should be surveyed from the shipyard's perspective and also their work within the shipyard premises. In this way, highly varied inputs from the use of subcontractors are leveled as much as possible.

1.4.2. Assumptions made during the study

(i) Effects to be used in the methodology should be the ones that have an impact only on the ship delivery schedule.
(ii) Effects on Subcontractors should be specified "as applied" within the survey questions.
(iii) All Effects, subprocesses, and processes should be weighted based on the responses to the survey questions. Normalization may be applied as necessary.
(iv) The initial study is to reference steel hull ship production under a common workflow. But Effects should be defined as such that they may be modified for different materials and ship types, sizes, and work styles/stages; then Shipbuilding Sector Weights should

be researched only or weighting not to be used for the "Ideal Shipyard" and its Effect magnitudes are set to be "1".

(v) The x-axis of the Cartesian coordinate system is to be the time axis (t-axis). Referencing a project, especially a series of sister ships provides a good reflection of shipyard productivity. Therefore, the evaluation of the shipyard should reference a selected shipbuilding project by the Shipyard; its project timescale forms the t-axis.

(vi) Several departments and processes may be surveyed with dedicated or general Effects, under related Effect groups.

(vii) For the "Ideal Shipyard", initial Effect magnitudes are set to "1". Then, the Effects of the "Ideal Shipyard" should also be weighted under a generalized Shipbuilding Sector weight. Therefore, they will have a value of $0 > \text{weight} \leq 1$.

(viii) More than 30 shipyards should be surveyed to obtain the shipbuilding sector weight of Effects. For the second survey phase, the target is two shipyards for validation if time allows.

(ix) Weights of the Effects on the Sector basis should be normalized within Effect subgroups for standardization. But weights of the Effects on the shipyard basis will not be normalized to reflect the actual status in each shipyard.

(x) Surveys are to be arranged in "expert opinion" type. Questions on Effect magnitudes are to be based on a 5-point itemized rating scale so that Effect magnitudes will change between 1 and 5, 1 being the best and 5 being the worst status. Questions to calculate Effect weights should be based on the conventional nine-point pairwise comparison scale of the Analytic Hierarchy Process (AHP).

(xi) For processes or sub-processes where shipyard data can not be obtained, other closest process or sub-process data in terms of the number of common Effects of the same shipyard can be used.

1.4.3. Limitations

Despite an initial positive intention, shipyards may hesitate to participate in this study for three reasons;

(i) difficulty in compiling necessary dense data in a busy work environment if requested,

(ii) protection of sensitive internal data and the yard's position in the competitive environment,

(iii) upon sufficient profit, slowing down the development to maintain stabilization.

(iv) Specific limitations to this study;

- The Thesis Defence should be completed within eight semesters,
- This research is not funded.

1.5. Significance of the Thesis

Shipbuilding plays an important role in the world economy at a macro level as stated in subsection 1.1. above. Shipyards provide jobs at a large scale and help technological development, along with the provision of means for maritime transportation and security. Productive shipyards may overcome competitive difficulties better. Improved productivity has effects at the national, industry sector, company, and personnel levels (Tangen, 2004).

In the literature review, no method was seen with a dimensionless numerical system to measure productivity for the entire shipbuilding process along with the provision of prioritized lists of required improvements. Data for research on the shipyard productivity is also very little. This study has the aim to fill this gap.

The methodology developed is expected to be reviewed by shipyards. If decided to be applied in their yards, positive outcomes may contribute to improved profitability and better financial returns to the shipyard and local economy.

The methodology in this thesis may also be adapted to other industrial sectors which produce unique products for long periods such as aircraft manufacturers, heavy ship equipment manufacturers, etc.

This Thesis will bring a new perspective to the academic field and literature. It is believed that further studies will be made by academia to improve this methodology.

1.6. Thesis Outline

In Section 2, brief information will be given on constituents of the shipbuilding process with its major and sub-processes, and some classification of shipyard-related works will be made. The referenced shipbuilding processes flow in this research will be explained. Then information productivity will be given with a focus on productivity in shipbuilding. This theoretical background will be followed by the part on the literature survey.

In Section 3, starting with the analogy to Propeller Shafting Alignment, the basics of the methodology and the mathematical model, then data gathering from shipyards, and finally the numerical analyses to utilize the developed method will be presented. The test case, which is data gathering from the shipyards and accompanying analyses, necessitated some corrections and changes on the mathematical model. Therefore, the test case was preferred to be in the Section 3 rather than as a separate section.

In Section 4, the utilization of the methodology in practice and the results of the numerical analyses will be discussed.

Finally in Section 5, a general evaluation of the thesis and the conclusions along with the recommendations for further research will be presented.

1.7. Summary

This thesis is on a novel methodology to calculate a dimensionless "Productivity Number" system for a shipyard and to provide a visual tool to identify a shipyard's productivity numerically for major processes of shipbuilding and the entire shipbuilding process. The developed method also provides prioritized lists of required improvements, at any time, during, before, or after the production, for any type of ship.

To develop a new methodology, preferably with dimensionless metrics, to evaluate the shipyard productivity and prioritize the improvement needs that are compatible with the entire shipbuilding process formed the main research question. Major and sub-processes in

shipbuilding; the referenced process flow in this research, developing a mathematical model based on a similar logic in Propeller Shafting Alignment, Effects acting on the shipyard productivity, data gathering to make numerical analyses on the methodology formed the follow-on research questions. The assumptions and limitations in this research were defined.

2. PRELIMINARIES AND LITERATURE REVIEW

Before the literature review, it is deemed helpful to provide some background information on shipbuilding and productivity subjects. Then, the literature review part in subsection 2.3. may become more meaningful.

2.1. Constituents of the Shipbuilding Process

In the books by Storch et.al. (1988, 1995) the term "Shipbuilding" was defined to designate the total industry. But in this thesis "shipbuilding" is defined as an overall process that covers ship production, management of shipyard and projects, ship design, and finally manufacturing and procuring all the materials & equipment required to build the ship and to be installed on the ship.

The two common expressions, shipbuilding and ship production are used with slight differences while in literature there are cases where both were used interchangeably. In this thesis, the term ship production is used as a subset of shipbuilding. It should be mentioned that a common third expression "ship construction" is used as an equivalent of the term ship production (SNAME, 1980) since ship production is a construction type of production (Lamb, 2003), but this expression was not used in this thesis, not to be confused with hull construction subprocess.

Ship production is a major process with necessary subprocesses to build a ship. It covers the three consecutive but overlapped subprocesses namely

(i) hull construction,

(ii) outfitting of this hull and

(iii) launching the ship from land into the water.

The tests & trials subprocess, a part of quality assurance, also continues throughout all these subprocesses.

A generic cost breakdown of shipbuilding projects is shown in Figure 2.1 as adopted from ECORYS (2009). This breakdown differs on shipyard location, ship type, and project basis

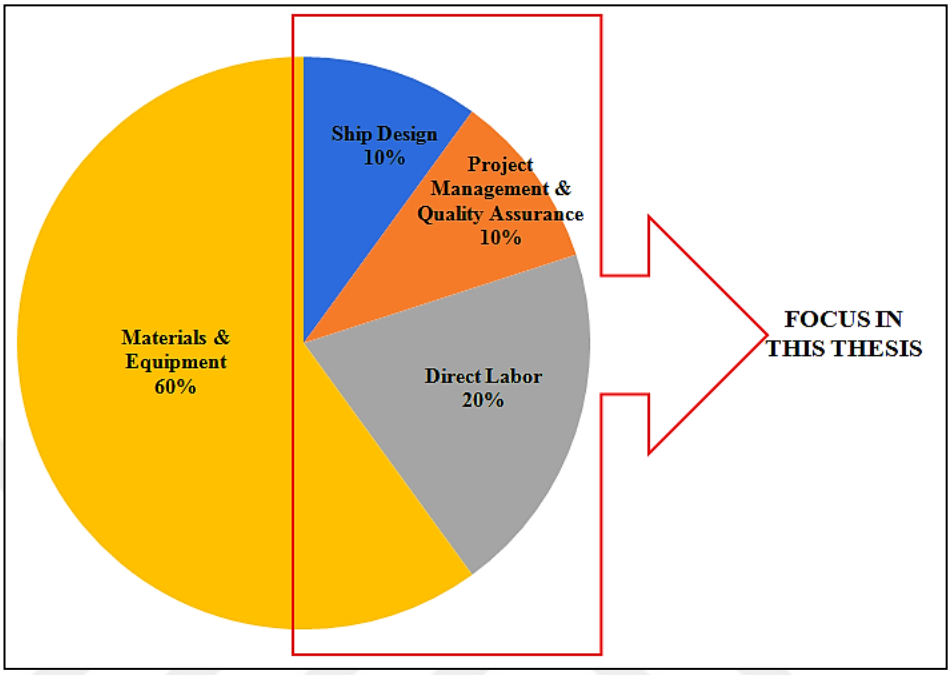


Figure 2.1: Generic breakdown of a shipbuilding project (adopted from ECORYS (2009)) and main focus area in this thesis.

but can be accepted as general from the cost or labor effort aspects. As shown in Figure 2.1, 60% of a shipbuilding project is related to the production and procurement of materials and equipment to be used during ship production and to be installed onboard. The majority of this work is executed at manufacturers' and suppliers' own premises. The related parts of work in the shipyard are the preparation of technical specifications for order, preparation of purchase orders for the ready-on-the-shelf materials, and making subcontracts for new productions, to check the quality and conformance of the products before or at the arrival in the shipyard, to store them and use them. Direct labor covers about 20% of the shipyard work while 10% of the efforts in the shipyard is spent on Shipbuilding Management and also Quality Assurance activities. Ship Design effort requires between 5%-10% of the total shipbuilding activities, which can be done also outside the shipyard if subcontracted. In this thesis, the focus is on shipyard productivity for the processes, subprocesses, and activities on the three right-hand side half which mainly occur in the shipyard premises. The ship production process mainly covers the direct labor part, but in this thesis it also covers a

portion of project management and quality assurance. Manufacturing and procuring the materials & equipment will not be covered as a whole process but related subjects, works will be investigated within ship production, management, and ship design processes.

The end product of a shipbuilding process, a ship or a floating or a subsea structure is made of materials, equipment, and systems. Materials like metal such as steel or aluminum plates or composites form the structure of a ship while materials like pipes and equipment like pumps form the systems onboard. To bring them all together as a ship or a floating, diving structure mainly,

- human effort is needed, both by the white- and blue-collar workforce,
  - to manage a total production process named as a shipbuilding project,
  - to design the end product (usually named as ship design),
  - to produce the end product (usually named as ship production or ship construction), and
  - to assure the end product's quality while,
- an infrastructure is needed for this workforce to produce the end product (in general named as a shipyard).

2.1.1. Major and Sub-Processes

There exist variations in shipbuilding processes and workflows on shipyard basis due to different product types, project requirements, utilized technologies in the shipyards, etc. Detailed information on processes and workflows exists in books such as Storch et.al. (1988, 1995) and in many references. In this subsection, a simple summary is provided. A generic shipbuilding project time frame is provided in Figure 2.2 as a sample.

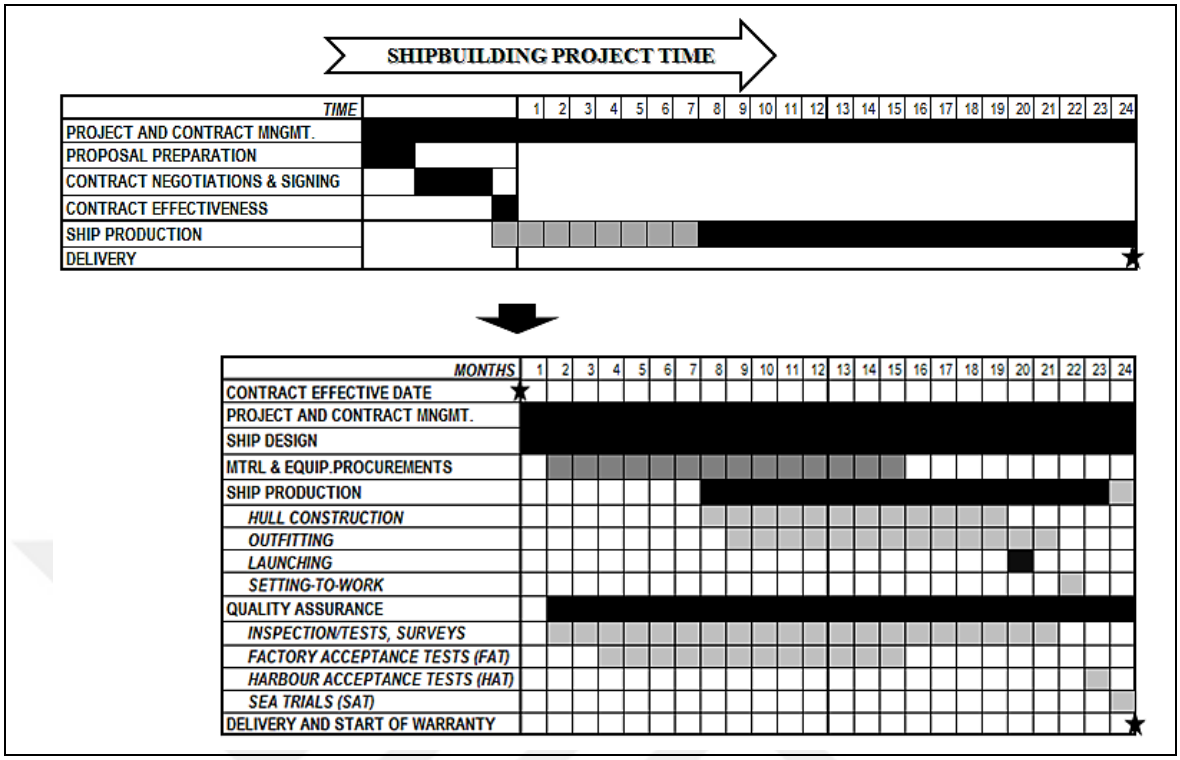


Figure 2.2: A generic shipbuilding project time frame (Koçak et al., 2022; The University of Michigan, 1995; Gourdon & Steidl, 2019).

As common for all large industrial companies, shipyards have a management organization in a pyramid structure composed of a top management body and an executive management body under its contract, accounting and financial, planning & scheduling, production, purchasing & logistics, human resources, marketing & business development, infrastructure, information technology (IT) and quality assurance departments at minimum (SNAME, 1980, 2003; Storch et.al. 1988, 1995). Shipyards run one or usually more projects simultaneously. These projects are managed either under the aforementioned pyramid (functional) organization or by a matrix organization. For shipbuilding and ship repair & modernization projects, more departments under the executive management or a project management team also work on estimation, planning & scheduling and budgeting. Production facility, usually called a workshop, managers work under production management, while project field engineers (usually called as pier-front engineers in shipbuilding) work either under production management or project management.

The **Shipbuilding Contract** phase is maybe the most important governing subprocess of the management process for the successful completion of a shipbuilding project, which starts at

the very beginning. A shipbuilding process to build a maiden ship usually commences with a tender process or an invitation for a proposal addressed to the shipyard(s). After its preparation and submittal by the shipyard, contract negotiations are held between the customer and the shipyard if the proposal is found satisfactory. Upon a mutual agreement on all parts of the contract, legal, administrative, financial, and technical, the shipbuilding contract is signed. When the formal and financial requirements are met, including an advance payment to the shipyard to start initial material purchases and project preparations if contracted, the contract becomes effective, and its date is accepted as the start of the production schedule, "Time Zero (T0)", by almost all shipyards. Before T0, some preparation activities, such as subcontractor selection and pre-agreements, maintenance at the production facilities, ship design at an increasing pace, hiring for the workforce, etc. are held to start and continue with the shipbuilding timely. The contracting subprocess continues for subcontracts and their management on material and equipment acquisition and for outsourcing during the project.

Ship Design is also one of the major processes in shipbuilding. Contracted technical requirements are translated into design, production, installation, integration, and testing & quality assurance documentation and data in the form of paper and electronic media. Ship design is held in four consecutive and as overlapped as possible phases. The Concept Design phase is held during the proposal preparation and before the shipbuilding contract signing to identify major ship characteristics, properties of equipment, producibility, and project cost aspects. It is followed by the Preliminary Design phase to finalize major ship characteristics, the ship's hull form, and propulsion system powering requirements to meet contracted or to be contracted arrangement, tonnage, and speed requirements. Then, the Contract Design phase covers the functional design of systems such as several different piping systems onboard and approvals by the classification society[10]. The Transition Design and Detailed Design phases covers workmanship design activities for production and installation documentation and data. Based on the technological level of the shipyard and its shipbuilding approach, design documentation may be prepared under zone construction methodology and as work packages to reduce shipbuilding costs and ship delivery periods.

[10] "Classification societies are organizations which develop and apply technical standards for the design, construction, and survey of ships and which carry out surveys and inspections on board ships (https://www.emsa.europa.eu/inspections/90-classification-societies.html)."

Part lists for material and equipment are prepared as an outcome of design work for the procurement by the shipyard management and for the production and outfitting by the production entities of the shipyard. The design work must be technically correct and is subject to the control and approval of the classification society and also of the owner in specific areas as per the contract requirements. The ship design process has three important effects on the successful execution of the shipbuilding process:

(i) design, especially if realized by a subcontractor, must be compatible with the shipbuilding practices and infrastructure of the shipyard, where the concept of "Design for Production"[11] plays a critical role (Bethlehem Steel Corporation Sparrows Point yard, A&P Appledore Ltd. & J. J. Henry Co., Inc., 1985);

(ii) maturity level and delivery of the design documentation to production should match with the shipbuilding project time schedule; a) to prevent reworks in production due to correction requirements later on in the design; b) to start the ship production as early as possible and continue accordingly to receive milestone payments and also to free the shipbuilding spaces by the earliest delivery of the ship so that a new building/project may start (Moyst and Das, 2005, 2008);

(iii) design should be correct; the cost and labor effort in design is usually between 5-10% of the shipbuilding project but it has an effect of up to 6 % on the project cost due to the definition of materials & equipment to be purchased, their own and integrated system's performances, along with the required shipbuilding labor effort by the design (Michalski, 2004).

In some developed shipyards, complete design packages for the same type of commercial ships but with different dimensions and capacities at specific intervals are kept ready in hand so that no lead time for design is spent and hull construction immediately starts after the contract effective date. When accompanied by modern shipbuilding methods, those projects may have shorter delivery periods and shipyards may be more productive.

The materials and equipment are mainly procured from subcontractors and suppliers. For unique, non-standard and ship-specific materials & equipment such as the propellers,

[11] A critical ship design approach to concern practical workmanship instructions and consider the capabilities of the shipyard in design to save labor time and effort.

subcontracts are made with the manufacturers by the shipyard and project management as per the technical specifications available as standard in the shipyard or prepared by the design department. They have relatively longer lead times. Ready-on-the-shelf, industry-standard materials & equipment such as bolts & nuts, pumps, etc. are purchased from suppliers with purchase orders and they have shorter lead times. Key materials for ship hull construction are ordered from suppliers but depending on the density of orders in the sector some lead time, around up to 4 months may occur especially for special types of material such as high-strength steel plates. Some fittings, substructure, and equipment such as piping, internal ladders, etc. may be **manufactured within the shipyard**. Decisions on this and necessary work are mainly based on economics (cost and feasibility), domestic industrial capabilities, shipbuilding culture, and available facilities in the shipyard. Before subcontracted equipment are delivered to the shipyard, they may be subject to a Factory Acceptance Test (FAT) as per classification society rules and more if contracted; acceptance quality checks are applied by the shipyard's quality assurance department for the others when arrive in the shipyard for storage. Logistics group in the shipyard management coordinates the transportation out of the (if contracted) and in the shipyard and material and equipment storage, their periodical maintenance as required during the storage until they are taken onboard. Periodical maintenance of material, equipment, and systems are managed by the project management until the ship is delivered to the owner.

The ship production process begins with the **Hull Construction** phase, which contains two important subprocesses, the first one is **Hull & Superstructure Blocks Construction** and the second is **Hull & Superstructure Blocks Erection.** The erection of the blocks forms the ship's hull. In the case of the metallic hull, where shipbuilding steel is the reference material in this thesis, purchased plates and profiles arrive in the shipyard and if not delivered with a primer coat, are usually primed at the shipyard's plate priming facility against corrosion. In accordance with the project schedule first steel cutting is executed in the hull shop, usually with a small ceremony to mark the first major milestone of the shipbuilding project (Gourdon & Steidl, 2019), along with an initial milestone payment to the shipyard if contracted. Hull & Superstructure blocks are manufactured in the Hull Shop, which is a key workshop in a shipyard. Blocks' construction starts with plate cutting and profile processing, bending, etc., then continued with the assembly of the blocks and finalized by the quality

control of the blocks including the accuracy of their dimensions. The next step for the blocks is blasting and painting at the given standards. If the shipyard is capable of on-block outfitting as explained later on below, blasting & painting may be an intermediate step before completion of the block assembly work. The size and means of the hull shop, along with safe transport means to the hull erection site in the shipyard and lifting capacity at the hull erection site defines the maximum dimensions and weight of the blocks. Where possible, two or more blocks are combined to form a grand block (usually around 300 tons in weight) or mega blocks (more than 300 tons) in or outside of the hull shop to reduce the time and labor during the hull erection.

Hull Erection is the follow-on subprocess starting with the keel-laying of the first hull block on the slipway or the location where the ship hull will be built. It is the second major milestone of a shipbuilding project as generally applied (Gourdon & Steidl, 2019), and sometimes also leads to another ceremony. Depending on the infrastructure of the shipyard, hull erection activities are executed on a slipway or at an open/closed field where the ship is to be transported to a lift for launching, or in an open or closed (due to climatic reasons) floating or a dry dock. Blast & painted and maybe outfitted at some level hull & superstructure blocks are transported to the hull erection site and usually parked until their turn for erection. In an alignment order, such as the first blocks to be laid are the middle bottom blocks of the cargo areas, then the others in front and aft directions, and then upwards of the ship, the hull & superstructure blocks are welded to each other to form the ship. Hull erection activities are critical from the correct hull construction perspective due to staying in required ship dimensions including tolerances and alignment of the keel structure throughout the length of the ship. Different than commercial ships, the alignment of the longer propeller shafting line is also critical in this subprocess. As the hull becomes visible, substructure works in and out of the hull are held starting with the hot works (welding, etc.) for the substructure and installation of equipment arrived from the shipyard warehouses.

Outfitting is simply the process of installation of equipment to form and integrate the systems on board. Those equipment are classified as Hull outfit including deck machinery, accommodations, etc., Machinery outfit including piping, machinery, etc., Electrical outfit including cabling, switchboards, Navigation & Electronics outfit, and in the case of naval

ships the weapon systems. Installation of the equipment and systems initially requires a substructure outfitting work, also named as hot works, such as foundations of equipment, pipe hangers, cable trays, etc. Depending on the technological level of the shipyard and the maturity of the ship design, to provide time and by more ergonomic work conditions, a labor advantage, the substructure installation can start at the panel level of blocks during the block construction, called as pre-outfitting. For the same purpose, the on-unit method may be applied, assembling some equipment of a system to form a complete unit as an interim product to be installed on the block or onboard (NSRP, 1979). Again, depending on the same basis, at least the substructure but if possible some more outfit activities such as piping, cabling, installation of some machinery, and maybe some electrical system components may be installed during the hull blocks construction process, called as on-block outfitting (Storch et.al. 1988, 1995). In the manufacturing of ship equipment and their deliveries from the subcontractors, the lead times play another important role in the timing of outfitting activities. Especially for the first ship of a series or a single ship case, not to cause a delay on the project schedule, installation, and fitting of equipment & machinery onboard is planned after the hull erection if the ship design is not mature at the necessary time for pre-outfitting or on-block outfitting. This is the most adverse case due to the additional time requirement for cutting and re-welding of patches on the hull for the installation, and then continuing with the outfit activities. This case is called on-board outfitting (Storch et.al., 1988, 1995). For commercial ships like tankers, container ships, etc., the aim is not to leave any outfitting work after the ship is launched and immediately to start the commissioning activities. Especially for the case of on-board outfitting, some outfitting activities may continue after the ship launching to free the hull erection area for the follow-on ships, or for the naval shipbuilding to complete different ship outfitting requirements (RAND, 2005b).

Ship Launching is another important process and another major milestone in shipbuilding (Gourdon & Steidl, 2019), When the hull construction is complete and the ship can float safely, depending on the project time schedule, the ship is launched into the water. Classical launching methods are end launching on a slipway or side launching on cradles. Classical launching methods require more preparation time before the launching, maybe more than a month, and cause a delay in other activities due to stopping them when necessary. There exists a relatively new end-launching technique on the pressurized balloons from a slipway

to reduce preparation time and effort. Depending on the available lifting capacity, heavy-lift crane launching is another method but except for relatively small in size yachts, pleasure craft, etc., it is rarely used. More technologically developed shipyards may prefer to use lifting platforms if the ship weight is compatible, or launching the ship on a floating dock, or in a dry-dock if the hull was erected therein. These lift or dock launching techniques require less preparation time and provide more safety from any structural damage aspect during the launching. Ship launching is usually celebrated by a ceremony, also called name-giving ceremony in many countries.

Through the end of outfitting and the ship is in the water, when all ship equipment and systems become ready for a start, commissioning activities commence with the initial start of them usually called **Setting-to-Work (STW)** activities. STW activities are followed by a series of operational major quality control tests called **Harbor (Acceptance) Trials (HAT)** (also named as Dock Trials and Basin Trials) as required in the project contract and by the classification society. To give an idea, STW and Harbor Trials may take one month for commercial ships but sometimes around six months for naval ships or special vessels. When the HATs are complete and satisfactory, **Sea (Acceptance) Trials (SAT)** are executed at sea again as per the contract and classification society requirements. SATs may take one week for commercial ships while sometimes more than a year for naval ships. After the end of SATs some time, like two weeks, is spent by the shipyard for correction of defects detected during HATS and SATs and also for final docking for bottom cleaning and last external final coat painting if contracted. Then with the mutual agreement between the shipyard and the customer, the ship is accepted by and delivered legally to her owner. It is also the final payment stage of a shipbuilding project as applied commonly (Gourdon & Steidl, 2019). After the delivery a warranty period, usually 12 months long, is applied for shipbuilding processes' defects found onboard by the owner during the ship’s operational period. Then the shipyard applies corrective measures as per the project contract. At the successful end of the Warranty Period, the shipyard's relation with the ship is terminated. Maintenance & Repair activities of the ship continue as per her owner.

Quality of the ship's hull construction, equipment & systems, and outfitting are continuously controlled and surveyed by the shipyard's quality assurance department, classification

society and if contracted, by the customer representatives. Before subcontracted equipment are delivered to the shipyard, they may be subject to a Factory Acceptance Test (FAT) as per classification society rules and if contracted for more requirements. Acceptance quality checks are applied by the shipyard's quality assurance department for the other materials and equipment upon their arrival into the shipyard for storage. STWs (partly), HATs, and SATs are executed under the supervision and review of the quality assurance department, classification society, and customer representatives.

In light of the aforementioned brief information on processes and activities it is deemed to submit information a global understanding on technological levels, or the best practice levels by another definition (Lamb, 2007), of shipyards in Table 2.1.

Table 2.1: Technological Level (TL) classification of shipyards in a global sense (Lamb 1998, 2007; Storch et.al. 1988, 1995).

Level (TL)	Years	Shipbuilding Key Practices
1	1960s	A number of Slipways, Small Cranes, Small Hull Blocks, Outfit after Ship Launching, Manuel Management applications
2	1970s	Few Slipways/Building Docks, Larger Cranes, some on-block outfit, some Computer Aided Design/Manufacturing Applications (CAx)
3	1980s	Single dedicated (open or closed) dock, Larger Cranes, large mechanization, more CAx also including management
4	1985s	Grand Hull Blocks, some pre-outfit, advanced Zone outfit – ship is almost complete at launch, more CAx, Automation
5	1990s	Accuracy Control methods mastered, outfitted Blocks, more Automation and Welding robots, effective CAx
6[12]	2000s	Covered production sites as much as possible, Large/ultra-large blocks, Material movement by conveyors, Robots, Standardized hull & outfit for different ship types

Major changes occurred after the 1960s, following the technological developments in industrial machinery, and the application of new industrial methods and manufacturing techniques in shipbuilding, as a result of increased demand for commercial ships and high competitiveness.

[12] Some Japanese, S. Korean, and European shipyards are known to have reached up to TL 6 at the end of the 1970s.

2.1.2. Shipbuilding Processes in this Research

For further work in this thesis, the major processes and subprocesses of a total shipbuilding process are taken as follows:

Major Processes:

- Shipbuilding Management,
- Ship Design, and
- Ship Production, where its subprocesses are,
    - Contracting,
    - Hull and Superstructure Blocks Construction,
    - Hull Erection,
    - Parts Manufacturing in the Shipyard,
    - Outfitting before Ship Launching
    - Ship Launching,
    - Outfitting after Ship Launching (also named as Quay outfitting) and,
    - Setting-to-Work (STW), Harbor (HATs) and Sea Trials (SATs).

There exists a deviation in this thesis from the aforementioned information in subsection 2.1.1. on contracting. In this study, contracting is included as a subprocess of the Ship Production process. It is the experience of the student that, contracting has a critical effect on ship production and ship delivery period due to its compliance with the facts of the shipyard. The phase shifting between the contract signing and ship deliveries due to the shipbuilding periods can be seen in Figure 2.3. For example, the increase in deliveries in 2009 and 2010 is the outcome of the contracts signed in 2007.

By the receipt of the tender/invitation document, the shipbuilding contract preparations start during the proposal preparations. The ship's concept design also starts to meet the ship performance requirements requested in the tender. During the concept design main material and equipment data is obtained and accordingly technical financial information exchange, and initial agreements with candidate subcontractors, manufacturers, and suppliers

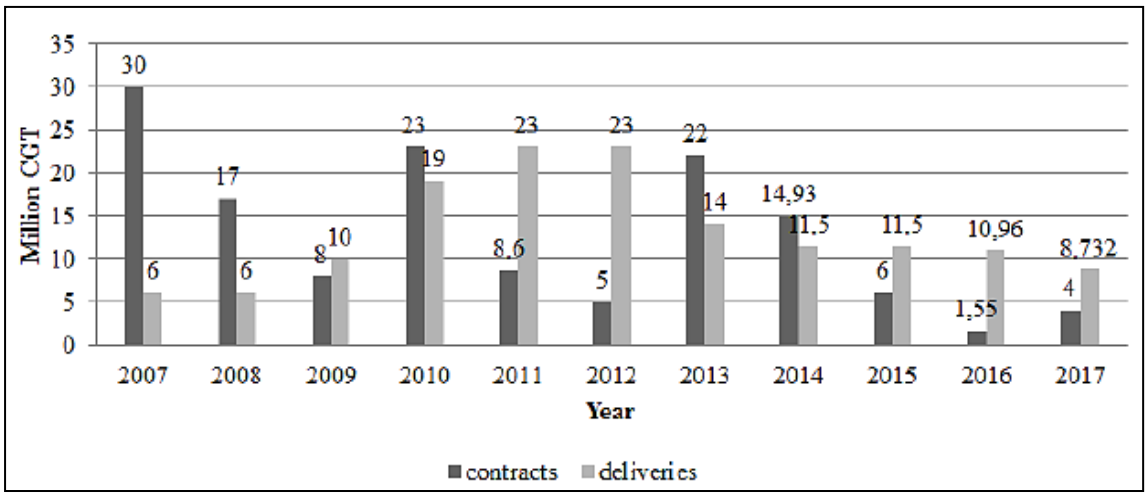


Figure 2.3: New orders and deliveries for Bulk carriers (Gasparotti, 2018).

commence in the shipyard. Simultaneously, project cost calculations and planning & scheduling at the master level continue. After the proposal, they are adjusted during the contract negotiations in accordance with the finalized requirements. Then, after the contract signing, usually before the contract effective date when the first advance payment arrives, if ship production facilities are free from ongoing ship productions (Gourdon & Steidl, 2019) initial purchase orders for material, such as steel plates and profiles, welding electrodes, are placed and infrastructural preparations, supply of additional tools & machinery to be used during the hull construction, necessary heavy maintenance of the cranes etc., start in the shipyard to minimize the required lead times and to save time in the project schedule. Therefore, the performance of the shipyard during the contracting, correctness, and compatibility of the terms and commitments in the contract with the shipyard facts are realized before the commonly accepted T0 (contract effectiveness date). This has a definite impact on shipyard productivity. A similar discussion was made in the past on the inclusion of Contract Design[13] in the ship production process, an important reflection of technical contractual requirements to the shipyard's building strategy (Lamb, 1985). In this thesis, contrary to common application in shipbuilding, T0 (Week 1), the start of the shipbuilding process was decided to be the bid/proposal receipt week rather than the Contract Effective date due to the reasons explained above.

[13] For naval ship projects in general, the shipbuilding contract is signed after the concept, preliminary, and contract design phases. Contract design covers the initial part of the functional design phase.

At the shipyards with high technological levels at 4 and above, outfitting after launching may not be necessary due to the maximum application of pre-outfitting, on-block outfitting, and/or Integrated Hull-Outfitting-Painting (IHOP) methods but thinking of lower technological levels at the global scale and also production of naval ships, outfitting after ship launching is kept among the subprocesses in this thesis.

Subcontractors and suppliers are significant participants in shipbuilding projects, in and out of the shipyard. Due to the study time frame, the involvement of the material & equipment subcontractors and manufacturers at their premises is left out in this study, but being important players in shipbuilding projects, their performances are evaluated from the shipyard perspective on management (including subcontracting and materials & procurement), production (including the performance of outsourcing), design & production engineering, and workforce aspects as applicable.

2.2. Productivity and Shipbuilding

2.2.1. Productivity

As industrialization developed, numerical measures, parameters, and values were needed to indicate the performances of production facilities at several production areas, steps, and levels. Until the 1950s, effectiveness was almost the single indicator. Due to the increase in the complexity of the businesses, more indicators were added. Until the 2000s, gradually efficiency, key performance indicators, productivity, profitability, and competitiveness became additional performance indicators (Tangen, 2004).

There exists no single accepted agreement on these indicators, and they are usually confused with each other (Tangen, 2004). For clarity in this thesis, their definitions in the business environment are provided below in short form and shown in Figure 2.4 by Tangen (2004).

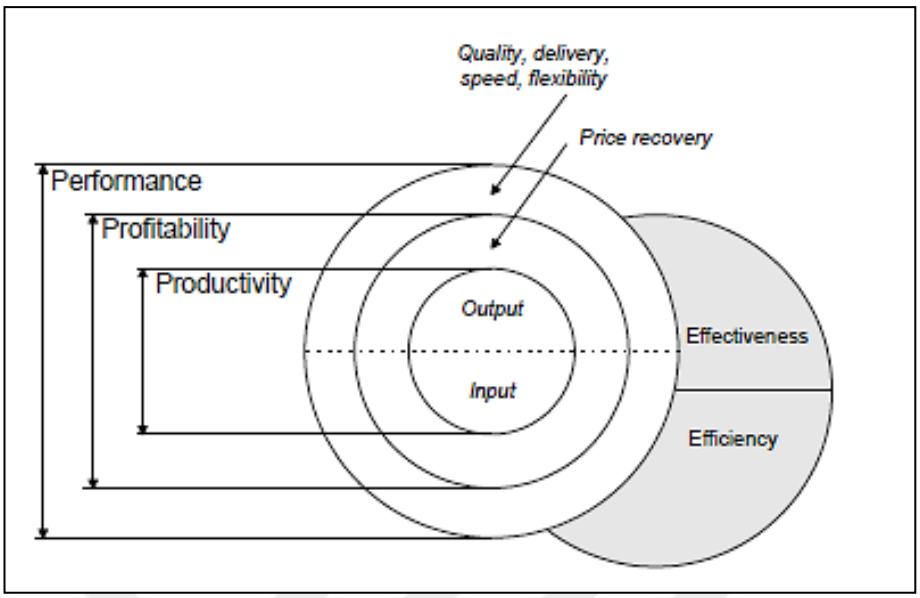


Figure 2.4: Basic performance indicators, Triple-P model (Tangen, 2004).

Effectiveness is the degree to which goals are attained (Prokopenko, 1998). It can be defined as the ratio between actual and expected output (Tangen, 2004). A system is said to be effective when it meets or exceeds a preset output target (Ray and Chen, 2015)

Efficiency can be defined as the ratio between the expected and actual consumption of inputs, or actual output attained to expected output, or the use of targeted resources and actual resources to transform an input into an output (Tangen, 2004). Efficiency is one of the major performance indicators and in managing production, there are about 10 different uses such as technical efficiency, operating efficiency, etc. and usually defined in percentage (Kolinski, 2013).

Key performance indicators (KPI) are the critical indicators focused on organizational performance in different areas such as management (Bilen, 2022).

Profitability is a performance measure from the financial aspect where influences of price-factors (Bilen, 2022) such as "Revenue", "Gross Profit", "Earnings Before Interest and Tax", "Net Income", "Gross Profit Margin" and "Return on Sales" are included (Çağlar and Nişel, 2017, p.359).

Performance is a broad term that covers productivity and profitability along with some non-cost factors like quality (Tangen, 2004);

Competitiveness is the ability of a firm to keep its power of rivalry among other firms for the same market (Porter, 1985). For the measurement of competitiveness, there exist several benchmarking methods.

This research is focused on "shipyard productivity" and also "productivity improvement". In shipbuilding, efficiency is thought to be more appropriate for partial measurements such as on a workshop basis by the student and not used in this thesis. Effectiveness was deemed as a rather subjective perspective while KPIs and Competitiveness are subject to other studies.

The Organisation for Economic Cooperation and Development-OECD (2001) defined **productivity**, the main focus in this thesis, as "a ratio of a volume measure of output to a volume measure of input use", which serves as a measurement of output, normally expressed as some units per amount of time. Tangen (2004) mentioned that the concept of productivity has been available for over two centuries and was simply defined as the relation between output and input but there is no correct universal definition of productivity. 16 different definitions of productivity can be seen between 1883 and 2004 (Tangen, 2004). Productivity is a subjective concept, and it is a common method by dividing the number of provided products by the required resources (Chen, 2017). According to OECD (2001), there exist many different productivity measures; the choice depends on the purpose and availability of data, and productivity measures can be either as single factor productivity measures (related to a measure of output to a single measure of input) or multifactor productivity measures (related to a measure of output to a bundle of inputs). In manufacturing usually, the capital, equipment, humans, materials, and energy are used as resource inputs, but outputs can be different such as pieces, tons, or gallons (Ross, 2001, pp.1561)**.** The use of industrial engineering techniques in the manufacturing industry, such as work measurement, work sampling, and proper layout may lead to improvement in productivity (Ross, 2001, pp.1561)**.**

Bernolak, (1997, p.204) says that *"Productivity means how much and how well we produce from the resources used. If we produce more or better goods from the same resources, we increase productivity. Or if we produce the same goods from lesser resources, we also increase productivity. By 'resources', we mean all human and physical resources, i.e., the people who produce the goods or provide the services, and the assets with which the people can produce the goods or provide the services. The resources that people use include the land and buildings, fixed and moving machines and equipment, tools, raw materials, inventories and other current asset."* for the manufacturing area where shipbuilding is also included. Therefore, the use and availability of resources are closely related to productivity (Tangen, 2004)

Furthermore, there exist two classical reasons to investigate shipyard productivity and its improvement, first *"Without productivity objectives, a business does not have direction; without productivity measurement, it does not have control* (as cited from Drucker, 1974 in Tangen, 2004, p.7)*";* second, it represents one of the key competitive advantages of the shipyard by achieving cost and quality advantages over their competition (Tangen, 2004),

Tangen (2004) cited Summanth (1994) that, ratios of output to one source of input, such as labor, is one of the index productivity measures named as Partial Productivity Measure. As in the total shipbuilding process, if total output to the sum of all input factors is considered, it is then named as Total Productivity Measure (Frankel, 1983).

The Total Productivity and the Total Factor Productivity (also called multi-factor productivity), both reflect the overall productivity where labor and capital inputs are used together in the production process to generate an output (Benzaquen 2017, Gourdon, 2019). Total productivity is the ratio of the real value of output to the real value of all the inputs while total factor productivity is the ratio of the real value added of outputs to the real value of all the inputs as stated by Frankel (1983). There are many different inputs and outputs within the major and subprocesses during the overall shipbuilding process but at the end of the process, the output is single, and it is a ship or a floating structure. Shipbuilding can be specified as an assembly industry and the final value of the output, the ship, as the contributions come from shipbuilding processes and intermediate inputs (Gourdon & Steidl,

2019). But, as it was shown in Table 2.1, around 30-40% of the value is created by the shipyards while 60%-70% is created by the subcontractors and suppliers which own the maximum share of the value of the final output. For complex ships and naval ships this can be as high as 80% (ECORYS, 2009; Gourdon & Steidl, 2019). Therefore, in this thesis, where the focus is on the shipyard, rather than the value-added, the real value of the output is the main concern. For the method developed in this study, there is no classical output-input ratio calculation. But the quantified factors affecting shipbuilding processes and the total process currently in a shipyard can be assumed as an output while their quantification representing the "Ideal" version of the same shipyard may be assumed as input. Then the result of this study may be assumed as a Total Productivity Measure. It is also a Time-based productivity measure. When the output is a single product, but that output is varying models of a single product, or even varying models of a number of individual products without existing a common unit, one of the approaches is to use the time to perform operations, the unit common to all products as suggested by Arnold et al. (2008). The use of time is easy to understand, and it helps to compare different workshops (Tangen, 2004). In Industrial Engineering, the volume of work produced per unit of time is also called the output rate. The first step to measure the output rate is to determine a normal level of performance, which resembles the "ideal" shipyard in this study. In industrial engineering, the rate of output is influenced by strategy, process selection, technology, and work design, as the similar approach is used in this study. Comparison of a shipyard's actual status during a shipbuilding process to an ideal status of it numerically may also be thought of as a ratio of output to input. As stated by Chen (2017), productivity can be defined as the performance of an organization in converting time, capital, labor, capacity, raw materials, and other resources into products. Then it can be concluded that, as applied in this research, the number of ships delivered in a specific period can be taken as the output of a shipyard and, the ratio of the status of the actual shipyard to its Ideal version during this specific period can be a measure for its productivity. One of the critical needs is the desire to have dimensionless measure (Lamb, 2007), which was one of the research questions in this study.

In this thesis, the developed productivity measure is an "index" type among three diverse traditional techniques (Tangen, 2004). The other two measurement techniques, linear programming and econometric models (Singh et al., 2000) are not included in this research.

However, the Data Envelopment Analysis (DEA) method from linear programming is explained in the Literature Review subsection 2.3.2 below.

2.2.2. Productivity in Shipbuilding

Four engineering and related areas differ from other engineering and industrial disciplines due to their heavy integration requirements in both industrial and engineering disciplines. These are;

- Aerospace engineering and industry,
- Naval Architecture and Marine Engineering, shipbuilding industry,
- Civil engineering for complex civil construction projects such as nuclear power plants and,
- Mechanical engineering again for complex unique products.

The common point of these four engineering areas is that the end products are unique, designed as per customers' requirements, and produced over a long period. In this way, they differ from mass production and its methodologies, and standardized applications. In shipbuilding, unique pieces, and parts are produced at variable cycle times and output rates. The exception may be only some standardized fittings to be used in construction and piping in general but other mass pieces and parts for the shipyard use are produced by the suppliers. Except for only a very few research purposes, prototype ships are not produced, and the maiden ship enters the service fully functional. The processes in shipbuilding are complicated and there is a complex functional relationship between the work stages and processes. Therefore, mass production and measurement methods can not be applied in shipbuilding easily.

For the performance measurements of a shipyard, there are three major groups in the shipyard with their own focus from efficiency to competitiveness & profitability referencing the shipbuilding projects, as shown in Table 2.2.

Table 2.2: Groups and their performance measurement focus in a shipyard.

Groups	**Production workforce and Shipyard Workshop & Field Managements**	**Project and Production Managements, Planning and Budgeting Departments**	**Shipyard Top and Executive Managements and Contracting, Financial, and Quality Managements**	
Performance Measures	Efficiency, Workshop productivity	Project and Shipyard Management Performances, Productivity of processes	Shipyard Productivity	Competitiveness, Profitability
Focus areas	Workstation, Work teams, Production & process improvement	Processes' interrelated flow improvement	Product based evaluation (Start to End of Project)	Benchmarking with competitors; Shipbuilding costs
Sample methods	- Industrial Engineering methods, - basic productivity measures (weight based etc.)	- KPIs, - basic productivity measures (weight based etc.) - CSD + Simulation, - DEA	- CGT, - DEA, - Business Administration. methods	- CGT, - DEA - SPPE - Business Administration. and Financial methods

The focus of the management units at workshop and field levels is basically to measure the efficiency of the workforce with appropriate Industrial Engineering methods at workstations and work teams and, to provide necessary training along with production and process improvement means. This is of course also necessary for the outsourced workforce in the shipyard. Where possible, despite the non-mass production characteristics of the business, productivity measurements may be applied by application of basic parameters such as steel weight processed per MxH or pipe length per MxH. In the shipyards which use Japanese or U.S.-based methods such as Lean Production and Six Sigma respectively etc. to measure, evaluate, and increase efficiency and productivity, these measurements became a part of daily life even at the workforce level. But it should be noted that, through the long track of a shipbuilding project with the involvement of many and different processes, workflows, and their interdependencies, local and limited improvements, as named "island solutions" by Brodda (1990, p.1B-1-6), may not help to lever an entire improvement in the total shipbuilding process.

The use of KPI would be more appropriate for Project Management, Production Management, and managements of the Planning and Budgeting departments. Information on Key Performance Indexes (KPI), Data Envelopment Analysis (DEA), Computational Shipyard Dynamics (CSD), and Compensated Gross Tonnage (CGT) are summarized in the following parts and in the Literature Review subsection. Despite very limited examples exist, DEA and CSD methods would also help for a more detailed evaluation of performance management. Real-time management by new technological means such as the Internet of Things (IoT) would help especially in project management for meeting the schedule, budget, and also materials flow

Top management of shipyards usually concentrates on profitability and competitiveness. But the route to both passes through shipyard productivity as previously shown in Figure 2.4 and Table 2.2. Internal and external factors affect shipyard productivity. Those factors are controlled by short-, medium- or long-term improvements. Productivity also affects production cost and delivery duration which are inputs of competitiveness and profitability. Competitiveness is mainly under the effect of production cost, delivery duration, and product quality but is measured by benchmarking with other shipyards. But, for productivity, the main focus in this thesis, was defined by OECD (2001) as "a ratio of a volume measure of output to a volume measure of input use", which serves as a measurement of output here expressed as some units (i.e., newly built ships) per amount of time. An example of this is the delivery of two container ships per year. This requires more of an internal evaluation in a shipyard first rather than jumping into a competitiveness analysis. To evaluate the performance of a shipyard, top managers and the owners are expected to ask "Are we using our resources in the best way in the shipyard? Is it possible to produce ships at shorter periods from the same inputs? If so what are problem areas and improvement needs without creating bottlenecks and by spending correctly in the total shipbuilding process?".

For the correct management of the shipyard, the executive group should care of the productivity of the shipyard as well as its competitive power. To do so and for preparation of top management's questions above, product-based evaluations, from start to end of shipbuilding projects in hand should be made by appropriate methods and to be readily available in hand. Correct contracts and their management, continuous financial

management, and quality management help both in the productiveness of the shipyard and its competitiveness. Strategic thinking, long-term plans and academic support for measurements and evaluations in tactical and strategic issues provide the needed information to both executive and top management as guidance and decision-making assistance.

Lamb (1998, 2007), Kim et al. (2018), and Xue et al. (2020) classified some factors affecting productivity in a shipyard as shown in Table 2.3. In his research, Lamb (1998, 2007) classified those factors under Technology Levels (Best practice), Facilities, Planning, Management capability, Work organization, Work practices, Worker motivation, and Worker skills headings. During another long-term research, Kim et al. (2018) classified the factors affecting the entire shipbuilding process under the Product, Process, Facility, Space, Human, and Schedule headings. Xue et al. (2020) preferred the classification under Building technique, Resource ability, and Management level. Despite most of them being common, the changes in the classifications were directly related to their approaches in their studies.

Table 2.3: Major Factors affecting the entire shipbuilding process.

Lamb (1998, 2007)	**Kim et al. (2018)**	**Xue et al. (2020)**
Technology (Best practice) Levels as given in Table 2.1)	Product	Building technique
Facilities	Process	Resource ability
Planning	Facility	Management level
Management capability	Space	
Work organization	Human (labor)	
Work practices	Schedule	
Worker motivation		
Worker skills		

During the literature review, 62 papers & references were reviewed which strictly cover overall shipyard efficiency or productivity measurements and/or evaluations in 21 different methods as adopted from business and industrial management areas or developed originally starting from 1980 as listed in Table 2.4. The methods in research in Table 2.4 are sorted methodologically and chronologically and then summarized in the Literature Review subsection 2.3.2.

Table 2.4: Methods previously studied on shipyard productivity.

S. No.	Method
1.	Compensated Gross Tonnage (CGT) System
2.	Productivity Space
3.	Global and Local Performance Matching
4.	Performance gradient, Break- even Threshold
5.	Shipbuilding Productivity Prediction Equation (SPPE)
6.	Overall aspects, production function and Group Technology
7.	Search-Based Heuristic Algorithms
8.	Value Added, Value Chain
9.	Linear Programming (LP)
10.	Data Envelopment Analysis (DEA) along with the new DEA based ESAM ve SSML methods
11.	Analytic Hierarchy Process (AHP)
12.	Labor and Material
13.	Quality Function Deployment (QFD)
14.	Bayesian Network
15.	Total Factor Productivity (TFP)
16.	Theory of Constraints (TOC)
17.	Computational Shipyard Dynamics (CSD), process-centric simulation
18.	Shipbuilding Maturity and Capability Model (S-MCM)
19.	Key Performace Indicators (KPI)
20.	Value Engineering and Risk Assessment (VENRA)
21.	Shipyard Technological Level Evaluation

Historical use of weight as a parameter on shipyard productivity metric changed to volume as a parameter in the 1960s since steel weight, lightship weight, and displacement would give similar results. For commercial ships, a volume-based metric, the compensated gross tonnage (CGT), taking into ship complexity based on her type and size, became a fair measure. To represent the output of a shipyard, MxH[14]/CGT and CGT/MxY[15] have been (Lamb, 1998, 2007) and are still a globally favored shipyard productivity measure. It should be remembered as a side note that, MxH/CGT is actually the inverse of the classical productivity definition, ratio of output to input. Other current CGT-based metric samples are CGT/Shipyard Total Area (sq.m.), Annual CGT/Shop Area (sq.m.), and CGT/Building Berth Area (sq.m.) (Lamb, 1998, 2007). Some numerical examples of these metrics are provided later in Table 2.11.

[14] Man x hour
[15] Man x year

Steel weight, usually in tons, and labor effort in terms of MxH per defined period, such as a year, were basic two shipyard capacity metrics in the first half of the 20th Century. Examples of this are processed steel weight/year or ship production MxH/year. Through the mid-20th Century, as the ship types evolved, tonnage-related two metrics, Dead Weight Tonnage and Gross Register Tonnage were introduced to provide information on the delivery capacities of shipyards (Parkinson, 1959). Dead Weight Tonnage (DWT) is the load-carrying capacity of a ship in tons. Gross Register Tonnage (GRT), changed to Gross Tonnage (GT) in 1982, is also a load carrying capacity of a ship but related to the volumes onboard. In the mid -20th Century, the focus was on the output at a given input (Lamb, 2007) to measure shipyard productivity. Productivity measure examples were then the delivered DWT/year or MxH/DWT or MxH/GRT. The GRT developed among countries with rules, and regulations over the years. In 1969, it was internationally accepted by the Intergovernmental Maritime Consultative Organization's (IMCO) 1969 International Convention on Tonnage Measurements of Ships (SNAME, 1980). GT became a function of the total volume of the spaces in a ship's hull and of the enclosed spaces above the deck available for passengers, crew, stores, cargo, and fuel, converted to a numerical value by application of a specific coefficient. The increase in the importance of efficiency and productivity in parallel with developments in Industrial Engineering in the 1960s forced the shipyards to use a reliable metric while the production of ships became more complex (Lamb, 2007). The OECD adopted the concept of compensated gross tonnage (CGRT) in the 1960s to take production complexities (Craggs et al., 2003). A related work- content compensation factor, based on the same standard ship type, was multiplied by the CGRT (Craggs et al., 2003). Following the change of CGRT from a new tonnage measure of Gross Tonnage (GT), west European and Japanese shipbuilder associations proposed a new CGT system jointly. OECD adopted a new CGT system with a set of new factors (compensation coefficients) in 1984 (Craggs et al., 2003; OECD, 1984;) and updated in 1994 (OECD, 2007). In 2007, an update on the CGT system was published by the OECD, based on the joint improvement proposal of European, Japanese, and S. Korean shipbuilder associations (OECD, 2007). In the system, which is currently in effect, more accuracy on a worldwide basis is aimed. The current calculation is based on a formula;

$$GT = A \times GT^{B} \quad (2.1)$$

where the A and B factors are given in Table 2.5 below.

Table 2.5: The A and B factors of the CGT system (OECD, 2007)

Ship Type	**A**	**B**
Oil tankers (double hull)	48	0.57
Chemical tankers	84	0.55
Bulk carriers	29	0.61
Combined carriers	33	0.62
General cargo ships	27	0.64
Reefers	27	0.68
Full container	19	0.68
Ro-Ro vessels	32	0.63
Car carriers	15	0.70
LPG carriers	62	0.57
LNG carriers	32	0.68
Ferries	20	0.71
Passenger ships	49	0.67
Fishing vessels	24	0.71
NCCV- non-cargo carrying vessels (cruise, offshore ships, dredgers, and workboats)	46	0.62

Compensated Gross Tonnage (CGT) compensation factors for yachts and naval ships were not covered by the OECD (1984, 2007). For Naval Ships, Lamb and Hellesoy (2002), Lamb (2003), and Craggs et al. (2003) made studies but no further studies on naval ship CGT factors were seen in the literature. For motor yachts, Hopman et al. (2010) and Pruyn et al. (2010) proposed the CGT factors given in Table 2.6.

Table 2.6: The CGT system A and B factors of motor yachts up to 1000 GT (Hopman et al., 2010)

Ship Type	**A**	**B**
Motor yachts up to 1000 GT	278	0.58

The association representing the European Shipyards and Maritime Equipment Manufacturers, SEA Europe declared their view that there is no need to establish a new system, but the current CGT system needs to be updated (SEAEUROPE, 2017).

Despite exponential developments in technology and materials during the last 50 years, "**human (workforce)**" is still the most important factor in shipbuilding both from physical labor and mental labor aspects. Human, the origin of labor productivity, is the game setter in shipbuilding productivity due to the production of a unique product over a very long period, slower developments in automation for works onboard and non-standard parts, along the flow of many processes different than mass production. The white- and blue-collar workforce is recruited and administrated by the human resources department but managed by their own department, workshop, or group managers depending on their workplace and position. A happy worker, whose shoes will not go back in the mornings at the shipyard's gate and who devotes him/herself to his/her job throughout the work period, as well as satisfactorily trained, psychosocially, environmentally (including health and safety measures) and ergonomically protected, and with satisfactory income is a critical player for a productive shipyard. To manage labor productivity, the utilized production methods are important such as the comparison of one MxH per Weight (ton) to four MxH per Weight (ton) ratio of on-block and on-board outfitting respectively (Lamb, 1998). In today's popular industrial work share and collaboration environment, subcontracting and outsourcing are used heavily in the shipbuilding sector to reduce infrastructure, labor, and production costs and times. Therefore, outsourcing of ship design and/or certain parts of the production and/or hiring temporary labor to augment shipyard's own labor have become regular applications in shipbuilding (RAND, 2005a). In this way, shipyards keep a key team of workforce to manage know-how in the yard but outsource and subcontract shipbuilding processes as much as possible, feasible, and technically appropriate. Among them are subcontracting ship design, outsourcing hull construction, ship outfitting, ship launching, etc. Experience and the learning curve have two important positive effects on productivity improvement. As the ratio of experienced employees to the total number of employees becomes greater the workforce is expected to be more productive (Storch et.al.,1988, 1995). Building a series of sisterships results in a learning (experience) curve and until a limiting threshold (e.g., 32% less man-hour labor for the 8th ship of a series of chemical tankers (Roque and Gordo, 2020)), it results in shorter shipbuilding time periods for consecutive ships causing a reduction in costs and increase in productivity (Storch et.al., 1988, 1995). The provision of 449,800 jobs in Germany in 2018 (OECD, 2023a) and 87,595 jobs in 2022 in Türkiye are two examples to give an impression of the size of the workforce in the shipbuilding industry.

Infrastructure, in terms of location of the shipyard (environmental factors such as closeness to main transport routes, side industry, climate, etc.), the layout of the facilities in the shipyard, and the number, capacity, arrangement, and technological level of the material handling equipment such as cranes, manufacturing and construction machinery, and information technology systems play a great role in shipbuilding process, which also directly affect productivity. To overcome limitations in infrastructure, for shorter ship delivery periods or to manage more shipbuilding processes at a defined period, also collaboration in shipbuilding is reached to high levels such as sharing the production of large pieces of a ship (Lamb, 2002) or production of a series of sister ships at several close or far shipyards at the same periods. But in any case, investing only in infrastructure doesn't provide a continuous increase in productivity without organizing the work more efficiently (Varela, 2017).

The flow of **materials, equipment, and supplies** needed for the ship to be built and for the infrastructure of the shipyard for the projects is another important factor in shipbuilding productivity. The shipyard's infrastructure and production departments, along with the specific project's management keep up with the necessary material, tools, equipment, and machinery needed in the shipyard for ship production while the purchasing department places the orders to the suppliers as per the parts lists of the design work and taking care of the lead times, for the ship to be built throughout the project. Proper warehouse management in the shipyard is important for the correct and timely flow of required materials and supplies. For better management and to reduce related efforts, applications like Just-In-Time (JIT) deliveries are used by the shipyards depending on the management strategies and economical environment. For parts manufacturing in the shipyard, hull & superstructure block construction and similar interim products, the shipyard infrastructure and labor may be organized under the Group Technology-based shipbuilding approach (Lamb, 1988). This helps "to gain production economies of scale for non-standard products even when produced in moderate volume" (Lamb, 2003, p.25-5).

Given the explanations in subsections 2.1. and 2.2. above, examples of key factors influencing shipbuilding productivity are presented in Figure 2.5.

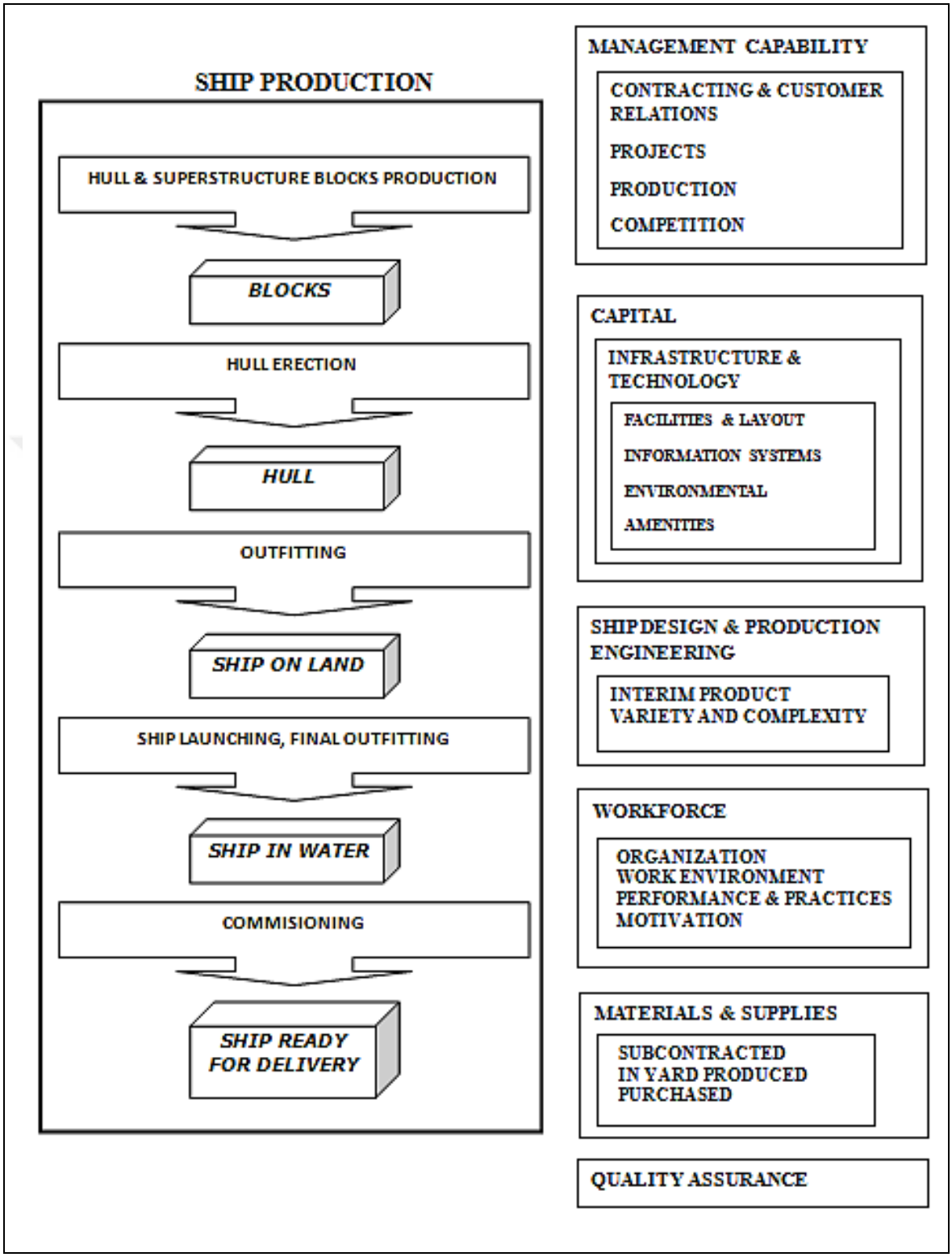


Figure 2.5: Examples of key factors influencing the shipbuilding productivity (Lamb, 2007; Tangen, 2004)

Lamb (2007) stated that highly productive shipyards have good work organization and clear objectives and policy, short build cycles, overlapped and integrated hull construction and outfit, applied design for production, and an awareness of performance measures.

There are also a few rules of thumb on shipbuilding productivity developed throughout the time by experiences such as;

- Shipyard capability improvement should aim to reduce costs and increase profit; an appropriate level of technology is necessary to reduce costs, improve delivery speed, and meet quality requirements. But it is not necessary that most automated shipyards become the most productive. Investment in technology should be within profit margin (Lamb, 1998, 2007);
- Technology brings more worker lay-offs which is a dilemma from the social perspective;
- "A shipyard with a higher productivity does not necessarily produce a vessel that has the lowest cost" (Craggs et al., 2003), and "a yard with a higher cost base must have a higher productivity to be able to compete with a yard with a lower cost base" (Craggs et al., 2003);
- Improvement targets should be carefully set, for example, a rate of 4% improvement per annum in shipyard productivity might be regarded as a good achievement (Craggs et al., 2004) but for S. Korea, it was 8% then;
- A shipyard should be competitive to get more contracts, but a fast shipyard in deliveries without continuous demand results in frequent layoffs;
- From customers' viewpoint "the most important performance measure is the cost performance expressed in terms of added value (contract price less the out-turn cost of material, equipment, and other bought-in items) per CGT" (Craggs et al., 2003).

Before the Literature Review subsection, it is deemed helpful to provide some information on the size and status of shipbuilding globally. In the following parts, the data and information are gathered from several reliable sources as referenced. This thesis has a global focus but as to be expected normally, the student also provided some information on shipbuilding in his own country, the Republic of Türkiye. The statistics below mainly represent commercial ships and shipbuilding.

2.2.3. Ships, the Output at Seas and in Waters

The number, total GT, and DWT of commercial ships in the World and of Türkiye are shown in Table 2.7.

Table 2.7: Commercial ships in the World and in Türkiye
(Sources: U.K. Department for Transport, 2023, GİSBİR 2020a, SAJN 2022).

Year	Number of All Commercial Ships	Total Gross Tonnage of All Commercial Ships (million GT)	Total DWT of All Commercial Ships (million DWT)	TR GT (million GT)	TR DWT (million DWT)
2010	80,950	1,297	1,352	5.8	8.6
2011	83,844	1,419	1,468	6.2	9.3
2012	86,420	1,543	1,552	6.4	9.7
2013	88,690	1,637	1,612	5.9	8.7
2014	90,690	1,699	1,670	5.7	8.4
2015	92,583	1,756	1,725	5.9	8.5
2016	94,417	1,813	1,778	5.6	8.1
2017	95,846	1,871	1,834	5.6	7.8
2018	97,145	1,933	1,885	5.3	7.3
2019	98,434	1,984	1,966	4.9	6.7
2020	100,101	2,066	2,033	4.5	6.4
2021	101,368	2,129	2,095	4.4	5.9
2022	102,849	2,191	2,168	5.6	6.5

Between 2010 and 2022, there is an average 2% increase in number of ships each year, but with a reduction in the rate of increase to 1.4% for the last five years. In 2022, the total number of Commercial ships above 1000 GT in the World was 102,849. Between 2010 and 2022, there is an average 4.5 % increase in the total Gross Tonnage of all commercial ships each year, but with a reduction in the rate of increase to 3% for the last five years. In 2022, the total Gross Tonnage of all commercial ships in the World was 2,190,800,000 and the total Dead Weight Tonnage of all commercial ships in the World was 2,168,000,000 DWT; of those, 5,643,000 GT and 6,530,000 DWT respectively belong to Türkiye.

The distribution of those ships as of 2022, based on GT is provided in Figure 2.6. Bulk Carrier type of commercial ships form 43% of the World fleet, followed by Crude Oil

Tankers at 20%, Container Ships at 13%, and Product Tankers at 9%. The remaining types are LNG Tankers (3%), General Cargo ships (2%), LPG Tankers (1%), Chemical/Special tankers (2%), Multi-Purpose Product carriers (1%) and non-Cargo ships (6%).

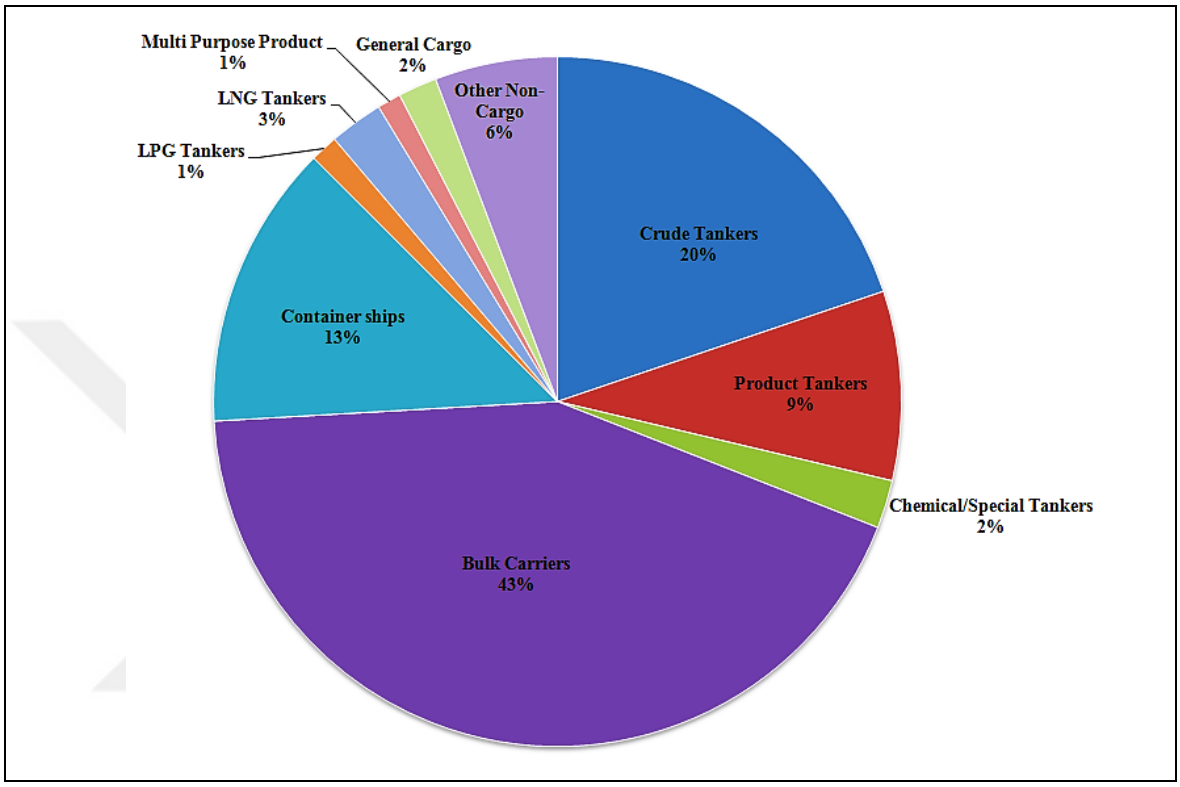


Figure 2.6: Distribution of commercial ship types by GT in 2022 (SAJN, 2022).

2.2.3.1 Number of Shipyards

The number of active shipyards compiled and put together in August 2021, during the initial phase of this study, was 1030 shipyards all around the world (GISBIR 2020b; Infomarine On-Line, n.d.; Marine Vessel Traffic, n.d; Trustteddocks.com, n.d.). Half of them, 514 in number, were counted as concentrated on shipbuilding (143 solely on shipbuilding, 371 on both shipbuilding and ship repair) while the remaining were on ship repair and/or ship recycling. To provide the most recent data in this thesis before its defense, statistics were reviewed, and it has been noticed that the data for 514 was possibly based on the statistics from the year 2014. The final information is given in Figure 2.7. As of the end of 2022, the number of active shipyards was 353 (Gordon, 2023) worldwide. The trend in dropping the number of shipyards seemed partly stopped at the end of 2021 where the number of active

shipyards with at least one order for bigger than 1,000 GT ships reached 425 (Gordon, 2023) possibly an aftermath of COVID-19.

Years	Global	Türkiye
2003		37
2004		38
2005		40
2006		45
2007		51
2008		64
2009		65
2010		69
2011		71
2012		71
2013		72
2014	514	84
2015	494	80
2016	440	80
2017	389	78
2018	315	78
2019	281	82
2020	287	84
2021	425	84
2022	353	84

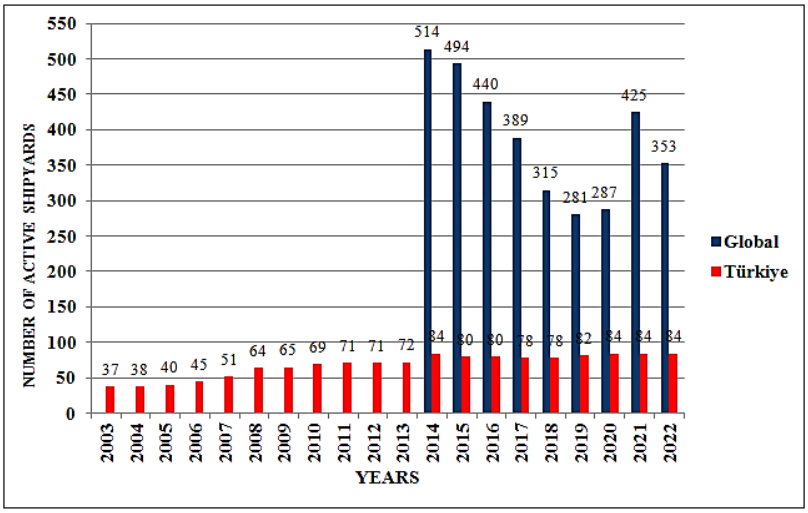


Figure 2.7: Data and graph of active shipyards, only shipbuilding and both shipbuilding and ship repair (Sources: Gordon, 2023 for global; GİSBİR, 2020a, Ministry of Transportation 2023 for Türkiye).

Türkiye has a shipbuilding tradition of over 800 years (Baykal, 2017) and currently has 85 active shipyards, with 33 floating and 11 dry-docks, working on commercial, naval shipbuilding and yacht building, repair and modernization activities (GİSBİR, 2023). The declining demand in shipbuilding after the 2008 global financial crisis also affected the shipbuilding industry in Türkiye. Earlier, the Turkish shipbuilding was focused on small to mid-sized commercial vessels. After 2010, the shipyards in Türkiye diversified their activities into ship repair and maintenance as well as naval ship production in response to the changing market conditions. Another important production area of Turkish shipyards is the yacht building. In mega-yacht production, for total delivered yacht-length criteria, Türkiye currently exchanges 3rd and 2nd positions between the Netherlands, Italy being the first (GİSBİR 2020, 2023; OECD TR, 2021).

2.2.3.2 Shipyard Capacities

Production capacities of the shipyards are shown in Table 2.8 and Figure 2.8 along with realized total global ship production between 2004-2021. As of 2021, the total maximum

average production capacity of the shipyards worldwide was approximately 143,500,000 Gross Tons but the average capacity estimation was 63,000,000 Gross Tons and total completion was 60,600,000 Gross Tons. Real applicable maximum capacity and excess capacity of shipyards, their accurate measurement is critical information for shipbuilding and maritime trade stakeholders. To manage this requirement OECD has made a study on maximum average and average shipbuilding capacity assessment globally based on 15-year deliveries of the shipyard (Gourdon et al., 2023). In Table 2.8 and Figure 2.8, those more reliable estimates were used. It should be noted that between 2010 and 2014, the completions were record high at all times due to LNG Tanker orders and rapid infrastructural developments in China.

Table 2.8: Global shipbuilding completion (SAJN, 2022), approx. Average and Max. Production Capacities of global shipyards in Million GT (Gourdon et al., 2023).

Year	Estimated Average Production Capacity (approx.)	World Completion (Total)	Estimated Max. Avg. Production Capacity (approx.)
2004	38	40.8	50
2005	41	47.0	58
2006	48	53.2	61.5
2007	52	57.2	71
2008	60	68.1	80
2009	70	78.5	92
2010	82	98.1	106
2011	95	103.4	122
2012	100	96.5	135
2013	92	71.4	138.5
2014	80	64.2	139.5
2015	70	67.7	140
2016	68.5	66.6	140
2017	66	65.9	140
2018	65.5	58.3	140
2019	65	66.2	140.5
2020	63	57.8	142
2021	63	60.6	143.5

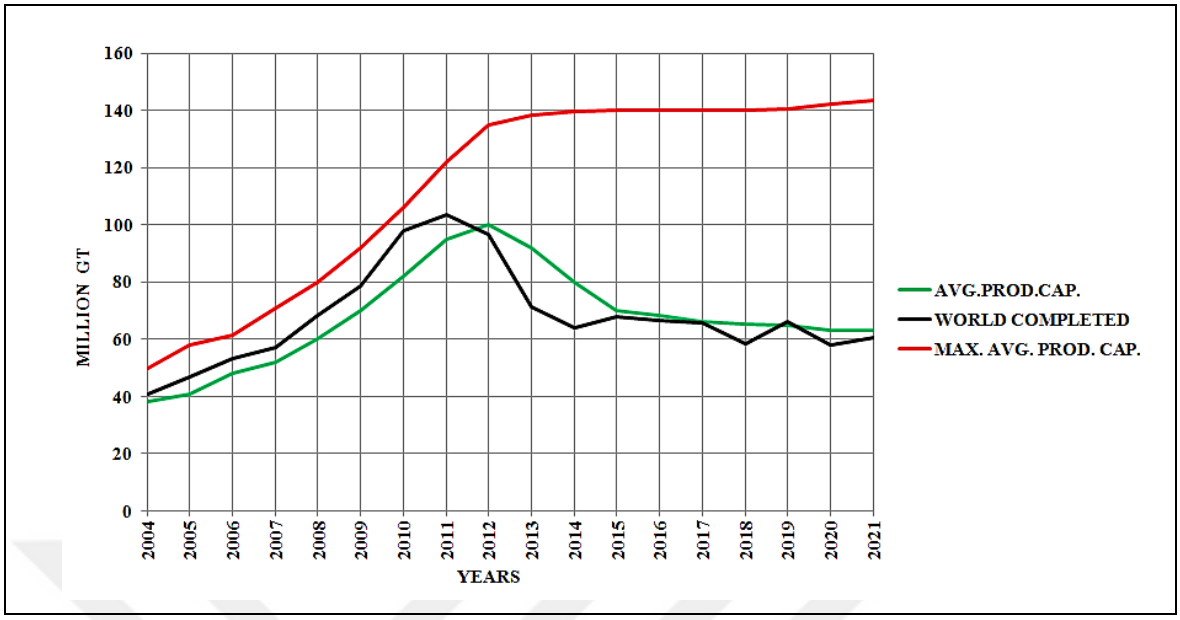


Figure 2.8: Global shipbuilding completion (SAJN, 2022), approx. Average and Max. Production Capacities of global shipyards in Million GT (Gourdon et al., 2023).

The maximum production capacities of shipyards in Türkiye are given in Figure 2.9. Demand for product tankers helped an increase in the number of shipyards in Turkiye after 2007 with the 4,740,000 DWT maximum production capacity reached in 2022.

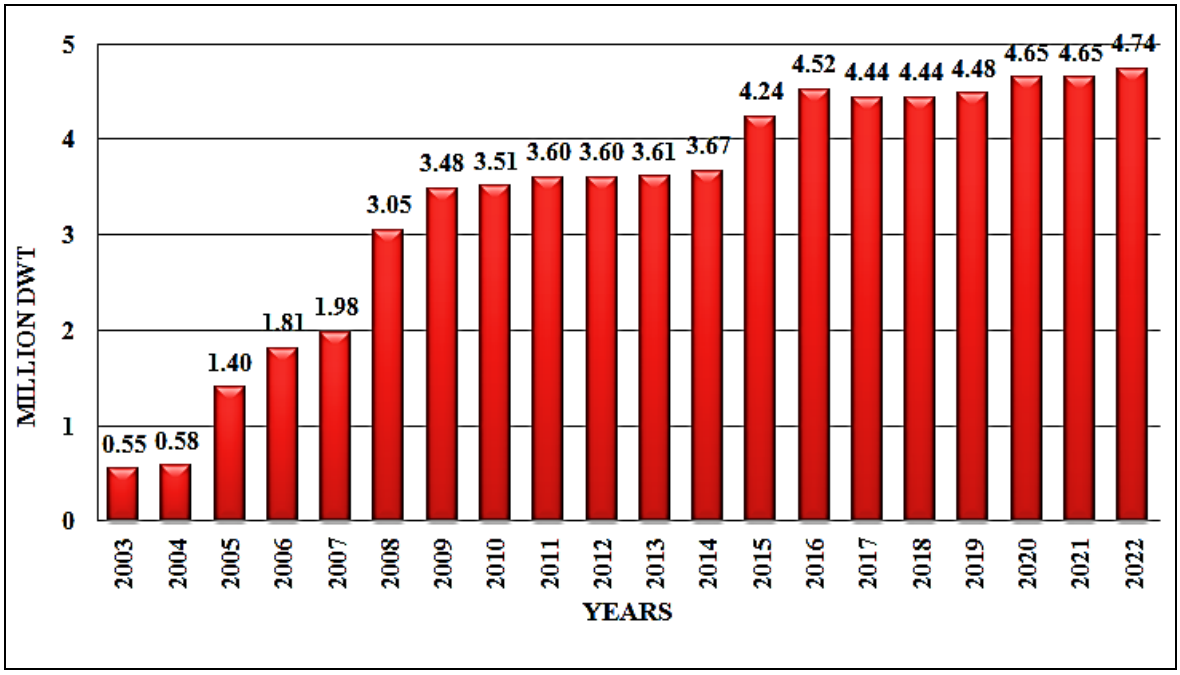


Figure 2.9: Maximum production capacities of Turkish shipyards (in million DWT) (Ministry of Transportation, 2023).

2.2.3.3 Global Commercial Shipbuilding

As shown in Table 2.9 and Figure 2.10, three Asian countries, Japan, South Korea, and China lead in commercial shipbuilding globally for the last two decades. While until 2008, the total completions of Japan, South Korea, and China was about 5 times higher than the rest of the World, after 2009 this difference was reached about 12-15 times higher. This was mainly due to the larger size of the ships built by those three countries such as the largest LNG Tankers and Container Ships, and also shipyards' higher technological levels than the rest of the World.

Table 2.9. Global shipbuilding completions between 2001-2022 in Million GT (Source: SAJN, 2022).

Year	S. Korea	Japan	China	Europe	Others
2001	11.900	11.800	1.800	4.500	1.100
2002	13.000	12.100	2.600	5.100	1.400
2003	13.800	12.500	3.800	4.700	1.500
2004	15.200	14.600	4.900	4.600	1.500
2005	18.200	16.400	6.300	4.600	1.500
2006	19.000	18.100	8.400	5.800	1.900
2007	20.600	17.400	10.800	6.400	2.000
2008	26.400	18.800	14.400	6.400	2.100
2009	28.900	19.000	23.500	5.000	2.100
2010	32.200	20.100	37.800	4.800	3.200
2011	35.900	19.300	41.200	3.000	4.000
2012	31.400	17.400	40.300	2.300	5.100
2013	24.800	14.500	27.000	2.000	3.100
2014	22.300	13.400	23.200	1.800	3.500
2015	23.800	12.900	25.400	1.600	4.000
2016	25.700	13.400	22.100	2.700	2.700
2017	22.600	13.100	23.900	2.400	3.900
2018	15.000	14.400	23.300	2.100	3.500
2019	21.700	16.200	23.500	2.500	2.300
2020	18.300	12.800	23.300	1.700	1.700
2021	19.700	10.700	26.900	1.900	1.400
2022	7.800	4.800	14.400	2.500	1.100

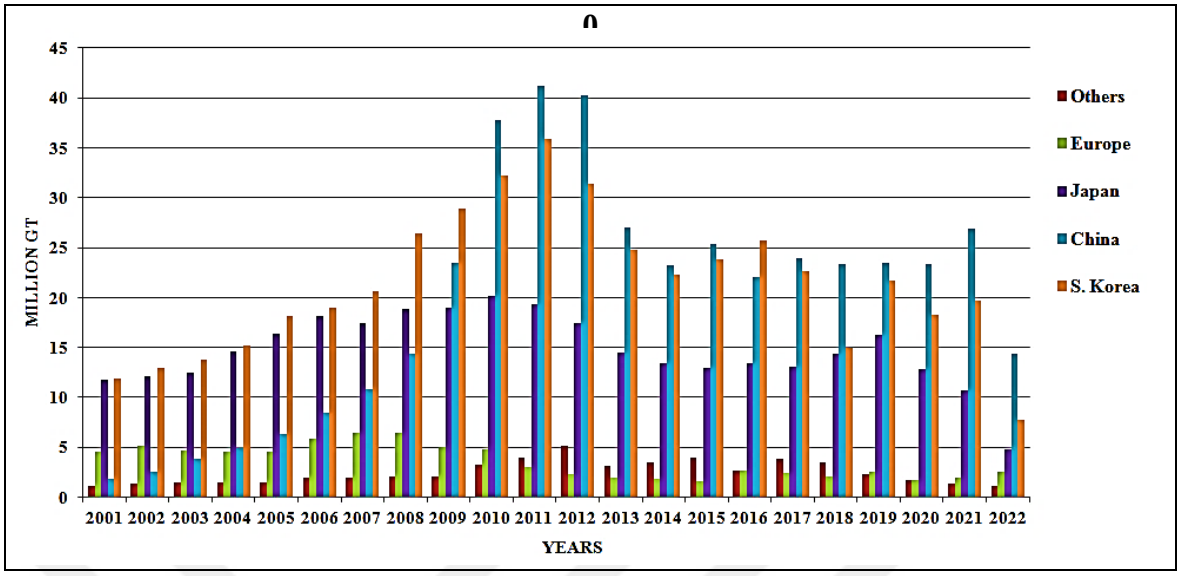


Figure 2.10: Global shipbuilding completions between 2001-2022 in Million GT (Source: SAJN, 2022).

The increase in deliveries between 2010 - 2012 is the effect of a continuous increase in orders before 2008, their deliveries. While the total completions reached 103,400,000 Gross Tons in 2011, a sharp decline in reduced orders due to the global recession in 2008 and the following years and the effect of the COVID-19 period in 2022 are also seen in Figure 2.11.

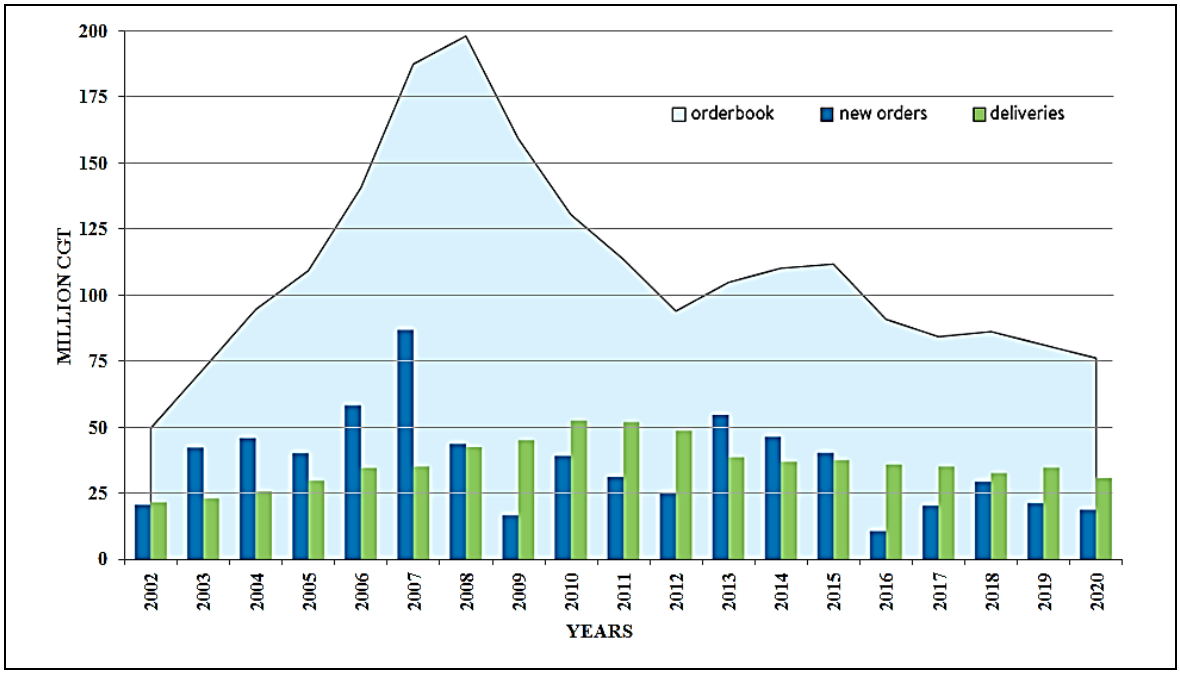


Figure 2.11: Global commercial shipbuilding activities between 2002-2020 in million CGT (Source: SEAEUROPE, 2020).

A four-year time frame for completions at leading nations of Europe in commercial shipbuilding is given in Table 2.10 and Figure 2.12 for the 2014-2017 period, At this period, Romania led the completions followed by Germany and Italy. Also, the status for a larger time frame with 29 European nations is given in Figure 2.13.

Table 2.10: Shipbuilding completions at some European countries in Million GT (Source: UNCTAD, 2019).

Year	Romania	Germany	Italy	Norway	Netherlands	Türkiye	Finland	France	Croatia
2014	0.329	0.499	0.304	0.249	0.131	0.140	0.102		0.038
2015	0.403	0.383	0.219	0.167	0.134	0.119	0.115		0.075
2016	0.848	0.431	0.421	0.135	0.174	0.107	0.108	0.228	0.074
2017	0.591	0.470	0.470	0.068	0.106	0.115	0.173	0.173	0.123

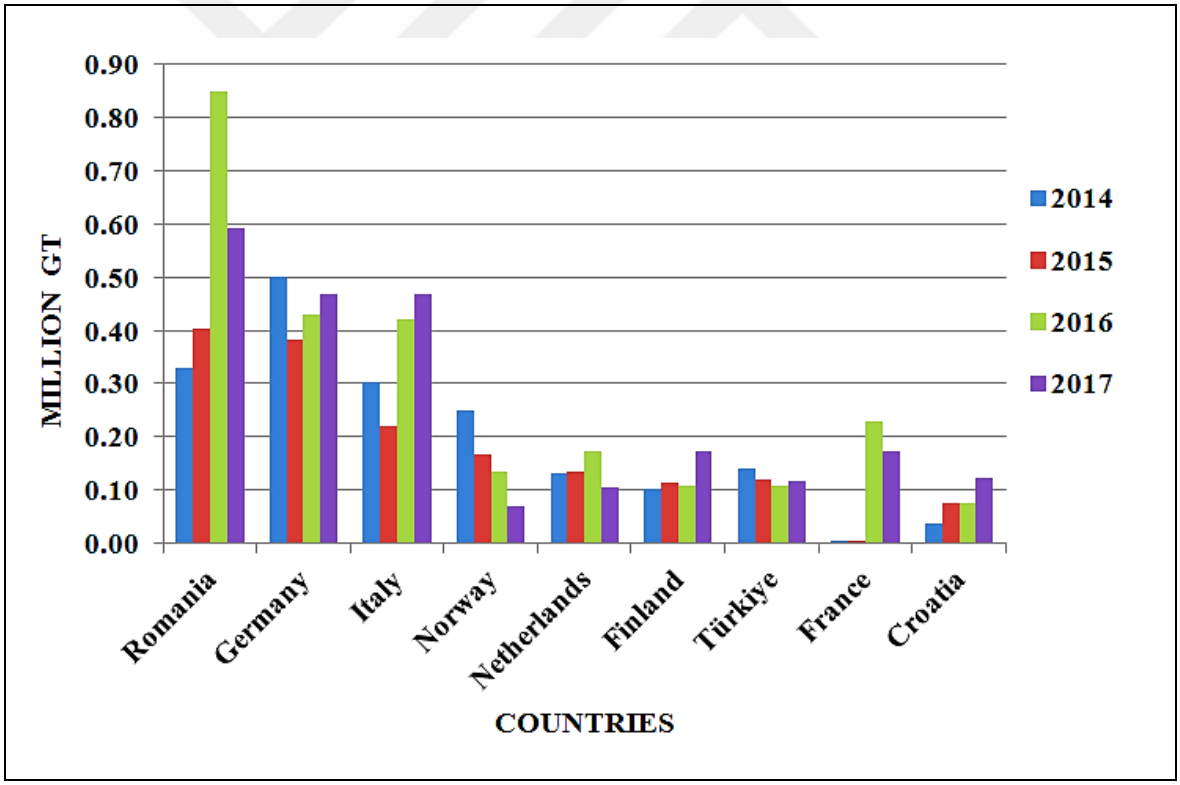


Figure 2.12: Shipbuilding completions in some European countries in Million GT. (Source: UNCTAD, 2019)

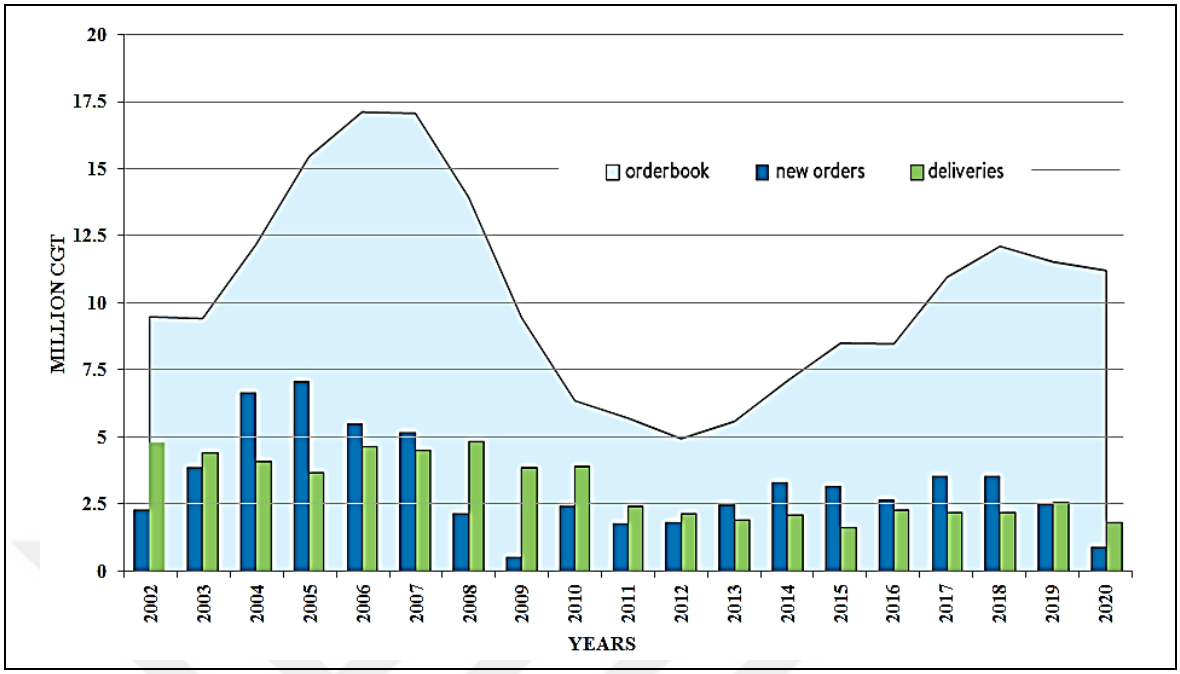


Figure 2.13: Shipbuilding completions at 29 European countries in Thousand CGT (Source: SEAEUROPE, 2020).

Completions in Türkiye between 2000 - 2019 and Türkiye's share in the global market is given in Figure 2.14.

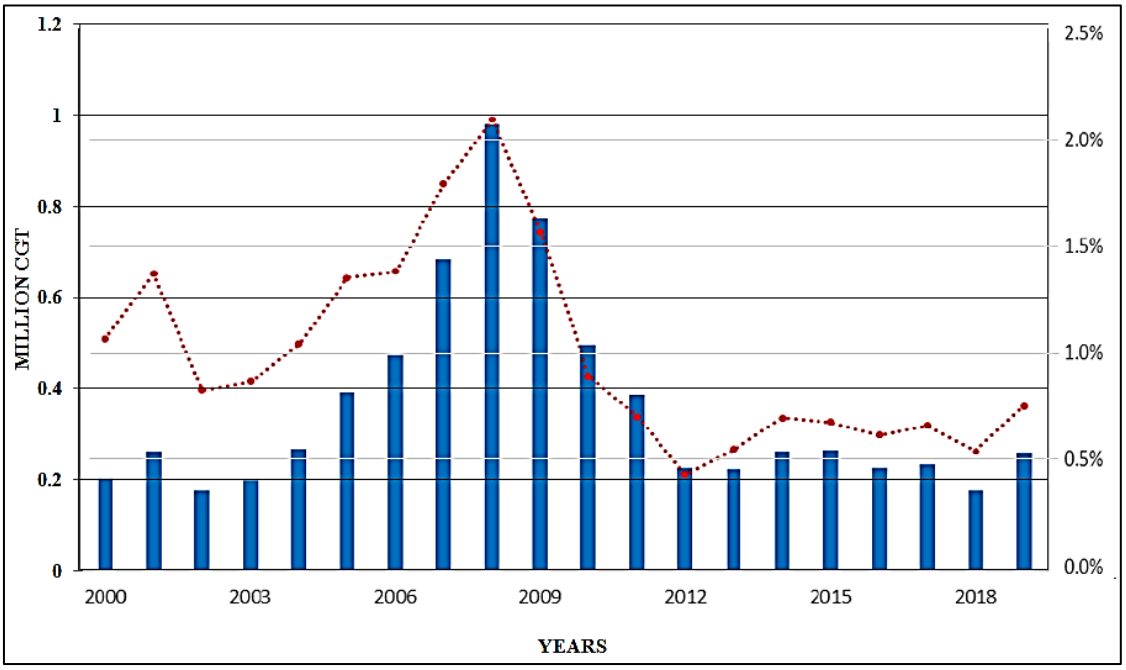


Figure 2.14: Shipbuilding completions in Türkiye and global market share in Thousands CGT (OECD, 2021).

In addition to information on tonnage, the economical size of the shipbuilding industry is important. The global shipbuilding industry, at its maximum-ever high production period at the end of the first decade of the 2000s, provided an output of USD 346 billion in 2015 (Gourdon and Steidl 2019). Then global recessions, COVID-19 effects and economical de-stabilization in the world affected the shipbuilding industry adversely. In 2021, the global shipbuilding market was valued between USD 132.52 billion (Hossain 2023) and USD 138.9 billion (Skyquest, 2023). For 2022 value of orders was USD 124.3 billion (Gordon, 2023) and the expectation was USD 143.34 billion (Skyquest, 2023). Revenue of the top ten shipyards in the World in 2020 changed between USD 39.33 billion and USD 1.18 billion (Hossain, 2023).

2.2.3.4 Order book and Forecasts

It was estimated that shipbuilding capacity is about 40% lower compared to the last decade and moderate or marginal capacity increases in the medium term are expected only (OECD, 2023b). Orders are expected to continue based on ship renewals, due to aging and also emissions reduction regulations. Freight rates, market expectations, and prices of second-hand ships are the other factors influencing the demand for ships (OECD, 2023b). From the shipyard side, higher new-build prices due to price increases in inputs (labor and material), berth availability due to reduced numbers of active shipyards, exchange rates, and government subsidies are important factors (OECD, 2023b). Therefore, shipyards should be more competitive and more agile (Gordon, 2023). Current figures show an optimistic increase in orders than forecasted as shown in Figure 2.15.

Years	Forecast (Approx.)	Actual Orders (Approx.)
2022	26.0	55.7
2023	27.0	70.0
2024	28.0	59.0
2025	29.0	29.0
2026	30.0	12.5
2027	31.5	
2028	32.5	
2029	34.0	
2030	35.0	

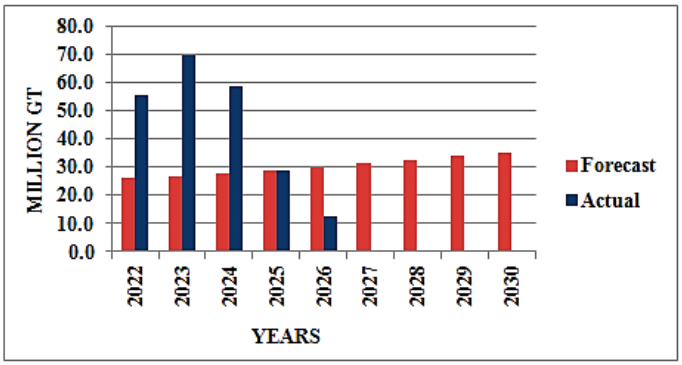


Figure 2.15: Global commercial shipbuilding order forecast (approx.) (Source: Daniel et al., 2022) and current actual orders (approx.) (Source: Willmington, 2023) in Million GT.

It should be noted that the actual orders were higher than the forecast and for the 2022-2024 period, reached around 60,000,000 Gross Tons, which is at the arithmetical mean of the World completions between 2001- 2022.

2.2.3.5 Shipyard Productivity

From the productivity of the shipyard's aspect, here some numerical information will be provided.

The Compensated Gross Tonnage (CGT), as explained before, is currently the most in-use shipyard productivity measure parameter globally. In the search of shipbuilding productivity-related literature, it is the second method with regard to the maximum number.

The information in Table 2.11 is for three major shipbuilding countries in Asia and Europe. Several productivity metrics and their values based on CGT as presented in 2007 are given in Table 2.11. (Lamb, 2007). However, the factors used during the calculation of values in Table 2.11. is thought to be from 1984. According to Table 2.11, Japan leads in CGT per Man x Year and Steel Weight in tons per Man x Year. China has the highest value compared

Table 2.11: Several productivity metrics and their values based on CGT (Lamb, 2007).

S. Nr.	Productivity Metric	Japan	S. Korea	China	Europe
1.	CGT/MxY incl. OS*	125 - 205	95 - 121	22 - 39	25 - 140
2.	MxH/CGT incl. OS	9 - 15	16 - 21	52 - 103	12 - 15
3.	Steel Weight (tons)/MxY	100 - 270	33 - 56	15.6 - 30	8 - 36
4.	Steel Weight (tons)/Shop Area (sq.m.)	1.7 - 2.8	1.9 – 3.0	1.0	0.48 - 0.52
5.	CGT/Shipyard Total Area (sq.m.)	0.3 - 0.8	0.4 - 1.25	0.18 - 0.5	0.28 - 0.78
6.	Annual CGT/ Shop Area (sq.m.)	3 - 6	3 - 8.5	0.5 - 1.41	1.12 - 2.04
7.	CGT/Building Berth Area (sq.m.)	3 - 10.5	10.5 - 17.5	6.24 - 10.9	7 - 14

*OS. Outsourcing (in shipyard subcontracted labor)

to Japan, S. Korea, and Europe in Man x Hour per CGT which shows a problem while Japan and Europe were more productive. South Korea leads in steel processed per shop area, CGT per shipyard area, and building berth area.

As given in Table 2.12 and Figure 2.16 below, between 1999 - 2011 Türkiye was not in the top league but it was not also at the lowest productivity ranks. Since the data was not and the utilized method is not robust (i.e., from the source reference and also applied by the student in transforming the tabulated information therein to a Man x Year calculation), making sharp judgments will not be correct. But there were periods when Turkish shipyards' productivity was close to those of China and Europe's 14 countries. This assessment is indicative only, but it shows that there is still room for Türkiye for improvement to strengthen its competitiveness (OECD, 2011).

Table 2.12: Turkish shipyards' productivity metrics based on CGT/MxY and comparison for 2007 (Source: OECD, 2011).

Year	Türkiye	Japan	S. Korea	Europe 14 (*)	China
1999	45.2				
2000	19.8				
2001	21.6				
2002	8.2				
2003	14.7				
2004	17.3				
2005	13.8				
2006	15.6				
2007	19.8	179.3	100.1	40.5	26.0
2008	23.7				
2009	35.2				
2010	21.7				
2011	19.7				

(*) The 14 European countries: Croatia, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Spain and the U.K.

Data Envelopment Analysis (DEA) is the first method with regard to the maximum number of references reviewed during the shipbuilding productivity-related literature. It will be

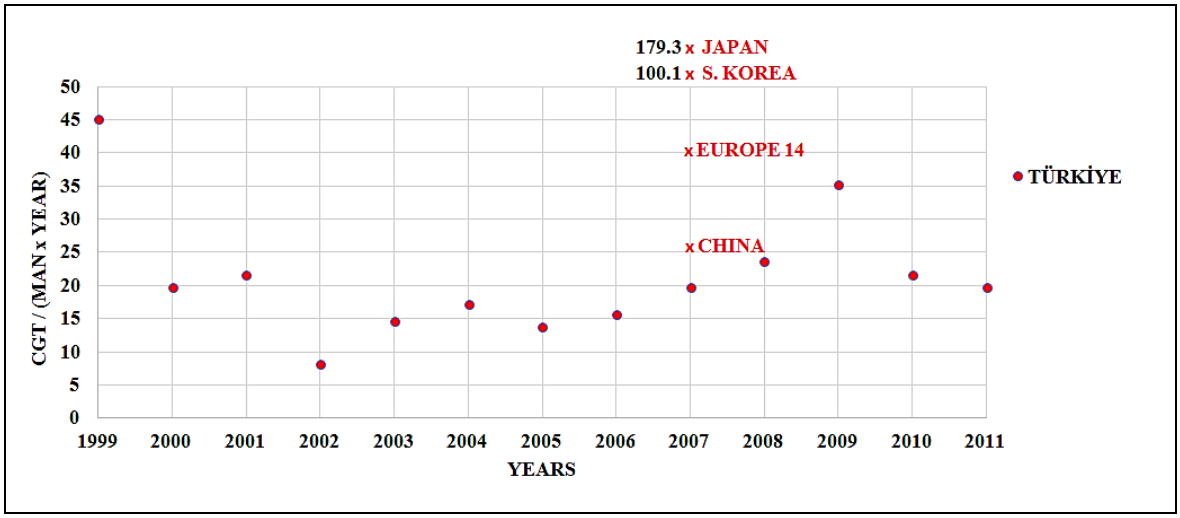


Figure 2.16: Turkish shipyards' productivity graph based on CGT/MxY and comparison for 2007 (Source: OECD, 2011).

explained in more detail in the Literature Review subsection below but as initial information; DEA is a linear programming method introduced by Charnes et al. (1978) through a development period from the 1950s to the 1980s (Charnes et al., 1994). It is mainly used in operations research and economics fields for the estimation of production frontiers at multiple input or output conditions and to measure relative efficiency and productivity (Krishnan, 2012).

The initial use of this method was seen at the beginning of the 2000s. Despite it is rather used as a competitiveness measure and for specific time frames based on the periods of the data, it provides some brief information on the shipyard productivity and limited major improvement areas as shown in Table 2.13, just to give some numerical examples. In Table 2.13, changes in shipyard efficiency, best practices, and technical leadership of eight South Korean, seven Chinese and six Japanese shipyards were measured by Chao and Yeh (2020) for the 2014-2015 period.

As mentioned earlier, the "human" factor is a key element in shipbuilding productivity. In Figure 2.17, the changes in shipbuilding productivity due to changes in unit labor costs and employee compensation is shown, a sample from Japanese shipbuilding between 1985-2008. The opposite relationship between productivity and unit labor cost and the parallel relationship between productivity and compensation has been demonstrated.

Table 2.13: Example DEA results (Source: Chao and Yeh, 2020).

S. No.	Result Sets	Shipyards	Change in Efficiency	Change in Best Practices	Change in Technical Gap
1	Shipyards with efficiency gain, technology progress and technical leadership progress		**≥ 1**	**≥ 1**	**≥ 1**
		K1	1.74	1.05	1.02
		K4	1.00	1.13	1.03
		C2	1.00	1.11	1.00
		C3	2.17	1.11	1.51
		C7	1.35	1.21	1.24
		J1	1.11	1.01	1.28
		J5	2.13	1.18	1.00
2	Shipyards with efficiency gain, technology progress and **technical leadership regress**		**≥ 1**	**≥ 1**	**≤1**
		K6	1.23	1.05	0.90
		J2	1.07	1.01	0.64
		C5	5.83	1.12	0.71
3	Shipyards with efficiency gain, **technology regress** and technical leadership progress		**≥ 1**	**≤1**	**≥ 1**
		J6	1.00	0.61	1.00
4	Shipyards with **efficiency loss**, technology progress and technical leadership progress		**≤1**	**≥ 1**	**≥ 1**
		C4	0.29	1.19	1.11
		C6	0.46	1.11	1.00
		J3	0.70	1.05	1.00
		J4	0.50	1.18	1.00
5	Shipyards with efficiency gain, **technology regress** and **technical leadership regress**		**≥ 1**	**≤1**	**≤1**
		K2	1.10	0.95	0.96
		K3	1.04	0.94	0.98
6	Shipyards with **efficiency loss**, technology progress and **technical leadership regress**		**≤1**	**≥ 1**	**≤1**
		K5	0.56	1.01	0.98
		C1	0.74	1.22	0.84
7	Shipyards with **efficiency loss**, **technology regress** and technical leadership progress		**≤1**	**≤1**	**≥ 1**
		K8	0.97	0.98	1.04
8	Shipyards with **efficiency loss**, **technology regress** and **technical leadership regress**		**≤1**	**≤1**	**≤1**
		K3	0.90	0.92	0.93

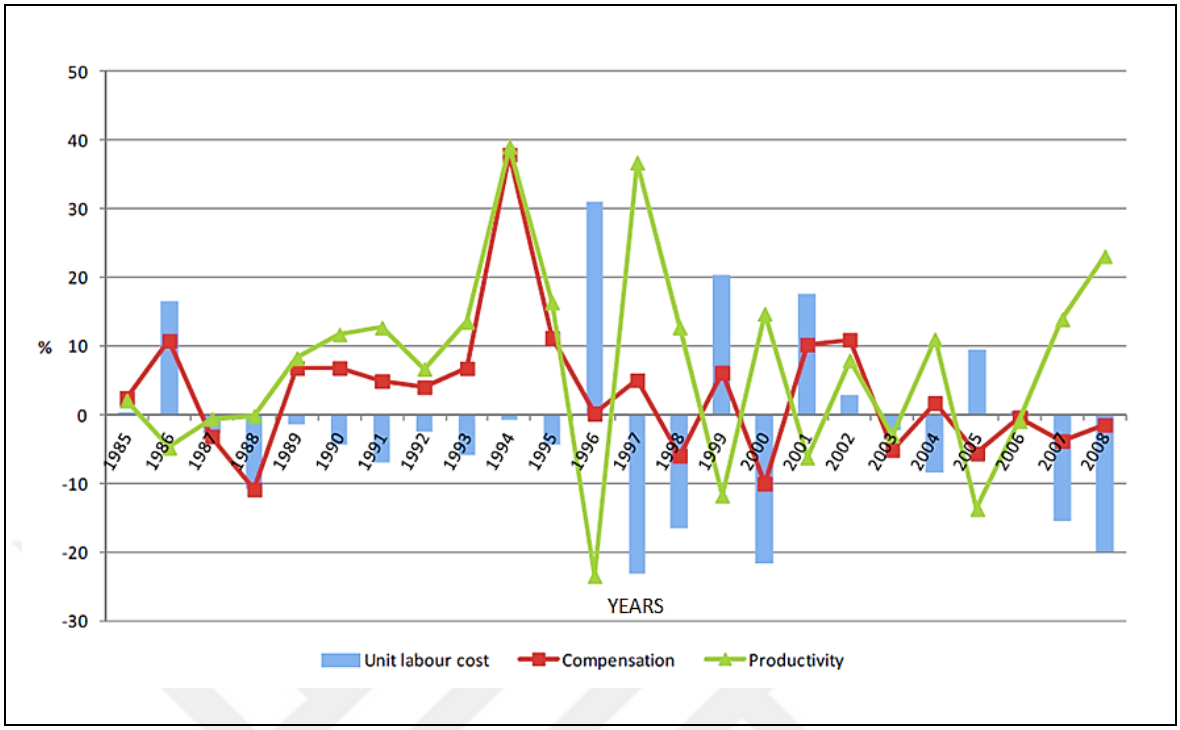


Figure 2.17: The contribution of changes in unit labor cost and employee compensation on productivity in Japanese shipbuilding (OECD, 2016).

At the end of this presentation on preliminaries, the important question is how to improve a shipyard at Technological Level 3 with one or two ship deliveries in a year to a shipyard at Technological Level 6 which also can deliver 33 giant size ships in 2021 (HD HYUNDAI, 2023). There exist a few shipyards already at Technological Level 5 or 6 which deliver a high number of large-size ships in a year. But also, there are many shipyards at Technological Level 3 or 4 with a low number of ship deliveries in a year and there must be some means for improvement strategies at least internally.

2.3. Literature Review

To investigate the need and in search of a gap in previous research, an extensive literature survey, initially by a quick review, classification, and archiving (prints, soft media) before the Thesis Proposal was deemed necessary. As this Ph.D. study aim was shaped on productivity, which is a very broadly used concept by industrial sectors, a survey on Industrial Engineering and Business Administration literature was made to review developed methods and approaches in previous research in addition to the literature on shipbuilding. Literature on the mathematical aspects of spline curves, and references on elasticity in

physics were also taken into consideration. During the Ph.D. study, the literature review continued with a more focus on shipyard productivity and with the help of other related references. During the study period, the new publications were also followed. In the following subsections, first, the breakdown of the literature review will be listed, then major previous studies on methods developed in the past on shipyard productivity will be explained. The references on the "Effects" and "Curves" will be investigated later in Section 3 of this thesis in their dedicated subsections.

2.3.1. Classification

During the literature review about 2850 references, composed of books, research and conference papers, reports, graduate and undergraduate theses, course notes, and internet data sources reviewed from open sources (internet and libraries), student's and his advisors' libraries. About 10% of the references are duplicated in the classification due to their cross-disciplinary content, therefore actual number of references can be taken as 2560 roughly. It was not possible to read them all, except 62 special publications as mentioned in subsection 2.3.2. below in due time of this research but they have been reviewed as needed. A few references in other languages than Turkish and English were translated into English with the help of DeepL[16] website.

The literature was classified under the major headlines of;

- Industrial Engineering field, published between 1928 and 2023 on Productivity, Efficiency, Factory Physics, Operations Research, Stochastic Methods incl. Decision-Making Methods, Production & Progress Functions, Queuing & Sequencing, Production Techniques & Methods, etc.
- Business Administration field, published between 1958 and 2020 on Productivity, Efficiency, System Dynamics, Planning & Scheduling, etc.
- Mathematics field, published between 1960 and 2022 on Optimization, Spline Curves, Mathematical Modeling, etc. and physics field, published between 1957 and 2018 on Elasticity of Materials, and

[16] A document translation website https://www.deepl.com

- Shipbuilding field, with about 1550 references published between 1959 and 2023 on Shipyard Efficiency and Productivity, Competitiveness in Shipbuilding, Shipbuilding Processes & New Technologies in Shipbuilding including Hull Block Production & Assembly, Piping, Outfitting-Painting, Shaft Alignment, Materials Management & Supply Chain, Simulation in Shipbuilding (Virtual Shipyard, Virtual Reality), Robots, Green Technologies and Quality Assurance and also Human Factors and Ergonomics

There are about 30 citations in this thesis to references with publication dates before 2000. Twelve of them are directly related to the special focus on the entire shipbuilding process productivity as explained in subsection 2.3.2. below. The others are referenced due to their importance in the subject of this thesis, or to identify their position as a key reference still, or to remember the historical origin of the related subject.

2.3.2. Methodology Based Review

Numerous research exists on efficiency, performance, and productivity measurement and evaluations on Ship Production, Shipbuilding Management, Ship Design processes and competitiveness in shipbuilding. During the literature review, with a special focus on the entire shipbuilding process productivity, it was observed that the U.S. National Research Council (1982) prepared a comprehensive report on productivity improvements in U.S. Naval Shipbuilding; Weiers (1984) prepared another comprehensive report on the productivity problem in the U.S. shipbuilding for commercial ships. But none of these references proposed a numerical method. However, 62 papers & references were reviewed which strictly cover shipyard total efficiency or productivity measurements and/or evaluations in 21 different methodologies. Table 2.14 below lists the research on these 21 methodologies, also in chronological order.

It is noted that only three of these 21 methods were more emphasized in 53% of the reviewed papers & references, but even these methods have not become a globally applied productivity measurement and evaluation method for the Shipbuilding industry yet. The yearly distribution graph of the 62 references in Figure 2.18 shows the increasing trend in shipyard productivity, especially 4-5 papers per year after 2016.

Table 2.14: Methodologies and references on entire Shipyard Productivity.

No.	Methodology	References
1.	**Compensated Gross Tonnage (CGT) System**	OECD 1984; Lamb 1998; Koenig et al., 2003; Craggs et al. 2003, 2004; Bruce 2006; First Marine International (FMI) 2005; OECD 2007; Cagalj 2009; Zakaria et al.,2010; Roque 2019. Roque and Gordo 2020
2.	**Productivity Space**	Todd 1980, Lamb 1986.
3.	**Global and Local Performance Matching**	Bruce 1992.
4.	**Performance gradient, Break-even Threshold**	Birmingham et al.,1997.
5.	**Shipbuilding Productivity Prediction Equation (SPPE)**	Lamb 1998; Lamb and Hellesoy 2002; Lamb 2002; Lamb 2007; GİSBİR 2016.
6.	**Overall aspects, production function and Group Technology**	Storch et al. 1988; Storch et al. 1995.
7.	**Search-Based Heuristic Algorithms**	Lee et al. 1996.
8.	**Value Added, Value Chain**	Frankel 1983, OTA 1983, Koenig 2002.
9.	**Linear Programming (LP)**	Moyst and Das 2008.
10.	**Data Envelopment Analysis (DEA) along with the new DEA based ESAM ve SSML methods**	Zhangpeng and Flynn 2006; Pires and Lamb 2008; Pires et al., 2009; Colin and Pinto 2009; Park 2010; Krishnan 2012; Lee 2013; Rabar 2015; Chudasama 2016; Açık et al., 2017; Guofu 2017 Mayo 2018; Fareza 2020; Chao and Yeh 2020; Xue 2020; Woo et al. 2021.
11.	**Analytic Hierarchy Process (AHP)**	Kirdagli 2010; Stanic et al. 2017.
12.	**Labor and Material**	Sharma 2014; Huijgens 2016.
13.	**Quality Function Deployment (QFD)**	Hadjina et al., 2015.
14.	**Bayesian Network**	Hellgren 2016; Hellgren et al. 2017.
15.	**Total Factor Productivity (TFP)**	Benzaquen 2017; Gourdon 2019
16.	**Theory of Constraints (TOC)**	Çelebi 2018
17.	**Computational Shipyard Dynamics (CSD), process-centric simulation**	Kim et al. 2018; Shin et al. 2020.
18.	**Shipbuilding Maturity and Capability Model (S-MCM)**	Yıldırım 2018.
19.	**Key Performace Indicators (KPI)**	Bilen 2022; Bilen et al.,2022; Cui 2022.
20.	**Value Engineering and Risk Assessment (VENRA)**	Baihaqi et al. 2022
21.	**Shipyard Technological Level Evaluation**	Rubesa et al., 2023.

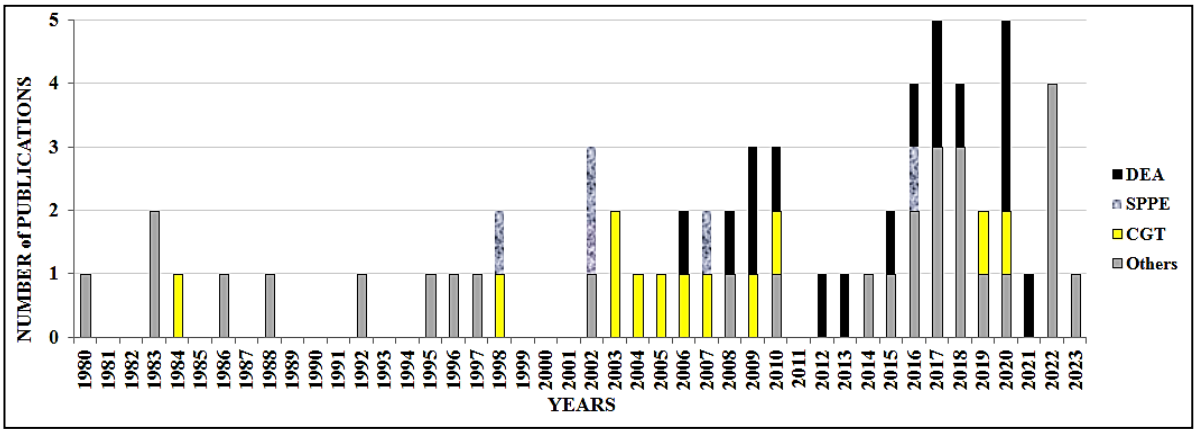


Figure 2.18: Yearly distribution of 62 references.

2.3.2.1 Compensated Gross Tonnage (CGT) System

The Compensated Gross Tonnage (CGT) is the most globally in-use shipyard productivity measure parameter. In the search of shipbuilding productivity-related literature, the second method with regard to the maximum number of references is on the CGT. Twelve of the 62 publications emphasize this method. *(The first method Data Envelopment Analysis (DEA) and the third method Shipbuilding Productivity Prediction Equation (SPPE) will be explained below later on.)*

Below are the references reviewed on which the focus is on the shipyard productivity by the use of CGT as a parameter.

Frankel's (1983) symposium paper is the first time it was seen that CGRT/employee/year and MH/CGRT measures were mentioned. The purpose was to show growth in private U.S. Shipyards' productivity per year for a 10-year period (1970-1980). Despite in this paper the focus was on Value Added approach, the length of the shipbuilding cycle time was also defined as a function of shipbuilding productivity for the first time. Then, in the course notes of the University of Michigan (1995), it was stated that if "MxH/CGT" and "Cost/MxH" are known, "Cost/CGT" can be obtained. He pointed out "CGT/MxH" as a cost indicator. In his conference paper, Lamb (1998) stated that CGT had changed from a country-scale measure to an individual shipyard-scale measure and started to be used as a productivity metric parameter in terms of CGT/MxY or MxH/CGT which is a significant improvement over the

use of steel weight as a productivity measure. Lamb was correct and CGT/MxY or MxH/CGT is still the most widely used among shipyards as a productivity measure in the world. However, the student believes that the CGT measure has handicaps as mentioned by other researchers in their work below and by the student at the end. Its weakest part is not defining a solid target productivity for a specific shipyard, and this is one of the gaps found for this thesis.

In their study, Koenig et al. (2003) made comparisons between Japanese and S. Korean shipyards on an annual time scale, mainly in terms of CGT/MxY. Craggs et al. (2003) proposed a set of CGT coefficients for naval ships which were not available in OECD (1984). Discussions on the Craggs et al. (2003) paper continued in 2004 and after the FMI (2005) study, then the use of the CGT system for naval ship production diminished in literature. In this thesis, the methodology does not differentiate naval ships and commercial ships in analyses. A benchmarking study was presented by FMI (2005) to compare the U.S. and International Shipyards on a global shipbuilding industrial base. In this study, the shipyards were compared against their performances on a best practice scale; priority areas for improvement and industry-wide actions for improvement were listed. Productivity (MxH/CGT) is compared to the overall best practice rating of FMI. Cost/CGT was used in the decision on the use of best practices at a required minimum. FMI (2005) was one of the references for the investigation of Effects in this thesis.

Bruce (2006) highlighted some of the uses of CGT in shipyard performance mainly in terms of CGT/MxY. He proposed a new approach for simplification and clarification. Further research to review the compensation factors, and to seek a mathematically derived function to define the compensation factors was recommended. Later in 2007, as mentioned above OECD (2007) was published.

In his study, Cagalj (2009) mentioned that finding a method for productivity measurement in shipbuilding is harder than in other industries. He expressed that shipyard productivity can be expressed in two ways: MxH/CGT and CGT/employee/year. This was also mentioned in Frankel (1983). In their paper, Zakaria et al. (2010), took MxH/CGT to study the productivity of shipyards nationwide and identified the areas to be improved. In Roque's

M.S. Thesis (2019), and in the related paper Roque and Gordo (2020) proposed “a systematic approach to quantify and monitor the productivity of shipyards” in MxH/CGT terms along with the evaluations on the effect of the learning curve in productivity; data of 30 ships built in a shipyard was used therein.

CGT is currently a global parameter in measuring shipyard productivity but there exist shipyards that refrain from using it, or declaring it even though they use it, due to concerns about revealing their competitiveness level information. This shows that CGT may be accepted as a measure of competitiveness rather than providing a comfortable metric that a shipyard can evaluate its position and its target for improvement, along with a missing list on prioritization of its improvement needs. Discussions on calculation standards for "MxH" continue due to the complex involvement of subcontractors, and outsourced labor in the shipbuilding processes while the CGT system still keeps naval shipbuilding, a major production field, out of the scope.

2.3.2.2 Productivity Space

Todd (1980) and later (Lamb 1986, 1998) and the University of Michigan, (1995) mentioned the "Productivity Space", which is one of the three geometrical approaches seen during the literature review on shipbuilding productivity, with the definition of major elements in productivity. Todd (1980) defines the work output as the volume of a cube. Then, the x-axis represents the "performance", the y-axis represents the "utilization" and the z-axis represents the "method level" which is composed of "productivity factors" as also stated in Lamb (1986). The productivity space is shown in Figure 2.19. Todd (1980) provided a numerical example with some given percentage improvement on each axis, resulting in the growth in percent in the volume of the cube, namely work output.

In his "Design and Engineering for Ship Production" textbook, Lamb (1986) explained the benefits of integrated engineering in detail which leads to overall productivity improvement. Ideal conditions for work tasks were mentioned. Based on the Productivity Space approach, Lamb (1986) stated that shipyard facilities, management, and labor utilization can be

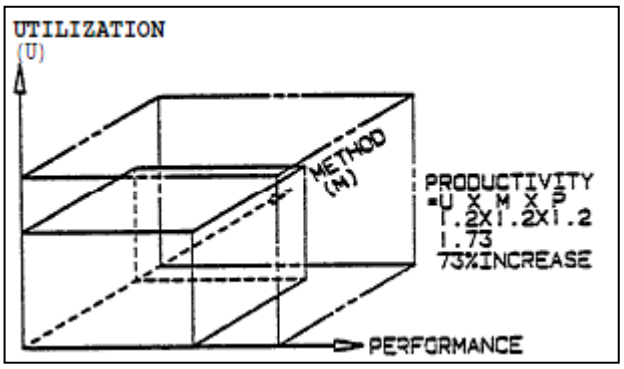


Figure 2.19: Productivity Space (Lamb, 1986).

considered as performance, method, and utilization which may define the productivity in the three coordinates. Productivity can be increased directly if any of them can be improved but when improvements are realized on three of them at the same time, rather than simply adding at different times, greater productivity can be reached at multiplied levels. Levels of the three productivity factors should be determined by the shipyard and improvements on the lower two should be made initially. If management and labor utilization need improvements first, facility improvement can wait. As an exception, if improvements in all three are intended, the productivity of the shipyard may have a quantum jump. In this thesis a similar intention exists, looking at the entire shipbuilding process as a whole to evaluate shipyard productivity. Lamb (1986) provided a similar simple numerical example to compare some shipyards.

2.3.2.3 Global and Local Performance Matching

In his paper, Bruce (1992) a systematic approach to use performance data to update the shipyard production model at local, corporate, and global levels and match them for achievable targets. After applying the provided steps, in his methodology, he proposed obtaining two performance targets, one bottom-up, the other top-down, then building a series of intermediate targets for each level of processes. This reference does not contain a numerical method to measure or evaluate the shipyard productivity but, in this thesis, a similar intention existed to set targets or major processes along with the target for the entire shipbuilding process

2.3.2.4 Performance gradient, Break- even Threshold

For a product, the breakeven point is reached when the costs of production become equal to the revenues. Birmingham, Hall and Kattan (1997) made a very valuable study on a capital investment program decision-making approach via performance gradient, break-even threshold methodology for shipyard technological development covering hardware and soft technological aspects. In this paper, the role of analytical methods in decision-making for shipyard improvement investments was explained very well, which also supports this thesis.

2.3.2.5 Shipbuilding Productivity Prediction Equation (SPPE)

In the shipbuilding productivity-related previous research review in this thesis, the third method with regard to the maximum number of references is the Shipbuilding Productivity Prediction Equation. Five of the 62 publications emphasize this methodology. This methodology was originated and developed by Prof. Dr. Thomas Lamb by the end of the1990s.

Lamb (1998) mentioned the "potential for developing a prediction equation for Productivity metric based on technology and other shipbuilding factors" after providing comprehensive information on shipyard productivity and competitiveness. Then, in Lamb and Hellesoy (2002) paper, and Lamb (2002) training notes, the Shipbuilding Productivity Prediction Equation was described, and numerical examples were provided. This is the first time in the literature review that actual shipyard productivity and target shipyard productivity were seen as mentioned, to benchmark internally in a shipyard. This approach also forms the soul of this thesis. But Lamb and Hellesoy (2002) carefully stated that "it is not the intent that the Productivity Predictor presented should be used by any shipyard to predict a “Target Productivity” based on its values of the parameters, but rather to show an approach of how it could be done and validate it." It was stated by Lamb and Hellesoy (2002) that, in the development of the equation, a questionnaire was distributed to 33 shipyards worldwide and only 10 shipyards responded. The expectation in this paper was the support by shipyards around the world which unfortunately was not realized despite the proposed equation covered naval shipbuilding. In Figure 2.20, the SPPE with updated coefficients throughout the time is shown (Lamb, 2007).

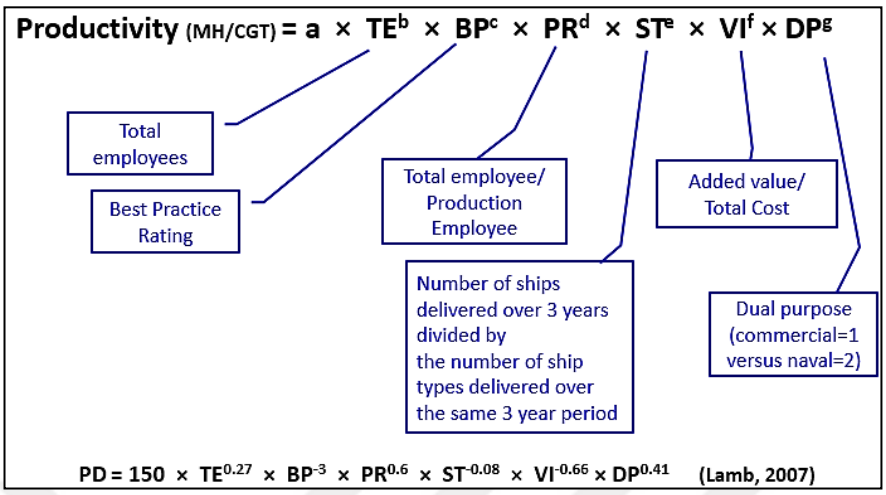


Figure 2.20: Shipbuilding Productivity Prediction Equation (SPPE) structure (Lamb, 2007).

Lamb and Hellesoy (2002) stated that the CGT system is not precise, and it is a representative value for the production capacity at the shipyard. CGT system is not an indicator to represent production management in the shipyard." But in Shin et al. (2020), criticism was made such that the Productivity Prediction Equation is general, and it is also not a production management indicator, especially for individual processes.

GISBIR (2016) study was the last reference the student saw. In this study, the Shipbuilding Productivity Prediction Equation was explained to shipbuilders in a nationwide frame to measure their competitiveness.

2.3.2.6 Overall aspects, production function and Group Technology

A production function is a mathematical equation system that defines the technological factors and quantity of production input sets (Shephard, 1970), and its relationship with quantities of output of goods. Lamb (1986) defined Group Technology as the integration of common job problem areas and tasks to improve productivity physically where mass production techniques are applied to widely varying products in type and quantity.

Storch et al. (1988, 1995) in their book "Ship Production", which is still one of the key books even after 40 years of its first edition, explained modern shipbuilding methods and processes

overall. This book is a compilation of know-how transfer on "Product Work Break Down (PWBS) methodology and respective studies from Japanese shipbuilding methods to the U.S., especially under the National Ship Research Program (NSRP). Under the Shipbuilding Management Theory in the book, important aspects of shipyard productivity were explained, and for the first and the last time the student saw a production function to be used for shipbuilding processes in previous literature. The book was first published during the student's master's degree study majoring in Ship Production at the University of Michigan and one of the authors, his advisor late Prof. Howard M. Bunch (RIP), presented this book to all his Ship Production class participants including the author of this thesis. Some of the teachings from the book were applied in his class. The student always wished for more information on shipyard productivity and maybe an extended part on some analytical models to be covered in this book. But later Prof. Bunch's successor Prof. Thomas Lamb's studies filled this gap. In this thesis, the student tried to put one more step ahead to those teachings with the shipbuilding productivity function in Section 3 below. When needed, also the terminology used in this thesis referenced to this book.

2.3.2.7 Search-Based Heuristic Algorithms

A heuristic algorithm procedure is used to determine near-optimal solutions to an optimization problem. Lee et al. (1996) concentrated on shipbuilding scheduling to level resource utilization in their paper, using a search-based heuristic algorithm methodology. Their analytical approach on ship production activities overall and their study to smooth workloads for a 5-year perspective were found interesting by the student. The work-load leveling method proposed for major shipbuilding processes doubtless has a positive effect on shipyard productivity. This study was made at one of the highly developed shipyards.

2.3.2.8 Value added, Value chain

Value added is the difference between the cost of purchased goods, services, and total revenues, all are under the effect of market imperfections (Frankel, 1983). A value chain is a string of activities that a firm performs based on its strategies to deliver a valuable product. The steps in the process at which value is added including sourcing, manufacturing, and marketing are identified by the chain (Porter, 1985)

In Frankel (1983) and OTA (1983) in a tabulated format, an annual Productivity Ratio for a 10-year time period (1970-1980) was shown where the productivity ratio is equal to the Value Added divided by the sums of Payroll and Depreciation. In Frankel (1983), the source of this table was given as J.A. Gribbin, and the student of this thesis unfortunately was not able to find this reference. This table is one of the earliest numerical definitions and evaluations of shipyard productivity during the student's literature review. Frankel (1983) also listed some productivity-enhancing measures for shipyards as available in the 1980s whereas today many shipyards are still trying to apply or have not applied yet. OTA (1983) was one of the important references in the 1980s in the U.S. which covered shipyards' productivity statuses and improvement problems & suggestions. This book was also given to all of his Maritime Management II class participants including the author of this thesis, by Prof. Dr. Anastassios N. Perakis in 1988 at the University of Michigan.

In his paper, Koenig (2002) defended that if the changes for value are achieved in productive processes, they are ultimately attributable to strategic changes in heavy industries. With a four-dimensional value chain approach he developed, he provided a review and evaluation possibility to the management of shipyards for different shipbuilding models. He suggested that decisions on the organization of production, the use of labor and capital, sourcing strategy, and product mix determine the competitive position, and breakdowns provide needed key information to be studied. This study was made at one shipyard. He took the shipbuilding process as a whole and considered the use of subcontractors.

2.3.2.9 Linear Programming (LP)

Linear programming (LP) is one of the mathematical modeling techniques. When subjected to various constraints, a linear function is minimized or maximized. This is an optimization problem where “the objective function is linear in the unknowns and the constraints have linear equalities and linear inequalities” (Luenberger and Ye, 2016). The ship production activities commonly start without waiting for the detailed design finalization. This is one of the key problems with multiple adverse effects on shipbuilding. In their paper, Moyst and Das (2008) studied an LP model under two scenarios and the LP model was used to find the optimum overlap for design and ship production along with the construction-associated total hours. LP scenarios in the paper were set on a reduction in overlap first, and secondly no

overlap. A reduction in direct labor hours, completion times, and entire project schedule were demonstrated. Despite this study being concentrated on reducing the adverse effects of rework, the analytical approach to improve the entire shipbuilding process and proposing a method to reduce project time are found important by the student, in parallel with this thesis.

2.3.2.10 Data Envelopment Analysis (DEA) along with the new DEA based ESAM and SSML methods

In shipbuilding productivity-related literature, Data Envelopment Analysis (DEA) is the first method with regard to the maximum number of references reviewed. Sixteen of the 62 publications emphasize this method. It was noticed from the reference lists of these 16 publications that there exist more publications on the use of DEA methodology for shipbuilding but unfortunately, they were not reachable by the student.

DEA is a linear programming method introduced by Charnes et al. (1978) through a development period from the 1950s to the 1980s (Charnes et al., 1994). It is mainly used in operations research and economics fields for the estimation of production frontiers at multiple input or output conditions and to measure the relative efficiency and productivity of DMUs (Krishnan, 2012). The point of interest for measurement, comparison, and evaluation is called Decision Making Unit (DMU) in DEA terminology. DEA helps in the identification of efficient DMUs, estimation of inefficiency scores, and through the projection of non-efficient DMUs on the efficiency frontier, estimating the improvement targets, or their potential performance (Pires, 2009).

The shipbuilding process, with its many inputs and outputs, was thought to fit in such a method and researchers have tried to apply it in the evaluation of the efficiency and productivity of shipyards. Limitations of the methodology, as to be mentioned later on below, have led researchers to use the DEA method for benchmarking shipyards rather than measuring and evaluating shipyard internal processes. Then, shipyards became the DMUs. Twelve of the 16 references reviewed have used DEA for the benchmarking of shipyards. But the other four references covered shipyard process efficiency and productivity studies with the DEA method to be explained later on below.

In DEA, two models are used; one is CCR (Charnes, Cooper and Rhodes) introduced in 1978 and the other is BCC (Banker, Charnes and Cooper) introduced in 1984 (Lee, 2013). CCR is an input-oriented model with Constant Returns to Scale (CRS) which allows modeling production processes where "inputs are resources or influencing factors, outputs are the expected results" (Pires, 2009). BCC is an output-oriented model with Variable Return to Scale (RTS) (Fareza, 2020). For the input-oriented model, DEA results provide a point of improvement by decreasing input, while for the output-oriented model, it provides a point of improvement by increasing output (Fareza, 2020). A DMU is inefficient "if it is possible to obtain the same results with fewer resources" or "if it is possible to obtain more output or better results with the same resources" (Pires, 2009).

Despite it being a useful numerical methodology to evaluate efficiency and productivity in shipbuilding, there are a few limitations of DEA. First and the most important one is the homogeneity requirement of DMUs. The DMUs should be relatively close to each other in their characteristics (Santos et al., 2013), and grouping of DMUs requires special consideration (Cook and Zhu, 2005). This restricts the researchers from working on shipyards or shipbuilding processes with close technical, environmental, and/or economical characteristics. It was seen in the literature that the researchers followed this limitation and when necessary grouped the subject shipyards (DMUs) such as large, medium, or small size shipyards separately during DEA for benchmarking their efficiencies and productivities. On the other hand, due to the different nature of shipbuilding processes within a shipyard where input and output are usually different and not homogenous, the tendency in DEA use was on benchmarking the shipyards rather than evaluating internal processes. But in four research, the homogeneity requirement was tried to be handled with careful approaches for the cases of internal processes in a single shipyard, as to be mentioned below later. This limitation shows the advantage of this thesis by benchmarking a shipyard only with its own Ideal status.

The second but discussable limitation is the number of DMUs. In the literature review it was seen that, as a common understanding, the number of DMUs (i.e., shipyards) were tried to be kept at least twice or three times of inputs and outputs due to possible diminishing effect on discriminating power of DEA. This restricts the number and selection of inputs and outputs, also as seen in Table 2.15. But Cook et al., (2014) stated that such restriction is "neither imperative, nor does it have a statistical basis".

The third limitation is the involvement of nondiscretionary variables, such as on-time material deliveries, managerial decision-making time frames, etc. as input. If these variables are not included correctly, the efficiency and productivity measurements may become incorrect. (Charnes et al., 1994; Krishnan, 2012).

Along with the DEA, some researchers used the Malmquist Productivity Index (MPI), an empirical index for productivity analysis (Chao and Yeh, 2020; Lee, 2013; Park, 2010). MPI "reflects progress or regress in efficiency along with progress or regress of the frontier technology over time" (Lee, 2013).

In Table 2.15, the 12 references are listed where DEA was used to benchmark shipyards' efficiencies and productivities.

As some important remarks, in Pires and Lamb (2008) capacity, technology, industrial environment, and productivity were taken as shipbuilding performance indicators and influencing factors. Productivity (learning curve implied CGT for series of ships) and Building Time Outputs were evaluated from "actual" and "target" standpoints. It was mentioned that even in less favorable conditions than for the global leaders, some shipyards with lower technological levels attain high efficiencies in performance indicators.

In their paper, Colin and Pinto (2009) provided a comprehensive study on asset turnover benchmarking based on DEA. Their analyses covered historical and from 2000-2006 period asset turnover of shipbuilders which were responsible for more than half of the global production.

In his paper, Krishnan (2012) provided a valuable compilation of shipyard productivity evaluation methods. He proposed that taking CGT and the shipbuilding effort (based on a work breakdown structure-WBS) into consideration, the estimation of efficiency by the use of DEA would be a scientific shipbuilding productivity measuring method. He mentioned that, by definition, productivity is the ratio of input to output which is indeed a measure of efficiency. Therefore, efficiency and productivity measurements are similar but for the latter, input and output units are different and hard to evaluate. It is also a similar thinking of the

Table 2.15: References in which DEA was used to benchmark shipyards' efficiencies and productivities.

No.	Ref.	Data Period	DMUs (# of Shipyards)	Inputs	Outputs
1.	Zhangpeng and Flynn 2006	2000-2006		• Dry dock areas; • Berth length; • Total crane load	• Deliveries (CGT).
2.	Pires and Lamb 2008	2003-2006	15 shipyards (12 shipyards from up to 7 countries (4+3?)	• Erection area; • Technological Development Index. • Industrial Environment Index (as the non-discretionary factor).	• Labor productivity (SCGT/MxH); • Building time.
3.	Pires et al., 2009	2004-2006	12 shipyards from up to 6 countries (3+3?)		
4.	Colin and Pinto 2009	2000-2006	36 shipyards from 8 countries	• Dry-dock area; • Berth length; • Lifting capacity.	• Average production (CGT); • Number of different types of ships built.
5.	Park 2010	2004-2009	7 domestic shipyards	• The number of employees	• Deliveries (CGT).
6.	Krishnan 2012	• No specific analysis; DEA methodology introduction in shipbuilding for domestic use		Proposed: • Labor (MxH etc.); • Process specific areas; • Labor Productivity (MxH/CGT)	Proposed: • Deliveries (CGT); • Profit (from the economic efficiency point of view).
7.	Lee 2013	2007-2012	17 domestic shipyards	• The number of labor units; • Capital; • Company age.	• Turnover; • Net profit.
8.	Rabar 2015	2007-2012	5 domestic shipyards	• Number of employees (as of 31 December of every year); • Number of effective working hours; • Total expenditures.	• Deliveries (CGT); • Total revenues.
9.	Chudasama 2016	2015	19 domestic shipyards	• Shipyard capacity (DWT); • Ship Construction Area; • Total employees.	• Income Earned by Shipyard
10.	Acik et al., 2017	2005-2016	80 domestic shipyards	• Shipyard capacity (DWT); Number of employees.	• Produced new buildings (DWT); • Production for repair & maintenance of ships (DWT).
11.	Fareza 2020	2000-2009	20 shipyards from 4 countries (for DEA Model-1) 18 shipyards from 4 countries (for DEA Model-2)	For DEA Model-1 Shipyard Productivity : • Total dock area; • Number of workers. As non-discretionary factors: • Building technique and managerial ability; • Related Industries For DEA Model-2 Shipyard ability to attract new orders: • Market price/CGT; • Delivery time /CGT. As non-discretionary factors: • Innovation and managerial ability • Government policy and subsidies	For DEA Model-1 Shipyard Productivity : • Deliveries (CGT). For DEA Model-2 Shipyard ability to attract new orders : • New contracts (CGT).

Table 2.15: References in which DEA was used to benchmark shipyards' efficiencies and productivities.

No.	Ref.	Data Period	DMUs (# of Shipyards)	Inputs	Outputs
12.	Chao and Yeh 2020	2014-2015	21 shipyards in 3 countries	• Dock area; • Number of Employees.	• Deliveries (CGT).

student and rather than an input-output ratio definition, in this thesis, the productivity measure of a shipyard is proposed as the output at a defined period. Though, in his paper, Krishnan (2012) was against this by stating that "the output delivered by a shipyard is a ship. However, measuring productivity in terms of the number of ships delivered per year (as done in the automobile industry) is not done in shipbuilding as ships are not produced in standard sizes which can be compared." Here the student defends that especially at developed shipyards it is seen that ships in standard series are produced and delivered in a specific period, sometimes at periods less than a year, so the productivity of those shipyards should be aimed.

Lee (2013) studied data from more than 17 Small and Medium-sized (SMS) shipyards at a national level for the period of 2007-2012, a recession period in shipbuilding. He mentioned that some of the SMS shipyards are highly efficient and productive, but they still need some governmental and financial support to sustain. He proposed other shipyards carefully consider focusing on other areas such as ship repair due to lesser competitiveness and concluded that objective results were reached through analysis of shipyard efficiency and productivity.

In her paper, Rabar (2015) used the DEA method and analyzed the relative efficiencies of five shipyards in the period of 2007-2012. Based on the empirical results, she stated that, if operations at optimal scales were provided and pure technical inefficiencies were eliminated the average overall technical inefficiencies of the 5 shipyards could be reduced by 29%.

In their paper, Açık et al. (2017) analyzed data of 80 shipyards at a nationwide scale by DEA for the period of 2005-2016 for both new building and also for repair & maintenance. The results showed that after the 2008 recession, the production function for new shipbuilding had not been efficiently utilized but the repair-maintenance function had been efficiently utilized. They suggested that production capacity and labor should be kept at a sustainable

level taking into supply-demand into consideration and a variety for high added value products should be applied.

The M.S. Thesis of Fareza (2020) is a comprehensive guide in application of the DEA method for shipbuilding competitiveness analysis. He used the DEA method for benchmarking three groups of shipyards, medium-sized, large-sized, and mega-sized shipyards, and selected top ones from different countries based on their market shares. He studied two DEA models with different objectives. The first one was the ability to execute shipbuilding orders, and the second was the ability to attract newbuilding orders.

The research in the above 12 papers provided numerical data on shipyard efficiency and productivity along with benchmarking information. Research, from the shipyard internal processes point, were made in the following 4 studies as listed in Table 2.16.

Table 2.16: References in which DEA was used for shipyard internal processes' efficiencies and productivities.

No.	Ref.	Data Period	DMUs	Inputs	Outputs
1.	Guofu et al. 2017	2009-2014	For Firm Efficiency: 15 domestic shipyards	• Dock quantities • Dock area • Lifting capacity • Lifting facilities	• Number of delivered vessels • Deliveries (CGT)
		2013-2014	For Organization Efficiency: 5 production departments in 2 domestic shipyards	• Dock quantities • Dock area • Lifting capacity • Lifting facilities	• Constructed hull blocks • Erected hull blocks
		2013-2014	For Activity Efficiency: In one domestic shipyard; Pre-erection of bow, engine room, stern, deck, bottom, bilge bulkhead Erection of Pre-erection of bow, engine room, stern, deck, bottom, bilge bulkhead	• Ability, working hours • Ability, service time • Unit area (or volume) • Ability, service time • Ability, service time • Ability, service time • Dosage • Quantity, weight	• Processing area • Weight • Welding volume • Weight • Surface area
		2011-2016	For Product Efficiency: In one domestic shipyard; 5 consecutive shipbuilding milestone periods for 16 ships in 3 types (Container, Tanker, Bulk cargo)	• Ability, working hours • Ability, service time • Unit area (or volume) • Ability, service time • Ability, service time • Ability, service time • Dosage • Quantity, weight	• Workdays

Table 2.16: References in which DEA was used for shipyard internal processes' efficiencies and productivities.

No.	Ref.	Data Period	DMUs	Inputs	Outputs
2.	Mayo et al. 2018	2015-2017	One domestic shipyard, Internal analysis for Docking Dept., Hull Dept., Piping Dept., Machinery Dept., OpAc Dept., Electrical Dept., Paint Dept. (department level, on specific work orders basis)	For internal (SY departmental) analysis: • Number of Employees	For internal (SY departmental) analysis: • Labor productivity (GT/hr); • Schedule Delay (1/days); • Refurbishment Time (1/days).
			4 domestic shipyards for external analysis on 15 work orders	For external analysis: • Shipyard Capacity (a composite index, comprised of max.drydock capacity(GT), • length and width of vessel; • Number of Employees; • Qualitative Factor: (Technology (advanced machinery, CMMS) and Management/Manpower Strategies (Organization, Planning & Scheduling, Efficiency Strategy, Apprenticeship Program and Outsourced Labor), as weighted)	For external analysis: • Labor Productivity (CGT/hour); • Refurbishment Time (1/days)
3.	Xue et al. 2020	2012-2014	1 domestic shipyard	For GAS: • Labor • Dock Lifting facility • Pre-erection area • Blocks assembly area • Erection crane • Steel cutting facility For Departmental Structure: • Total labor (manager, worker)	For GAS: • Mooring testing vessel • General assembly vessel • Pre-erection blocks • Blocks Model Assembly Parts For Departmental Structure: • (Pre) erected hull block
4.	Woo 2021	2019	8 domestic shipyards	For common (classical) model: • Number of employees • Number of docks & berths For Smart Shipyard Maturity Level (SSML) model: • Process • System & Automation	• New shipbuilding volume (CGT)

In Guofu et al. (2017), the conception of setting up a "central shipbuilding mode" and a Shipbuilding Breakdown System (SWS) in 2001, named as the General-Assembly Shipbuilding mode (GAS) was explained. In their study, they tried to overcome the limited overall efficiency measuring capability of the GAS system from a global perspective. They stated that the production, technology, and management activities were the combination of the production efficiency of the GAS system but there was a need for developing an efficiency measuring model. They studied the firm, organization, activity, and production efficiencies in a shipyard separately by DEA methodology and provided numerical data to the shipyard. This paper is a rare source in the literature on GAS system and also use of the DEA method in a shipyard.

Mayo et al. (2018) is an interesting research and report on the Repair & Maintenance aspect of the use of DEA for a shipyard. The importance of this report is the very well-organized recommendations on performance targets.

In their paper, Xue et al. (2020) explained the development of a two-stage efficiency structure analysis model named ESAM. According to their information, ESAM reflects the internal efficiency of a shipbuilding system from the operation, process, and management dimensions, each with multi-levels. To measure the effect of the driving factors of efficiency, they decomposed the shipbuilding production system into three dimensions namely “product structure, process structure, and production organization structure”, with several subsystems of production organization, shipbuilding process, and ship-based system output. They apply the DEA method in efficiency analyses. Xue et al. (2020) was one of the six references where a geometric definition approach was used and named as "Efficiency dimension space".

Woo et al. (2021) developed a new framework on shipyard maturity level to diagnose the application of smart technologies in a shipyard. They emphasize the automation and connectivity assisted, preferably unmanned, production in shipyards in parallel to technological developments in the Internet and communications, despite shipbuilding processes differ from factories and plants of mass production which already implement such smart technologies. They developed a model named Smart Shipyard Maturity Level (SSML). They have defined five smart shipyard maturity levels under four criteria with 61 items and

10 assessment areas of a shipyard, where connectivity, physical, and intellectual automation were observed. They stated that the DEA based on SSML provided more reliability than the DEA with common inputs. Through the development of the model, they made expert opinion surveys at eight shipyards and applied the model to the shipyards and their subcontractors.

2.3.2.11 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a very common decision-making method. It is used to select the best one among a number of alternatives with respect to several main and sub-criteria. The decision is based on first pairwise comparison judgments and then developing overall priorities to rank the alternatives. The comparisons may be taken either from actual measurements or if qualitative, then from a fundamental scale (R.W. Saaty, 1987; T.L. Saaty and Vargas, 2012).

In his Ph.D. thesis, Kırdağlı (2010), studied the parameters which affect shipyard productivity by the Fuzzy (Extent) AHP Analysis method. A hierarchy is presented covering ship design, planning, production, and purchasing for 17 effects. A survey is made among nine experts from the shipbuilding sector. This study was one of the initial studies in the literature on shipbuilding activities by the Fuzzy AHP method. Despite Kırdağlı's (2010) thesis focused on efficiency in naming, here the student thinks that the thesis focus was on productivity. In this thesis, the student also used the AHP method to calculate the weights of Effects, but the Fuzzy approach was not used due to the very high number of pair-wise comparisons.

In their paper, Stanic et al. (2017) proposed a novel methodology. They suggested the use of the AHP as an MCDM tool to implement principles of three important concepts namely "Design for Production, Design for Maintainability and Group Technology" through four phases to maintain shipyard competitiveness. The study was made at a shipyard. Analysis of the present situation in production line relations formed the first phase; a constraint analysis formed the second phase; alternative selections for Design for Production, Design for Maintainability and Group Technology formed the third phase and finally, the optimal solution was decided by using the AHP method. Improvements in 20 areas of the entire ship production process were investigated and prioritized.

2.3.2.12 Labor and Material

In his paper, Sharma (2014) proposed an evaluation systematic from the labor and material aspects of all areas of shipbuilding in a shipyard. Despite the proposed methodology being based on relatively old material weight and labor effort calculations, his complaint about the reluctance of shipyards to measure and evaluate their productivity is enlightening and supports the purpose of this thesis. Sharma (2014) also wrote that "No shipyard builds the ships in the same way as its competitors" which verifies the initial benchmarking with own shipyard capabilities thinking of this thesis.

Huijgens (2016), in his valuable M.S.Thesis, proposed a methodology based on a mathematical framework to quantify the technological complexity of manufacturing structure during a shipbuilding project. The calculation of complexity ratios, based on labor (man-hours) for components is combined into a subsystem, main system, and entire project complexity ratios; vertical and horizontal interdependencies are observed on material parameters. Huijgens's (2016) thesis is found to be one of the rare analytical studies in shipbuilding by the student.

2.3.2.13 Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a method to define first the prioritized set of customer needs and requirements, then to translate them into specific plans or system conceptual design to make production meet those needs. QFD was developed at the Kobe Shipyard of Mitsubishi Heavy Industries, Ltd. (Hadjina et al., 2015).

In their paper, Hadjina et al. (2015) studied the (adjusted) QFD methodology where a numerical sub-process design matrix is provided to rank the most influenced sub-processes for solving customer requirements. The feedback from the ship owners and ship crew during the ship production and then the ship operation period was classified based on the groups of basic problems and their frequency of occurrences. This data was used as input within the adjusted QFD method. The quality control matrix was proposed to improve ship design and production, as focused on outfitting, with an aim to reduce costs, shorten the ship production period, and improve the ship's quality. The authors provided a very important point, to

observe the shipbuilding activities from the value of the customer, which is a must for sustainability while the productivity of the shipyard improves in parallel.

2.3.2.14 Bayesian Network

Bayesian Networks (BN) is the process of reasoning under uncertainty. It is a probabilistic graphical model with a set of variables, nodes with interdependencies are used. Hellgren 2016

In her Ph.D. Thesis, Hellgren (2016) and in a related paper Hellgren et al.(2017), investigated the positive relation between production efficiency and process organization in shipbuilding by a Bayesian network. The variables were determined by the factors affecting the production efficiency. The study was realized in a shipyard and Expert Opinion methodology was used. Within the study, there exists a good classification of Effects which were taken into consideration during the study for this thesis.

2.3.2.15 Total Factor Productivity (TFP)

Total Factor Productivity (also called multi-factor productivity) reflects the overall productivity where both labor and capital inputs are used in the production process to generate an output (Gourdon, 2019).

In his paper, Benzaquen (2017) proposed an empirical model to obtain total factor productivity. The purpose was to determine the contribution of production and technology functions jointly along with the technical progress. A large shipbuilding industry, for a period of 21 years was analyzed with the data on product, labor, material, and costs. For the several activities, “conjoint contribution of production factor, technical progress, learning curve, and total factor productivity evolution” was obtained.

In Gourdon’s (2019) OECD Policy Paper on an analysis of market-distorting factors in global shipbuilding, a numerical analysis based on a Cobb Douglas production function for the shipbuilding companies of 12 nations for the period of the years 2000-2015 was provided based on total factor productivity.

2.3.2.16 Theory of Constraints (TOC)

TOC is a management approach developed by Goldratt and Cox (1986) that is mainly based on identifying the most important constraint (named as bottleneck) which limits achievement of the goals of a manageable system and then improving this constraint until it becomes a limiting factor no longer. TOC is used to fix the weakest link in the production chain (Çelebi and Bilgili, 2018).

Çelebi and Bilgili (2018) studied the TOC approach to improve the entire shipbuilding process and to reduce the delivery duration of ships in projects by identifying bottlenecks and applying critical chain principles in planning. They worked with a shipyard, monitored workflow, and used respective data during the production of a ship and proposed this TOC approach to the shipyards which especially produce ships in series.

2.3.2.17 Computational Shipyard Dynamics (CSD), process-centric simulation

The process-centric simulation, also known as discrete-event modeling, is used to capture business processes where the system contains a sequence of actions.

Kim et al. (2018) and Shin et al. (2020), under their CSD studies, which commenced at the beginning of the 2000s, approached the shipyard production problems and the dynamics of related factors by a computational methodology. A process-centric simulation model with input variables of six factors was used (Kim, 2018). These input variables are similar to the major groups of factors affecting the entire shipbuilding process used in this thesis (see Table 2.3). Kim (2018) was also one of the six references where a geometric definition approach was mentioned as a path between two points in Euclidean space and minimum path length in search of a functional. In Kim (2018), the simulation was focused on fabrication, while in Shin (2020), the focus was enlarged to a fabrication shop, panel block assembly line, and ship block logistics to reference a job shop, a flow in a shop, and a project activity. In Shin (2020), their research was named as "a model-based ship production system theory" with "production factors, production management indicators, and the relationships between them, called the simulation-based KPI functionals." They define the production factors with the six-factor model, and KPIs which are the production management indicators, are already used in shipyards.

2.3.2.18 Shipbuilding Maturity and Capability Model (S-MCM)

Capability Maturity Model (CMM) is a method used by the software development sector. In his Ph.D. Thesis, Yıldırım (2018) studied the adoptability of CMMI for the evaluation of shipyard maturity. Named as Shipbuilding Maturity and Capability Model (S-MCM), this was one of the studies in the student's university to measure a shipyard's productivity numerically. The model and assessment methodology assess the maturity of a shipyard at present. With this method, the status of the shipyard was given at a relatively large scale which may need a narrower focus.

In addition, as explained before in the DEA method review, Woo et al. (2021) also developed a model named Smart Shipyard Maturity Level (SSML) on shipyard maturity level to diagnose the application of smart technologies in a shipyard.

2.3.2.19 Key Performace Indicators (KPI)

Key Performace Indicators (KPI) are simple and nonfinancial, continuously measured indicators that focus on the aspects of organizational performance. KPIs are monitored by the management (Bilen, 2022a). The literature review signified that the research on KPIs in shipbuilding management shows an increasing trend during the last years.

In her Ph.D. Thesis (Bilen, 2022) and in a related paper by Bilen et al. (2022), the study was on Key Performance Indicators (KPI) for evaluating the productivity and producibility of small and medium-sized shipyards. A systematic approach was developed to use historical data for cost and producibility evaluation. Data from a shipyard for previously built 12 ships were used. This study showed a concrete example of the use of KPIs and hopefully raises awareness in shipyards for the utilization of historical data.

Almost at the same period, in her Ph.D. Thesis, Cui (2022) defended KPI principles in a strategic approach named SPPM (Shipyard Production Performance Management) which was “a strategic decision support tool for shipyard production performance evaluation and support in budgeting for performance improvement” to optimize shipyard performance management strategy. 30 KPIs were calculated and discussed from technical, human

resources, health and safety, economic, environmental, security, and supply chain management aspects. A numerical analysis system, including AHP and some other methods, was utilized in the optimization of the KPIs. A hypothetical small-medium size shipyard was analyzed. Despite Cui's (2022) thesis aims to provide guidance in budgeting, during the utilization of the method, a performance overview of the shipyard on the seven aspects was provided numerically. In this respect, it can be said that Cui's (2022) thesis had parallel thinking with this thesis in the most recent period, to look over the shipyard performance from some key aspects and to provide a numerical solution.

2.3.2.20 Value Engineering and Risk Assessment VENRA

Baihaqi et al. (2022) developed a methodology, named as VENRA, based on the "weighting of a number of attributes affecting shipyard performance and integrating the technical, business, external and safety/risk". They made an expert opinion-based survey among seven participants and referenced a shipyard. They prioritized the improvement areas based on weighting. The definition of main and subcriteria for evaluation and the approach for weighting have some similar thinking to this thesis

2.3.2.21 Shipyard Technological Level Evaluation

In their ongoing studies, Rubesa et al. (2023) proposed a methodology, with a defined hierarchical criteria and focus on the determination of the technological level of shipyards. The purpose was to provide a continuous improvement progress monitoring tool for the shipyard management. The productivity was observed from the competitiveness point of view. This paper is one of the latest research references throughout this thesis study period and many similar approaches were seen such as the series of several criteria and their evaluation methodology.

The method presented in this thesis, named as "**Dimensionless Productivity Number (DPN) Method**" is believed to be the 22nd method in this row.

Three problems were observed in the Literature survey. The first one was the high use of external, open-source shipyard data, possibly due to the reasons specified in subsection 1.4.3.

This raises questions on method validity. The other one was almost no application of repeated surveys to study the reliability of the used methods. However, when its dense work nature and high costs in shipbuilding are considered, survey duplications and applications to check method validity are not easy. The last problem was the non-availability of previous data in literature which may support the reliability evaluations of this thesis if available.

2.4. Summary

In this Section 2, basic information on shipbuilding and productivity is provided, followed by a literature review of 62 references on shipbuilding and shipyard productivity.

Shipbuilding is an overall process that covers four major processes 1) ship production, 2) management of shipyard and projects, 3) ship design, and 4) manufacturing and procuring all the materials & equipment needed to build the ship and to be installed on the ship.

Ship production is a major process with necessary subprocesses to build a ship. It covers the three consecutive but overlapped subprocesses namely
(i) hull construction,
(ii) outfitting of this hull and
(iii) launching the ship from land into the water.
The tests & trials subprocess, a part of quality assurance, also continues throughout all these subprocesses. This breakdown differs on shipyard location, ship type, and project basis but can be accepted as general from the cost or labor effort aspects. In this thesis, the focus is on shipyard productivity for the processes, subprocesses, and activities that occur on the shipyard premises. Manufacturing and procuring the materials & equipment will not be covered as a whole process but related subjects, works will be investigated within shipbuilding management, ship design, and ship production processes.

The end product of a shipbuilding process, a ship, a floating or a subsea structure is made of materials, equipment, and systems. To bring them all together as a ship or a floating, diving structure mainly,

- human effort is needed, both by the white- and blue-collar workforce,
    - to manage a total production process named as a shipbuilding project,

    - to design the end product (usually named as ship design),
    - to produce the end product (usually named as ship production or ship construction), and
    - to assure the end product's quality while,
- an infrastructure is needed for this workforce to produce the end product (in general named as a shipyard).

In this thesis, the major processes and subprocesses of a total shipbuilding process are taken as follows:

Major Processes:

- Management,
- Ship Design, and
- Ship Production, where its subprocesses are,
    - Contracting,
    - Hull and Superstructure Blocks Construction,
    - Hull Erection,
    - Parts Manufacturing in the Shipyard,
    - Outfitting before Ship Launching
    - Ship Launching,
    - Outfitting after Ship Launching (also named as Quay outfitting) and,
    - Setting-to-Work (STW), Harbor (HATs) and Sea Trials (SATs).

This research is focused on "shipyard productivity" and also "productivity improvement". OECD (2001) defined **productivity** as "a ratio of a volume measure of output to a volume measure of input use", which serves as a measurement of output, and is usually expressed as some units per amount of time. Tangen (2004) mentions that the concept of productivity has been available for over two centuries and is simply defined as the relation between output and input but there is no correct universal definition of productivity.

In shipbuilding, the end products are unique, designed as per customers' requirements, and produced over long period. This differs shipbuilding activities from mass production, its methodologies and standardized applications. Mass production and measurement methods

can not be applied in shipbuilding easily. For the performance measurements of a shipyard, there are three major groups in the shipyard with their own focus from efficiency to competitiveness & profitability. The focus of the management units at workshop and field levels is basically to measure the efficiency of the workforce with appropriate Industrial Engineering methods at workstations and work teams and, to provide necessary training along with production and process improvement means. The use of Key Performance Indexes (KPI) would be appropriate for Project Management, Production Management, and management of the Planning and Budgeting departments. Top management of shipyards usually concentrates on profitability and competitiveness, but their route passes through shipyard productivity. Internal and external factors affect shipyard productivity. Those factors are controlled by short-, medium- or long-term improvements.

During a comprehensive literature review, 62 papers & references were found that strictly cover overall shipyard efficiency or productivity measurements and/or evaluations in 21 different methods as adopted from business and industrial management areas or developed originally starting from 1980 as listed below:

- Compensated Gross Tonnage (CGT) System
- Productivity Space
- Global and Local Performance Matching
- Performance gradient, Break- even Threshold
- Shipbuilding Productivity Prediction Equation (SPPE)
- Overall aspects, production function and Group Technology
- Search-Based Heuristic Algorithms
- Value Added, Value Chain
- Linear Programming (LP)
- Data Envelopment Analysis (DEA) along with the new DEA based ESAM ve SSML methods
- Analytic Hierarchy Process (AHP)
- Labor and Material
- Quality Function Deployment (QFD)
- Bayesian Network
- Total Factor Productivity (TFP)
- Theory of Constraints (TOC)
- Computational Shipyard Dynamics (CSD), process-centric simulation
- Shipbuilding Maturity and Capability Model (S-MCM)
- Key Performace Indicators (KPI)
- Value Engineering and Risk Assessment (VENRA)
- Shipyard Technological Level Evaluation

To represent the output of a shipyard, Compensated Gross Tonnage (CGT) system-based metrics are still globally favored shipyard productivity measures, followed by the Data Envelopment Analysis (DEA) method.

3. METHODOLOGY, TEST CASES, AND NUMERICAL ANALYSES

After the research question of "Can we develop a new methodology, preferably with dimensionless metrics, to evaluate the shipyard productivity and can we prioritize the improvement needs that are compatible with the entire shipbuilding process?" formed and the literature survey concluded, the search in three environments started to develop a methodology. The first one was a possible model from nature, the second was a possible model from industrial applications and the third was from the student's experiences in his past shipbuilding career.

The hydrodynamics and lifestyle of some animals were investigated for modeling such as Navier-Stokes Equation from hydrodynamics and optimization on ant or bee colonies from nature due to the complex structure and continuous workflow in shipbuilding. But reviews on those showed that there may be problems due to flow characteristics of work or unwanted elimination properties, variable diminishing in this thesis. Industrial applications such as factory physics (Hopp and Spearman, 2008) and production function studies (Cobb and Douglas, 1928) were found to be concentrated mainly on mass production which differs from the shipbuilding process, methods like Industrial & System Dynamics (Forrester, 1958) were found to be studied previously on shipbuilding (Ding, 2019). On the other side, thinking on what will be measured and how (Tangen, 2004), a methodology to proceed with subjective data first and then quantification was taken into consideration due to the foreseen limitations in reaching shipyards' tangible and time-series data as mentioned in subsection 1.4.3. Accordingly, shipbuilding process steps were evaluated and one common application, the propeller shafting alignment was thought to be referenced as a similar industrial application basis with efforts to bring a misaligned shaft to its ideal condition at maximum. The second question was then how to model and manipulate this alignment procedure in a method. A more practical method than any Elasticity Theory (Timoshenko and Goodier, 1951) application was decided and, the student's education (Beier, 1989) and experience on B-Splines (Boor, 1972), and two interesting papers by Lange et al. (2017) and Kim et al. (2018) brought the idea of using such curves or surfaces in the mathematical model.

In this respect, first an overview, then the mathematical model, the test case, and numerical analyses will be presented in the following subsections.

3.1 Mathematical Model

An analogy to propeller shaft alignment, a common application during ship production, helped to formulate the research question and led to a mathematical model.

Before the Sea Trials, after the installation of the propulsion system of a ship is completed, propeller shafting at static condition, as simply shown in Figure 3.1, is subject to an alignment measurement (also called bearing load measurement) and adjustment to optimize loadings on the shaft system bearings.

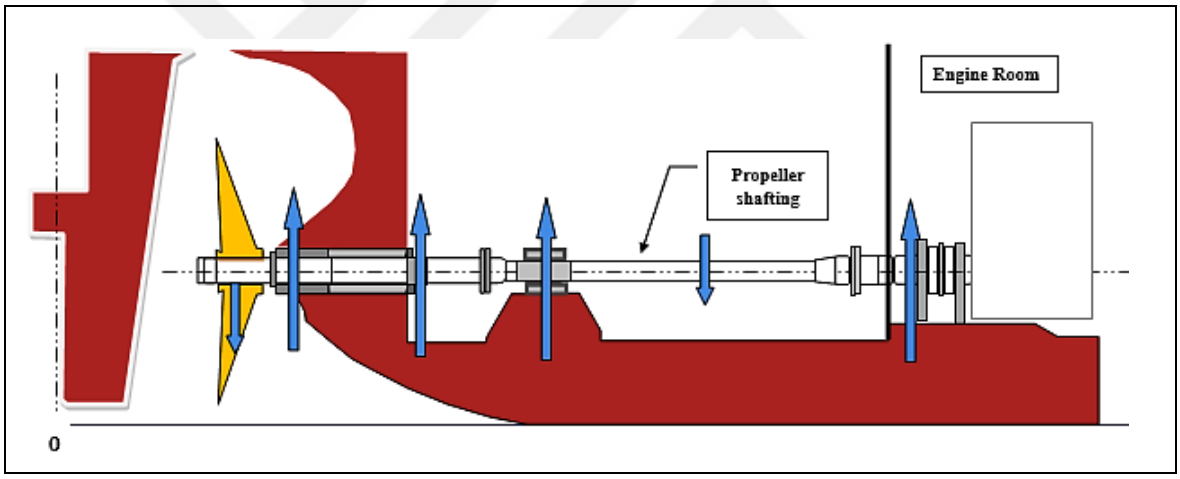


Figure 3.1: A simplified arrangement of ship propeller shafting (inspired from ABS, 2019)

The propeller shafting is subject to several forces in the vertical direction such as the forces acting at each bearing and the weight of the shaft pieces etc. The deflection of the ship's hull, such as hogging or sagging at different tank liquid loading conditions and corresponding changes depending on the rigidity & elasticity of the hull structure and shaft material; the thermal deviations close to the main engine, reduction gear area, bearing offset arrangement, etc. (ABS, 2019).A sample, generic graph on loading on a propeller shafting and nodal slope curve is shown in Figure 3.2.

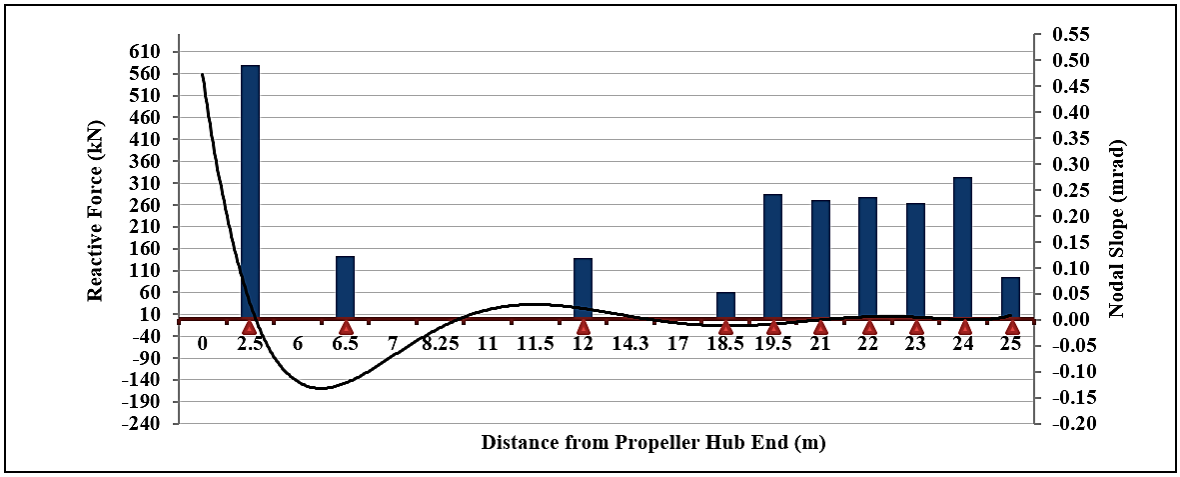


Figure 3.2: Sample graph of forces acting on a propeller shafting and nodal slope (rough data from ABS, 2019).

There are several calculation methods for the alignment of marine propulsion shafting such as empirical (SNAME, 2007), matrix solutions (Yang, 2011), and Computational Fluid Dynamics (CFD) (DNVGL, 2018). But due to the expectation of a high number of "Effects" in this study and possible on-screen manipulation of a B-Spline curve for improvements, a possible curve length measurement need, etc. a method on spline curves was decided at the initial phase of this study.

A misaligned propeller shafting is thought to resemble the entire shipbuilding process of a Shipyard and a perfectly aligned same shafting to resemble the "Ideal" version of it. Some "Effects" on the shipbuilding processes are assumed to resemble the vertical forces acting on the shafting. The purpose is now to smooth the current and actual shipbuilding processes and align them with the "Ideal" status as much as possible, by manipulating the Effects, comparing the shipyard to its ideal version. For the methodology to be developed, the "Ideal" version of a Shipyard is assumed to have the highest productivity; the differences between a shipyard's current status from its "Ideal" version depend on several Effects which can be represented in a numerical and geometrical model and, may provide productivity assessment information specific to the shipyard. The current trend shows an increase in the use of software simulation methods, digital, and virtual shipyard applications. The "Ideal Shipyard" can also be assumed as the "ideal, perfect twin" of a Shipyard.

For simplicity, hereon "Shipyard" denotes the actual status of a Shipyard, and the "Ideal Shipyard" denotes its imaginary and possibly unreachable perfect version.
The research aim is,

- first to calculate a dimensionless productivity number system that represents,
    - productivity status of the major shipbuilding processes and accordingly,
    - the shipyard's entire shipbuilding process productivity status

through a reference shipbuilding project, against the imaginary "Ideal" version of its own; and secondly,

- to obtain improvement area priority lists of the processes and,
- test the effects of the improvements on productivity. This also leads to a continuous improvement cycle.

Both for the Shipyard and the Ideal Shipyard, "Effects" affect the shipbuilding process, as explained in subsection 3.1.1. below, are assumed as the vertical vectors (like the vertical upwards forces acting on propeller shafting) positioned on the *x*-axis of a Cartesian coordinate system 1st Quadrant (Figure 3.3). Terminal points of those vectors formed the coordinate points where,

- *y*-value is the Effect magnitude,
- *x*-value is the Effect's position on the *x*-axis.

For this method, a dimensionless anchor value was needed to indicate a reference point or a line such as the axis of a perfectly aligned shaft or the position of the Ideal Shipyard, to represent the most productive state of a shipyard. It was decided this number be a positive and non-zero integer, therefore a natural number to prevent complexities in future calculations. Further thinking on the possible next stages of development, such as the representation of the processes mathematically, also the possible methodology during surveys, and possible future values between 0 and 1 due to weighting, "1" was decided to represent this anchor value.

The *x*-axis, denoted as the *t*-axis in Figure 3.3, was taken as the entire shipbuilding period (in weeks) of a class of ship the Shipyard wishes to take as a reference.

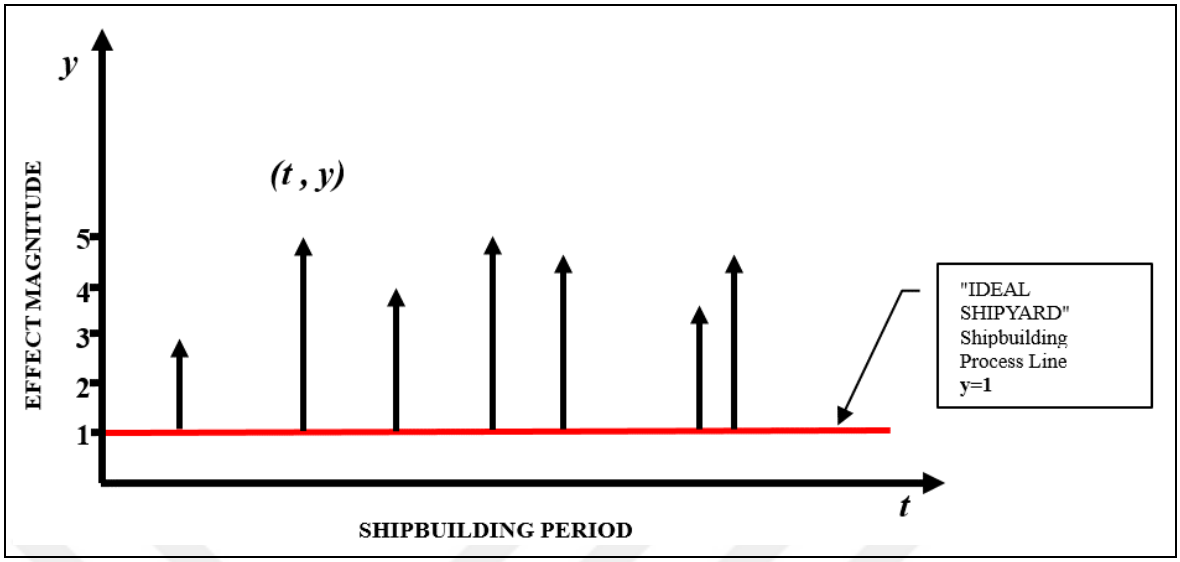


Figure 3.3: Ideal Shipyard line and Effects' placement on the scatter plot.

Each Effect is on the same *t*-coordinate for both the Shipyard and its Ideal state but with different magnitudes. The straight line (y=1) in Figure 3.3 represents the Ideal Shipyard, the most productive state of the shipyard. Effects of the Ideal Shipyard are always in perfect state, initially at y=1, but they are decided to be weighted on the shipbuilding sector basis to match better with the competitive status of the sector. The same Effects of the Shipyard change by the facts of the Shipyard and are weighted on the Shipyard basis.

One curve to fit the vector end coordinates is drawn to represent the actual state of the Shipyard as shown in Figure 3.4. When shipbuilding sector weights are applied to Ideal Shipyard Effects, the straight line at y=1 also changes to a curve of the same type in Figure 3.4.

The shipbuilding processes, which were selected for this study as explained in subsection 2.1.2., are shown symbolically in Figure 3.4. There were three major processes namely (i) Shipbuilding Management, (ii) Ship Design, and (iii) Ship Production. The Ship Production process contains eight consecutive subprocesses, (iii a) Contracting, (iii b) Hull and Superstructure Hull Blocks Construction, (iii c) Hull and Superstructure Blocks Erection, (iii d) Parts Manufacturing in the Shipyard, (iii e) Outfitting before Launching, (iii f) Ship Launching, (iii g) Outfitting after Launching, (iii h) Setting-to-Work, Harbor and Sea Trials.

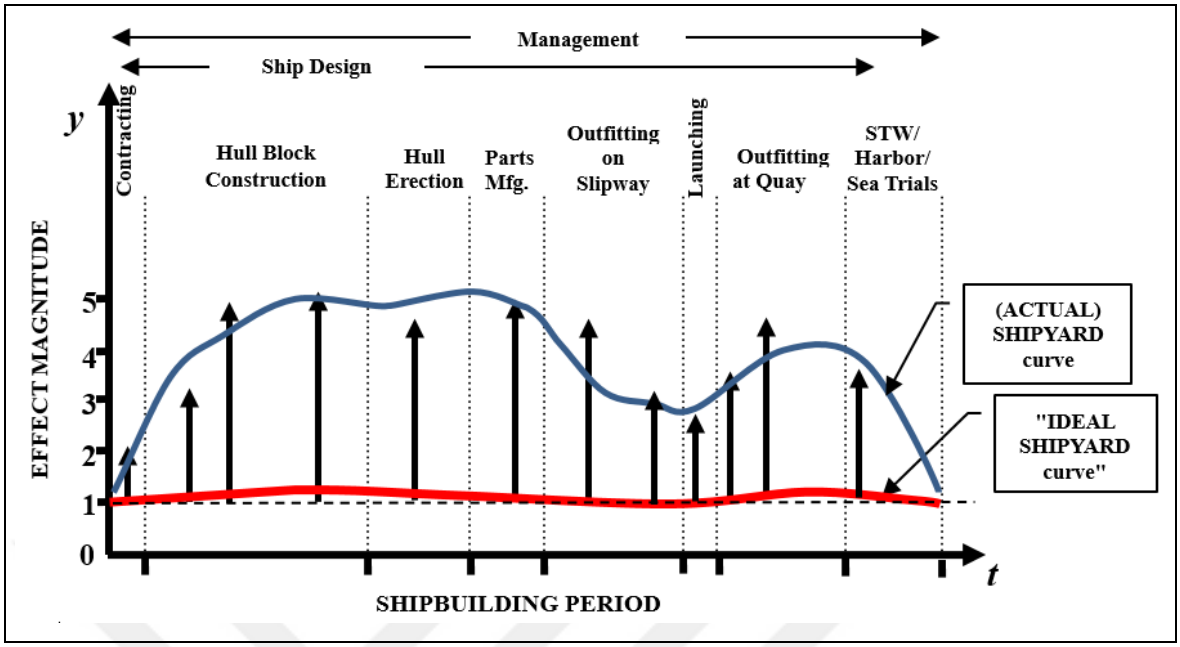


Figure 3.4: Symbolic representation of Effects, Shipyard and Ideal Shipyard curves and shipbuilding processes & subprocesses.

The ratio of the calculated areas under the curves above y=0, as shown in Figure 3.4, leads to a dimensionless number. The y-axis value was taken as zero to work with positive values in area calculations always. As the Shipyard, or a process, approaches its "Ideal" version because of some improvements, this ratio of the areas becomes closer to "1". Therefore, a ratio very close to "1" represents a productive shipyard.

During the study on the Effects, as explained below in subsection 3.1.1., there was a need for some classification. This classification work yielded a general definition that, the dimensionless productivity number is a function of "management capability (M)", "labor (H)", "infrastructure and technology (T)", "engineering, quality and documentation (E)" and "time (t)" (Equation 3.1). The dimensionless productivity number of a shipyard is denoted by "**U**" in this study and,

$$\mathbf{U} = f\,(\mathrm{M}, \mathrm{H}, \mathrm{T}, \mathrm{E}, \mathrm{t}) \tag{3.1}$$

If **U** =1, the Shipyard is in the most productive state.

Development of the mathematical model covered five steps:

(i) definition of the Effects,

(ii) Effects' data requirements,

(iii) curves and areas,

(iv) calculation of the productivity numbers,

(v) improvement areas priority lists.

3.1.1. Factors Affecting Shipbuilding: Effects

During the Literature Survey, previous research, studies, and publications are investigated for information on the factors affecting the total shipbuilding process. Accordingly, a list of internal and external "Effects" is derived from the aforementioned references.

Lamb (1998, 2007) listed and explained the influencers of shipyard productivity under a major classification (see Table 2.3) and then in detail such as elements of high shipyard productivity, technology, and good work organization, while in Liker and Lamb (2002), the necessary elements and wastes in Lean shipbuilding were defined. First Marine International (2005) brought out many elements (factors), also based on shipbuilding processes, in their shipyards benchmarking study report. In Doerry (2009), some important factors during complex ship design projects were mentioned. Kırdağlı (2010) studied factors in ship design, planning, production, and purchasing from time, cost, and quality aspects. KPIs for the shipbuilding industry as specified by Adarme et al. (2011), the criteria for evaluation of shipyard selection by Kafalı and Özkok (2015), and the study on the development factors for the shipbuilding sector by Turan and Cengiz (2015) helped in the development of the factors list. The outcomes leading to inefficiency and variables she used in her model on production efficiency and cruise shipbuilding in her Ph.D. thesis by Hellgren (2016) and organizational complexity elements in Huijgens (2016), consideration items in utilization of a project management method in shipbuilding in Doğan and Helvacıoğlu (2017) provided more factors to be added into the list. Extensive lists of factors affecting shipbuilding productivity in Sulaiman et al. (2017) and factors on job safety in shipbuilding in Nam and Öz (2020) contributed to the list. Finally, inputs were taken on contracting in shipbuilding from Koçak et al. (2021).

This search for the Effects affecting shipbuilding resulted in a list of 494 Effects in total, 366 from 14 references above and also by experience, 128 Effects more, such as “weight control”, “routine control of the ergonomics in workplace” etc. were added by the student, his thesis advisors and thesis supervisory committee. After the elimination to obtain the sole "Shipyard Productivity" and "direct ship delivery" influencers, 185 of those Effects, 71 from the literature and 114 by the student and his thesis advisors were decided to have an important impact on the ship delivery schedule from the start of contracting works until the end of sea trials. "Important impact on ship delivery schedule" means the relevant Effect has an impact on the shipbuilding process productivity resulting from management or labor or infrastructure or technological or engineering or quality aspects. The list of 185 Effects is given in Appendix A.

Lamb (1998, 2007), Kim et al. (2018), and Xue et al. (2020) classified the factors affecting productivity in a shipyard as shown in Table 2.3. During the listing of 494 Effects from the references mentioned above, classification was initially started under the breakdown of Lamb (1998, 2007) (see Table 2.3 and Table 3.1) but then for this study, it was changed to a new classification as needed, and grouped accordingly (Table 3.1 and Table 3.2).

Table 3.1: Classification of major factors in literature and groups of Effects in this study.

Lamb (1998, 2007)	**Kim et al. (2018)**	**Xue et al. (2020)**	**This Study** *(see also Table 3.2)*
Technology (Best practice) Levels	Product	Building technique	**Production**
Facilities	Process	Resource ability	**Infrastructure**
Planning	Facility	Management level	**Design & Production Engineering**
Management capability	Space		**Management**
Work organization	Human (labor)		**Contracting**
Work practices	Schedule		**Materials & Procurement**
Worker motivation			**Work Force**
Worker skills			**Quality**

Table 3.2: Breakdown of the Effects in groups and subgroups.

Group	Number of Effects	Subgroup	Number of Effects
Production	29	Hull & Superstructure Blocks	10
		Hull Erection	1
		Parts Manufacturing in the Shipyard	6
		Outfitting before Launching	9
		Ship Launching	1
		Outfitting after Launching	2
Infrastructure	29	Layout	16
		Environment	2
		Technology	6
		Amenities	5
Design & Production Engineering	22		
Shipbuilding Management	30	Planning & Budgeting	24
		Risk Management	6
Materials & Procurement	14		
Contracting	7	Main Contract	5
		Subcontracts	2
Work Force	43	Organization	8
		Performance & Practices	23
		Motivation	12
Quality	11		

Compared to the previous classification in literature as given in Table 3.1., in this study, more emphasis on the Effects for the Production subprocesses was deemed necessary; Infrastructure was to cover facilities, space, and also the use of technology. Work Force covered issues on “human” as a whole under organization, work practices, motivation, and work skills subgroups. Planning & Scheduling is considered under Shipbuilding Management. Despite "Contracting" being a subprocess of "Management" usually, for the shipyards without a separate contract management group especially, it is considered under the Ship Production process in this study due to its important effect on the shipbuilding time-schedule and also involvement with other yard entities for the related activities. The same applied to the Materials & Procurement, which is normally a subprocess of management, is taken separately again due to its important effect on the shipbuilding time-schedule. Design and Production Engineering, along with Quality, are deemed to be covered separately in this study due to their high importance in shipbuilding.

The breakdown of the 185 Effects in groups and subgroups is shown in Table 3.2 and their distribution into groups is shown in Figure 3.5. As shown in Table 3.2, there exist 29 Effects in the Production group, 29 Effects in the Infrastructure group, 22 Effects in the Design & Production Engineering group, 30 Effects in the Shipbuilding Management group, 14 Effects in the Materials & Procurement group, 7 Effects in the Contracting group, 43 Effects in the Work Force group and 11 Effects in the Quality group. The Production group has six, the Infrastructure group has four, the Shipbuilding Management group has two, the Contracting group has two, and the Work Force group has three subgroups.

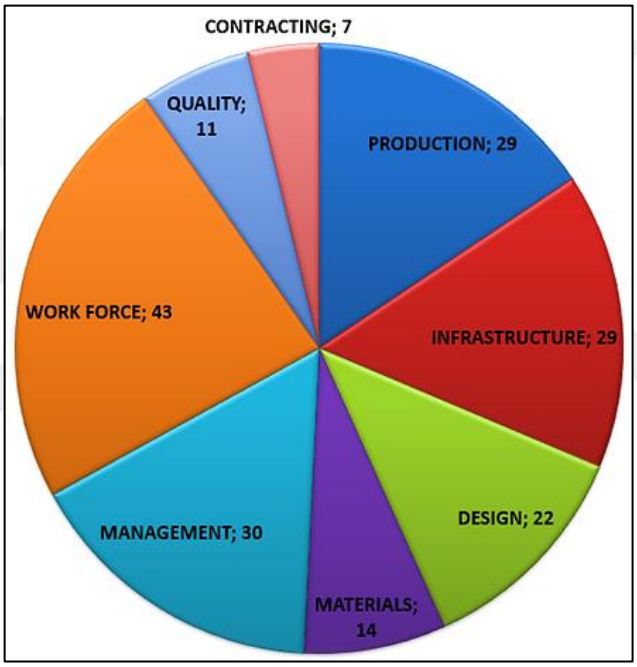


Figure 3.5: Distribution of Effects in groups.

The list of Effects as arranged under groups and subgroups is given in Appendix A, their distribution to the processes and subprocesses, also cross-repetitions, in Appendix B and Effect sub-details in Appendix C.

In the selection and decision of Effects to be used in this study, three questions were considered from the view of shipbuilding management, infrastructure, ship design, ship production, workforce, and quality aspects:

(i) if a problem occurs in the Effect or the Effect continues to be executed with deficiencies, does it result in some delay for the contracted delivery date of the ship?

- delay margins (slacks) in time schedules and for the delivery date in the shipbuilding contract will not be taken into consideration since minor delays usually add up to durations above the delay margin, as experienced in the student's shipbuilding career;

(ii) does the Effect cause a costly investment decision by the management of the shipyard due to problems, deficiencies, or unexpected conditions (such as new governmental regulations), even if it has limited consequences on ship delivery dates?

- since one of the aims of this method is to prioritize the improvement needs and observe their chain reaction among the processes and subprocesses;

(iii) does the Effect help the employees to have and keep good motivation, a positive feeling of commitment to the shipyard, and feel a happy and successful human while also feeling protected by the shipyard, so they work efficiently and productively?

- for the labor productivity.

If an Effect meets at least one of these three questions positively, then it is taken among the Effects to be used in this study and methodology.

Almost all of the Effects were chosen and decided against the question of delay in delivery date. There are some exceptions such as environmental issues where the Effect may not be time-related but relate to expensive improvement and investment decisions of the top management and result in budgetary cuts for improvement needs with higher priorities.

Effects on managerial issues were contained under risk management, planning and budgeting, materials and procurement. Contracting is included as a subprocess of the Ship Production process in this study, as mentioned in subsections 2.1.1. and 2.1.2, despite it being a managerial issue. Contracting has a critical effect on ship production starting from the bid/proposal preparation period until the ship delivery due to the signed contract's compliance level on the facts of the shipyard, including the shipbuilding contract's usually annexed first and thick appendix on the ship technical specifications. The Effects on contracting covered important points from bid/proposal preparation standardization to shipbuilding Contracting and subcontracting.

In parallel with the contracting, risk management is another important area, and several Effects were taken into consideration such as executing works on risk identification, risk mitigation, and change management, etc.

Planning and budgeting, an important managerial area in shipbuilding to manage such complex projects had several Effects identified for preparation, integration, and correctness of time schedules; dynamic schedule management by continuous monitoring and feedback, including production management to be used during progress and budget evaluations. Effects on job standardization, job-order system, accurate labor planning, performance measurements, tracking and management of costs were used. Being one of the important reasons for delays and cost-increasing problems in shipbuilding, the change requests and rework are revisited by some Effects. Some Lean Manufacturing wastes such as waiting times and overproduction of parts had their respective Effects.

One of the key activities in shipbuilding, the materials, equipment, and systems procurement area had several Effects on relations and selection of subcontractors/manufacturers, standardization in procurements, timely arrival of procurements in required quality including Buyer furnished ones, storage, and preventive maintenance issues.

Shipyard infrastructure was covered under layout, technology, amenities, and environment subgroups. Effects on meteorological conditions and shipyard closed/covered areas against adverse climatic conditions, appropriate layout for material flow and workflow, storage and warehousing, work equipment and machine park, waiting (parking) area of the completed hull & superstructure blocks, outfitting quay(s) deemed necessary. Again, some Lean manufacturing wastes such as minimum mobility requirement in the workstation areas, and the minimum worker and material movement distances had their respective Effects. From the human-factors aspects, the infrastructure group covered some Effects on sidewalks, walking zones, transport of loads and hull-side elevator, ventilation, air conditioning, illumination in working areas and cleaning of work areas, dressing-lockers, showers-toilets, dining-resting areas, proximity to public transport and parking lots, availability of nursery (preschool, kindergarten) in terms of “happy and productive” employees. From the technology aspects of infrastructure, the Effects were concentrated on the utilization of

up-to-date information technologies in shipbuilding, internal and external information integration including shipyard automation systems along with technical investments, investments in computer systems, and Research & Development (R&D). Despite some low consequences on delivery dates of ships, Effects on energy saving and protection of natural resources; use of clean (green) energy, and hazardous waste management in the workplaces and the shipyard were taken into consideration due to possible expensive improvement and investment decisions of the top management, voluntarily or due to regulations. Some side effects on timing may also happen during the shipbuilding period.

Effects on design and production engineering, either executed internally in the shipyard and/or by the design subcontractor of the shipyard, covered design methods (strictly defines ship production start time and project duration), compliance of design document deliveries with the ship production schedule, conformance of the design to shipyard including on-block outfitting and Design for Production, design documentation structure, content and work packages, their quality and easy-to-understand property, easy access of shipbuilding field workers to the ship's 3-dimensional design model and configuration management. Effects on the compatibility of the design and material/equipment supplied by subcontractors/ suppliers, consideration of Ship Acceptance Test requirements at early stages of design, technical coordination with the Classification Society and the Buyer, and ship weight management were also considered.

For the ship production subprocesses, following the contracting subprocess, starting with hull construction, Effects covered the stowage, protection, transportation of shipbuilding plates (steel or else) and profiles arrived in the shipyard; the cutting machines, profile processing, roll/press/benders and welding robots used during the hull & superstructure blocks construction; categorization of block panel/assembly lines according to their difficulties, pre-outfitting, block blasting & painting, on-block outfitting, weight and transportation of completed hull & superstructure blocks and their erection to form the hull.

Metal joining techniques, manufacturing and installation of piping systems in the ship, cast parts and their machining, use of high-tech materials, production of parts and molds from 3D printers, automation in manufacturing and installation and the use of robots had their

respective Effects on the production of parts mainly in the shipyard but some allowance if they are produced by subcontractors.

For outfitting before ship launching, then ship launching and follow-on outfitting subprocesses, the Effects covered manufacturing and assembly of the outfit infrastructure elements, modular outfit-units, on board-outfitting, embarkation of the equipment on board, external hull works and outfitting, painting and the paint manufacturer; provision of adequate capacity of compressed air, electricity, water, steam and the protection of the ship and equipment on board, ship launching infrastructure, methods and execution, remaining outfitting works after ship launching and installations on the shell and external hull, and exterior paint.

One of the basic inputs in shipbuilding, the workforce group contained Effects on the organization by the status of employees (shipyard's own etc.), number of experienced, permanent employees, backup of critical personnel, work planning suitable for the personnel with special conditions, quick workgroups for repetitive tasks and leveraging the learning curve; Effects on performance and practices by the utilization of outsourcing and use of Subcontractors (if used), their workers' experience, knowledge and work performance, on-time delivery performance, and delivery quality, finally manufacturers' technical support.

In terms of emotional and physical aspects of a productive workforce under the motivation subgroup, Effects were considered on employee motivation, their efficient and productive work, wages, salaries and promotions, employee circulation, job descriptions, work sharing, occupational safety, work ergonomics, compliance with working hours and improvement suggestions.

The quality group has Effects on the effectiveness of the Quality Assurance System and its certification status, dimensional accuracy control in hull construction, managing production from quality aspect, Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) preparations and management and coordination with manufacturers, Classification Society, and the Buyer.

Each Effect is numbered in accordance with its subgroup, as given in Table 3.3. The first two digit is the sequence number based on the group; the next three characters is the abbreviation of the subgroup (or group). The last two digit is "00" for the heading and followed by Effect number in order starting from 01 as can be seen in Appendix A.

Table 3.3: Group and subgroup heading numbers of the Effects.

Group	**Heading Number, Subgroup (or Group)**	
Production	11PSB00	Hull & Superstructure Blocks Construction
	12PSE00	Hull Erection
	13PPT00	Parts Manufacturing in the Shipyard
	14POS00	Outfitting before Launching
	15PLA00	Ship Launching
	16POQ00	Outfitting after Launching
Infrastructure	21IFL00	Layout
	221EN00	Environment
	23ITE00	Technology
	24IFA00	Amenities
Design & Production Engineering	30DES00	
Materials & Procurement	40MPP00	
Shipbuilding Management	51APL00	Planning & Budgeting
	52ARM00	Risk Management
Work Force	61WOR00	Organization
	62WPP00	Performance & Practices
	63WPM00	Motivation
Quality	70QAC00	
Contracting	81CMC00	Main Contract
	82CSC00	Subcontracts

Then, those 185 Effects are distributed to the processes as given in Table 3.4 and Figure 3.6. Thirty-six of the Effects are process-specific, and 149 of them are contained partially or in whole processes as listed in Table 3.4. Under the Ship Production process, the Contracting subprocess has 27, the Hull & Superstructure Blocks Construction subprocess has 88, the Hull Erection subprocess has 72, the Parts Manufacturing in the Shipyard subprocess has 72, the Outfitting before Launching subprocess has 94, the Ship Launching subprocess has 59, the Outfitting after Launching subprocess has 83, the STW, Tests & Trials subprocess has 61; the Ship Design process has 87 and the Shipbuilding Management process has 134 Effects. Applicable Effects in processes/subprocesses were evaluated independently for each process/subprocess so that improvements could be evaluated for both the respective process

and the entire shipbuilding process even if with the same content. For multiple processes repeating Effects' list, see Appendix B.

Table 3.4: Distribution of the Effects into the processes.

Process	Subprocess	Used only in this (sub)process	Total Effects in this sub(process)
Ship Production (SP)	Contracting (CON)	4	27
	Hull & Superstructure Blocks Construction (BLK)	10	88
	Hull Erection (ASLY)	1	72
	Parts Manufacturing in the Shipyard (PPT)	3	72
	Outfitting before Launching (OUT)	1	94
	Ship Launching (LCH)	1	59
	Outfitting after Launching (QAY)	2	83
	STW, Tests & Trials (TEST)		61
Ship Design (DES)		6	87
Shipbuilding Management (MNG)	Planning & Budgeting	4	134
	Risk Management		
	Materials & Procurement	4	

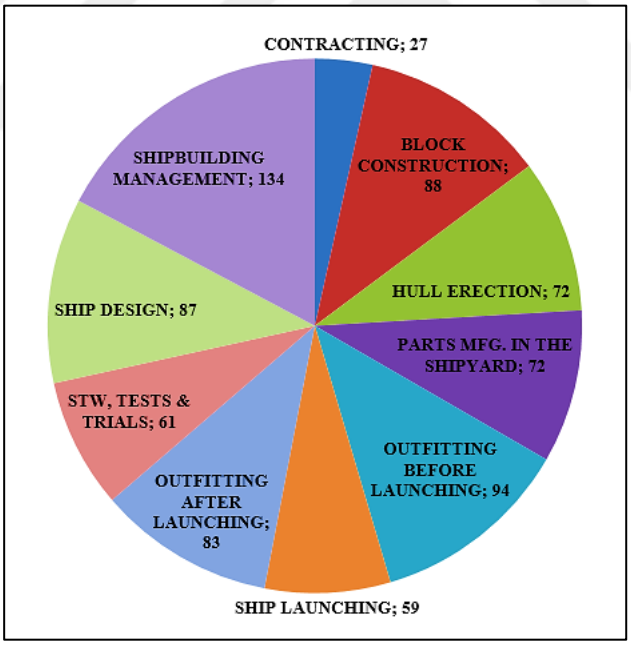


Figure 3.6: Distribution of Effects into processes and subprocesses.

As sampled in Table 3.5. and Appendix C, for some Effects sub-details exist to investigate weights of its break-down items during the shipyard surveys, if the Effect is too general. For example, the "Hull & superstructure blocks erection" Effect has three sub-details, such as the speed of block erection welding, the use of allowance for block erection edge hull/deck plating, and the block erection welding method.

Table 3.5: Sub-details of an Effect (sample).

EFFECT NR.	EFFECT and its sub-details
12PSE01	Hull & superstructure blocks erection
12PSE01.(1)	*Speed of block erection welding*
12PSE01.(2)	*Use of allowance for block erection edge hull/deck plating*
12PSE01.(3)	*Block erection welding method*

3.1.2. Effects' Numerical Properties

Three numerical properties are needed to characterize each Effect in applying the Effects to the mathematical model:

(i) Effect magnitude,

(ii) Effect weight, and

(iii) the timewise position of the Effect along the duration of the related process.

3.1.2.1. Effect Magnitude

Effect magnitude is used to define the y-axis coordinate of the Effect (y-axis value).

For the Shipyard, the Effect magnitude was initially decided to be a natural number and also between 1 to 5 due to a possible use of a 5-point itemized rating scale application to quantify qualitative responses during the test case. “One” is decided to denote the best and “five” to denote the worst condition of an Effect.

For the Ideal Shipyard, to be compared with the Shipyard, all Effect' magnitudes are initially set to y=1, the best status.

Application of weights later changes the Effect magnitudes to rational numbers, between $0<y\leq5$ for the Shipyard and $0<y\leq1$ for the Ideal Shipyard (still the best magnitude). Out of this thesis, if the sectoral weight information is missing due to different types of marine products or any other industrial product, the Effect magnitudes for Ideal conditions may continue to be taken as y=1.

3.1.2.2. Effect Weight

Weight is applied to each Effect (i.e., to the initial Effect magnitude *y*, denoted as "Weighted Magnitude (WM_i)" thereon instead of *y* value).

Considering the test case, Effect weights were decided to be calculated by pairwise comparisons, by the utilization of the Analytic Hierarchy Process (AHP) method (Saaty 1980). Weights were decided to be applied to the processes and subprocesses by the same method.

In this method, a pairwise comparison matrix is established based on *n* number of criteria at a given hierarchy (Koçak and Yercan, 2021). The element (*i*,*j*) of the pairwise comparison matrix is defined by a_{ij} and the criterion in row *i* (*i* =1,2,3,....,*n*) is ranked relative to each criteria represented by the n columns (Koçak and Yercan, 2021). A pairwise comparison scale, usually called the conventional nine-point rating scale in the AHP applications, is used in this study as given in Table 3.6. As the intensity of importance increases, the scale changes from one to nine while as the intensity of importance decreases, the scale changes from 1/3 to 1/9.

Table 3.6: Applied pairwise comparison scale (Saaty, 1977).

Definition	Intensity of Importance
Equally important	1
Moderately important	3
Strongly important	5
Very strongly important	7
Extremely important	9
Slightly less important	1/3
Less important	1/5
Much less important	1/7
Extremely less important	1/9

Solving for the principal eigenvector of the matrix and normalizing the result gives the weight “w” of each criterion (Equation 3.2) (R.W. Saaty, 1987).

$$w_i = \frac{\sum_{j=1}^{j=n} \left(\frac{a_{ij}}{\sum_{i=1}^{i=n} a_{ij}} \right)}{n} \quad (3.2)$$

As explained in R.W. Saaty (1987) and Saaty and Vargas (2012), for consistency checks of the pairwise comparisons, the Consistency Ratio (*CR*) is calculated. If the principal eigenvalue has the value n, then a positive reciprocal matrix of order n is consistent. If the principal eigenvalue exceeds n, it is inconsistent. The Consistency Index (*CI*) for each matrix of order *n* by the formula in Equation 3.3 is the variance of the error that occurred in the estimation of a_{ij}.

$$CI = (\lambda_{max} - n)/(n - 1) \quad (3.3)$$

The Consistency Ratio (*CR*) is calculated as the ratio of the Consistency Index (*CI*) to the Average Random Consistency Index (*RI*) as given in Equation 3.4.

$$CR = CI / RI \quad (3.4)$$

The average Random Consistency Index (*RI*) is the average of the corresponding distances from "*n* of the principal eigenvalues of a large number of matrices of randomly chosen judgments" (R.W. Saaty, 1987), has continued to be developed since Saaty (1977) and more recent, with 500,000 simulations by Franek and Kresta (2014) up to 15 *n*, as shown in Table 3.7.

Table 3.7: Random Consistency Index values (Franek and Kresta (2014).

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	0	0	0.525	0.882	1.110	1.250	1.341	1.404

n	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RI	1.451	1.486	1.514	1.536	1.555	1.570	1.584

If the CR of the comparison matrix is no higher than 0.1, the comparison is acceptable, otherwise, the pairwise comparisons should be revisited Franek and Kresta (2014).

An exception to the aforementioned consistency check is the "perfect consistency" approach, if all n is compared to only one anchor, usually i=1, in a pairwise attitude in a comparison matrix; then the consistency check is not applied (R.W. Saaty, 1987) accepting some inconsistencies.

3.1.2.3. Timewise Position of the Effect

Effects are distributed along the t-axis for their timewise position (x-axis value and in weeks) based on their realization dates during the total shipbuilding period.

Most of the Effects are distributed over a period and do not have a fixed time. Then, the period of such Effects at each process and a specific position to represent the t-coordinate of this period is needed. In this respect for all of the Effects, six alternative time-distribution types are decided to be defined as follows:

(i) happens only once,
(ii) distributed uniformly,
(iii) increases in time,
(iv) decreases in time,
(v) first increases then decreases and
(vi) first decreases then increases.

The matching distribution's centroid represents the timewise coordinate of the Effect on the t-axis. For the Ideal Shipyard, the Effects' timewise coordinate on the t-axis is taken as the same of the Shipyard.

The data gathering on magnitudes, weights are timewise positions for the Effects are presented in subsection 3.2.1.

3.1.3. Curves and Areas

A curve passing through the coordinates of the Effects was needed to use its length or area underneath or a volume around the x-axis for comparisons. However, due to the expected scarce distribution of the Effect coordinates and possible overlapping of some Effect coordinate points around the middle of processes, a method passing through all coordinates

such as interpolation was thought to be an unstable approach. Approximations, not passing through all coordinates, were thought to be a rough solution. Also, due to the possible use of subject curve on a computer-aided design (CAD) software, the use of explicit forms (i.e., a graph of a function *f(x)*) and implicit forms (i.e., a geometric curve as F(x,y) = 0) were not taken into consideration since CAD software in general do not carry such calculations internally (Chang, 2015). Therefore, the use of piecewise polynomial and parameterized curves was one of the initial decisions. Spline curves are composed of piecewise polynomial curves, and they can be manipulated by changing the positions of some control points which would fit better to this study's purpose.

Four points help to form a cubic spline curve at basic but as more points are added, the polynomial order of the curve increases (Chang, 2015). To overcome this, which may be a problem in this study, the B-Spline curve (Schoenberg 1969; de Boor 1972) is thought to be a convenient decision where the polynomial order and the number of control points are defined separately. The continuity at the piecewise polynomial connection points throughout the complete curve is also secured by the use of a cubic B-Spline. The continuity is the derivative up to the $(p-1)^{th}$ order where p is the order of the polynomial order of the curve and a 2^{nd} order continuity is provided for a cubic B-Spline (Beier 1989, Chang, 2015). Since any symmetry or identical shape in geometries is expected, a nonuniform B-Spline curve was planned to be used. Earlier checks on an interactive internet online site[17] (Pawan, 2016) with fictive Effect coordinates showed good results with a third-degree B-Spline curve compared to other degrees B-Spline curves and Non-Uniform Rational B-Spline (NURBS) curves (Piegl and Tiller 1987). Despite the intention to have an on-screen interactive possibility on a CAD software, later the decision was focused on the use of a single compact software to provide aimed portable visual integrity, which is MS EXCEL as available in every shipyard, to review and print complete graphical and numerical outputs, modification results easily. For the mathematical model, MS OFFICE 365 EXCEL (2021-2023), SRS1 Cubic Spline for MS Excel V2.5 add-on software of SRS1 Software, LLC[18] and MATLAB R2019 software of The MathWorks, Inc.[19] are used.

[17] http://nurbscalculator.in
[18] https://www.srs1software.com/SRS1CubicSplineForExcel.aspx
[19] https://www.mathworks.com/products/matlab.html

During the numerical analyses with SRS1 Cubic Spline for MS Excel V2.5 add-on using the actual data obtained during the shipyard surveys (see subsection 3.2.3.), the B-Spline curves followed a pattern below zero as shown in Figure 3.7, at quadrant IV and also high magnitudes were observed above y=5 (thicker black axis in Figure 3.7) which were not favored. Similar problems were observed during the tests with MATLAB R2019 for the use of cubic B-Spline as shown in Figure 3.8.

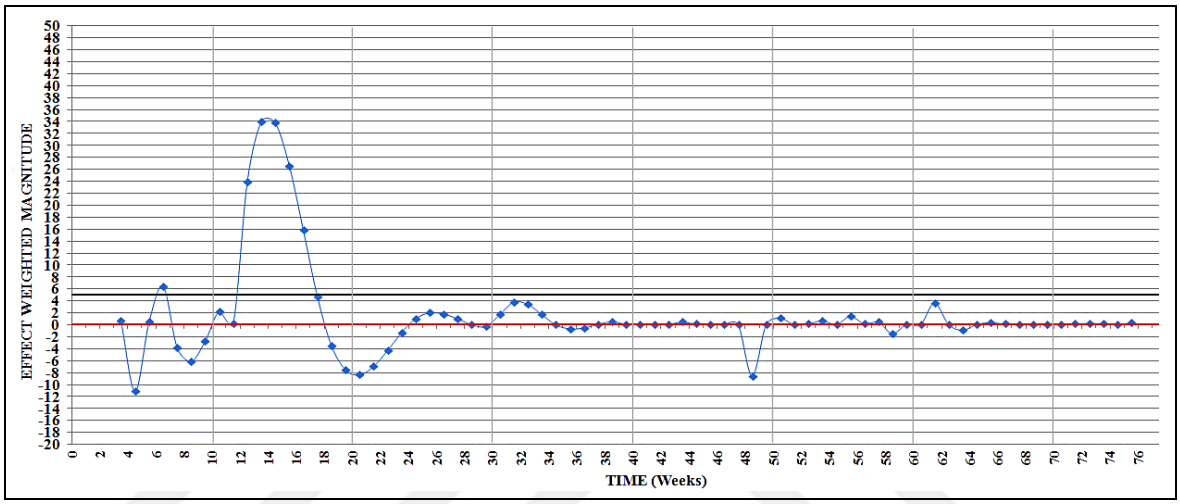


Figure 3.7: Shipbuilding Management process Effect-Time graph with cubic B-Spline; SRS1 Cubic Spline for MS Excel V2.5 add-on.

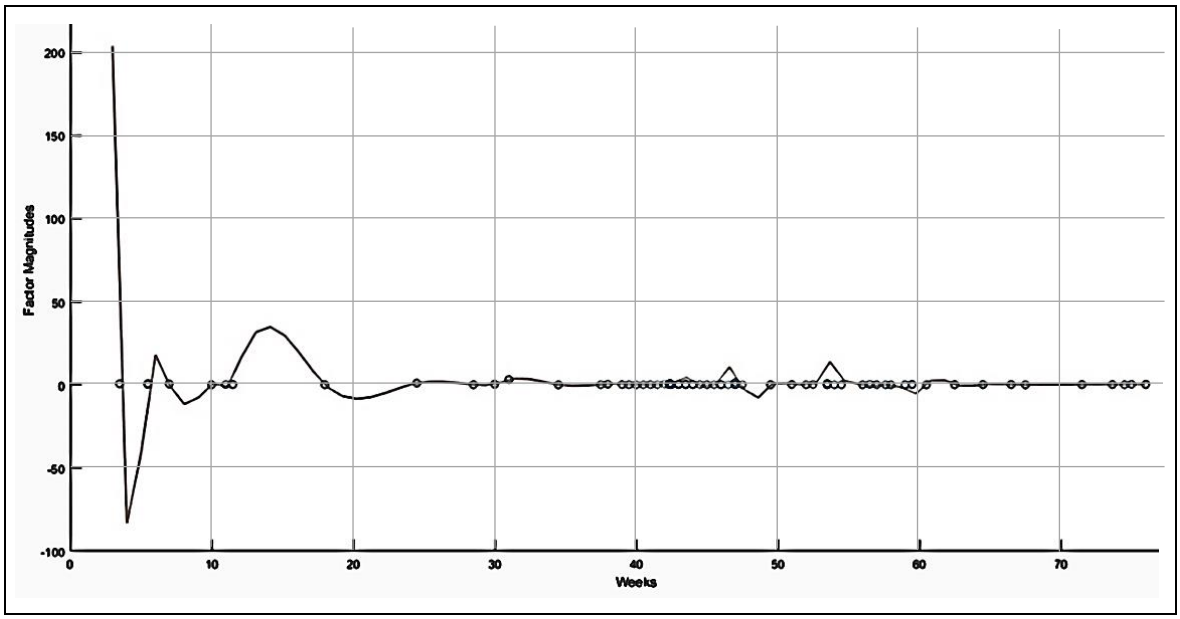


Figure 3.8: Shipbuilding Management process Effect-Time graph with cubic B-Spline; MATLAB R2019.

Then alternative curves were tested. Although the Effect coordinate points are not always monotonic and fluctuating, very good results in OneWay (monotonic) Spline, also named as Monotone Piecewise Cubic Interpolation, experiments with SRS1 Cubic Spline for MS Excel V2.5 add-on were reached, including an acceptable continuity (Figure 3.9).

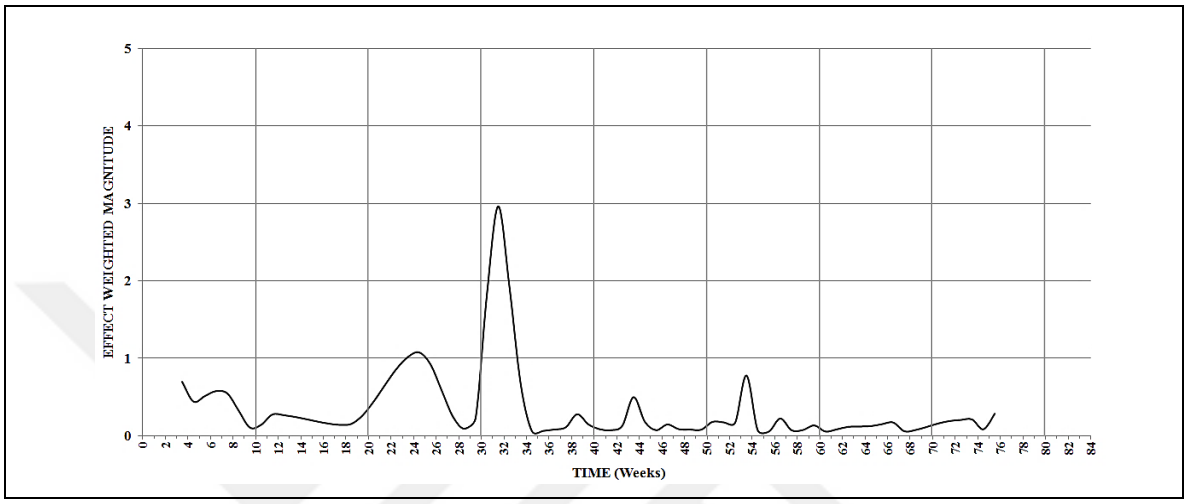


Figure 3.9: Shipbuilding Management process Effect-Time graph, OneWay (monotonic) Spline test with SRS1 Cubic Spline for MS Excel V2.5 add-on.

A monotonic cubic polynomial m is defined on the interval [a,b] and m is represented as in Equation 3.5 (Carlson and Fritsch, 1985).

$$m(x) = m(a)\,H_1(x) + m(b)\,H_2(x) + m'(a)\,H_3(x) + m'(b)\,H_4(x) \quad (3.5)$$

H_i are the cubic Hermite basis functions for [a,b] and defined on the interval [0,h] as given in Equations 3.6, 3.7, 3.8, and 3.9.

$$H_1(x) = (2x^3 - 3hx^2 + h^3) / h^3 \quad (3.6)$$

$$H_2(x) = (-2x^3 - 3hx^2) / h^3 \quad (3.7)$$

$$H_3(x) = (x^3 - 2hx^2 + h^2x) / h^2 \quad (3.8)$$

$$H_4(x) = (x^3 - hx^2) / h^2 \quad (3.9)$$

Experiments for Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) with MATLAB R2022b software gave highly similar results with OneWay (monotonic) Spline experiments with SRS1 Cubic Spline for MS Excel V2.5 add-on, except some continuity

problems (Figure 3.10 and Figure 3.11). In MATLAB R2022b software, the continuity problem was explained in the respective guideline such that, a 2nd order continuity may not be possible, and jumps are possible at piecewise polynomial connections, but 1st order continuity is provided. In this study, despite the non-monotonic nature of the data and the curve, the purposed curve type was obtained (see Figure 3.9) and found sufficient. The opinion of Carlson and Fritsch (1980) was that, to preserve interpolation, sacrifice in monotonicity is often used and this method is better than least squares or other approximation methods. In this study also in parallel with Carlson and Fritsch's (1989) "monotonicity in only one variable, in only coordinate direction" approach, here the time coordinate (*t*-axis) forming the coordinate, the study was decided to continue with OneWay (monotonic) Spline. Unless different methods are used for the processes and subprocesses or benchmarking intended with other shipyards using different methods, results in this study by using OneWay (monotonic) Spline at necessary steps do not cause a complexity.

```
% Read data from Excel file
[num,str] = xlsread ('Veri.xlsx','Sayfa1','A2:B135');

% t and y vectors
t = num (:,1);
y1 = num (:,2);

% Define intervals
solve = linspace (3,79,76); % 76 weeks between wk 3 and wk 79

% Solve for PCHIP Function phf
phf = pchip (t,y1,solve);

% Plot graph
plot (t,y1, 'o' ,solve,phf, '-' )
```

Figure 3.10: MATLAB Code for Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) test.

Numerical data obtained from the curve fit are used in the calculation of the areas under the curves by using a numerical integration method, Simpson's Second Rule which is also a historical method used in naval architecture. The decision to use numerical integration and Simpson's rules was based on the possibility of having different numbers of spacings related

integration of resulted data on surveys at different shipyards. Then different rules are possible to be applied in the model.

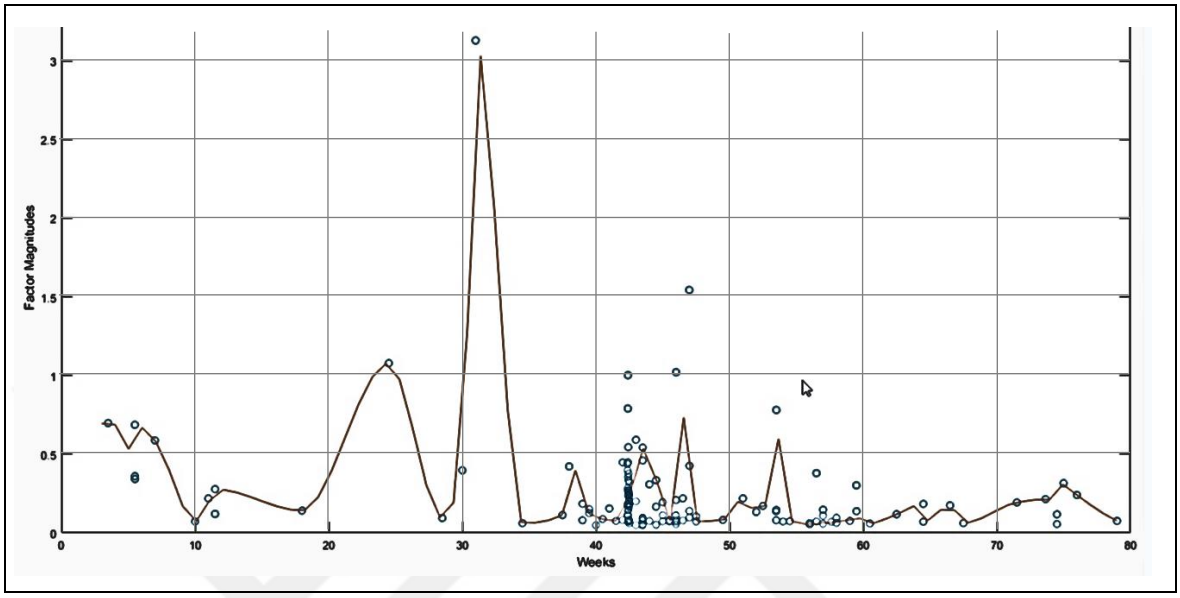


Figure 3.11: Shipbuilding Management process Effect-Time graph, Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) test with MATLAB R2022b.

Simpson's Second Rule is obtained by fitting a 3rd degree polynomial to four equally spaced discrete points and the integration of the entire range is obtained by applying Equation 3.10 (Hoffman, 2001),

$$\text{Area} = 3h/8\ (y_0 + 3y_1 + 3y_2 + 2y_3 + 3y_4 + \ldots\ldots + 3y_{n-1} + y_n \qquad (3.10)$$

where, h is the spacing of ordinates, taken as $0.4 \leq h \leq 1$ in this study. The endpoints of the curves are not at y=0 and at the first and last Effect coordinates but it was deemed as sufficient for this study. The error term of Simpson's Second Rule, in Equation 3.11 (Sastry, 2006) was also not considered for the time being.

$$\text{Error} = -3/80\ h^5\ y^{iv}(\zeta) \quad , \text{“}y^{iv}(\zeta) \text{ is the largest value of the } 4^{th} \text{ derivatives”} \qquad (3.11)$$

3.1.4. Productivity Numbers

Three key numbers are the first of two major outputs of this new methodology (the other output is the prioritized improvement list);

- the (dimensionless) Productivity Number "PN",
- the dimensionless Productivity Number (DPN) of the subprocess/processes "DPN", and
- the dimensionless Productivity Number of the Shipyard (entire shipbuilding process) **"U".**

Productivity numbers belonging to the Shipyard show the "current (actual)" state. Productivity numbers belonging to the Ideal Shipyard show the "target" state.

A shipyard's managerial task is to reach the "target" state by improvements and to make all DPNs and **U** equal to 1.

The classification of the processes and subprocesses is repeated in Table 3.8. (see subsection 2.1.2).

Table 3.8: Process classification in this study

Total Process	Major Processes	Subprocesses
Shipbuilding		
	Shipbuilding Management (MNG)	
	Ship Design (DES)	
	Ship Production (SP)	
		Contracting (CON)
		Hull and Superstructure Blocks Construction (BLK)
		Hull Erection (ASLY)
		Parts Manufacturing in the Shipyard (PPT)
		Outfitting before Ship Launching (OUT)
		Ship Launching (LCH)
		Outfitting after Ship Launching (QAY
		Tests & Trials (TEST)

Any process/subprocess abbreviation attached to the SY and ISY subscript below belongs to the Shipyard and Ideal Shipyard, respectively.

3.1.4.1. Shipyard's current productivity numbers:

For subprocesses of the Ship Production process, the calculated area under the curve referencing the coordinates of the Shipyard's Effects of a subprocess, when multiplied by the subprocess weight (obtained from the Shipyard's survey results) gives the "current Productivity Number" of the subprocess. Productivity Number (PN) of each subprocess of the Ship Production (SP) process is calculated as in Equation 3.12.,

$$PN_{SYsubprocess} = Aw \tag{3.12}$$

where,

the subprocesses are CON, BLK, ASLY, PPT, OUT, LCH, QAY and TEST,

A denotes the total area under the curve of the subprocess and,

w denotes the (shipyard) weight of the subprocess.

For the major processes, the calculated area under the curve referencing the coordinates of the Shipyard's Effects of a process, when multiplied by the process weight (obtained from the Shipyard's survey results) gives the "current Productivity Number" of the process. The "current Productivity Number" of the Ship Production process is reached when totaled for all subprocesses as given in Equation 3.13.

$$PN_{SP} = wb_{SYSP} \ (PN_{CON} + PN_{BLK} + PN_{ASLY} + PN_{PPT} + PN_{OUT} + PN_{LCH} + PN_{QAY} + PN_{TEST}) \tag{3.13}$$

wb denotes the process basis weight (general, cost, labor, or time), obtained from Shipyard specific survey results.

Productivity Number (PN) of Shipbuilding Management (MNG) and Ship Design (DES) processes are calculated as given in Equations 3.14 and 3.15 respectively.

$$PN_{SYMNG} = A \ wb_{SYMNG} \tag{3.14}$$

$$PN_{SYDES} = A \ wb_{SYDES} \tag{3.15}$$

For the total shipbuilding process, the current Productivity Number of the Shipyard is reached when totaled for all processes. The Productivity Number (PN) of the Shipyard is calculated as given in Equation 3.16.

$$PN_{SY} = PN_{SYMNG} + PN_{SYDES} + PN_{SYSP} \quad (3.16)$$

By the application of process-based weights, Equation 3.16 is also in parallel with the proposal of Ray and Chen (2015): “a natural solution would be to take some average of the partial productivities for a measure of total factor productivity”.

3.1.4.2. Ideal Shipyard’s productivity numbers:

For subprocesses of the Ship Production process, the calculated area under the curve referencing the coordinates of the Ideal Shipyard's Effects of a subprocess, when multiplied by the subprocess shipbuilding Sector weight (obtained from the survey results of all Shipyards) gives the "target Productivity Number" of the subprocess. Productivity Number (PN) of each subprocess of the Ship Production (SP) process is calculated as in Equation 3.17.

$$PN_{ISYsubprocess} = A\, w_s \quad (3.17)$$

where,

the subprocesses are CON, BLK, ASLY, PPT, OUT, LCH, QAY and TEST,

A denotes the total area under the curve of the subprocess and,

w_s denotes the Sector weight of the subprocess.

For the major processes, the calculated area under the curve referencing the coordinates of the Ideal Shipyard's Effects of a process, when multiplied by the shipbuilding Sector weight of the process (obtained from the survey results of all Shipyards) gives the "target Productivity Number" of the process. The "target Productivity Number" of the Ship Production process is reached when totaled for all subprocesses as given in Equation 3.18.

$$PN_{SP} = wbs_{ISYSP}\ (PN_{CON} + PN_{BLK} + PN_{ASLY} + PN_{PPT} + PN_{OUT} + PN_{LCH} + PN_{QAY} + PN_{TEST}) \quad (3.18)$$

wbs denotes the process basis weight (general, cost, labor, or time) of the Ideal Shipyard, obtained from the survey results of all Shipyards.

Productivity Number (PN) of Shipbuilding Management (MNG) and Ship Design (DES) processes are calculated as given in Equations 3.19 and 3.20 respectively.

$$PN_{ISYMNG} = A\ wbs_{ISYMNG} \quad (3.19)$$

$$PN_{ISYDES} = A\ wbs_{ISYDES} \quad (3.20)$$

For the total shipbuilding process, the target Productivity Number of the Shipyard is reached when totaled for all processes. Productivity Number (PN) of the Ideal Shipyard is calculated as given in Equation 3.21.

$$PN_{ISY} = PN_{ISYMNG} + PN_{ISYDES} + PN_{ISYSP} \quad (3.21)$$

3.1.4.3. Dimensionless Productivity Numbers

For the subprocesses, the ratio of the "current Productivity Number" to the "target Productivity Number" is the dimensionless "Productivity Number" of the subprocess. Dimensionless Productivity Number of the subprocesses CON, BLK, ASLY, PPT, OUT, LCH, QAY, and TEST is calculated as given in Equation 3.22.

$$DPN_{subprocess} = PN_{SYsubprocess} / PN_{ISYsubprocess} \quad (3.22)$$

For the major processes, the ratio of the "current Productivity Number" to the "target Productivity Number" is the dimensionless "Productivity Number" of the process. Dimensionless Productivity Numbers for SP, MNG, and DES processes are calculated as given in Equation 3.23

$$DPN_{process} = PN_{SYprocess} / PN_{ISYprocess} \quad (3.23)$$

Finally, the ratio of the "current Productivity Number of the Shipyard" to the "target Productivity Number of the Ideal Shipyard" is the dimensionless "Productivity Number "**U**" of the Shipyard. The dimensionless Productivity Number of the Shipyard (the total

shipbuilding process) is calculated as given in Equation 3.24.

$$\mathbf{U} = PN_{SY} / PN_{ISY} \quad \text{, where } \mathbf{U} \geq 1 \tag{3.24}$$

In a very exceptional situation, if for the majority of the processes & subprocesses,

- all Shipyard Effects are in the perfect state and/or,
- all Weighted Magnitudes of the Effects, not necessarily to be the same Effects, match with the Ideal Shipyard's and/or,
- Shipyard Spline curves are drawn under the Ideal Shipyard Spline curve, so their $PN_{SYprocess} < PN_{ISYprocess}$,

then it may be possible that the dimensionless Productivity Number of the Shipyard can be bigger than zero and smaller than one, i.e., $0 < \mathbf{U} < 1$. Then this may be called an extraordinary (super) productivity state which may occur mathematically, but very hard in real life.

3.1.5. Improvement areas Priority Lists

To list the improvement priorities is the second aim of this study to examine the needed improvements to reach the Ideal Shipyard state.

It may be said that due to the time pressure kind of reasoning or lack of experience in mathematical decision-making methods, calculated decisions may be superseded by intuitive decisions by managements. This may lead to wrong investment decisions. As in shipbuilding, with different-in-nature processes and subprocesses with interim inputs and outputs, improvement at one point carries the risk of creating new problems at another point of the production chain.

In this study, the use of the Analytic Hierarchy Process based weighting of the Effects was planned to help prioritize improvement needs. The Effects are to be listed and sorted by their Weighted Magnitudes. The weighted magnitudes of Effects of the Shipyard change between $0 < WM_i \leq 5$ as mentioned in subsection 3.1.2.1 previously. Starting with the highest Effect weighted magnitude (most unfavorable), the top-down improvement lists on process and subprocess basis were planned to be obtained. Due to repeated Effects at several processes and subprocesses (see subsection 3.1.1), a chain reaction of an improvement could be

observed as changes in the current Productivity Number of the respective process/subprocess positively or negatively. In the list on MS Excel, when an Effect's magnitude value is reduced to a value up to "1" (best condition) if it is currently higher than "1", the process/subprocess Spline curve and area under it changes accordingly, followed by the change in the Productivity Number.

For double-checking these improvement lists, the Pareto chart was also planned to be applied to the listed data. It is one of the fundamental tools used in quality assurance and business life to identify the most prevalent defects or factors. In Pareto charts with the 80/20 rule, it is stated that 80% of the results are determined by 20% of the causes. The Pareto chart used for this is actually a Pareto Type 1 cumulative distribution function where a Pareto random variable with α and x_m parameters is,

$$F_X(x) = \begin{cases} 1 - \left(\frac{x_m}{x}\right)^{\propto}, & x \geq x_m \\ 0 & , \ x < x_m \end{cases} \tag{3.25}$$

where the value of α is $\log_4 5 \approx 1.16$.

In this study, the Pareto chart was planned to be used according to the same 80/20 principle to detect the Effects that initially need to be reviewed since the first 20% of the unfavorable Effects affect 80% of the process productivity. For each process/subprocess, the Effects were to be listed in decreasing order in terms of their calculated Weighted Magnitudes (WM_i), WM_i max to WM_i min, then percentages were to be calculated for each effect ($WM_i / \sum WM_i$) and cumulative percentages were to be determined, then graphed. If the cumulative percentage of an Effect is smaller than 0.80, then the respective Effect is to be deemed to have a critical importance for improvement.

3.2 Test Cases

The aim of this research is to develop a basic methodology to identify a shipyard's productivity numerically, preferably in a dimensionless structure and covering the entire shipbuilding process. A systematic approach was necessary to be planned to obtain data from several shipyards to operationalize the conceptual methodology under development in this

study. Data to calculate Effects' numerical properties (i.e., magnitudes, weights, and timing as explained in subsection 3.1.2.) and time data on sample shipbuilding projects were needed to calculate some real shipyards' actual status and their Ideal status to test the methodology numerically. Tests were expected to provide some certainty if this new methodology is applicable and generalizable. For absolute certainty, an examination of all shipyards in the world, which forms the population from the statistical view, was necessary. But it was impractical from the time and cost aspects first. So, to represent this population some samples should be taken, and the sampling technique should be specified. The data gathered from the sample representing the population of interest helps to understand if we can generalize the results of this study. It should be remembered that the procedures applied may include a probability of wrong conclusions (Walpole et al., 2012).

It was necessary to see if this study may represent the shipyards globally and a shipyard itself; and if we could see some similarities between different shipyards, and also if calculated sector weights could represent the shipbuilding sector. Therefore, the sampling technique, data, and test statistics were needed. One of the challenges here was the non-availability of data on the population except the number of shipyards in the world. It would be very helpful for further statistical inferences if could have known some characteristics of the population, namely the shipyards and also the processes/subprocesses individually concerning this study such as means, variances, and standard deviations but no such data were available in the literature. Estimations in this respect could be misleading for the sparsely distributed shipyards all around the world, each with its own way of building ships, properties, and characteristics. But on a shipyard basis, when necessary cooperation was established, data on population could be obtained on the process/subprocess basis. There were also no critical regions or critical values within the methodology from the aspect of test statistics. As mentioned in Section 3 (see Equation 3.1). the only critical value in this method is if the dimensionless productivity number of a shipyard **U** is equal to "1" where the Shipyard is in the most productive state.

3.2.1. Preparing for Data Collection

Among several methods, the "survey" method was decided due to the participation of large groups in shipyards at a global scale and the expectation of data on many general

characteristics, also considering time and travel requirements. Therefore, the data were planned to be collected by the distribution of question lists to participants in person, or online.

For a survey, the initial needs were a decision on defining levels and scales of measurements, the sampling technique to be applied, a questionnaire design, and the identification of respondents (i.e., participating shipyards). The relationship among the values assigned to the opinions or attributes for a variable forms the level of measurement. Observation and recording of the gathered data form the measurement process while the assignment of objects to numbers or semantics based on a rule forms the scaling. Due to the early assumption of gathering non-sensitive data (see subsection 1.4.1) and possible limitations in gathering actual data from the shipyards as mentioned in subsection 1.4.3, questions were supposed to be mixed type, both qualitative and quantitative types. A convergent parallel design was decided by collecting qualitative data to calculate Effect magnitudes and weights; and quantitative data for information on the time issues. Then, a quantification process was necessary for the evaluation of qualitative questions for further calculations to draw overall conclusions.

To be able to draw conclusions on the population of the 10 processes/subprocesses as defined in subsection 2.1.2, the sampling focus was put on the processes/subprocesses at several shipyards. The participants from each process and subprocess in each shipyard were to form a unit as the elements of these populations. The units were to represent similar characteristics as the population so the results could be generalized from the sample to the population. Taking all employees of a shipyard together under the same single unit, which leads to simple random sampling (here with a finite population) could result in errors in sampling due to heterogeneity. To minimize this sampling error, every participant of the population should represent her/his own process/subprocess and should have an equal chance of being selected despite this might also not guarantee repetitiveness (Walpole et al., 2012). The minimum number of shipyards to be surveyed was decided to be calculated by the simple random technique (finite population) as formulated in Equations 3.26 and 3.27 (Cochran 1977). Different sample size determination techniques based on categorical and continuous data separation were not considered due to the possible use of both data types, so continued with the categorical data-based technique. In Equation 3.26, n_0 is the sample size if the population

is infinite, *z* is the precision, *e* is the confidence level, *p* is the proportion of an attribute that is estimated to be present in the population and N is the known population.

$$\text{Sample size (random, infinite population)} = n_0 = \frac{z^2 - pq}{e^2} \tag{3.26}$$

$$\text{Corrected sample size (random, finite)} = n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \tag{3.27}$$

For the evaluations at each shipyard, the stratified random sampling technique was thought initially to be applied in parallel with the classification of the 10 heterogeneous processes/subprocesses under observation, from the internal homogeneity in expertise aspect. This could be applied if the collectively exhaustive and mutually exclusive property requirement of this technique could be provided during the surveys. But there were two considerations,

(i) Effect weights were to be calculated for each dedicated process/subprocess internally and an inference to the whole population of a shipyard was not intended,

(ii) calculations to obtain sector weights of up to 185 Effects were to be made for 10 separate processes/subprocess which brings the problem of handling a big data size such as the number of surveyed shipyards time up to a number of 1850.

Therefore, the stratified random sampling technique was only considered in obtaining process/subprocess-specific sample size requirements. The advantage of stratified sampling is known as higher precision in estimation while was expected to be more time-consuming in implementation. Proportionate stratified sampling with allocating sampling effort proportional to strata size and without replacement was decided since the number of elements in each stratum and total population sizes could be obtained from the respective shipyards at the beginning of the surveys. Even if this technique couldn't be applied, it could have assisted in the sample size requirement for each process/subprocess of a shipyard. The formulae for the stratified random sampling technique are given in Equations 3.28 and 3.29 (Nişel, 2023). Here, n_0 is the weight-adjusted sample size for each strata, i is the strata

number, L is the total number of strata N_i is the population of each strata, N is the total population, and σ_i^2 is the variance of each strata population.

$$\text{Sample size (stratified)} = n_0 = n\,\frac{N_i}{N} \tag{3.28}$$

$$\text{where, } n = \frac{\sum_{i=1}^{L} N_i\,\sigma_i^2}{ND + \frac{1}{N}\left(\sum_{i=1}^{L} N_i\,\sigma_i^2\right)} \quad , \quad D = \frac{B^2}{z^2} \tag{3.29}$$

Preparation for a survey first resulted in a questionnaire set with eleven sections on "Expert Opinion". These sections were,

(i) Management : Basis Information,
(ii) Section 1 : Shipbuilding Management (MNG),
(iii) Section 2 : Contracting (CON),
(iv) Section 3 : Hull and Superstructure Blocks Construction (including Hull Block Outfitting, Block Blasting & Painting) (BLK),
(v) Section 4 : Hull and Superstructure Blocks Erection (on Slipway etc.) (ASLY),
(vi) Section 5 : Parts Manufacturing in the Shipyard (including thin metalwork, pipe manufacturing, casting and cast parts etc.) (PPT)
(vii) Section 6 : Outfitting before Launching (Outfitting on the slipway etc.) (OUT),
(viii) Section 7 : Ship Launching (LCH),
(ix) Section 8 : Outfitting works after Launching (at Outfitting Quay, in Dock etc.) (QAY),
(x) Section 9 : Setting-to-Work (STW), Harbor and Sea Trials (HAT-SAT) (TEST) and,
(xi) Section 10 : Ship Design (DES).

For each shipyard, these eleven sections were to be distributed to the related departments in the necessary numbers to fulfill the sample size requirement.

In each section, after the cover page, three divisions were arranged. The first division included four parts on the purpose of the survey; the second was the empty space for the name of the shipyard's liaison (survey coordination) personnel; the third contained samples of each question type and how to answer them and the last part was on participants' information. The last part covered information on start and finish dates of filling-in the questionnaire, each respondent's age, gender, specialty, current title in the shipyard, working time in this shipyard, last completed education level, experience in the shipbuilding sector,

number of previous workplaces (shipyard, ship design house, shipbuilding side-industry firm and other).

The following two divisions were reserved for questions, sample questions from these second and third divisions are provided below.

Different than the following 10 sections of the questionnaire set, the first section, Management:Basis Information, covered the questions on basic information of the shipyard initially, then major characteristics of the ship referenced for the survey, and her shipbuilding project durations (entire and major processes total duration in weeks along with the process weeks of start and finish) in its second division, as shown in Appendix D Figure D.1.

In all other 10 sections, the second division was composed of questions to calculate,

(i) Effect magnitudes (Figure 3.12.)

(ii) if the Effect has sub-details, an additional pairwise question to calculate the weights of the sub-details in finalizing Effect Magnitude (Figure 3.13.),

(iii) effective periods of the Effects (Figure 3.14) and

(iv) Effects' time distribution type (Figure 3.15)

for the 185 Effects listed in their respective process or subprocess sections as given in Appendix B.

For identification of the magnitude of each Effect, a 5-point itemized rating scale (Likert 5-scale like) matrix type question with one choice to be circled at each line was asked to each respondent, as shown in Figure 3.12. Likert scale question style and its method is rather simple for the respondent and easy to administer. Where possible and appropriate, classical choices changing from "strongly agree" to "strongly disagree" were used but when necessary, the question choices had semantic details as shown in Appendix C. The selected choice by the respondent which changes between y=1 and y_{max}=5 identifies the y-axis (Effect Magnitude) value. The order of the choices was arranged such that, the best condition was choice number 1, and the worst condition was choice number 5, but this was not verbally expressed to the respondents. Bold characters were used in some words to emphasize and differentiate the choices at a glance. The Effect number 11PSB03 in Figure 3.12 has sub-details, so the question has 2 more lines with respective choices to be circled. (For numbering

BLK Quest. : 3.a.	**The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing**					
		1	**2**	**3**	**4**	**5**
BLK Quest.: 3.a.(1)	Number of CNC plasma cutting machines and whether they all use the same type of nesting-cutting software	There are **at least 2 (two)** CNC plasma cutting machines; **at least 2 (two)** machines use the data from the **same type** of nesting-cutting software	There is **at least 1 (one)** CNC plasma machine, but in projects, most of the time plates arrive in the Shipyard as already cut	There are **at least 2 (two)** CNC plasma cutting machines; they receive data from **different types** of nesting-cutting software	There is **1 (one)** CNC flame cutting machine	**There is no** a CNC flame cutting machine; in all projects, plates arrive in the Shipyard as already cut
BLK Quest.: 3.a.(2)	Bevelling on the plates by the CNC machine	Always	Bevels are cut **by CNC** plasma cutting machine. However, in projects, mostly plates arrive in the Shipyard as their bevels cut	Bevels are cut **by CNC** plasma cutting machine. However, sometimes in projects, plates arrive in the Shipyard with their bevels cut	Bevels are **sometimes cut by CNC** plasma cutting machine and sometimes by hand grinding after they are cut	Bevels of the plates are **cut manually** by hand grinding after they are cut
BLK Quest.: 3.a.(3)	Availability of a submerged type plasma or laser or pressure water plate cutting machine to cut thin plates with reduced deformation/ distortion	**At least 2 (two)** of the CNC plasma cutting machines are submerged type; In addition, there is **at least 1 (one) laser beam or water jet cutting** machine.	**There is 1 (one)** submerged type CNC plasma cutting machine. In addition, there are **at least 1 (one) laser beam or water jet cutting** machine.	**There is 1 (one) laser beam or water jet cuttin**g machine	**There is 1 (one)** submerged type CNC plasma cutting machine	**There is no** submerged type plate cutting machine, laser beam or water jet cutting machine

Figure 3.12: A sample question format to find Effect magnitude (Effect number 11PSB03 with three sub-details).

of Effects, see subsection 3.1.1 and Table 3.3.) Each circled sub-detail magnitude was then multiplied by the calculated weight of the sub-detail, after a pairwise comparison (see subsection 3.1.2.2.) question shown in Figure 3.13 among sub-details, and then all totaled to obtain a single magnitude of the Effect. This operation resulted in Effect magnitudes in rational numbers where the magnitude y is $1 \leq y \leq 5$. In pairwise comparison, the first sub-detail (as BLK Question 3.b. in Figure 3.13) was always the anchor question and all pairwise comparisons were to be made with it.

BLK Quest.:3.b.	"Number of CNC plasma cutting machines and whether they all use the same type of nesting-cutting software", when compared to ..... as stated below, is ..... (tick one in the box underneath) :									
	↑	Extremely less important	Much less important	Less important	Slightly less important	Equally important	Moderately important	Strongly important	Very strongly important	Extremely important
BLK Quest.: 3.b.(2)	Bevelling on the plates by the CNC machine									
BLK Quest.: 3.b.(3)	Availability of a submerged type plasma or laser or pressure water plate cutting machine to cut thin plates with reduced deformation/ distortion									

Figure 3.13: A sample question format for the three sub-details of Effect number 11PSB03 in pairwise comparison style.

For the calculation of the Effect magnitudes, M_i, geometrical mean (GEOMN) was used. If there is only one line of question for an Effect,

Effect magnitude on process base =

$$y_i = M_i = \text{GEOMN}\,[(M_{i(r1)} + M_{i(r2)} + .. + M_{i(rn)}] \quad (3.30)$$

for r = 1,2,3,….,n representing each respondent of a process/subprocess.
If there are sub-details (more than one line of question) of an Effect then,

$$\text{for each } M_{i(r)}, \quad M_{i(r)} = \text{GEOMN}\,[(M_{i(a)}\, w_{i(a)}) + M_{i(b)}\, w_{i(b)}) + \ldots + M_{i(z)}\, w_{i(z)})] \quad (3.31)$$

where, w_i is the calculated weight of each sub-detail from the respective pairwise comparison.

During the calculations, the geometrical mean was preferred to the arithmetical mean for being more conservative and its openness to the future addition of more survey data. MS EXCEL 360 (2022 and 2023) software embedded functions and its statistical solver add-in were used for all descriptive statistics including geometrical mean and mode.

During the initial design of the questionnaire sets, a high number of questions and criteria in pairwise comparisons started to be observed. Not to overwhelm the respondents, the "perfect consistency" approach was decided where all sub-details are compared only with the first sub-detail as anchored but not among each other. This canceled the need for pairwise comparison consistency checks explained in subsection 3.1.2.2. Minor inaccuracies in this respect became possible but ignored.

As applicable for each Effect, effective period start- and end-week numbers are asked in handwriting or drawing in a similar format of a continuous rating scale as shown in Figure 3.14. This data was used to find the Effect's timewise interval on the *t*-axis during the centroid calculation as explained below.

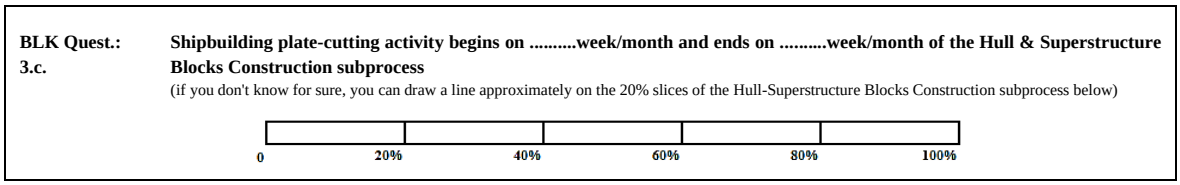


Figure 3.14: A sample question format to find effective periods of the Effects (here for Effect number 11PSB03).

To find the timewise position *t* of an Effect in weeks between the answered start and end week of the Effect during the entire shipbuilding, six choices were submitted. One of them asked to be marked to represent Effect's timewise distribution type, in a nominal (also named as categorical) scale, as shown in Figure 3.15. This structure does not express relationships between distribution types. But in the background for quantification, each choice from left to right had a discrete value from 1 to 6. In the calculations, the mode (MODE) of the respondents' choice T_i for timewise distribution denoted the timewise position t_i of an Effect on the *t*-axis within the time period specified (see Figure 3.14) in the respective process/subprocess time period, as given in Equation 3.32.

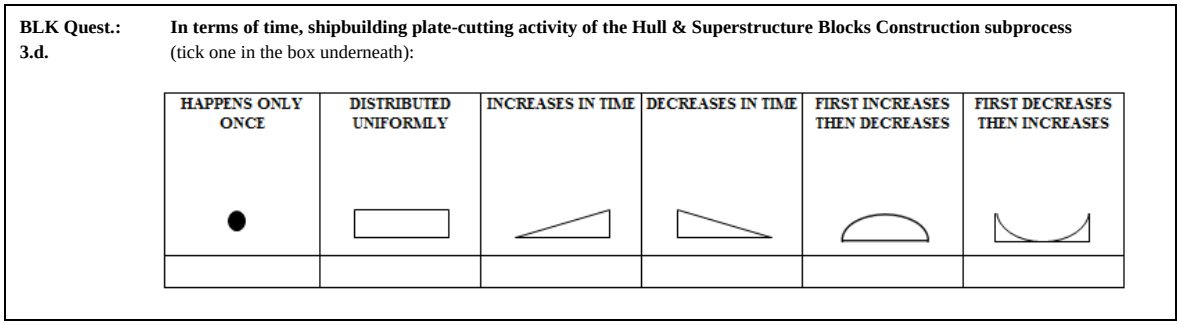


Figure 3.15: A sample question format to find Effects' timewise distribution type (here for Effect number 11PSB03).

For the calculation of the timewise position of an Effect t_i on process/subprocess base,

$$t_i = \text{Centroid of [MODE } \{(T_{i(r1)} + T_{i\,(r2)} + .. + T_{i\,(rn)}\}] \quad (3.32)$$
$$\text{on } \min T_{\text{finish}} - \max T_{\text{start}} \text{ specified by the respondents r} = 1,2,3,\ldots,n$$

and T_i is the choice of each respondent for the timewise distribution type. If MODE doesn't exist then the use of closest distribution in terms of centroid compatibility was planned and to be identified in Italics when tabulated.

For some Effects such as "Minimum worker movement distances" which may be a specific-time independent throughout a process, their specific timing (week) was decided to be the middle of its respective process/subprocess period. This also brings a problem of overlapping some Effect coordinate points at the mid-point of a process, but this was taken care of by the curve type used as explained in subsection 3.1.3. In this respect, timewise distribution type was not asked for such Effects with the duration of the whole process period. (In the questionnaire of the second phase of the shipyard survey, timewise distribution type was asked for 87 of 134 Effects in the Shipbuilding Management process section, 51 of the 87 Effects in the Design process section, and 58 of the 94 Effects in the Outfitting before Ship Launching subprocess questions.)

Again, different than the following 10 sections the first section of the questionnaire set, Management:Basis Information, covered the questions on cost, labor, time, and in general basis comparisons of the subprocesses (Figure 3.16) and major processes (Figure 3.17) in the form of pairwise comparison format, in its third division.

For the following 10 sections of the questionnaire, the third and last division covered pairwise comparison type questions on the Effects (Figure 3.18) and Effect groups & subgroups (Figure 3.19) to calculate their weights. Their weights were to be calculated from the pairwise comparison choice markings as applied in the AHP method (see subsection 3.1.2.2), from the perspective of the Shipyard's respondents.

In all third division questions, the first question was always the anchor question for pairwise comparisons.

MNGBS Quest.:101	**If "Costs" are considered, the "Shipbuilding Contract and Subcontractor Contracts" process,** when compared to ..... as stated below, is ..... (tick one in the box underneath) :									
	↑	**Extremely less important**	**Much less important**	**Less important**	**Slightly less important**	**Equally important**	**Moderately important**	**Strongly important**	**Very strongly important**	**Extremely important**
MNGBS Quest.:102	**Hull & Superstructure Blocks Construction**									
MNGBS Quest.:103	**Hull Erection**									
MNGBS Quest.:104	**Parts Manufacturing in the Shipyard**									
MNGBS Quest.:105	**Outfitting Before Launching**									
MNGBS Quest.:106	**Ship Launching**									
MNGBS Quest.:107	**Outfitting After Launching**									
MNGBS Quest.:108	**Setting-to-Work, Harbor and Sea Trials**									

Figure 3.16: A sample question on comparison of Ship production subprocesses on cost basis.

MNGBS Quest.:601	**If "Use of labor (man x hour etc.)" is considered, the "Ship Production stages" from contracting to ship delivery,** when compared to ..... as stated below, is ..... (tick one in the box underneath) :									
	↑	**Extremely less important**	**Much less important**	**Less important**	**Slightly less important**	**Equally important**	**Moderately important**	**Strongly important**	**Very strongly important**	**Extremely important**
MNGBS Quest.:602	**Management**									
MNGBS Quest.:603	**Ship Design**									

Figure 3.17: A sample question on comparison of major processes on labor basis.

The Effect weights calculated from all of the participating shipyard respondents together were used to provide the shipbuilding "Sector Weight" of each Effect after geometrical mean calculation. For the Sector Weights, normalization was also applied within and among the Effect groups & subgroups. Again, during the calculations to gather consolidated data on weights for each Effect, the geometrical mean was preferred, and MS EXCEL 360 (2022 and 2023) software embedded functions and its statistical solver add-in were used for all descriptive statistics.

After the theoretical methodology studies, the Questionnaire sets were prepared for shipyard surveys. Two shipyard survey phases, the first being simpler and the second being more complex became necessary due to limitations in the study time frame.

BLK Quest.:1.a.	**"Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard"** (11PSB01), compared to ..... as stated below, is ..... (tick one in the box underneath) :									
	↑	**Extremely less important**	**Much less important**	**Less important**	**Slightly less important**	**Equally important**	**Moderately important**	**Strongly important**	**Very strongly important**	**Extremely important**
BLK Quest.: 2.a.	**Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard** (11PSB02)									
BLK Quest.: 3.a.	**The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing** (11PSB03)									
BLK Quest.: 4.a.	**The use of CNC profile processing machine in the hull & superstructure blocks manufacturing** (11PSB04)									
BLK Quest.: 5.a.	**The use of roll/press/bender for sheet metal and profile bending processes** (11PSB05)									
BLK Quest.: 6.a.	**The use of welding robots in the hull & superstructure semi-block assembly stages** (11PSB06)									
BLK Quest.: 7.a.	**Categorization of block panel/assembly lines according to their difficulties** (11PSB07)									
BLK Quest.: 8.a.	**Use of jigs in the hull & superstructure blocks production** (11PSB08)									
BLK Quest.: 9.a.	**Block Blasting-Painting** (11PSB09)									
BLK Quest.: 10.a.	**Completion of outfitted or non-outfitted hull & superstructure blocks** (11PSB10)									

Figure 3.18: A sample question on comparison of Effects.

For the first phase, the Questionnaire set with 11 sections as explained above was prepared containing 435 question groups with 1425 pairwise comparisons only to obtain Shipyard and Sector Weight information on the Effects. This questionnaire set did not contain questions sampled in Figures 3.12, 3.14, and 3.15. Despite the number of questions looks like high in the questionnaire, separation into the 11 sections, each with around 30 pages for different departments, and single sided A4 size landscape format were found relatively easy to respond to.

Then, a second survey phase was planned at a limited number of shipyards, two or three shipyards, with again the full questionnaire set with 11 sections containing 946 questions on Effect magnitude and timing, along with 1571 pairwise comparison questions.

BLK Quest.: 1001	**"Hull & Superstructure Blocks Construction"** (11PSB00), compared to ..... as stated below, is ..... (tick one in the box underneath) :									
	⬆	Extremely less important	Much less important	Less important	Slightly less important	Equally important	Moderately important	Strongly important	Very strongly important	Extremely important
BLK Quest.: 1002	**Hull Erection** (12PSE00)									
BLK Quest.: 1003	**Parts Manufacturing in the Shipyard** (13PPT00)									
BLK Quest.: 1004	**Outfitting before Launching** (14POS00)									
BLK Quest.: 1005	**Infrastructure : Layout** (21IFL00)									
BLK Quest.: 1006	**Infrastructure : Environment** (22IEN00)									
BLK Quest.: 1007	**Infrastructure : Technology** (23ITE00)									
BLK Quest.: 1008.	**Infrastructure : Amenities** (24IFA00)									
BLK Quest.: 1009	**Design & Production Engineering** (30DES00)									
BLK Quest.: 1010	**Materials & Procurement** (40MPP00)									
BLK Quest.: 1011	**Management : Planning & Budgeting** (51APL00)									
BLK Quest.: 1012	**Work force : Organization** (61WOR00)									
BLK Quest.: 1013	**Work force : Performance & Practices** (62WPP00)									
BLK Quest.: 1014	**Work force : Motivation** (63WPM00)									
BLK Quest.: 1015	**Quality** (70AQC00)									

Figure 3.19: A sample question on comparison of Effect groups & subgroups.

The distribution of questions on process-basis during two survey phases is given in Table 3.9. Pairwise questions were designed on the "perfect consistency" basis as explained above. The pairwise comparisons were tried to contain less than seven comparisons, since after nine pairwise comparisons the respondents were expected to be non-consistent (Saaty 2003), Only 67 comparisons of the first survey phase, and 42 comparisons of the second survey contained above nine, up to 23 comparisons which are 4.7% and 2.7% of the total pairwise comparisons respectively.

Table 3.9: Question groups and pairwise comparisons in the sections of the survey questionnaires.

Section	# of Effects	First Survey Phase		Second Survey Phase	
		# of question groups	# of pairwise comparisons	# of question groups	# of pairwise comparisons
BASIS		35	42	35	42
MNG	134	48	207	149	250
CON	27	12	35	35	34
BLK	88	51	168	104	176
ASLY	72	47	142	87	149
PPT	72	44	142	86	140
OUT	94	49	172	108	200
LCH	59	36	122	73	129
QAY	83	40	146	97	182
TEST	61	32	108	72	125
DES	87	41	141	100	144
	TOTAL	**435**	**1425**	**946**	**1571**

3.2.2. Shipyard Surveys

As mentioned in subsection 1.1., 514 shipyards were found as concentrated on shipbuilding from the literature and internet surveys. The sample size requirement calculation by Equation 3.27 as per Cochran's corrected for finite population, 514 here, with 0.05 level of precision indicated a sample size of 220 shipbuilders. A cross-check by the Tao Yamane formula (Yamane 1967) was made again with a 0.05 level of precision and it indicated a sample size of 225 shipbuilders. These two sample size requirements were found very high for this study and to be able to have a sample size of at least 30 shipyards, providing a 0.177 level of precision, plus 50% reserve (15 shipyards), 45 shipbuilders were decided to be selected for application on the survey all around the world.

To select the candidate shipyards and prepare a short-list for a survey, a review was made on the shipyards' own or other websites. A short-list was prepared based on technology level (2 to 5) and production experience on different types of steel commercial and/or naval ships longer than 70-80 meters criteria, also resulting in some shipyards that were known as very capable and specialized in some ship types.

Forty-two shipyards all around the world (see Table 3.10) were applied with e-mail or phone calls for the first survey phase between January-September 2022.

Table 3.10: Applied shipyards.

Continent	Number of Applied Shipyards	Application Period
Europe	30	January – August 2022
N. America	2	May 2022
Asia	9	June 2022
Australia	1	June 2022

Thirty of the shipyards were from Europe, two of the shipyards were from North America, nine of the shipyards were from Asia and one of the shipyards was from Australia. Their correspondence information were obtained from the Internet and shipbuilding-related publications. The application e-mails contained the purpose, request for a survey and a liaison point, proposed information exchange (confidentiality) agreement, and samples of questions.

Two shipyards returned with positive responses. After liaison persons were named, communications were set, confidentiality agreements signed and survey Questionnaire sets provided in printed format, the surveys were executed between May and August 2022. Due to confidentiality agreements, they do not know each other and cannot be identified in this thesis and will be denoted as "Shipyard 5" and "Shipyard 12" from hereon. The other 40 shipyards did not respond but some were communicated, and their reasons were learned mainly as work density, data protection due to competency, and local regulatory restrictions. The participating two shipyards also stated that possibly they could not fulfill the sample size requirements and involve the workers, outsourced labor but senior level workers and white-collar employees due to busy workloads.

Responses from these two shipyards, with 21 respondents in total (4 from Shipyard 5 and 17 from Shipyard 12) at different specialties, and positions (see Appendix E) were evaluated and applied in the mathematical model between June and September 2022.

As given in Table 3.11, Shipyard 5 referenced a 4,700 DWT Chemical Tanker, and Shipyard 12 referenced an 8,500 Gross Ton Product/Factory Ship. The total shipyard employees (registered to the shipyards) were approx. 180 and 900 respectively and shipyard technological levels are both "4". Both shipyards were able to build different types, and sizes of commercial and naval ships.

Table 3.11: Information on Shipyard 5 and Shipyard 12, with their referenced shipbuilding projects' summary.

SHIPYARD INFORMATION AND REF. PROJECTS	**Shipyard Number**	
	5	**12**
Total years that the Shipyard builds ships	25	14
Total area of the Shipyard (square meters)	107,000	140,000
Ratio of the closed area of the Shipyard to the total area (%)	34	35
Total number of Shipyard employees (registered to the Shipyard)	174	900
Whether if the Shipyard builds both commercial and naval ships	YES	YES
Technological Level of the Shipyard (out of 6)	4	4
The ship type/class will be taken as the reference in the Survey	CHEMICAL TANKER	PRODUCT/ FACTORY SHIP
Approx. Dead Weight Tonnage (DWT)	4700	
Approximate Gross Tonnage	3020	8500
Approx. Length overall (meters)	110	85
Approx. max. Beam (meters)	14	20
Approx. Summer loaded draft (meters)	4.8	7.5
Main propulsion engines fuel type	Hybrid	MDO (*)
Number of delivered reference ships until 1 January 2022	0	8
Number of reference ships under construction as of 01.01.2022	1	2

(*) MDO = Marine Diesel Oil

The second phase of the survey was expected to play an important role in measuring the reliability and validity of the developed method. If a shipyard from the first survey phase would join the second phase again, it would be a very good opportunity to measure the reliability of the survey results and the methodology by the reception of responses on the same questions from the same shipyard after a few weeks. For the first-time participating shipyards, their survey by the second phase Questionnaires would provide some information on the validity of the developed methodology even by the application of no-cost improvements in the shipyard. Unfortunately, no positive invitation was received for the

second survey phase which possibly repeats the common problem of low interest of shipyards to participate in academic surveys.

As an alternative solution to complete the study on the methodology by second phase survey, Likert simulation or some other simulation techniques to resemble six hypothetical shipyards were evaluated. But differently, by the advice of the thesis supervisory committee, known 32 experts to the student and his thesis advisors, who are known to have extensive shipbuilding, ship design, and project management experiences were communicated by e-mails and by phone to participate and simulate the crew of two hypothetical shipyards, in October 2022. The application e-mails contained the purpose, information exchange (confidentiality) agreement, and samples of questions. Twenty-six experts accepted to join the second phase of the survey. Their statistics are given in Table 3.12. and in Appendix E.

Table 3.12: Specialty, frequency, and job position of the 26 second phase survey participants.

Specialty	Frequency	Job Position
Naval Architecture & Marine Engineering	21	Managers (Top Level, General, Planning and Quality, Group)
		Chief Engineers
		Engineers (Senior, Leader, Group)
Naval Architecture & Offshore Technology	1	Leader Engineer
Materials Management	1	Technician
Hull Outfitting	1	Senior Engineer
Industrial Engineering	1	Top Manager
Interior Architecture	1	Ship design

The participants were divided into two groups as per two hypothetical shipyards based on their known backgrounds. Within the introduction part of the Questionnaires delivered online, the 26 experts were given the key information on these two hypothetical shipyards (see Table 3.13.), denoted as "Shipyard 200" and "Shipyard 300". From here on, these two hypothetical shipyards are also denoted as "Shipyard 200" and "Shipyard 300" in this thesis.

Table 3.13: Given information on hypothetical shipyards.

Information on the Imaginary Shipyards	**Shipyard Number**	
	200	**300**
Total years that the Shipyard builds ships	70	35
Total area of the Shipyard (square meters)	100,000	200,000
Ratio of the closed area of the Shipyard to the total area (%)	30	30
Total number of Shipyard employees (registered to the Shipyard)	1,800	250
Whether if the Shipyard builds both commercial and naval ships	YES	YES
Technological Level of the Shipyard (out of 6)	2	3
The ship type/class will be taken as the reference in the Survey	OIL TANKER	CHEMICAL TANKER
Approx. Dead Weight Tonnage (DWT)	11000	6500
Approx. Length overall (meters)	160	100
Approx. max. Beam (meters)	22	18
Approx. Summer loaded draft (meters)	7.5	7
Main propulsion engines fuel type	MDO	MDO

MDO = Marine Diesel Oil

These two hypothetical shipyards represent shipyards with different characteristics. The experts were also divided into three processes/subprocesses, again based on background, and provided with the electronic version (MS EXCEL) of the Questionnaire. The division into three processes/subprocesses was decided based on the number of Effects they have, and the maximum Effect shared with other processes/subprocesses in this study (see Table 3.4). Therefore, the participants were divided into "Outfitting before Launching" subprocess (of the Ship Production process), the "Ship Design" process, and the "Shipbuilding Management" process. Then using same respective Effect data (repeating Effects) were planned to be used for the other remaining seven (not asked) subprocesses during the numerical analyses as appropriate. All Questionnaires were for the second phase survey, but without the effective period start and end week numbers of the Effects since all participants were to respond independently and no project time-schedule information was provided to them.

3.2.3. Numerical Analyses

As the filled questionnaires were received from the real and hypothetical Shipyards, numerical analyses were necessary to utilize the developed methodology, as one of the research objectives. The flow of the study on numerical analyses is given in Figure 3.20.

During the design of the questionnaire, the tables were prepared in parallel as necessary for the numerical analyses. Several calculation draft templates and tables were prepared by the MS EXCEL software to gather obtained data from the questionnaire responses, to make calculations, and to evaluate them. In this respect,

- Pairwise comparison calculation templates up to 24 criteria separately (see Appendix F for a sample),
- Template to gather process/subprocess based Effects weights of the total shipyards (see Appendix G for a sample), including separate pages on participant statistics, Management Basis information gathered from the shipyards, and Effects' sector weights consolidation were prepared.
- Template to gather and calculate Effect magnitudes, time distribution type, Effect weights, curve-area calculation pages (see Appendix H for a sample), and Pareto Chart on the shipyard basis,

Upon receiving responded Questionnaires, data on the respondents were compiled first for the respondent statistics and to evaluate the realized sample sizes.

Responses of 21 participants in total from two actual shipyards for the first phase of the survey, and responses of the 26 experts from two hypothetical shipyards for the second phase of the survey (see Appendix E for survey participants' statistics) were evaluated to be applied in the mathematical model. In total, from four shipyards 47 respondents participated in the surveys. Four participants were from Shipyard 5, 17 participants from Shipyard 12, 12 participants from Shipyard 200, and 14 participants from Shipyard 300. In summary, 42 of them were male and two were female (three undisclosed); 40.4% of them were between 31-40 years old, 34% between 41-50 years old, 4.3% between 20-30 years old, and 12.8% between 51-70 years old (8.5% undisclosed); 34 of them had experience in the shipbuilding

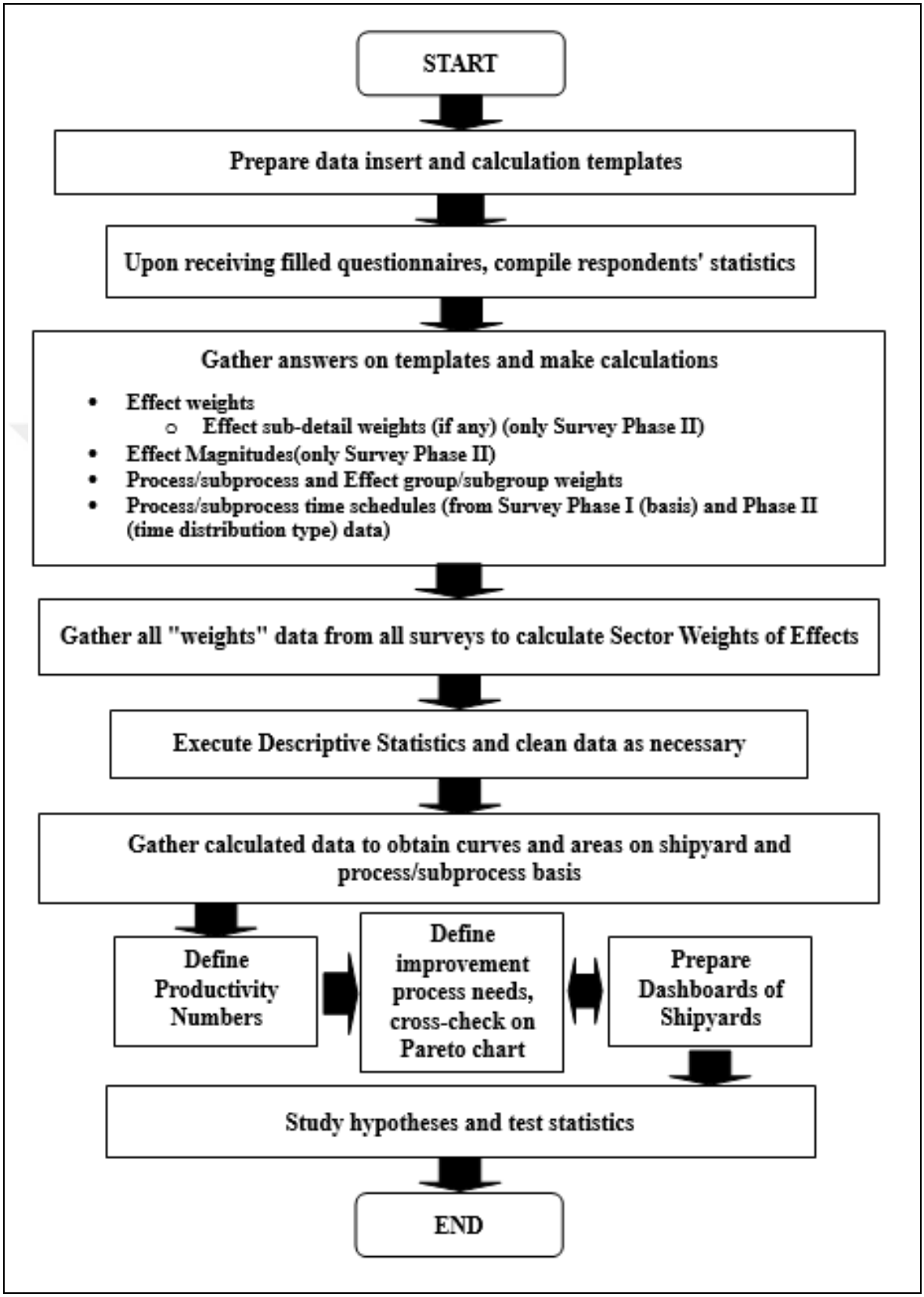


Figure 3.20: Flow chart of numerical analyses.

sector for more than 11 years and up to 40, 8 of them had 3 to 10 years of experience (5 undisclosed); 53% of them had B.S. degree, 26% of them had M.S. degree.

As given in Table 3.14a, The targeted sample sizes were unfortunately not achieved due to limited participation in the shipyards due to workloads in the yards. Still, there was no choice

Table 3.14a: Process/subprocess population, needed and actual sample sizes.

	Processes		**Subprocess of Ship Production Process**							
	MNG	**DES**	**CON**	**BLK**	**ASLY**	**PPM**	**OUT**	**LCH**	**QAY**	**TEST**
Shipyard 5										
Population	40	14	6	6	6	13	5	6	9	33
Needed sample size (Strata)	38	13	6	6	6	12	5	6	9	32
Actual sample size	2	1	1	1	1	1	1	1	2	1
Shipyard 12										
Population	5	8	10	4	3	3	4	3	14	12
Needed sample size (Strata)	4	7	9	4	3	3	4	3	12	11
Actual sample size	2	3	2	3	3	3	3	3	3	3
Shipyard 200 (*hypothetical, population unknown)*										
Needed sample size	Not applied, unknown population									
Targeted sample size	5	5	Not applied				5	Not applied		
Actual and hypothet. (*) Sample size	5	4	5* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3	3* (Hypo.)	3* (Hypo.)	5* (Hypo.)
Shipyard 300 *(hypothetical, population unknown)*										
Needed sample size	Not applied, unknown population									
Targeted sample size	6	6	Not applied				6	Not applied		
Actual and hypothet. sample size	5	6	5* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3	3* (Hypo.)	3* (Hypo.)	5* (Hypo.)
For Sector Weight *(compiled from all four shipyards)*										
Population	45**	22**	16	10	9	16	9**	9	23	45
Needed sample size (Strata)	41	2	15	9	8	15	8	8	21	41
Sample size	14	14	3	4	4	4	10	4	5	4

* No surveys were made on these subprocesses; responses to MNG (5 participants) and OUT (3 participants) were imitated for the same Effects.

** Population represents only two shipyards

but to thank them for their participation. Their contribution was highly appreciated and very valuable. One handicap was noticed that each of the two Questionnaires, Shipbuilding Management process, and Outfitting after Ship Launching subprocess of the Shipyard 5 were filled by two respondents together. This reduces their sample size to one statistically, but this was overridden for the sake of keeping the achieved small sample size at a level for further calculations.

Then, from the filled questionnaires, the shipyard and their referenced shipbuilding project information were compiled as given in Table 3.14b. below, along with the actual projects' time schedules. The properties of the two hypothetical shipyards were defined by the student before the survey questionnaires were send, as detailed in subsection 3.2.2 and in Table 3.13 above.

Table 3.14b: Shipyards' and their referenced shipbuilding projects' summary.

	Shipyard Number			
	5	**12**	**200**[20]	**300**
A. Basic information of the Shipyards				
Total years that the Shipyard builds ships	25	14	70	35
Total area of the Shipyard (square meters)	107,000	140,000	100,000	200,000
Ratio of the closed area of the Shipyard to the total area (%)	34	35	30	30
Total number of Shipyard employees (registered to the Shipyard)	174	900	1,800	250
Whether if the Shipyard builds both commercial and naval ships	YES	YES	YES	YES
B. Information on the ship type/class that taken as the reference by the Shipyards in the Survey				
The ship type/class will be taken as the reference in the Survey	CHEMICAL TANKER	PRODUCT/ FACTORY SHIP	OIL TANKER	CHEMICAL TANKER
Approximate Dead Weight Tonnage (DWT)	4700	-	11000	6500
Approximate Gross Tonnage	3020	8500	-	-
Approximate Length overall (meters)	110	85	160	100
Beam (meters)	14	20	22	18
Approximate Summer loaded draft (meters)	4.8	7.5	7.5	7
Main propulsion engines fuel type	Hybrid	MDO[21]	MDO	MDO
Number of delivered reference ships until 1 January 2022	0	8	-	-
Number of reference ships under construction as of 01.01.2022	1	2	-	-

[20] Shipyards Nr. 200 and 300 are hypothetical shipyards.
[21] MDO = Marine Diesel Oil

From both survey phase Questionnaire responses, pairwise comparison calculations were made on Effect weights on a process/subprocess basis, including Effect sub-detail weights from the second phase, as per subsection 3.1.1.2. and raw data were obtained as tabulated in Appendix G and Appendix I. Sample view from the tables in Appendix I is given in Figure 3.21. The abbreviation "r" shows each respondent. Weights according to the responses to Management: Basis Information questions were similarly calculated and also given in Appendix I.

EFFECT Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
14POS00	0.073	0.025	0.124	0.350	0.011	0.071	0.031	0.086	0.317	0.095	0.302	0.071
14POS03	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21IFL00	0.073	0.075	0.014	0.050	0.080	0.071	0.031	0.086	0.045	0.095	0.060	0.024
21IFL01	0.084	0.096	0.068	0.275	0.014	0.029	0.099	0.014	0.095	0.019	0.061	0.009
21IFL02	0.028	0.096	0.014	0.039	0.041	0.088	0.020	0.100	0.014	0.094	0.183	0.063
21IFL03	0.084	0.096	0.068	0.039	0.014	0.088	0.020	0.100	0.019	0.094	0.061	0.063
21IFL04	0.084	0.019	0.123	0.039	0.068	0.088	0.020	0.100	0.019	0.094	0.061	0.063
21IFL05	0.009	0.096	0.123	0.039	0.068	0.088	0.020	0.071	0.014	0.019	0.012	0.063
21IFL06	0.084	0.032	0.005	0.039	0.068	0.088	0.020	0.071	0.019	0.056	0.012	0.063

Figure 3.21: Sample view, Table I.1. Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard surveys responses (raw data).

From the second survey phase Questionnaire responses, Effect Magnitudes, along with sub-detail weights inclusion as per Appendix-C if applicable, were calculated as per subsections 3.1.1.1. and 3.2.1, Equations 3.30 and 3.31, and tabulated on shipyard and process/subprocess basis as sampled in Figure H.1. Calculated Effect Magnitudes are presented in Appendix J. Sample view from the tables in Appendix J is given in Figure 3.22.

During the first phase of the survey, the Questionnaire did not have questions on time information of Effects due to limitations in the study time frame as mentioned in subsection 3.2.1. During the second phase of the survey, the processes'/subprocesses' start- and end-week numbers question for Effects (see Fig 3.14) were removed since the shipyards were hypothetical. But, Timewise Distribution Type questions (see Figure 3.15) were asked. For the two hypothetical shipyards, the shipbuilding project time information received from one

actual shipyard during the first survey phase was superimposed for the Effects' period data within their respective processes, as shown in Figure K.1. The purpose was to have a stable

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
14POS03	5.0	3.0	2.0	5.0	2.0	3.1	1.000	3.129
21IFL01	1.4	4.3	4.0	1.9	2.4	2.6	0.043	0.112
21IFL02	4.2	2.7	3.7	4.7	3.9	3.8	0.049	0.184
21IFL03	3.0	3.0	3.0	3.0	3.0	3.0	0.039	0.118
21IFL04	4.0	4.0	4.0	3.0	2.0	3.3	0.054	0.178
21IFL05	3.0	4.0	4.0	4.0	2.0	3.3	0.051	0.166
21IFL06	1.0	3.0	1.0	3.0	1.0	1.6	0.051	0.078
21IFL07	2.3	2.7	2.4	3.7	2.0	2.5	0.043	0.110
21IFL08	5.0	2.7	2.7	4.8	2.7	3.4	0.064	0.218
21IFL09	3.0	3.0	3.0	5.0	1.0	2.7	0.064	0.171

Figure 3.22: Sample view, Table J.1. Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

time schedule baseline for the comparisons of the results during the numerical analyses despite the referenced ship sizes were different, but the ship types are similar. The referenced process/subprocess time periods in this study for the two hypothetical shipyards, which briefly form the Master Time Schedule, are given in in Tables 3.15 and K.7.

Table 3.15: Process/subprocess time periods of the two hypothetical shipyards.

Process, subprocess	**Total (weeks)**	**Start week**	**Finish week**
Entire process	84	1	84
Shipbuilding Management	84	1	84
Ship Design	80	1	80
Ship Production	80	3	82
Contracting	64	3	66
Hull & Superstructure Blocks Construction	24	25	48
Hull Erection	24	37	60
Parts Manufacturing in the Shipyard	36	28	63
Outfitting before Ship Launching	32	32	63
Ship Launching	4	61	64
Outfitting after Ship Launching	16	65	80
Set.-to-Work, Harbor and Sea Trials	16	67	82

The entire shipbuilding process, along with the shipbuilding management process was scheduled as 84 weeks while the ship design process was scheduled as 80 weeks. The Ship Production process covers 80 weeks with its subprocesses that the contracting subprocess was scheduled as 64 weeks, the hull & superstructure blocks construction subprocess was scheduled as 24 weeks, the hull erection subprocess was scheduled as 24 weeks, the parts manufacturing in the shipyard subprocess was scheduled as 36 weeks; the outfitting before ship launching subprocess was scheduled as 32 weeks, the ship launching subprocess was scheduled as 4 weeks, the outfitting after ship launching subprocess was scheduled as 16 weeks, and the setting-to-work, harbor and sea trials subprocess was scheduled as 16 weeks.

It should be noted that, in this thesis, contrary to common application in shipbuilding, Week 1 (or T0), the start of the shipbuilding process is at the bid/proposal receipt week rather than the Contract Effective date due to reasons explained in subsection 2.1.2. Also, a two-week period for last repairs and final docking if contracted after the end of Sea Trials. During these two weeks, the Shipbuilding Management process is in effect.

Based on each respondent's answer for Effects' timewise distribution type (T_i) and "r_i" being each respondent as shown in Figure 3.23 as a sample and detailed in Tables K.1. to K.6., for each Effect (as applicable) Mode of the respondents formed the timewise distribution type. The timewise positions of the Effects (*t*-axis coordinates) (see subsection 3.1.1.3) were obtained when distribution centroids were applied to the Effect periods. If a Mode can not be obtained from the responses for each Effect, then the use of closest distribution in terms of centroid compatibility were used by the student and this was identified in Italic numbers in Tables K.1 to K.6.

Since data was not available from the shipyard surveys, the periods of Effects within each process/subprocess were assigned by the student based on his experience in the sector. Initially, this work started with ProjectLibre[22] a freeware critical path method (CPM) planning software but due to the excessive numbers of Effects (activities in CPM terms) to be planned, later MS EXCEL was chosen as a suitable software for the Gantt Chart type

[22] ProjectLibre Version 1.9.3., ProjectLibre Inc.

scheduling effort. The detailed list is provided in Table K.8. and a sample from Table K.8. is given in Figure 3.24.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
14POS03		2	2	1	3	2
21IFL02	3	4	5	6	2	2
21IFL05		5	5	5	5	5
21IFL06	2	5	2	5	3	2
21IFL07	2	2	5	5	5	5
21IFL08	5	6	2	6	4	6
21IFL13	5	5	5	3	3	5
21IFL14	3	2		3	3	3
21IFL16	5	5	2	3	2	5
22IEN01		2	2	3	2	2
22IEN02	3	5	2	5	2	5
23ITE01		2		2	3	2

Figure 3.23: Sample view, Table K.1. Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

Process/Subprocess	EFFECT Nr.	Start week	Finish week
MNG	14POS03	15	47
MNG	21IFL01	10	82
MNG	21IFL02	10	68
MNG	21IFL03	65	84
MNG	21IFL04	1	84
MNG	21IFL05	31	58
MNG	21IFL06	10	83
MNG	21IFL07	10	82
MNG	21IFL08	22	80
MNG	21IFL09	25	80
MNG	21IFL10	10	82
MNG	21IFL11	1	84

Figure 3.24: Sample view, Table K.8. Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule for Ship Management process.

To obtain the Sector Weights of Effects, all "weight" data from all surveys, at all process/subprocesses of the same Effects were gathered together (compiled) and tabulated in the table format as its sample is given in Figure G.1. Then, along with the other raw data, compiled sector weights were also subjected to a data cleaning process and their geometric means were taken as the single resulting value, to be explained later below. Cleaned Sector Weights of Effects on Effect group/subgroup basis were normalized within each group/subgroup due to different numbers in each of them (see Table 3.2). The cleaned Sector Weights are listed in Effect group/subgroup in Table L.1., a sample view is given in Figure 3.25. (The 95% Confidence Interval column will be explained below in the statistical analyses part). For future readers of this thesis, it should be mentioned that the Sector Weights were calculated within a relatively small sample size, may not be suitable for generalization at this stage and they should be used with caution for any follow-on study. There also exist two bad data as marked in Table L.1. All Sector Weights are subject to be improved by more shipyard surveys after this thesis time frame.

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
11PSB00	**PRODUCTION : HULL BLOCKS (PSB)**	4	0.141	**0.121**	0.001 - 0.366
11PSB01	Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard	3	0.141	**0.190**	0.001 - 0.489
11PSB02	Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard	4	0.086	**0.115**	0.001 - 0.301
11PSB03	The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing	4	0.053	**0.071**	0.001 - 0.195
11PSB04	The use of CNC profile processing machine in the hull & superstructure blocks manufacturing	4	0.053	**0.071**	0.001 - 0.195
11PSB05	The use of roll/press/bender for sheet metal and profile bending processes	4	0.118	**0.159**	0.001 - 0.486
11PSB06	The use of welding robots in the hull & superstructure semi-block assembly stages	4	0.060	**0.081**	0.001 - 0.166
11PSB07	Categorization of block panel/assembly lines according to their difficulties	4	0.046	**0.062**	0.001 - 0.156
11PSB08	Use of jigs in the hull & superstructure blocks production	4	0.043	**0.057**	0.001 - 0.154
11PSB09	Block Blasting-Painting	4	0.065	**0.088**	0.001 - 0.175

Figure 3.25: Sample view, Table L.1. List of Effects' sector weights based on groups and subgroups, with cleaned data.

A list of Sector Weights on Effects' group/subgroup is also provided in Table L.2. in the order of calculated priorities. Its first part is given in Figure 3.26 as a sample. The "Hull &

superstructure blocks construction" subgroup leads here as it is very common in shipbuilding for shipyards building mainly commercial steel ships.

Group/Subgroup Nr.	Effects' Group/Subgroup	Normalized Sector Weight
11PSB00	PRODUCTION : HULL & SUPERSTRUCTURE BLOCKS CONSTRUCTION (PSB)	0.121
12PSE00	PRODUCTION : HULL ERECTION (PSE)	0.095
13PPT00	PRODUCTION : PARTS MANUFACTURING IN THE SHIPYARD (PPT)	0.078
30DES00	DESIGN & PRODUCTION ENGINEERING (DES)	0.055
70QAC00	QUALITY (QAC)	0.055
51APL00	MANAGEMENT : PLANNING & BUDGETING (APL)	0.050
62WPP00	WORK FORCE : PERFORMANCE & PRACTICES (WPP)	0.049
63WPM00	WORKFORCE : MOTIVATION (WPM)	0.047
52ARM00	MANAGEMENT : RISK MANAGEMENT (ARM)	0.047
81CMC00	CONTRACTING : MAIN CONTRACT (CMC)	0.047

Figure 3.26: Sample view, Table L.2. List of Effects' group/subgroups sector weights in the order of priority.

A list of Effect Sector Weights in the order of priority is given in Table L.3. and its first part is given in Figure 3.27. as a sample. Here again two important shipbuilding Effects, the hull & superstructure blocks construction and ship launching leads (caution: by bad data!) followed by another critical subcontractor contracts preparation Effect, with clean data.

EFFECT Nr.	EFFECTS	Normalized Sector Weight
12PSE01	Hull & Superstructure blocks erection (Hull Construction)	1.000 (*)
15PLA01	Ship launching	1.000 (*)
82CSC01	Subcontractor Contracts preparations	0.797
22IEN01	Energy saving and protection of natural resources; use of clean (green) energy	0.608
16POQ02	Minimum outfitting effort requirement after launching	0.524
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching	0.476
14POS01	Manufacturing and assembly of the outfit infrastructure elements	0.455
13PPT01	Metal joining techniques	0.405
22IEN02	Hazardous waste management	0.392
24IFA01	Dressing-Lockers, Showers-Toilets	0.336

Figure 3.27: Sample view, Table L.3. List of Effects' sector weights based on groups and subgroups, with cleaned data.

In research activities, control of the data and if necessary the data cleaning process are necessary before further calculations and achieving results. In this respect, the first step was to obtain Descriptive Statistics of the Effect weights, Effect magnitudes, and Sector Weights data. Gathered data on shipyard and process/subprocess basis were subjected to Descriptive Statistics analyses. Accordingly, the following were calculated in all weight calculation tables using MS EXCEL functions;

(i) Sample size
(ii) Mean
(iii) Median
(iv) Mode
(v) Geometric mean
(vi) Minimum
(vii) Maximum
(viii) Range
(ix) Total

(x) Variance
(xi) Standard deviation
(xii) Standard error
(xiii) Skewness
(xiv) Standard error of skewness
(xv) Kurtosis
(xvi) Standard error of Kurtosis

(xvii) Degrees of Freedom (*dF*)
(xviii) *t*-value (N<31); z=1,96 (N>30)
(xix) %95 Confidence Interval Upper Bound
(xx) %95 Confidence Interval Lower Bound
(xxi) Margin of error for confidence interval

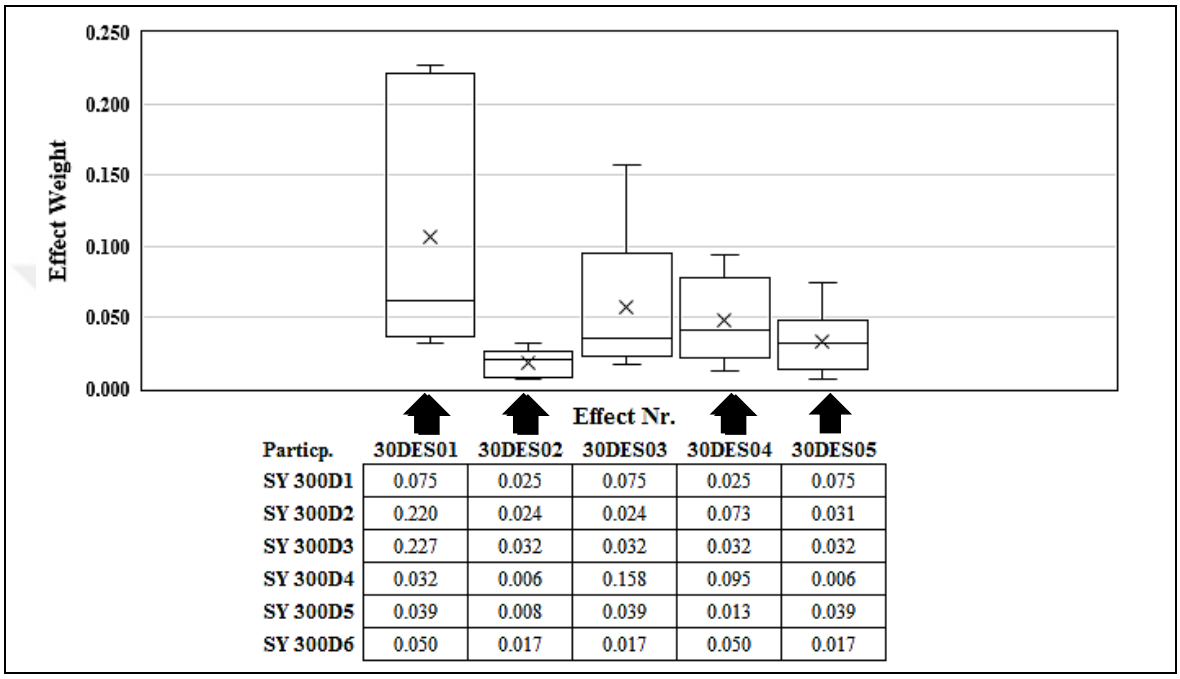
(xxii) Lower Quartile Q1 (*)
(xxiii) Upper Quartile Q3 (*)
(xxiv) Interquartile Range (IQR)

(*) Multiple of the IQR for Upper and Lower Extremes were applied as 1.5.

A sample from descriptive statistics for Sector Weights is given in Table M.1.

After descriptive statistics were calculated, a data analysis process was applied to select an appropriate averaging method based on skewness results (Nişel, 2023), to control the existence of bad data and also outliers to obtain a data set closer to a normal distribution and

to continue with the geometrical mean. As shown in Figures 3.28 and 3.29, even with the maximum number of respondents for a process, the response data (Shipyard 300 Design process, Effect weights and magnitudes), had variating means and medians, different interquartile ranges showed a need for analysis and cleaning as necessary.



Particp.	30DES01	30DES02	30DES03	30DES04	30DES05
SY 300D1	0.075	0.025	0.075	0.025	0.075
SY 300D2	0.220	0.024	0.024	0.073	0.031
SY 300D3	0.227	0.032	0.032	0.032	0.032
SY 300D4	0.032	0.006	0.158	0.095	0.006
SY 300D5	0.039	0.008	0.039	0.013	0.039
SY 300D6	0.050	0.017	0.017	0.050	0.017

Figure 3.28: Box plot of Shipyard 300 Design Process' five sample Effects' weights as responded by six participants (after pairwise matrix calculation).

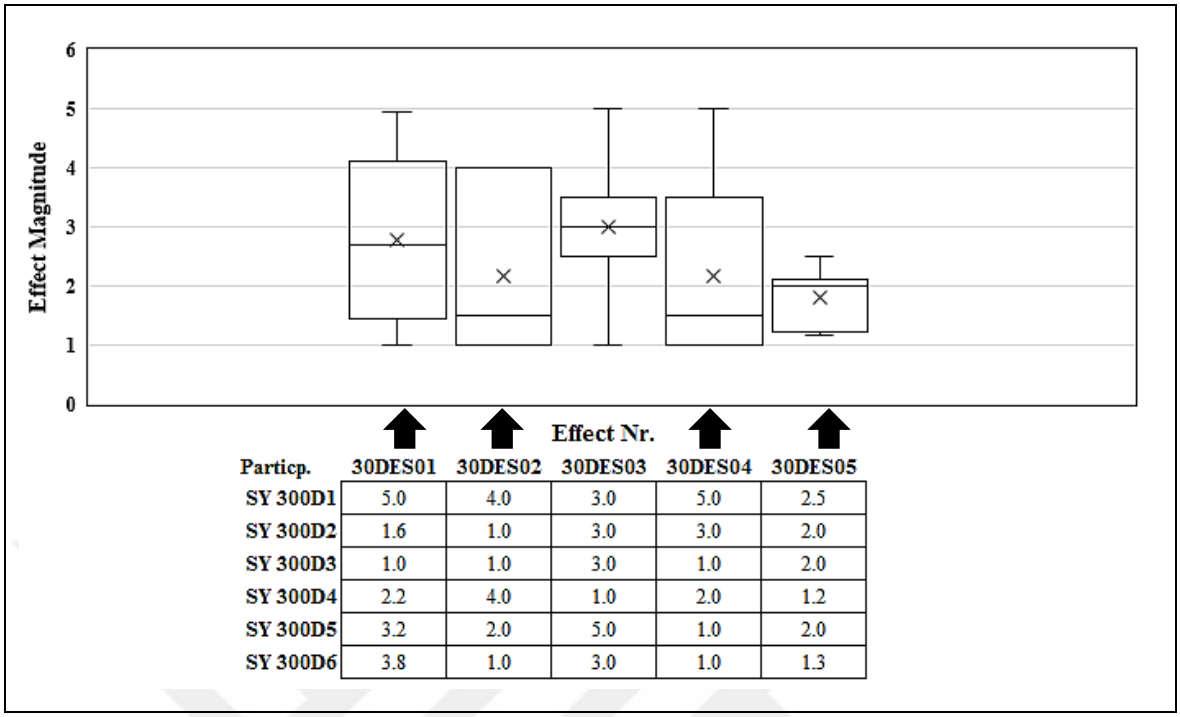
In this respect, each Effect weight data and Effect magnitude data, on sector and process/subprocess basis of the shipyards were subjected to the following data analysis from the measure of skewness (Nişel, 2023):

(i) check for extreme skewness or no extreme skewness based on z=1.96,

(ii) location of Mode value, check if on or close to the minimum or maximum of the data set,

(iii) existence of a value with extreme characteristics, if extreme or outlier,

(iv) decision on outliers' position in population or apply Bowley measures of skewness.



Particp.	30DES01	30DES02	30DES03	30DES04	30DES05
SY 300D1	5.0	4.0	3.0	5.0	2.5
SY 300D2	1.6	1.0	3.0	3.0	2.0
SY 300D3	1.0	1.0	3.0	1.0	2.0
SY 300D4	2.2	4.0	1.0	2.0	1.2
SY 300D5	3.2	2.0	5.0	1.0	2.0
SY 300D6	3.8	1.0	3.0	1.0	1.3

Figure 3.29: Box plot of Shipyard 300 Design Process' five sample Effect's Magnitudes as responded by six participants (as intervals after Effect subdetail weights were applied).

Accordingly, some bad data and outliers were detected and trimmed. A summary was given on the Effect base for the compiled sector weights in Table 3.16.

Table 3.16: Bad data and trimming in compiled sector weights data of Effects on process/subprocess basis.

Process/subprocess	# of Effects	Effects with Bad data	# Trimmed Effects
In all	185	24	46
Shipbuilding Management (MNG)	134	5	42
Contracting (CON)	27	0	9
Hull & Superstructure Blocks Construction (BLK)	88	1	33
Hull Erection (ASLY)	72	2	31
Parts Manufacturing in the Shipyard (PPT)	72	1	31
Outfitting before Launching (OUT)	94	2	2
Ship Launching (LCH)	59	2	22
Outfitting after Launching (QAY)	83	1	32
STW, Tests & Trials (TEST)	61	0	26
Ship Design	87	0	28

Especially after data analysis and cleaning, smaller sample sizes led to the use of Median instead of Mean in Productivity Number calculations along with some Modes being close to maximum or minimum values of the data set. But for Productivity Number calculations and further evaluations on hypotheses and test statistics, instead of the Median, the Geometric Mean was taken into consideration for a future possibility of an increase in sample size and its more conservative averaging property. A comparison was made to observe Median and Geometric Mean differences for Sector Weights as shown in Figure 3.30. It was decided to continue with Geometric Mean values instead of Median values for all interval scale data. On the other side, Mode continued to be used for nominal scale timewise distribution type data.

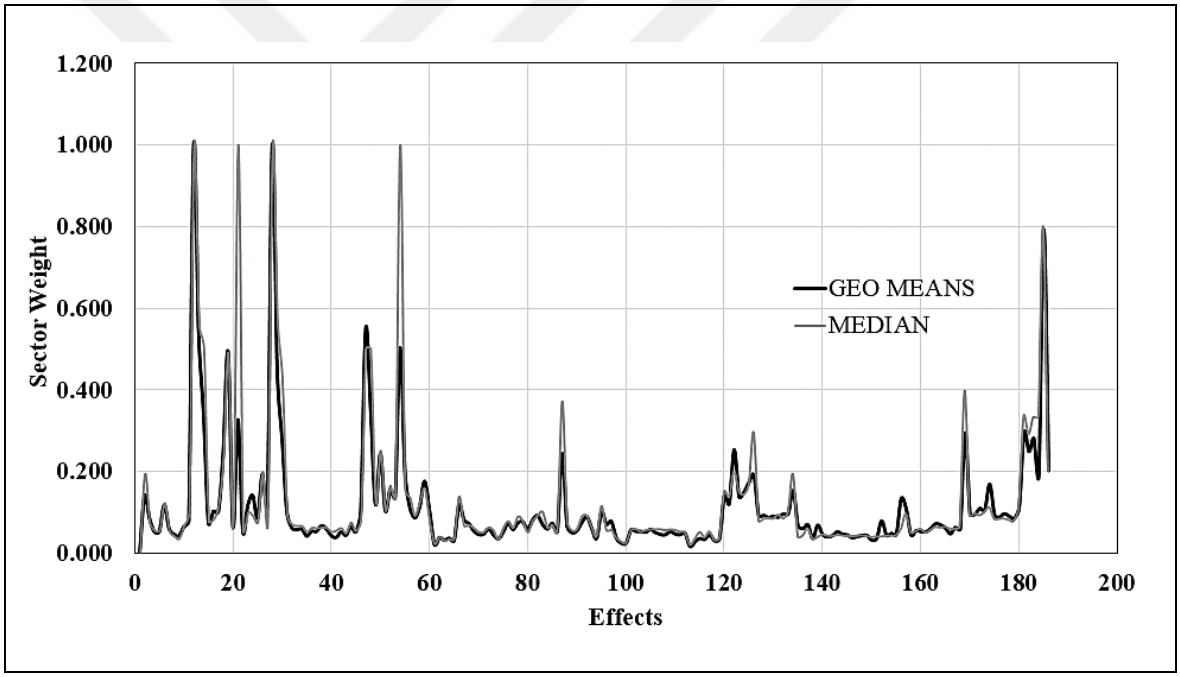


Figure 3.30: Comparison of geometric means and medians of the compiled Sector Weights from four shipyards with raw data and on 185 Effects base.

After all available data became appropriate for further numerical analyses, for the two hypothetical shipyards, Shipyard 200 and Shipyard 300 namely, Productivity Number calculations started for the surveyed Ship Management, Ship Design processes, and Outfitting before Ship Launching subprocess on dedicated MS EXCEL templates as shown in Figure H.2. On the same worksheet, each Effect was listed by;

- number and name;
- for the shipyard,
  - magnitude,
  - weight,
  - weighted magnitude;
- for the Ideal shipyard,
  - magnitude (which is 1),
  - sector weight
  - weighted magnitude

where weighted magnitudes form the *y*-coordinates input for the monotonic cubic spline curves of Shipyard and Ideal Shipyard separately; and,

- for both the Shipyard and the Ideal shipyard,
  - timewise distribution type,
  - Effect start week,
  - Effect finish week,
  - timewise position of the Effect within the process/subprocess period

where the timewise position of the Effects form the *t*-axis coordinates input for the monotonic cubic spline curves of Shipyard and Ideal Shipyard together.

From the curve data information, curves were drawn and areas under the Shipyard curve and Ideal Shipyard curve were calculated as explained in subsection 3.1.3.

Then for each process/subprocess' Shipyard area and Ideal Shipyard area, process/subprocess weights were used to calculate the Productivity Number of the respective process/subprocess. The Productivity Number calculations were explained in subsection 3.1.4. and weight information from the calculations on Management:Basis Information section of the Questionnaires are presented in Tables N.1. and N.2. As it was mentioned in subsection 3.1.4., the Management:Basis Information section of the Questionnaire had pairwise comparison questions and resulting weights to differ final productivity calculations from the cost, labor, time, and in general aspects as to be chosen by the Shipyard

Management in Productivity Status evaluation. These different weights were gathered in Figure N.1. and N.2. for the hypothetical Shipyards 200 and 300 respectively.

For the missing seven subprocesses of the second survey phase, the weighted magnitude data from shipyards' responses were used for the repeating Effects (see Appendix B) but with each subprocess's own, unique timewise information. The following subprocesses used the responses from the Outfitting before launching subprocess:

- Hull & Superstructure Blocks Construction (BLK)
- Hull Erection (ASLY)
- Parts Manufacturing in the Shipyard (PPT)
- Ship Launching (LCH)
- Outfitting after Launching (QAY)

The following subprocesses used the responses from the Shipbuilding Management process:

- Contracting (CON)
- STW, Tests & Trials (TEST).

The decision on this separation was due to the common nature of the works.

Multiplication of the calculated areas under the curves and respective process/subprocess weights provided current Productivity Numbers, target Productivity Numbers and their ratio provided the Dimensionless Productivity Number (DPN) of respective process/subprocess as explained in subsection 3.1.4. The sum of the Productivity Numbers of three processes, Shipbuilding Management, Ship Production, and Ship Design provided the Productivity Numbers of the Shipyard and Ideal Shipyard. Then, their ratio provided the Shipyard Dimensionless Productivity Number (**U**). A Shipyard Dashboard was prepared to submit the Productivity Numbers, process/subprocess curves and improvement needs priorities summary. Samples from a Shipyard Dashboard are given in Figure 3.31. and in Appendix O; a sample from the Productivity Numbers part (key numerical output) of the Shipyard Dashboard is given in Figure 3.32.

In Figure 3.31, the middle-top part of the Dashboard covers the shipyard name, the basis of the Dashboard (i.e., calculations for "in general", "cost", "labor" or "time" basis), date and version of the Dashboard, key numerical output of Productivity Numbers, proposed first five

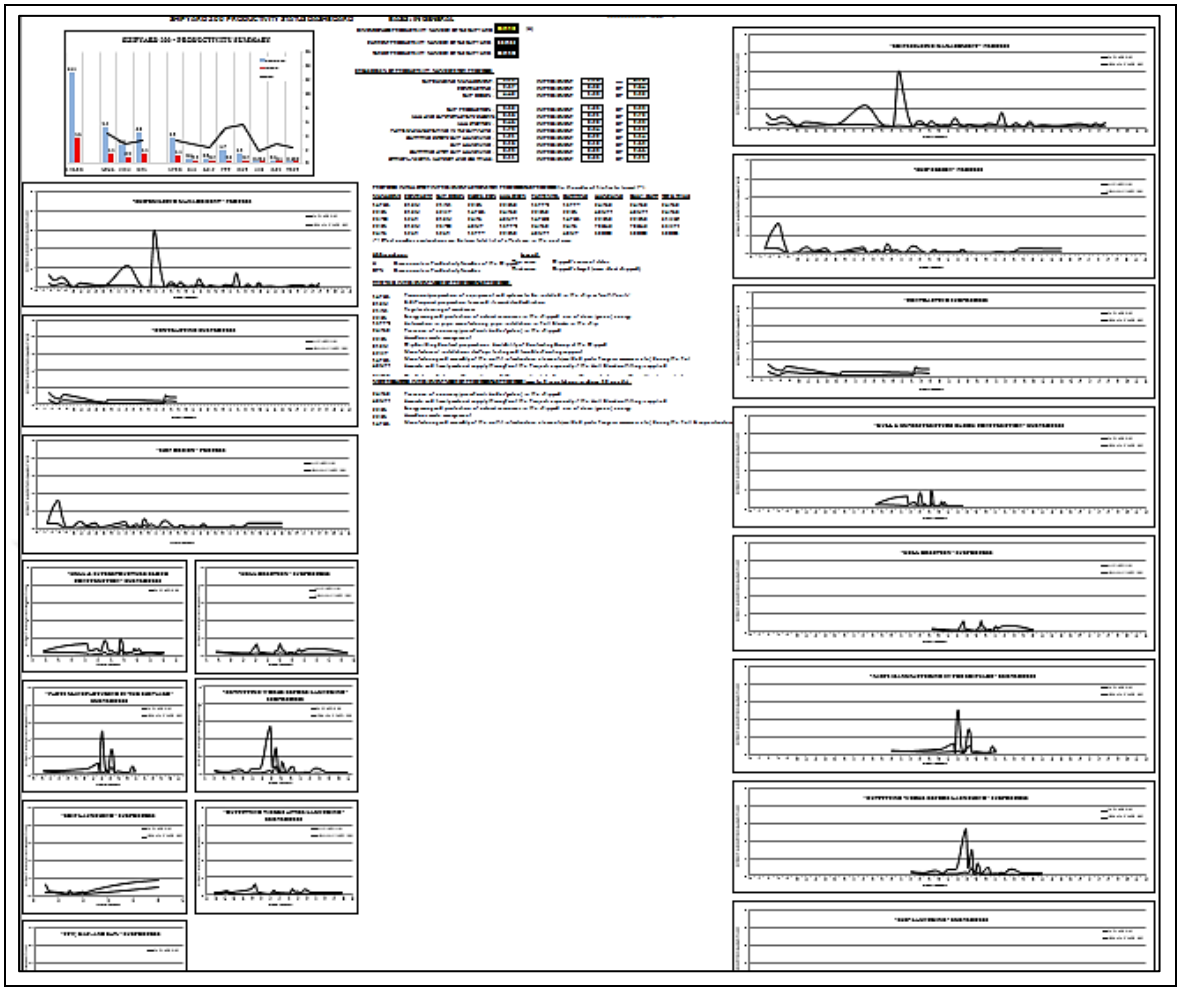


Figure 3.31: Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view).

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.60	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.13				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

Figure 3.32: Key numerical output on the dashboard of Shipyard 200.

Effect improvement actions for processes/subprocesses (in the order of higher to lower), Effect definitions of first two improvement needs of processes/subprocesses, and most requested improvement needs of processes/subprocesses (max. to 3 repetitions in above 50 needs).

The left part of the Dashboard covers the Productivity Summary graph on top and then, current-Ideal status graphs of processes/subprocesses in narrowed form, each having their own process/subprocess periods on the time axes.

The same graphs are put on the right side of the Dashboard, with all process and subprocess time axes are the total shipbuilding project period, from the Shipbuilding Contracting works start week (T0 in this thesis) to the ship delivery week.

Middle-bottom part is reserved for further interactive facilitation after this thesis.

On the Shipyard Dashboard, the "Shipbuilding Management" and "Ship Design" processes, which commence with the start of a shipbuilding project and at the end of the project, were studied as two stand-alone scatter plots (see Appendix O). The subprocesses of the Ship Production overlap during the shipbuilding time period and they are studied as separate scatter plots (XY graph) for clarity. The Productivity Number calculations care for this stand-alone structure to overview the entire shipbuilding process for improvement needs.

The weighted magnitudes of each Effect define the improvement need order in each process/subprocess. Therefore, they were sorted from highest weighted magnitude to lowest, and improvement priorities of the Effects were identified in each process/subprocess. Also, for double checking, as explained in subsection 3.1.5, Pareto charts were used with the 80/20 principle to detect the Effects initially need to be reviewed, as given in Figure 3.33 as a sample.

Inferential statistics are used to generalize findings from a particular sample to a broader population from which the sample was drawn (Fitzgerald et al., 2001). As required for scientific research, additional statistical analyses on the data of the test cases are necessary

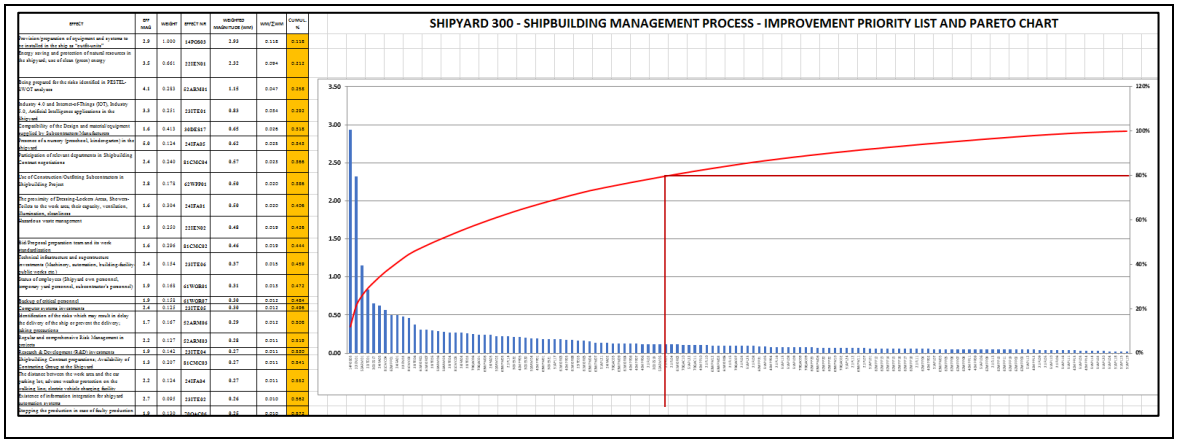


Figure 3.33: Shipyard 300, Shipbuilding Management process improvement needs Pareto chart.

to evaluate the reliability and validity of the study, to make inferences about the population from the data gathered from samples (Nişel, 2023), in addition to the Descriptive Statics held before in this subsection.

For the reliability of the study, the main concerns are representativity and generalizability. Sample size with respect to population size forms the "size of data" which is one of the factors affecting reliability. The degree of the heterogeneity of the sampled population data and target population definition forms the "content of the data" factor, the second one affecting reliability (Nişel, 2023).

This study deals with two different populations. The first one is the shipyards building new ships in the world. For this, each shipyard to be surveyed forms a sample. The second population is the employees of each shipbuilding process/subprocess dealt with in this methodology. The participants (respondents) of surveys in each shipyard, working at 10 different shipbuilding processes/subprocesses form the sample of these processes/ subprocesses.

As mentioned in subsection 3.2.2., the calculated sample size for the 514 shipyards all around the world was 220 shipyards and this was a very high sample size to be tested within the study time frame. To have a smaller sample size, 45 shipyards were intended and 42 were applied for surveys. The achieved result was the surveys at two actual shipyards with

reduced question content (first survey phase), and at two hypothetical shipyards with more content (second survey phase). This resulted in surveys at four shipyards, a small sample size.

For the second population, the shipbuilding process/subprocess employees, calculated sample sizes were almost impossible to achieve as mentioned in subsection 3.2.2. and actual status of population-calculated sample sizes-realized sample sizes are presented in Table Table 3.17 (repeat of Table 3.14a). In Shipyard 12, which is an active real shipyard that was surveyed, the population, targeted and actual sample sizes were realized (due to the outsourced status of other employees) for three processes (Hull Erection (ASLY), Parts Manufacturing in the Shipyard (PPT) and Ship Launching (LCH)). For the Shipbuilding Management (MNG) process of Shipyard 200 and for the Ship Design process of Shipyard 300, targeted and realized sample sizes matched; but since these shipyards were hypothetical, no process/subprocess populations were considered and the target sample size was only based on the availability of possible participants (i.e., the experts).

Except for the three subprocesses of Shipyard 12 where the number of population is equal to the sample size, so any data from the samples represents the population, the other sample sizes were deemed as small. During the Descriptive Statistics studies and data cleaning, it was also noticed that, due to the small sample size, there exist non-normality, low kurtosis, and high skewness problems in the data to be worked for inferential statistics. Data cleaning helped to reduce non-normality, and skewness problems up to a level, but further cleaning would cause loss of data for test cases. On the other side, all population parameters, such as mean, standard deviation, etc., to meet the Effect magnitudes, Effect weights, and Effect timewise distribution-type information needs of this study were not known, and not available in the literature. Since this study is on the development of a new methodology this seemed normal, but the non-availability of population parameters also affected the statistical inference works of this study and the generalizability of the results negatively.

The lack of requests for the second survey phase, at least by the actual shipyards that participated in the first phase, resulted in the non-repetition possibility of the same survey

Table 3.17: Process/subprocess population, needed and actual sample sizes.

	Processes		**Subprocess of Ship Production Process**							
	MNG	**DES**	**CON**	**BLK**	**ASLY**	**PPM**	**OUT**	**LCH**	**QAY**	**TEST**
Shipyard 5										
Population	40	14	6	6	6	13	5	6	9	33
Needed sample size (Strata)	38	13	6	6	6	12	5	6	9	32
Actual sample size	2	1	1	1	1	1	1	1	2	1
Shipyard 12										
Population	5	8	10	4	3	3	4	3	14	12
Needed sample size (Strata)	4	7	9	4	3	3	4	3	12	11
Actual sample size	2	3	2	3	3	3	3	3	3	3
Shipyard 200 (*hypothetical, population unknown)*										
Needed sample size	Not applied, unknown population									
Targeted sample size	5	5	Not applied				5	Not applied		
Actual and hypothet. (*) Sample size	5	4	5* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3	3* (Hypo.)	3* (Hypo.)	5* (Hypo.)
Shipyard 300 *(hypothetical, population unknown)*										
Needed sample size	Not applied, unknown population									
Targeted sample size	6	6	Not applied				6	Not applied		
Actual and hypothet. sample size	5	6	5* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3* (Hypo.)	3	3* (Hypo.)	3* (Hypo.)	5* (Hypo.)
For Sector Weight *(compiled from all four shipyards)*										
Population	45**	22**	16	10	9	16	9**	9	23	45
Needed sample size (Strata)	41	2	15	9	8	15	8	8	21	41
Sample size	14	14	3	4	4	4	10	4	5	4

* No surveys were made on these subprocesses; responses to MNG (5 participants) and OUT (3 participants) were imitated for the same Effects.

** Population represents only two shipyards

after a few weeks. This was needed to measure the reliability of the data obtained during the surveys, and also to measure the validity of the data and the developed methodology.

Therefore, the reliability measure of the gathered data remained only with executed Descriptive Statics where, central tendency, variation, skewness, and kurtosis information (Nişel, 2023) were obtained as explained previously in this subsection. Validity shows the accuracy of the method and must be proved. Again, the lack of an actual shipyard to measure

the accuracy of the developed method, only the results of two hypothetical shipyard surveys provided information performance of the method, as explained in Section 4. Concerning the factors affecting validity (Nişel, 2023),

- target population definition was correct,
- sampling was on a random basis within shipyards also taking care of bias problems,
    - bias problem was also considered in the selection of experts for the hypothetical shipyards with the provision of as much as limited information (see Table 3.13)
- to prevent computational mistakes, double-checks were made in calculations, interpretation of the results was always tried to be refrained while the correct method of analysis was observed.

In this respect, statistical analyses in this study were decided to follow some estimations and non-parametric methods, considering the available sample size and, data which probably have some unequal variance and still in an approximate normality level. The parametric methods, where normality and variance equality are two of the main assumptions may not be met in this study.

In this study, especially the dispersion of the shipyard into two phases and low sample size brought some questions to be investigated by estimations and non-parametric analyses.
Some of these questions were translated into hypotheses to be tested as follows:

(i) Were the responses of the participants internally consistent?
(ii) Can we assume that there is no significant difference between the actual shipyards (Shipyards 5 and 12) and hypothetical shipyards (Shipyards 200 and 300) responses?
(iii) Were the Sector Weights calculated for actual shipyards (Shipyards 5 and 12 together) different than those of hypothetical shipyards (Shipyards 200 and 300 together)?
(iv) Can the calculated Sector Weight values represent the whole Shipyards in the World?

Each of these questions was statistically analyzed in the order of the following steps. During the analyses, MS EXCEL 360 software was used for data preparation and student's calculations, and an R-based JASP open statistical analysis software (Version 0.16.4) was used for non-parametric tests. Due to study time, analyses were made for selected items

(processes, etc.) with data at the maximum sample size. In all analyses, the significance level and confidence interval were taken as follows:

- **Significance level (α) = 0.05**
  - while the null hypothesis is true, it is the probability of making the wrong decision, i.e., Type I error: rejecting a null hypothesis that is indeed true (Walpole et al., 2012)

- **Confidence level** = **0.95** = 1- α
  - helps to determine whether the results from sample data apply to the entire population; and indicates the probability of obtaining the same results if the same data collection is repeated (Walpole et al., 2012).

3.2.3.1. QUESTION (i) :

Were the responses of the participants internally consistent?

In the earlier phases of the statistics study, three graphics were prepared from the raw and cleaned data as given in Figures 3.34a, 3.34b, and 3.35. based on geometric means of Sector weights.

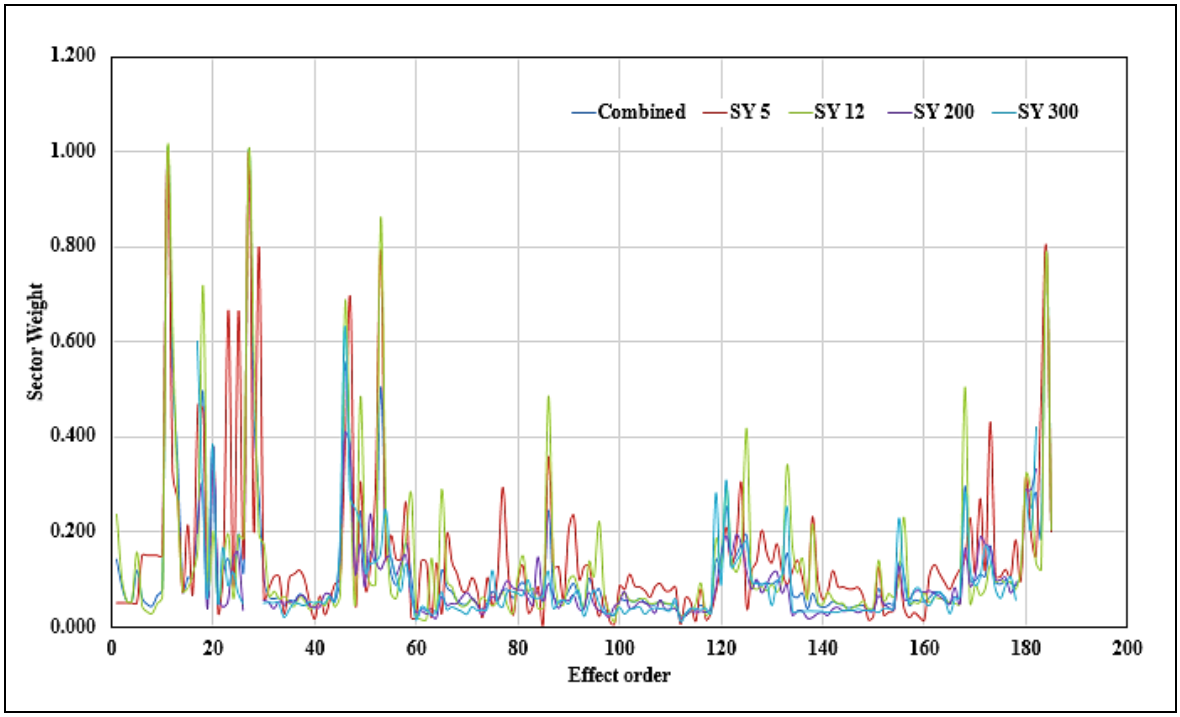


Figure 3.34a: Comparison of geometric means of the compiled Sector Weights from four shipyards with raw data and on185 Effects' numerical order base.

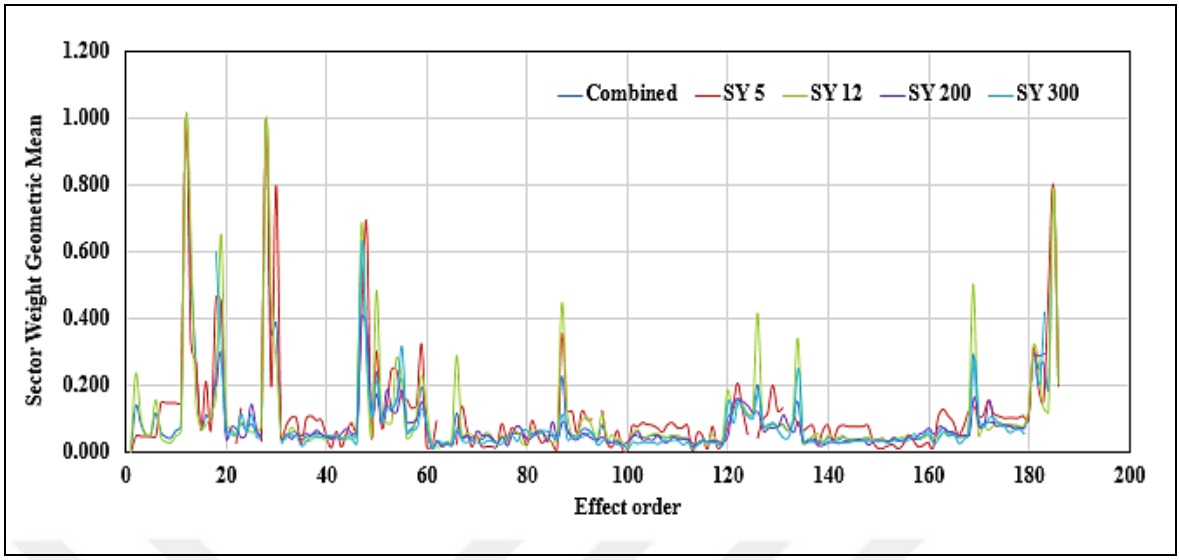


Figure 3.34b: Comparison of geometric means of the compiled Sector Weights from four shipyards with cleaned data and on 185 Effects' numerical order base.

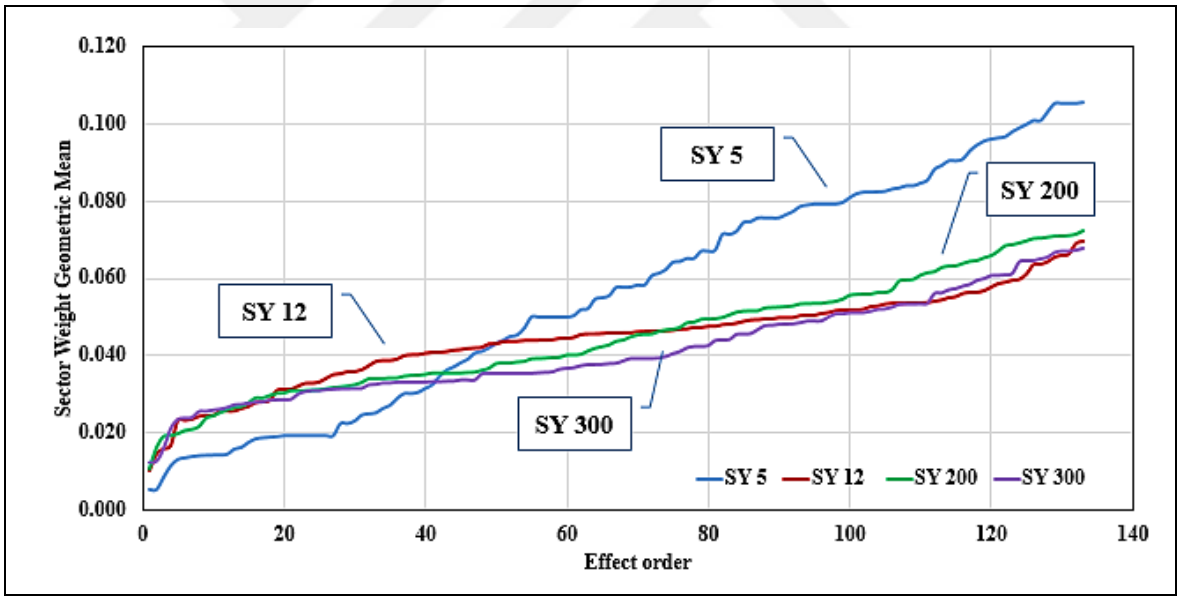


Figure 3.35: Comparison of geometric means of the compiled Sector Weights from four shipyards with approximately normalized data before test statistics analyses, on 133 Effects' numerical order base.

As observed on the dense data media in Figures 3.34a, 3.34b, and 3.35, it can be said that there may be correlations in the data. In Figure 3.35, two interesting points stood out, Shipyard 5's separation from the other shipyards and some kind of correlation between the

other Shipyards. But by these graphs, one cannot reach significant results without more statistical analyses.

Responses for each Effect were more important for evaluation but since low sample sizes existed (up to 1) for Effects and the number of Effects changed between 27 and 205; internal consistency checks were made for Shipyard 200 and Shipyard 300 responses on Effect Magnitudes (*M*) and Effect Timewise Distribution Types (*T*) on respondent basis. MS EXCEL 360 was used for data compilation and the tests. The student prepared and executed the Internal Consistency tests on the MS EXCEL 360 software.

- **Test statistics method:**

Cronbach's alpha, and if needed Coefficient of concordance (Kendall's W)

- **Major criteria for decision, null and alternative hypotheses:**

If (Cronbach's) alpha > 0,70, responses are consistent

If Kendall's W =0 no agreement; if W=1 perfect agreement

For Kendall's Concordance of Coefficients:

H_0 = rankings of the objects are independent of one another

H_1 = rankings of the objects are dependent of one another

- **Assumption check (normality):**

Raw data; may not be in normal distribution, and empty responses exist.

- **Assumption check (equality of variances):**

Raw data; may not have equality in variance between items and between respondents, empty responses or full same responses exist.

- **Analysis:**

In MS EXCEL 360, on the data input tables of survey responses (see Table 3.18).

Table 3.18: Internal consistency measurement results.

	Cronbach's Alpha			
	SY 200		**SY 300**	
	M	***T***	***M***	***T***
MNG process	0.979 (*r*=5, *k*=134)	0.978 (*r*=5, *k*=87)	0.963 (*r*=5, *k*=134)	0.962 (*r*=5, *k*=87)
DES process	0.900 (*r*=4, *k*=87)	0.910 (*r*=4, *k*=51)	0.950 (*r*=6, *k*=87)	0.940 (*r*=6, *k*=51)
OUT subprocess	0.965 (*r*=3, *k*=94)	0.871 (*r*=3, *k*=58)	**-0.290** (*r*=3, *k*=94)	0.895 (*r*=3, *k*=58)

M = Effect magnitude responses

T = Effect timewise distribution type responses

r = number of respondents

k = number of items (number of Effects)

Further investigation for SY 300, OUT subprocess, Effect Magnitude (*M*) responses:

- After empty answers deleted, new Cronbach's Alpha: **0,72** (*r*=3, *k*=62)

Further investigation for SY 300, OUT subprocess, Effect Magnitude (*M*) responses by Coefficient of Concordance (Kendall's W):

- Before empty answers deleted (*r*=m=3, *k*=n=94):

W = 0.000871, p=1.0000 ➔ do not reject H_0

- After empty answers are deleted, new W and p (*r*=m=3, *k*=n=62):

W = 0.0018336, p=1.0000 ➔ do not reject H_0

- **Decision report:**

Shipyard 200 and Shipyard 300 responses for Effect Magnitudes and Timewise Distribution types were consistent except for Shipyard 300 Outfitting before Ship Launching subprocess. For Shipyard 300, the Outfitting before Ship Launching subprocess responses were inconsistent and rankings of the objects are independent of one another. Further investigation of the data showed acceptable results; one respondent with deviating responses was found

to be highly eligible to respond to this subprocess, therefore, data cleaning continued for further analyses for this subprocess.

Additionally, in terms of the content of data to check the degree of the heterogeneity of sampled populations here (Nişel, 2023) and to make generalizations if possible, Karl Pearson's Measure of Kurtosis with fourth-order central moment of distribution approach was used to test randomly selected Shipyard 300 Shipbuilding Management process responses for Effect magnitude responses (M). For 134 responses (Effects), the result was calculated as $\alpha 4 = 1.463$, where $\alpha 4$ is smaller than 3, therefore the distribution is platykurtic and the data is not homogenous.

3.2.3.2. QUESTION (ii) :

Were the Sector weights calculated for each shipyard variate from each other? Can we compare using compiled Sector weights (i.e., as compiled from all participants of a shipyard).

Six data sets were prepared in MS EXCEL 360 and analysis was made on JASP software. The data sets belong to,

- Shipyard 5 (SY 5),
- Shipyard 12 (SY 12),
- Shipyard 200 (SY 200),
- Shipyard 300 (SY 300),
- Shipyard 512 (SY 512) is the data of Shipyards 5 and 12 (actual shipyards) together,
- Shipyard 2300 (SY 2300) is the data of Shipyards 200 and 300 (hypothetical shipyards) together. These abbreviations will be used as same in the following analyses.

Number of items in original data from the survey was: 205
Number of items in cleaned data (after data brought to normal distribution based on checks with descriptive statistics of the raw data extreme and outlier values cleaned) used in this analysis: 133
Geometric means (GEOMEAN) of compiled sector weights formed the data sets.

- **Test statistics method:**

Non-parametric test => four independent, unpaired data sets => Kruskal-Wallis test, followed by Dunn's Post Hoc test.

- **Major criteria for decision, null and alternative hypotheses:**

H_0 = Shipyards' compiled Sector Weights do not variate

H_1 = Shipyards' compiled Sector Weights variate

- **Descriptive Statistics** (see Table 3.19)**:**

Table 3.19: Descriptive statics, geometric means of compiled sector weights (JASP output).

	SY12	SY200	SY2300	SY300	SY5	SY512
Valid	133	133	131	133	131	133
Missing	0	0	0	0	0	0
Mode (*)	0.026	0.036	0.035	0.035	0.019	0.036
Median	0.046	0.044	0.043	0.038	0.058	0.049
Mean	0.044	0.045	0.043	0.041	0.056	0.047
Std. Deviation	0.012	0.015	0.013	0.013	0.029	0.014
IQR	0.013	0.022	0.019	0.018	0.054	0.022
Variance	1.369×10^{-4}	2.153×10^{-4}	1.619×10^{-4}	1.607×10^{-4}	8.666×10^{-4}	1.993×10^{-4}
Skewness	-0.463	0.119	0.262	0.320	-0.030	-0.340
Std. Error of Skewness	0.210	0.210	0.212	0.210	0.212	0.210
Kurtosis	0.199	-0.820	-0.621	-0.553	-1.294	-0.538
Std. Error of Kurtosis	0.417	0.417	0.420	0.417	0.420	0.417
Shapiro-Wilk	0.976	0.973	0.978	0.965	0.940	0.980
P-value of Shapiro-Wilk	0.018	0.010	0.030	0.002	< .001	0.043
Minimum	0.010	0.011	0.014	0.012	0.005	0.008
Maximum	0.070	0.072	0.071	0.068	0.106	0.072

- **Assumption check (normality)** (see Table 3.20)**:**

Table 3.20: Normality fit statistics, geometric means of compiled sector weights (JASP output)**.**

Fit Statistics

Test	Statistic	p
Shapiro-Wilk	0.974	< .001

The chosen significance level (α) is 0.05 and if the p-value in the Shapiro-Wilk test is less than 0.05, then the null hypothesis that the data are normally distributed is rejected. But still an approximation to normality can be seen in Figure 3.36 and Figure 3.37 except Shipyard 5 which has the least sample size.

Figure 3.36 is a Q-Q (quantile-quantile) graph to assess if a set of data comes from some theoretical distribution. Two sets of quantiles are plotted against one another and if both sets of quantiles come from the same distribution, the points form a roughly straight line.

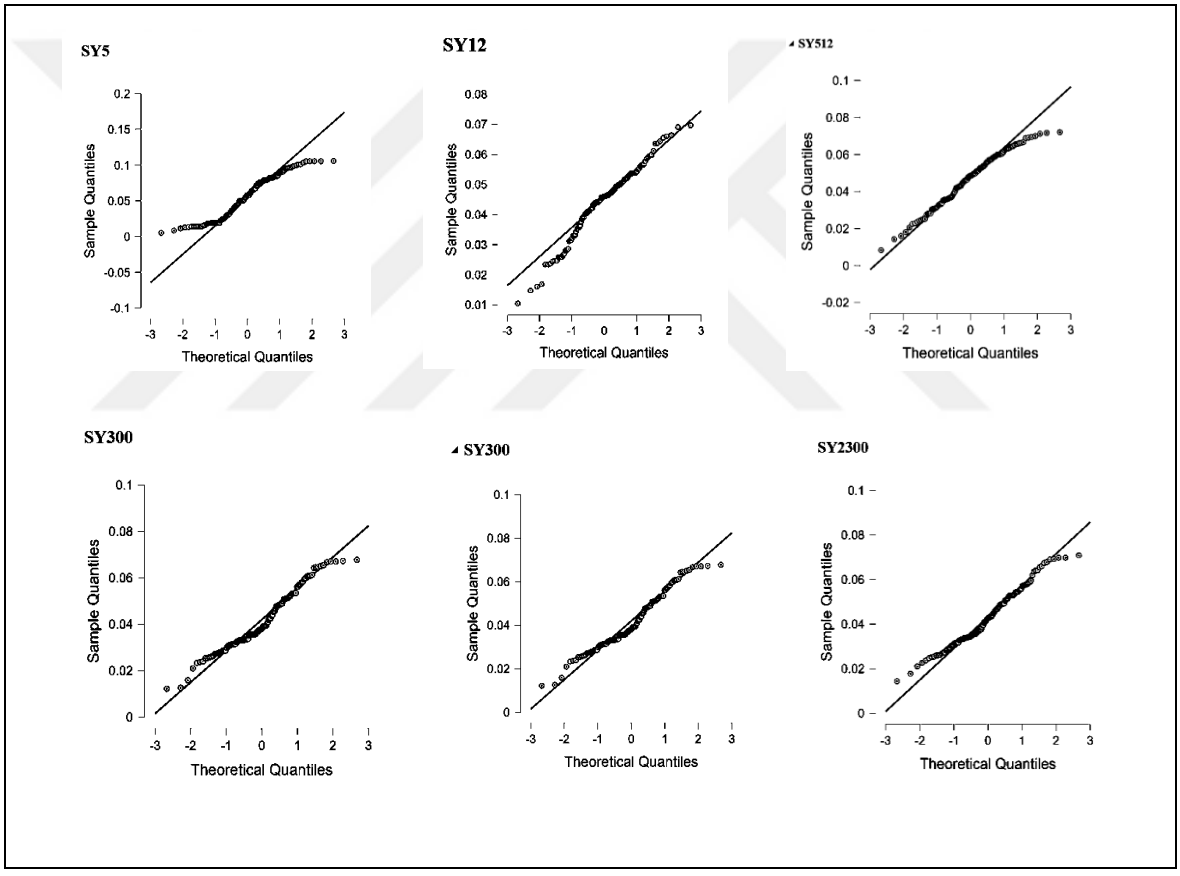


Figure 3.36: Q-Q graphs, geometric means of compiled sector weights (from JASP output)

The raincloud plot is a combination of data distribution (the cloud) and jittered raw data (the rain). As seen in Figures 3.36, 3.37, and 3.38, there are still a few outliers despite the data being cleaned.

The two peaks (bimodal distribution) of the normal distributions in Figure 3.37. represent two local maximums and in here shows two different groups may be in the data sets. For this study, it is also considered as different and distant thinking on the pairwise comparisons by the respondents.

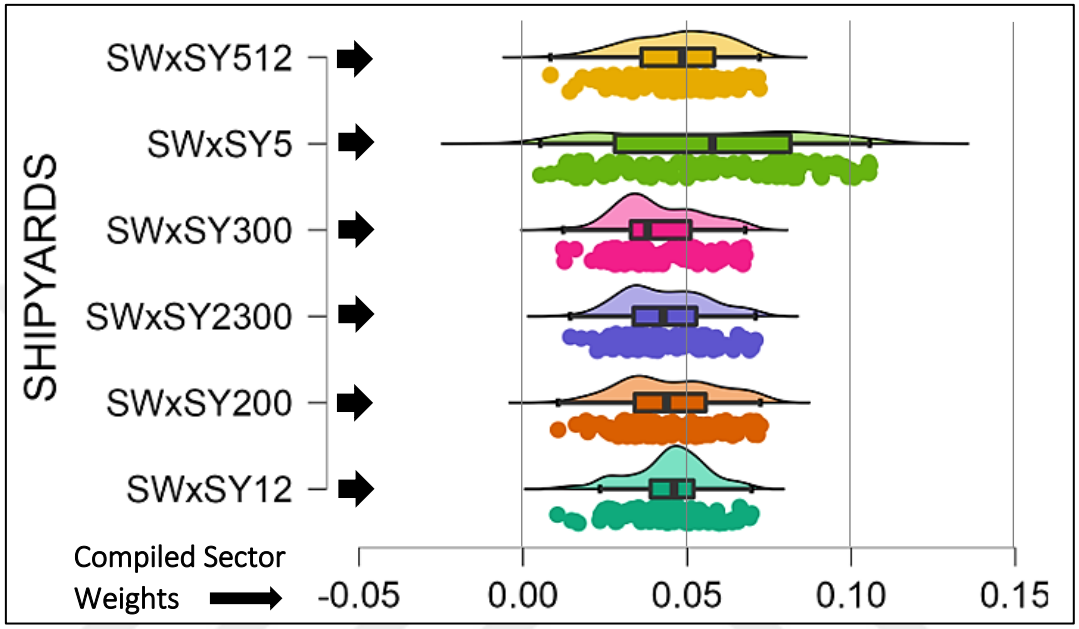


Figure 3.37: Raincloud plots of the geometric means of compiled sector weights (JASP output)

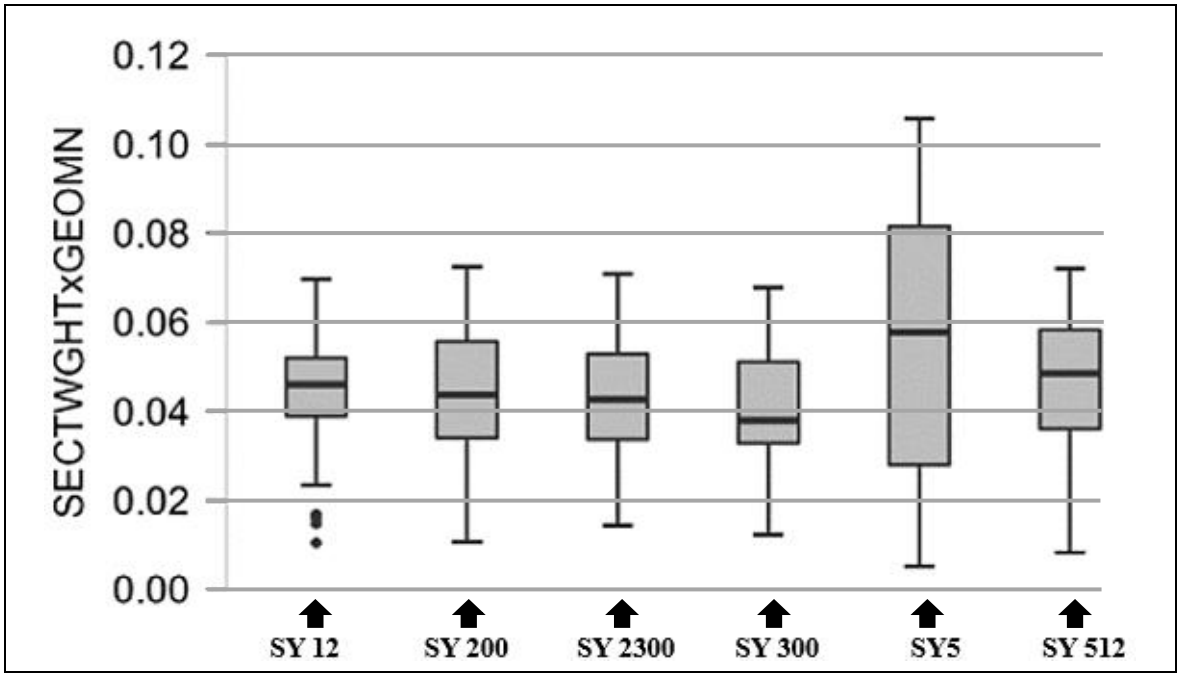


Figure 3.38: Boxplots, geometric means of compiled sector weights (from JASP output)

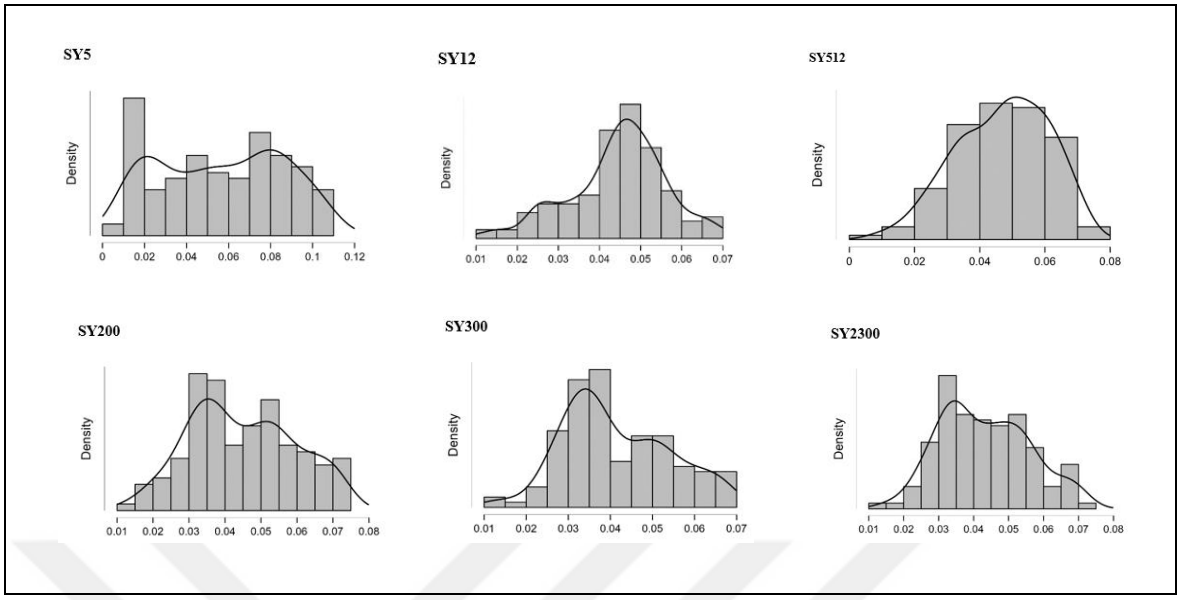


Figure 3.39: Histogram & Density plots, geometric means of compiled sector weights (from JASP output).

Density plots in Figure 3.39 for the geometric means of compiled sector weights and the frequencies of the total data in Figure 3.40 show bimodal distributions.

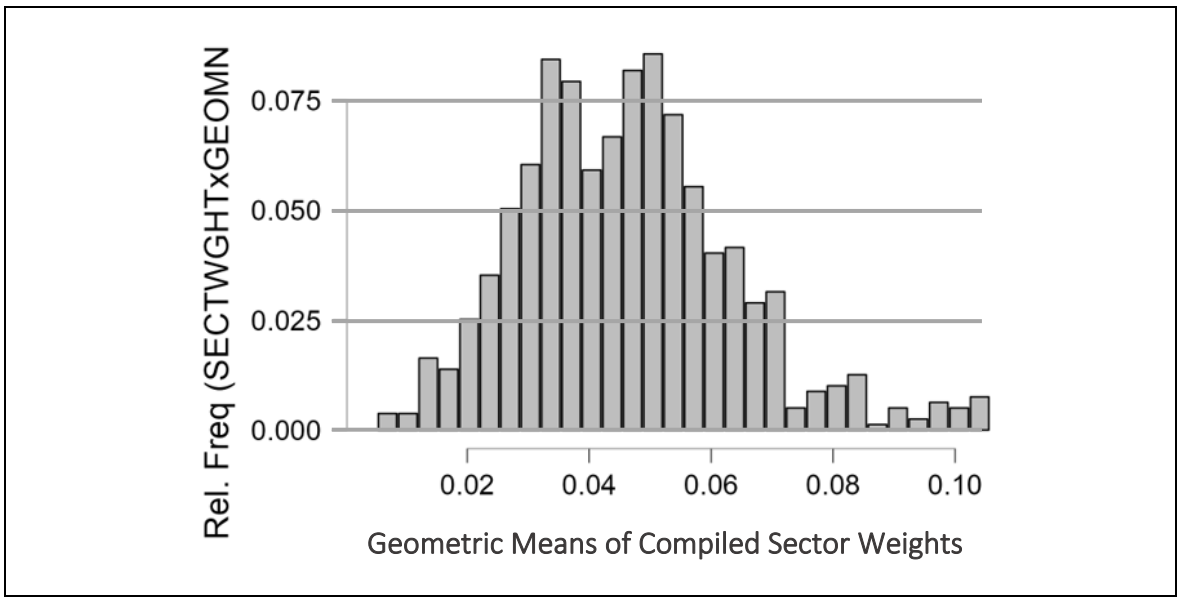


Figure 3.40: Histogram of total data, geometric means of compiled sector weights (JASP output).

- **Assumption check (equality of variances)** (see Tables 3.21 and 3.22)**:**

Table 3.21: Descriptives, geometric means of compiled sector weights (JASP output)**.**

SHIPYARDS	N	Mean	SD	SE	Coefficient of Variation
SWxSY12	133	0.044	0.012	0.001	0.263
SWxSY200	133	0.045	0.015	0.001	0.327
SWxSY2300	131	0.043	0.013	0.001	0.294
SWxSY300	133	0.041	0.013	0.001	0.307
SWxSY5	131	0.056	0.029	0.003	0.522
SWxSY512	133	0.047	0.014	0.001	0.301

(The means in data is close to zero and data is in interval scale, coefficient of variation may be misleading.)

Table 3.22: Test for equality of variances (Levene's), geometric means of compiled sector weights (JASP output)**.**

Test for Equality of Variances (Levene's)

F	df1	df2	p
63.576	5.000	788.000	< .001

In Levene's test for equality of variances, the p-value should be greater than 0.05 if the variances of groups were equal. That is, the variances were not significantly different from each other, and the homogeneity assumption of the variance was met, so the null hypothesis for Levene's test was not rejected). In this analysis, $p<0.05$ (Table 3.22) so that the homogeneity assumption of the variance was not met and the null hypothesis for Levene's test was rejected. If this test was done for two groups (data sets), the Student's T-Test (if variances were equal) or the Welch test (if variances were not equal) could be used. However, since there are more than two groups, the Kruskal-Wallis test (non-parametric) was necessary.

- **Analysis of variance: Kruskal-Wallis test** (see table 3.23)

Table 3.23: Kruskal-Wallis test result, geometric means of compiled sector weights (JASP output)**.**

Kruskal-Wallis Test

Factor	Statistic	df	p
SHIPYARDS	30.337	5	< .001

The test revealed (Table 3.23) significant differences ($p<0.001$) and H_0 is rejected).

Since the result of a Kruskal-Wallis test is statistically significant, then it was appropriate to conduct **Dunn's Test.** This is to determine exactly which groups were different. Dunn's Test performs pairwise comparisons between each independent group and shows which groups are statistically significantly different.

- **Analysis of variance: Post Hoc Test, Dunn's test** (see table 3.24)

Table 3.24: Dunn's Post Hoc Comparisons, geometric means of compiled sector weights (JASP output).

Comparison	z	W_i	W_j	p
SY12 - SY200	0.085	391.816	389.421	0.932
SY12 - SY2300	0.925	391.816	365.702	0.355
SY12 - SY300	2.014	391.816	335.165	0.044 *
SY12 - SY5	-2.998	391.816	476.458	0.003 **
SY12 - SY512	-1.256	391.816	427.147	0.209
SY200 - SY2300	0.840	389.421	365.702	0.401
SY200 - SY300	1.929	389.421	335.165	0.054
SY200 - SY5	-3.083	389.421	476.458	0.002 **
SY200 - SY512	-1.341	389.421	427.147	0.180
SY2300 - SY300	1.082	365.702	335.165	0.279
SY2300 - SY5	-3.908	365.702	476.458	< .001 ***
SY2300 - SY512	-2.176	365.702	427.147	0.030 *
SY300 - SY5	-5.005	335.165	476.458	< .001 ***
SY300 - SY512	-3.270	335.165	427.147	0.001 **
SY5 - SY512	1.747	476.458	427.147	0.081

* p < .05, ** p < .01, *** p < .001

With regard to Shipyard's own data sets, Dunn's test results (Table 3.24) showed that compiled Sector weights of

- Shipyard 12 (actual) and Shipyard 200 (hypothetical) were statistically insignificant since $p>0.05$ and H_0 was not rejected,
- Shipyard 200 (hypothetical) and Shipyard 300 (hypothetical) were statistically insignificant since $p>0.05$ and H_0 was not rejected.

So, the medians of these shipyards' compiled Sector weights do not variate including an actual shipyard and a hypothetical shipyard.

- **Decision report:**

To evaluate the differences across six complied Sector weight data sets Kruskal-Wallis test was used. The test revealed significant differences ($p<0.001$, H_0 is rejected) in the complied Sector weights data sets of four shipyards and two shipyard groups. After the Dunn's Ad-Hoc Test, it was observed that

- Difference between Shipyard 12 (actual) and Shipyard 200 (hypothetical) were statistically insignificant since $p>0.05$ and H_0 was not rejected,
- Difference between Shipyard 200 (hypothetical) and Shipyard 300 (hypothetical) were statistically insignificant since $p>0.05$ and H_0 was not rejected.

So, the medians of these shipyards' compiled Sector weights do not variate including an actual shipyard and a hypothetical shipyard. This showed that hypothetical shipyard results may be used in this study.

Similarly, several statistical analyses were held for the following questions and their results were briefly listed below:

3.2.3.3. QUESTION (iii)

Were the Sector Weights calculated for actual shipyards (Shipyards 5 and 12 together) different than those of hypothetical shipyards (Shipyards 200 and 300 together)?

Two data sets from Shipbuilding Management (MNG) process responses were prepared in MS EXCEL 360 and analysis was made on JASP software.

The data sets belong to,

- Shipyard 512 (SY 512), which is the data of Shipyards 5 and 12 (actual shipyards) are together,
- Shipyard 2300 (SY 2300), which is the data of Shipyards 200 and 300 (hypothetical shipyards) are together.

Number of items in original data from the survey was: 148

Number of items in cleaned data (after data brought to normal distribution based on checks with descriptive statistics of the raw data extreme and outlier values cleaned) used in this analysis: 100

Geometric means (GEOMEAN) of compiled sector weights formed the data sets.

- **Test statistics method:**

Non-parametric test => two independent, unpaired data sets => Mann-Whitney U test was aimed but JASP software provided a complete result set including Independent samples t-Test, Welch's test and Mann-Whitney U test. Despite not being necessary, a test was also made by Kruskal-Wallis statistics.

- **Major criteria for decision, null and alternative hypotheses:**

H_0 = Actual and Hypothetical Shipyards' Shipbuilding Management process Sector Weights does not variate

H_1 = Actual and Hypothetical Shipyards' Shipbuilding Management process Sector Weights variate

- **Descriptive Statistics** (see Table 3.25)**:**

Table 3.25: Descriptive statics, geometric means of Shipbuilding Management process sector weights (JASP output).

	SY2300	SY512
Valid	100	94
Missing	0	0
Mode	0.032	0.036
Median	0.040	0.042
Mean	0.042	0.042
Std. Deviation	0.015	0.019
IQR	0.023	0.029
Variance	2.204×10^{-4}	3.678×10^{-4}
Skewness	0.398	0.139
Std. Error of Skewness	0.241	0.249
Kurtosis	-0.877	-0.836
Std. Error of Kurtosis	0.478	0.493
Shapiro-Wilk	0.953	0.975
P-value of Shapiro-Wilk	0.001	0.070
Minimum	0.018	0.007
Maximum	0.075	0.082

Note. Excluded 6 rows from the analysis that correspond to the missing values of the split-by variable SHIPYARDS

- **Assumption check (normality)** (see Table 3.26)**:**

Table 3.26: Normality fit statistics, geometric means of Shipbuilding Management process sector weights (JASP output)**.**

Test of Normality (Shapiro-Wilk)

		W	p
SECTWGHTgGEOMN	SWmgSY2300	0.953	0.001
	SWmgSY512	0.975	0.070

Note. Significant results suggest a deviation from normality.

Fit Statistics ▼

Test	Statistic	p
Shapiro-Wilk	0.980	0.007

Normal distribution of the data of actual shipyards (SY 512) is not rejected ($p>0.05$) as shown in Table 3.26.

The raincloud plot in Figure 3.41 shows better approximations to normal distribution than the previous Question (ii) distributions.

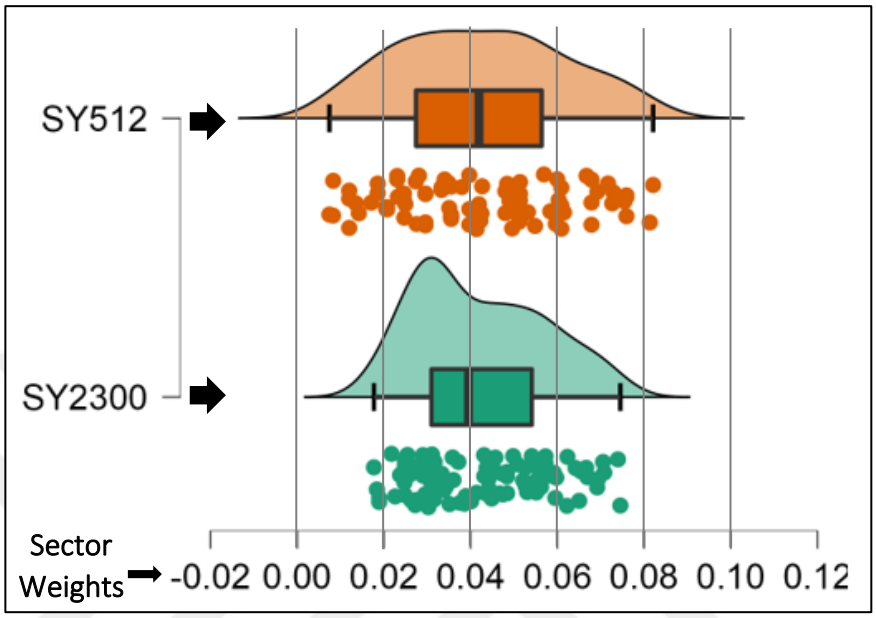


Figure 3.41 Raincloud plots, geometric means of Shipbuilding Management process sector weights (JASP output).

- **Assumption check (equality of variances)** (see table 3.27)**:**

Table 3.27: Test for equality of variances (Levene's), geometric means of compiled sector weights (JASP output)**.**

Test for Equality of Variances (Levene's)

F	df1	df2	p
6.405	1.000	192.000	0.012

In this analysis, $p<0.05$ so that the homogeneity assumption of the variance was not met and the null hypothesis for Levene's test was rejected. Welch's test and Mann-Whitney U tests should be used.

Analysis of means (see Table 3.28)**:**

Table 3.28: Independent Samples T-Test (Student's T-Test), Welch's test and Mann-Whitney U test results, actual shipyards vs. hypothetical shipyards (JASP output).

Independent Samples T-Test

	Test	Statistic	df	p	Effect Size	SE Effect Size
SECTWGHTgGEOMN	Student	−0.118	192.000	0.906	−0.017	0.144
	Welch	−0.117	175.095	0.907	−0.017	0.144
	Mann-Whitney	4684.000		0.968	−0.003	0.083

Note. For the Student t-test and Welch t-test, effect size is given by Cohen's d. For the Mann-Whitney test, effect size is given by the rank biserial correlation.

All three tests revealed insignificant differences ($p>0.05$, H_0 is not rejected) as given in Table 3.28. This also can be seen in Figure 3.42 as the geometric means of the actual and hypothetical shipyards are close to each other.

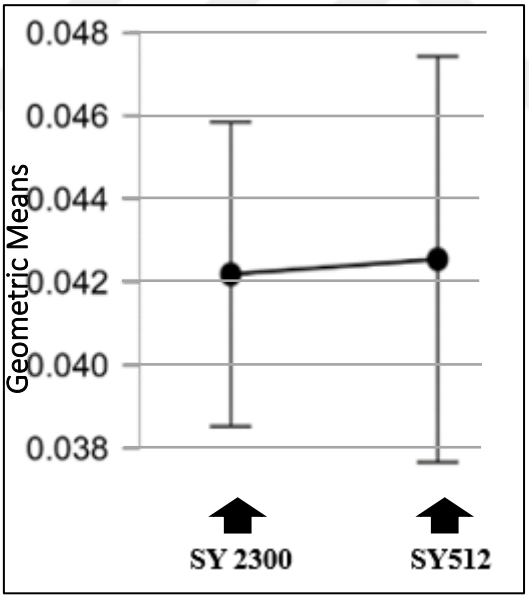


Figure 3.42: Descriptive plots, geometric means of Management Process sector weights, actual shipyards vs. hypothetical shipyards with 95% confidence intervals (from JASP output).

Analysis of variance : Kruskal-Wallis test (see Table 3.29)**:**

Table 3.29: Kruskal-Wallis test result, geometric means of Management Process sector weights, actual shipyards vs. hypothetical shipyards (JASP output).

Kruskal-Wallis Test

Factor	Statistic	df	p
SHIPYARDS	0.002	1	0.967

The Kruskal-Wallis test also revealed (Table 3.29) an insignificant difference ($p>0.05$, H_0 is not rejected).

- **Decision report:**

To evaluate the differences across two Shipbuilding Management process Sector weight data sets, the tests revealed insignificant differences ($p>0.05$, H_0 is not rejected) for the Sector weights data sets of two shipyard groups. This showed that hypothetical shipyard results may be continued to be used in this study.

3.2.3.4. QUESTION (iv)

Can the calculated Sector Weight values represent the whole Shipyards in the World?

For this analysis, compiled Sector Weights data from the four sample shipyards, as cleaned was planned to be used. The data is also can be seen in Appendix L.

But no parameter data on the population, i.e., those of the 514 shipyards building ships in the world, were available, guessing does not give robust results due to very different and dispersed properties of the population. Therefore, the use of Confidence Interval for each Effect was decided as an interim solution for further work on this methodology after the thesis. As the sample size enlarges and some population parameters can be obtained in the future, then statistical interference may be executed.

For the sector weights data, the 95% Confidence Interval upper and lower bounds were obtained from Descriptive Statistics and normalized within the Effect groups/subgroups as applied to the sector weights (normalized sector weights in Table L.1.). For the Confidence Intervals, rather than Effect means, geometric means were used as the standard application in this study; and where the sample size was below 31 (i.e., N<31) t-value from the table, where the sample size was above 30 (i.e., N>30) z=1,96 value was used. Some lower bounds of Confidence Interval dropped to negative values, but they were revised as 0.001 since Effect weights can not be negative. An excerpt is provided from Table L.1. where Sector weights and 95% Confidence Intervals were given. in Figure 3.43.

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
51APL00	**MANAGEMENT : PLANNING & BUDGETING (APL)**	56	0.067	**0.050**	0.041 - 0.059
51APL01	Shipbuilding Project Schedule groups	19	0.071	**0.039**	0.028 - 0.049
51APL02	Scope of the Shipbuilding Projects Labor Planning	35	0.078	**0.032**	0.026 - 0.038
51APL03	Integration of schedules	23	0.038	**0.036**	0.027 - 0.044
51APL04	Scheduling techniques	25	0.025	**0.026**	0.019 - 0.032
51APL05	Project scheduling simulations	10	0.024	**0.018**	0.004 - 0.031
51APL06	Dynamic schedule management : Continuous monitoring and feedback	52	0.057	**0.057**	0.050 - 0.062
51APL07	Dynamic schedule management : Progress and Budget evaluation	11	0.054	**0.054**	0.036 - 0.072
51APL08	Accurate time-schedules	56	0.054	**0.050**	0.042 - 0.056
51APL09	Accurate labor planning	54	0.052	**0.051**	0.043 - 0.058
51APL10	Job-order system	41	0.058	**0.058**	0.049 - 0.066
51APL11	Performance measurements, Efficiency calculations	59	0.050	**0.055**	0.047 - 0.062
51APL12	Job standardization; Visible indication of job performance metrics and values at the workstation	54	0.046	**0.049**	0.040 - 0.056
51APL13	Density of the Change Requests, Rework	50	0.045	**0.048**	0.038 - 0.057

Figure 3.43: An excerpt from Table L.1.

Again, to check the degree of the heterogeneity of the data (Nişel, 2023) and to make generalizations if possible, Karl Pearson's Measure of Kurtosis with fourth-order central moment of distribution approach was used to test the compiled Sector Weights data. For 183 weights, the result was calculated as $\alpha 4 = 1.073$, where $\alpha 4$ is smaller than 3, therefore the distribution is platykurtic and data is not homogenous.

3.3. Summary

An analogy to propeller shaft alignment, a common application during ship production, helped to formulate the research question and led to a mathematical model. A misaligned propeller shafting is thought to resemble the entire shipbuilding process of a Shipyard and a perfectly aligned same shafting to resemble the “Ideal” version of it. Some "Effects" on the shipbuilding processes are assumed to resemble the vertical forces acting on the shafting. The purpose is now to smooth the current and actual shipbuilding processes and align them with the “Ideal” status as much as possible, by manipulating the Effects, comparing the shipyard to its ideal version. For the methodology to be developed, the "Ideal" version of a Shipyard is assumed to have the highest productivity; the differences between a shipyard’s current status from its "Ideal" version depend on several Effects which can be represented in a numerical and geometrical model and, may provide productivity assessment information specific to the shipyard.

Both for the Shipyard and the Ideal Shipyard, "Effects" affecting the shipbuilding process, were assumed as the vertical vectors (like the vertical upwards forces acting on propeller shafting) positioned on the *x*-axis of a Cartesian coordinate system 1st Quadrant. Terminal points of those vectors formed the coordinate points where,

- *y*-value is the Effect magnitude,
- *x*-value is the Effect's position on the *x*-axis.

One curve to fit the vector end coordinates is drawn to represent actual state of the Shipyard. Shipbuilding sector weights are also applied to Ideal Shipyard Effects which are initially a straight line at $y=1$ and they change to a curve of the same type.

The ratio of the calculated areas under the Shipyard and Ideal Shipyard curves, above $y=0$, leads to a dimensionless number. As the Shipyard, or a process, approaches its "Ideal" version because of some improvements, this ratio of the areas becomes closer to "1". Therefore, a ratio very close to "1" represents a productive shipyard.

Development of the mathematical model covered five steps:

(i) definition of the Effects,
(ii) Effects' data requirements,

(iii) curves and areas,
(iv) calculation of the productivity numbers,
(v) improvement areas priority lists.

A list of internal and external "Effects" was derived from references during the Literature Survey. This search for the Effects affecting shipbuilding resulted in a list of 494 Effects in total. After the elimination to obtain the sole "Shipyard Productivity" and "direct ship delivery" influencers, 185 of those Effects were decided to have an important impact on the ship delivery schedule from the start of contracting works until the end of sea trials.

The Effects were arranged under groups of Production, Infrastructure, Design and Production Engineering, Materials and Procurement, Shipbuilding Management, Work Force, Quality, and Contracting. The Effects were also appointed to subgroups, distributed to the processes and subprocesses, also with some cross-repetitions. Each Effect was numbered in accordance with its subgroup.

Three numerical properties were needed to characterize each Effect in applying the Effects to the mathematical model:
(i) Effect magnitude,
(ii) Effect weight, and
(iii) the timewise position of the Effect along the duration of the related process.

For the Shipyard, the Effect magnitude was initially decided to be a natural number and also between 1 (best) to 5 (worst) due to a possible use of a 5-point itemized rating scale application to quantify qualitative responses during the test case. For the Ideal Shipyard, to be compared with the Shipyard, all Effect' magnitudes are initially set to y=1, the best status.

Weight is applied to each Effect (i.e., to the initial Effect magnitude y, denoted as "Weighted Magnitude. Effect weights were decided to be calculated by pairwise comparisons, by the utilization of the Analytic Hierarchy Process (AHP) method (Saaty 1980). Weight was decided to be applied for processes and subprocesses by the same method.

Effects were distributed along the t-axis for their timewise position (x-axis value and in weeks) based on their realization dates during the total shipbuilding period. For each Effect,

one of six alternative time-distribution types was decided to be defined so that the distributions' centroids specify the time positions of the Effects during their respective process/subprocess period.

In search of an appropriate curve type to fit Effect (y,t) coordinates during a process/subprocess, OneWay (monotonic) Spline was decided.

Numerical data obtained from the curve fit were used in the calculation of the areas under the curves by using a numerical integration method, Simpson's Second Rule. The decision to use numerical integration and Simpson's rules was based on the possibility of having different numbers of spacings related integration of resulted data on surveys at different shipyards.

Three key numbers are the major outputs of this new methodology;

- the (dimensionless) Productivity Number "PN",
- the dimensionless Productivity Number (DPN) of the subprocess/processes "DPN", and
- the dimensionless Productivity Number of the Shipyard (entire shipbuilding process) **"U".**

Productivity numbers belonging to the Shipyard show the "current (actual)" state. Productivity numbers belonging to the Ideal Shipyard show the "target" state. A shipyard's managerial task is to reach the "target" state by improvements and to make all DPNs and **U** equal to 1.

Analytic Hierarchy Process based weighting of the Effects was planned to help to prioritize improvement needs. The Effects are to be listed and sorted by their Weighted Magnitudes. For double-checking of these improvement lists, the Pareto chart was also planned to be applied to the above-listed data.

Among several methods, the "survey" method was decided due to the participation of large groups in shipyards at a global scale and the expectation of data on many general characteristics. An Expert Opinion type questionnaire set was prepared with eleven sections based on processes/subprocesses used in this study. The calculated sample size requirement of 220-225 shipyards was found very high for this study and to be able to have a sample size of at least 30 shipyards, providing a 0.177 level of precision, plus 50% reserve (15 shipyards),

45 shipbuilders were decided to be selected for application on the survey all around the world. A short-list was prepared based on technology level (2 to 5) and production experience on different types of steel commercial and/or naval ships longer than 70-80 meters criteria. Forty-two shipyards all around the world were applied with an e-mail or phone call for the first survey phase between January-September 2022. Two shipyards returned with positive responses. After liaison persons were named, communications were set, confidentiality agreements signed and survey Questionnaire sets provided in printed format, the surveys were executed between May and August 2022.

No positive invitation was received for the second survey phase, which also created the problem of measuring the reliability and validity of the developed method. As an alternative solution to continue with the methodology, known 32 experts with extensive shipbuilding, ship design, and project management experiences were communicated to simulate the crew of two hypothetical shipyards, in October 2022.

After the responses to the Questionnaires from two actual and two hypothetical shipyards were received, numerical analyses started. Numerical analyses were executed in the following order;

(i) preparation of data insert and calculation templates,
(ii) compilation of respondents' statistics
(iii) calculations of,

- Effect weights and shipbuilding sector weights,
- Effect Magnitudes,
- Process/subprocess and Effect group/subgroup weights,
- Process/subprocess time schedules.

(iv) descriptive Statistics and data cleaning,
(v) obtaining curves and areas on the shipyard and process/subprocess basis,
(vi) calculation of Productivity Numbers,
(vii) definition of improvement process needs, cross-check on the Pareto chart,
(viii) preparation of Dashboards of Shipyards,
(ix) study on the test statistics and hypotheses.

4. RESULTS AND DISCUSSION

To develop a new methodology preferably with dimensionless metrics, to evaluate the shipyard productivity and prioritize the improvement needs which are compatible with the entire shipbuilding process formed the main research questions, as given in subsection 1.2.3. An analogy to propeller shaft alignment was the starting point of the methodology.

Four participants from Shipyard 5, 17 participants from Shipyard 12, 12 participants for the hypothetical Shipyard 200, and 14 participants for the hypothetical Shipyard 300, 47 participants in total attended to the shipyard surveys. Their statistical details are given in Table 3.17 and Appendix E.

After the numerical analyses with the data gathered from shipyard surveys to obtain Productivity Numbers, priority lists of improvement needs and to observe the statistical significance of the methodology as detailed in Section 3 above, following results were achieved on the analyses.

4.1. Shipyard Based Results and Discussion

For a shipyard, initially, the 185 Effects acting on shipyard productivity during its shipbuilding processes and subprocesses were defined; their magnitudes, weights, weighted magnitudes, and timewise positions during their respective process/subprocess periods were calculated and embedded in the Productivity Calculations as explained in Section 3. A shipyard-specific Dashboard was prepared in MS EXCEL 360 software to present found results.

After actual and hypothetical shipyard surveys and numerical analyses, two separate Dashboards were finalized for the hypothetical Shipyard 200 and Shipyard 300. In the following parts, the visual presentation of the calculated Productivity Numbers and visual identification of process/subprocess productivity statuses, along with the summarized priority lists of needed improvements will be presented.

4.1.1. Shipyard 200

A Shipyard Dashboard was prepared to submit the Productivity Numbers, process/subprocess curves and improvement needs priorities summary. General screen-view samples from Shipyard 200 Dashboard are given in Figures 4.1., 4.2. and in Appendix O.

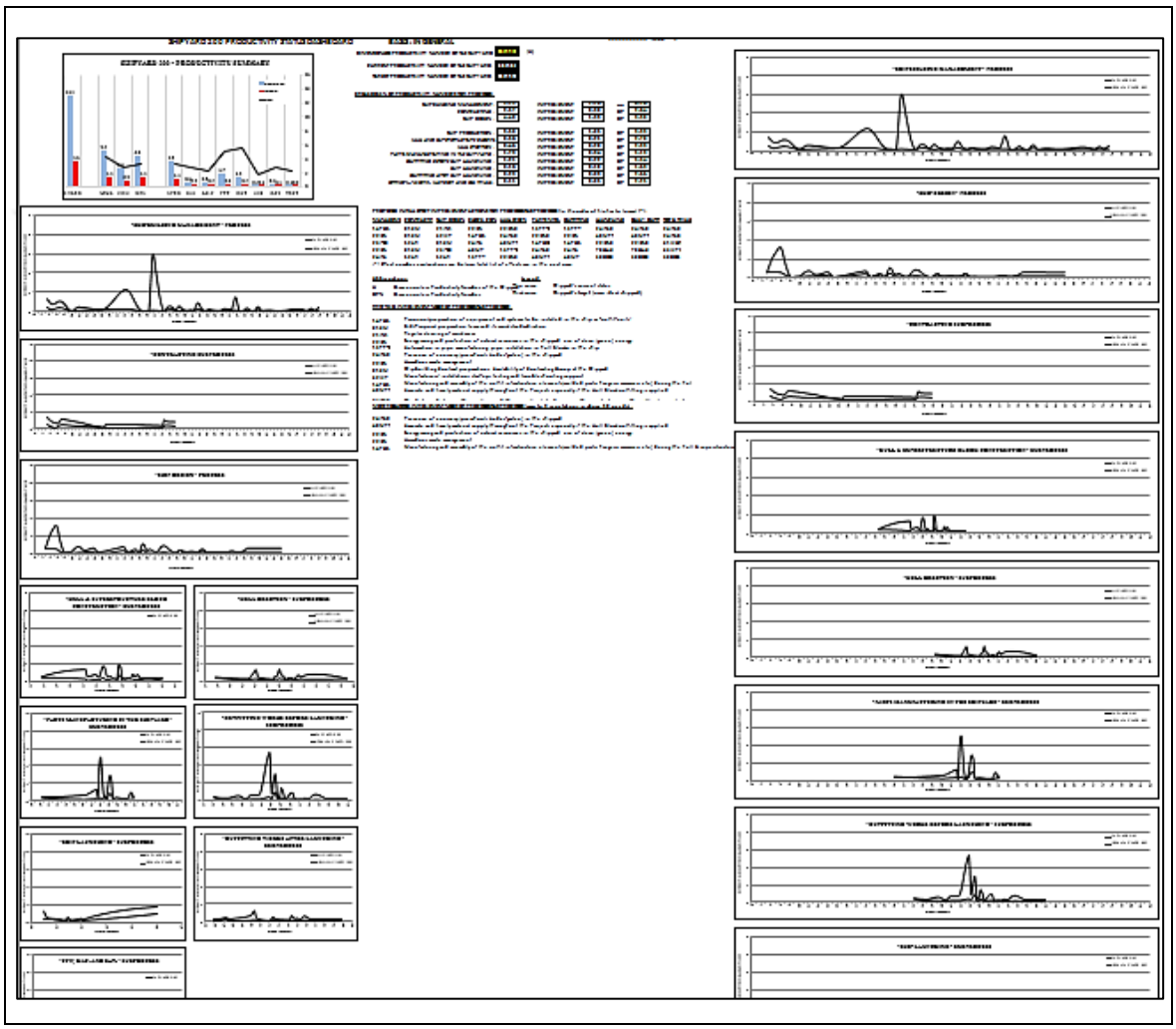


Figure 4.1: Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view).

In Figure 4.1., the middle-top part of the Dashboard covers the shipyard name, the basis of the Dashboard (i.e. calculations for “in general”, “cost”, “labor” or “time” basis), date and version of the Dashboard, the key numerical output of Productivity Numbers, proposed first five Effect improvement actions for processes/subprocesses (in the order of higher to lower), Effect definitions of first two improvement needs of processes/subprocesses, and most

requested improvement needs of processes/subprocesses (max. to 3 repetitions in above 50 needs).

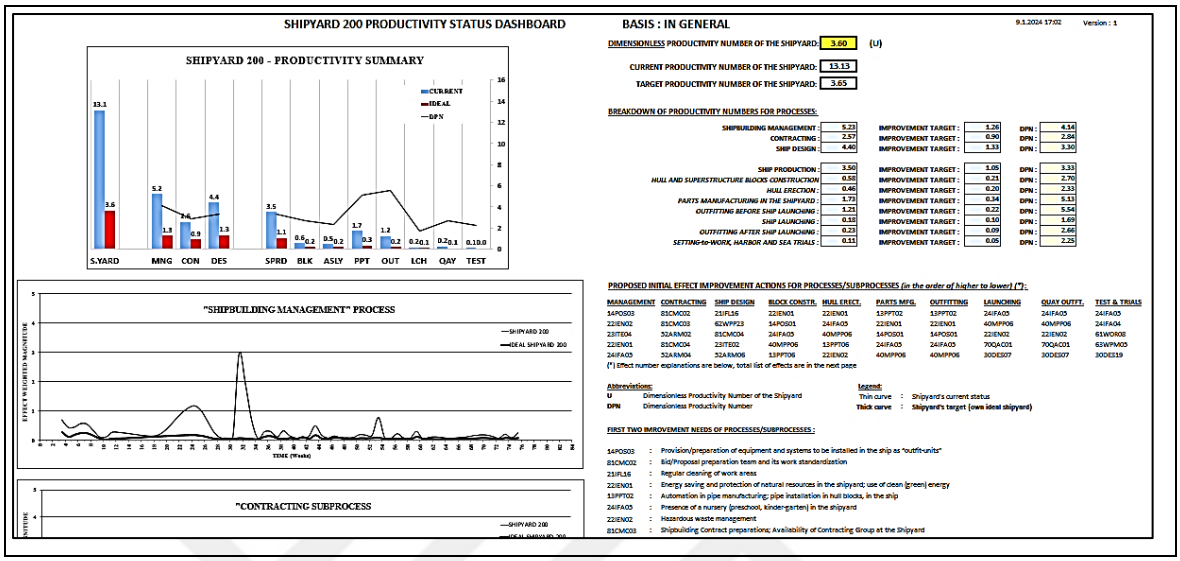


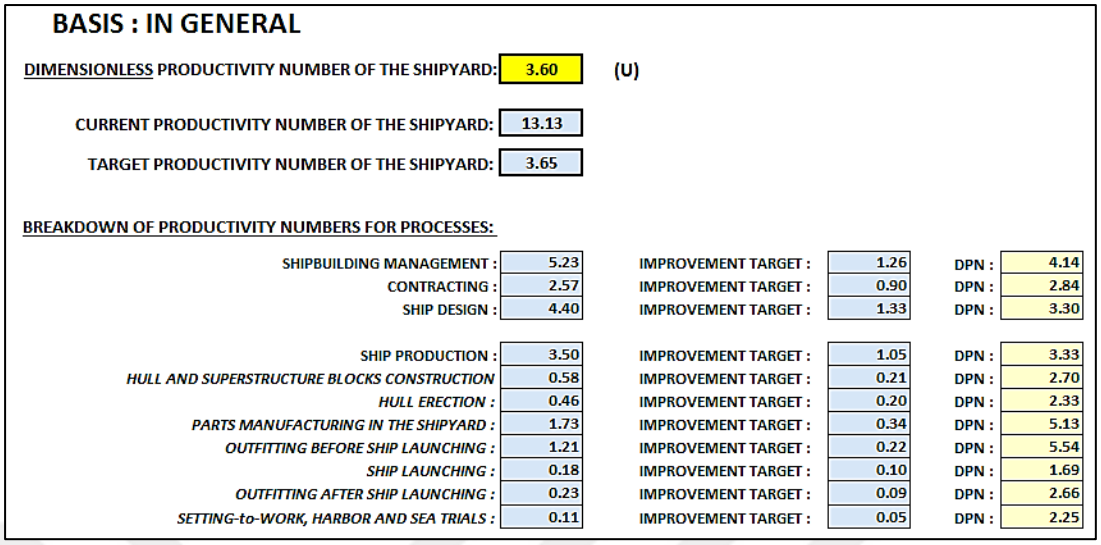
Figure 4.2: Sample screen-view of Shipyard 200 Productivity Status Dashboard, top middle and left parts.

The left part of the Dashboard covers the Productivity Summary graph on top (see Figure 4.2 and 4.4) and then, current-Ideal status graphs of processes/subprocesses in narrowed form, each having their own process/subprocess periods on the time axes.

The same graphs are put on the right side of the Dashboard, with all process and subprocess time axes are the total shipbuilding project period, from Shipbuilding Contracting works start week (Week 1 in this thesis, see subsection 2.1.2) to the ship delivery week.

Middle-bottom part is reserved for further interactive facilitation after this thesis.

As on the Shipyard 200 Dashboard, the calculated Productivity Numbers, including the Shipyard Dimensionless Productivity Number (**U**) are given in Figure 4.3.



BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.60	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.13				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

Figure 4.3: Key numerical output on the dashboard of Shipyard 200.

On "In General" basis, which can be changed to Cost or Labor or Time basis for different evaluations based on their weights as given in Figure N.1., the current Productivity Number of the Shipyard was calculated as 13.13. Target Productivity Number of the Shipyard, which is the "Ideal" version of Shipyard 200, was calculated as 3.65. Their ratio gives the Dimensionless Productivity Number "**U**" of the Shipyard as 3.60 which should be "1" if the Shipyard 200 reaches to its Ideal version. To achieve this, some improvements are needed in the processes/subprocesses.

Processes and subprocesses' current Productivity Numbers, Improvement Target Numbers (process/subprocess Ideal Productivity Number), and Dimensionless Productivity Numbers (DPN) are given in Figure 4.3.

The Outfitting before Ship Launching subprocess has the highest DPN of 5.54, which shows the maximum difference between the current status and Ideal status of the process. Despite this looks like the Outfitting before Ship Launching subprocess deserves the initial attention for improvements, but this is not the case. Tests during the Numerical Analyses showed that, if the current Productivity Number of a process/subprocess is close or less than "1", improvement attention should not be given to such processes, but to the ones with high current Productivity Numbers along with high DPNs. In this respect, the Shipbuilding

Management process deserves the first improvement checks with its highest current Productivity Number of 5.23 and DPN of 4.14. Because, despite having the highest DPN, the Outfitting before Ship Launching subprocess' current Productivity Number is 1.21, which is indeed very close to "1", the best status. On the other hand, the Shipbuilding Management process has both a high Productivity Number, away from the best status, and also have a high DPN which shows a high effort to come close to the Improvement Target of 1.26.

Similarly, the initial improvement investigations should be given to the Ship Design process and Contracting subprocess, which have high current Productivity Numbers and DPNs. The Ship Production process is the compilation of its subprocesses, so any changes in those subprocesses will change the Productivity Numbers (current and target) and its DPN, so the Ship Production process can not be manipulated on its own on the Dashboard.

Visual outputs, the current and Ideal status graphs of processes and subprocesses help to gain some insight as shown in Figures 4.4 to 4.8. When the Weighted Magnitude of an Effect is changed, for example for an improvement test, these linked graphs also revise themselves due to the change in the area under the respective process/subprocess curve and the Productivity Number.

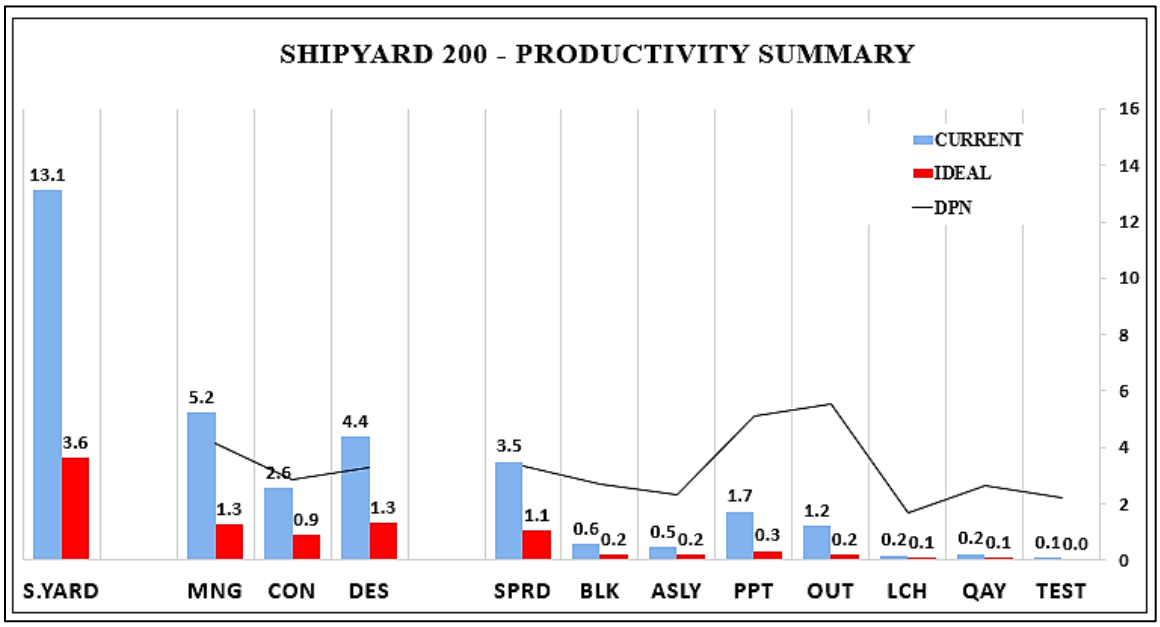


Figure 4.4: Productivity Summary graph of the dashboard of Shipyard 200.

In Figure 4.4, the Productivity Summary graph of the dashboard of Shipyard 200 is shown. It shows the current Productivity Numbers, Ideal Productivity Numbers, and DPN on the shipyard and process/subprocess basis.

In Figure 4.5, the Shipbuilding Management and Ship Design processes' curves of Shipyard 200 are shown throughout the process periods (Weeks 1-84 for Shipbuilding Management, Weeks 1-80 for Ship Design (see Table 3.15). The thin curves show the current status while the thick black curves show the Ideal Shipyard 200. For Shipbuilding Management, the two peaks above the y=1 line show that some Effects around Week 25 (23ITE04 with WM=1.17, the third in priority order) and Week 32 (14POS03 with WM=3.13, the highest in the priority order), are to be checked for improvements first. The Effect number 22IEN02 has a Weighted Magnitude (WM) of 1.54 with the timewise position on the 47th week and in the second place for improvement but due to other Effects around it, it may have a lesser need for improvement when interactively tested.

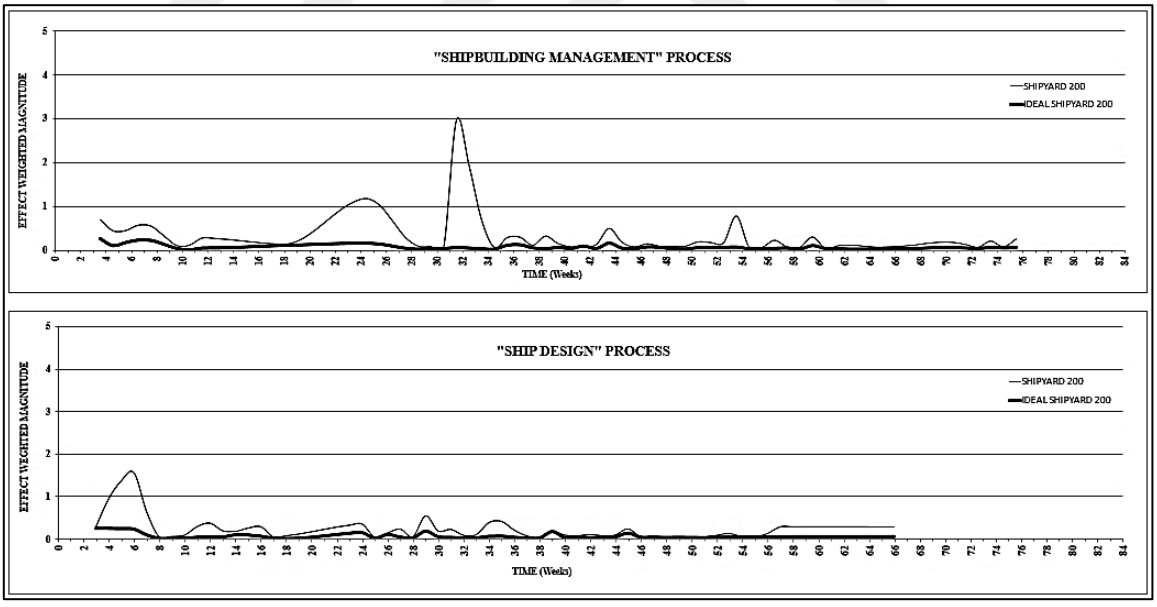


Figure 4.5: Shipyard 200 – Shipbuilding Management and Ship Design processes' graphs.

Again, in Figure 4.5, for the Ship Design process one peak is above y=1 and it shows that some Effects around Week 6 (81CMC04 with WM=1.58, the third in priority order) are to be checked for improvements first. The Effect number 21IFL16 has the highest Weighted

Magnitude (WM) of 2.45 with the timewise position on the 40th week and in the first place for improvement but due to other Effects around it, it may have a lesser need for improvement when interactively tested. As Effect improvements are applied, the thin curve approaches to the thick Ideal Shipyard curve. Due to the "centroid" of timewise distribution application in the methodology, the Effect curves end earlier than the process/subprocess finish weeks. But, those end points are almost through the end of the processes, unless differently emphasized by the survey participants during Effect Magnitude and timewise distribution type decision during the survey, this does not cause a problem in general.

In Figure 4.6, the graphs of Contracting, Hull & Superstructure Block Construction, and Hull Erection subprocesses are below the y=1 line. Despite having some peaks for the current status, improvement tests for them may wait until some improvements in the Shipbuilding Management and Ship Design processes cause some new peaks on these three subprocesses.

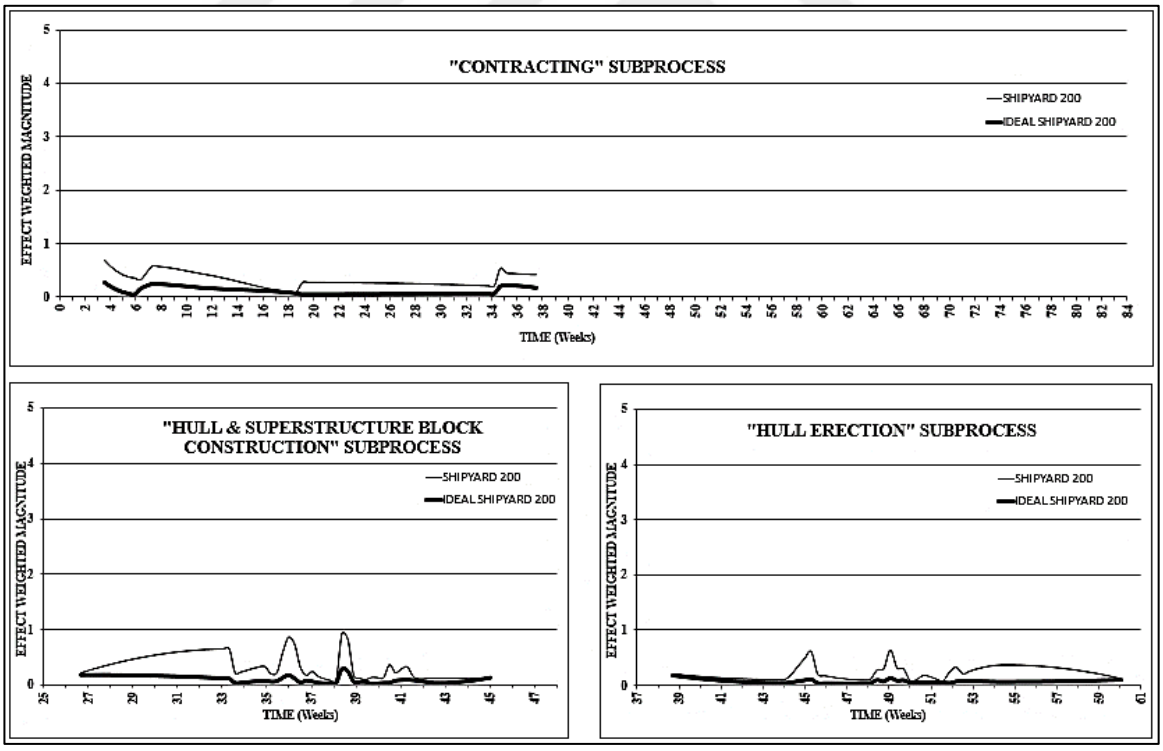


Figure 4.6: Shipyard 200 – Contracting, Hull & Superstructure Block Construction and Hull Erection subprocesses' graphs.

In Figure 4.7, Ship Launching and Outfitting after Ship Launching subprocesses may wait on hold for improvement since they are below the y=1 line. But, the peaks of the Parts

Manufacturing in the Shipyard and Outfitting before Launching subprocesses may be investigated mainly to make internal improvements (which may also have adverse results on other processes/subprocesses) and tested after the improvement tests on the Shipbuilding Management and Ship Design processes.

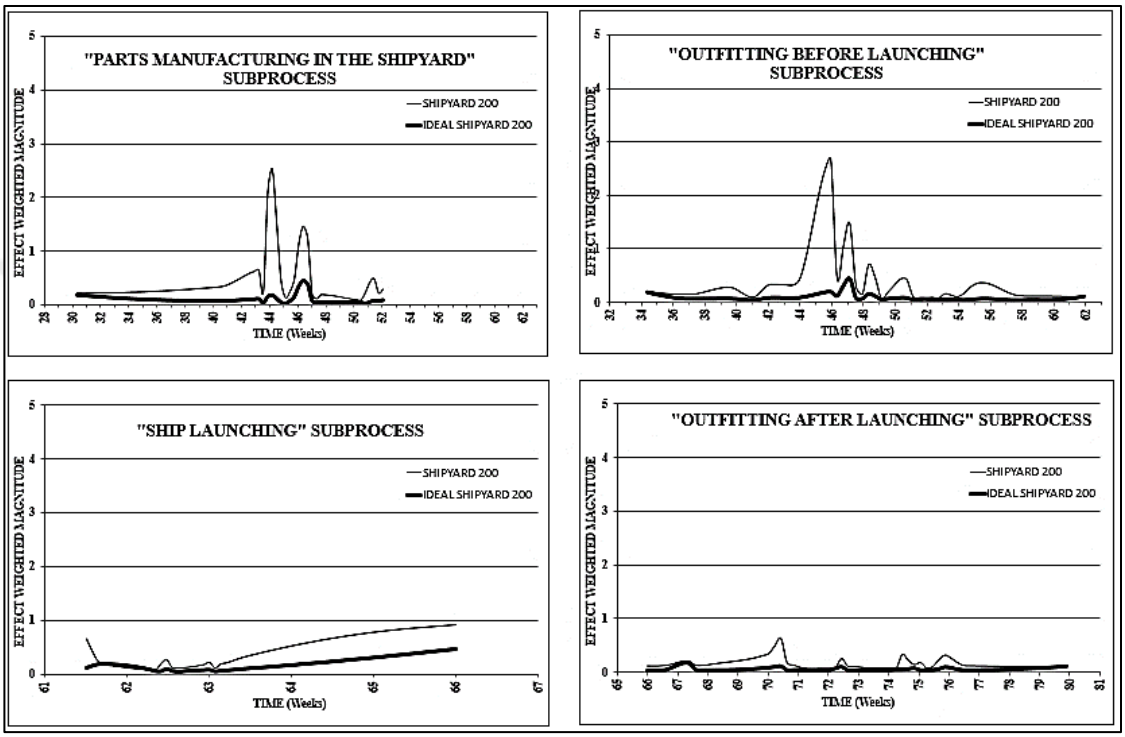


Figure 4.7: Shipyard 200 – Parts Manufacturing in the Shipyard, Outfitting before Launching, Ship Launching, and Outfitting after Ship Launching subprocesses' graphs.

For Parts Manufacturing in the Shipyard subprocess, the two peaks above the y=1 line show that some Effects around Week 44 (13PPT02 with WM=2.69, the highest in priority order) and Week 46 (22IEN01 with WM=2.53, the second in the priority order), are to be checked for improvements first. Effect 13PPT02 is the automation in pipe manufacturing, pipe installation in hull blocks and onboard while Effect 22IEN01 is the energy saving and protection of natural resources in the shipyard and the use of clean (green) energy. In Figure 4.8, improvements were applied to 13PPT02 and 22IEN01 (i.e., Effect Magnitudes were changed to "1"), and the resulting new curve is presented while the new Key numerical output on the dashboard of Shipyard 200 is presented in Figure 4.9. While there is a change

on the curve for Week 44, a minor change happened for Week 46 which identifies that more improvement around Week 46-47 is needed.

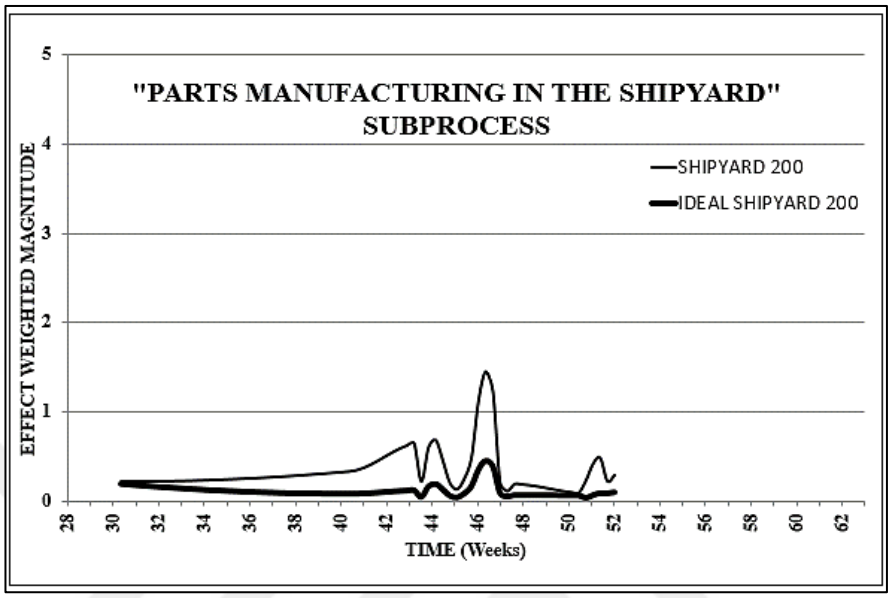


Figure 4.8: Shipyard 200 – Parts Manufacturing in the Shipyard graphs after two improvements were tested.

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.52	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	12.83				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.20	IMPROVEMENT TARGET :	1.05	DPN :	3.05
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.43	IMPROVEMENT TARGET :	0.34	DPN :	4.24
OUTFITTING BEFORE SHIP LAUNCHING :	0.91	IMPROVEMENT TARGET :	0.22	DPN :	4.14
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

Figure 4.9: Key numerical output on the dashboard of Shipyard 200, revised after two improvements tested.

In Figure 4.9, it was observed that the Dimensionless Productivity Number "**U**" of the Shipyard, which was 3.60 before, reduces to 3.52 as a result of the two improvements in

Parts Manufacturing in the Shipyard subprocess. Despite four other process/subprocesses having the same repeating Effect (see Appendix B) a change in the Productivity Number and DPN occurred only for the Outfitting before Ship Launching subprocess. This means these two improvements may not have much impact on the other three processes/subprocesses.

In Figure 4.10, the graph of the Setting-to-Work, Harbor and Sea Trials subprocess is presented. Since the curves are well below y=1, any improvement actions for this subprocess may not be considered at an initial evaluation stage.

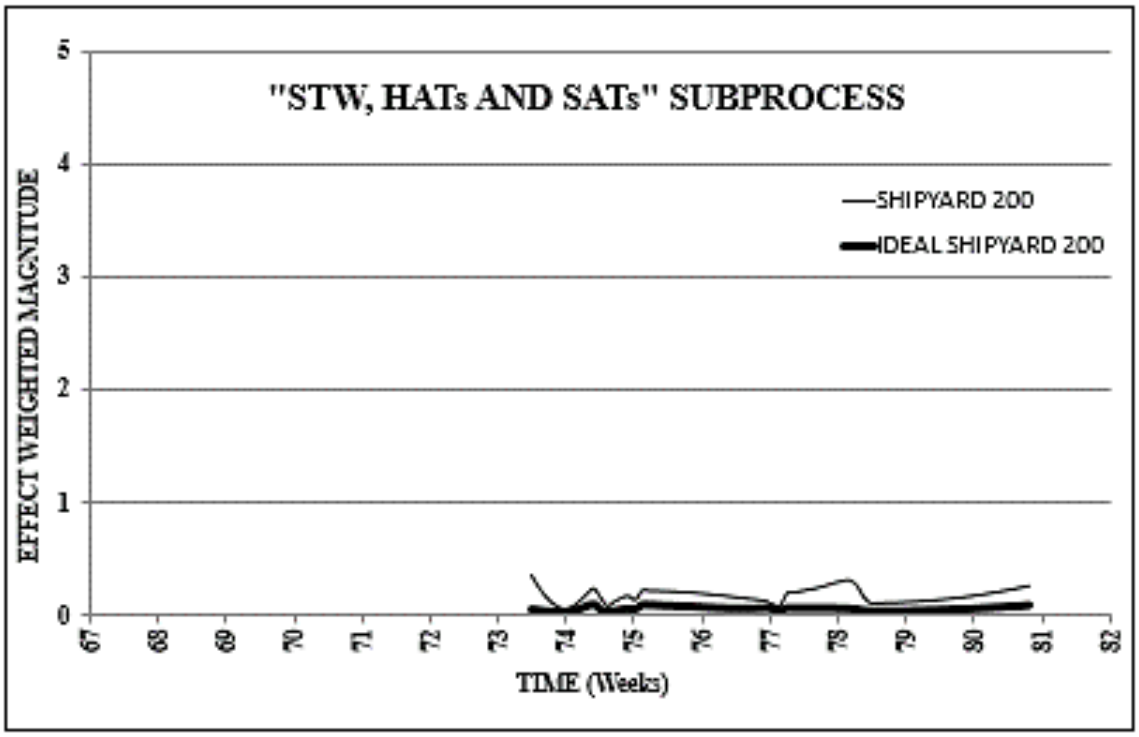


Figure 4.10: Shipyard 200 – Setting-to-Work, Harbor and Sea Trials subprocess graph.

The second research aim was to obtain improvement area priority lists of the processes and, test the effects of the improvements on productivity leading to a continuous improvement cycle. In this respect, along with the Productivity Number calculations, priority lists for needed improvements on the Effects of the processes/subprocesses were obtained by the order of the Weighted Magnitudes of the Effects.

For Shipyard 200, the initial five Effects to be tested for improvement in process/subprocess and for the entire shipbuilding process (i.e., to reduce the dimensionless Productivity

Number **U** of Shipyard 200) are listed in the priority order Figure 4.11, and 24 of them are named in the Effect number order in Table 4.1.

MANAGEMENT	CONTRACTING	SHIP DESIGN	BLOCK CONSTR.	HULL ERECT.
14POS03	81CMC02	21IFL16	22IEN01	22IEN01
22IEN02	81CMC03	62WPP23	14POS01	24IFA05
23ITE04	52ARM02	81CMC04	24IFA05	40MPP06
22IEN01	81CMC04	23ITE02	40MPP06	13PPT06
24IFA05	52ARM04	52ARM06	13PPT06	22IEN02

PARTS MFG.	OUTFITTING	LAUNCHING	QUAY OUTFT.	TEST & TRIALS
13PPT02	13PPT02	24IFA05	24IFA05	24IFA05
22IEN01	22IEN01	40MPP06	40MPP06	24IFA04
14POS01	14POS01	22IEN02	22IEN02	61WOR08
24IFA05	24IFA05	70QAC01	70QAC01	63WPM05
40MPP06	40MPP06	30DES07	30DES07	30DES19

Figure 4.11: Shipyard 200 – Proposed initial five Effects for improvement testing for processes/subprocesses (in the order of higher to lower priority).

The 50 Effects shown in Figure 4.11 have the highest Effect Weighted Magnitudes in their respective process/subprocess. In simple thinking, when the Magnitudes of these Effects are changed to "1" from the current Magnitudes, a substantial improvement can be obtained in the Shipyard. But this is not the case. Due to the repeating Effects (see subsection 3.1.1 and Appendix B) and the use of process/subprocess weights calculations which cause chain reactions in the calculation of Productivity Numbers. Accordingly, it doesn't mean that the improvement of the first five Effects provides a substantial improvement in the Shipyard. Each first two Effects are better tested, starting with the process having the highest current Productivity Number, the Shipbuilding Management process of Shipyard 200, followed by the Ship Design process and Contracting subprocess as listed in Table 4.2.

Table 4.1: Subjects of the first 24 Effects in Figure 4.11 (in Effect nr. Order).

Effect nr.	Effect
13PPT02	Automation in pipe manufacturing; pipe installation in hull blocks, in the ship
13PPT06	Automation in manufacturing and outfitting, use of robots
14POS01	Manufacturing and assembly of the outfit infrastructure elements(welded parts, hangers, carcasses, etc.) during the hull & superstructure blocks assembly
14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"
21IFL16	Regular cleaning of work areas
22IEN01	Energy saving and protection of natural resources in the shipyard; use of clean (green) energy
22IEN02	Hazardous waste management
23ITE02	Existence of information integration for shipyard automation systems
23ITE04	Research & Development (R&D) investments
24IFA04	The distance between the work area and the car parking lot; adverse weather protection on the walking line; electric vehicle charging facility
24IFA05	Presence of a nursery (preschool, kindergarten) in the shipyard
30DES07	Compliance of design document deliveries with the ship production schedule
30DES19	Consideration of Ship Acceptance Test requirements at the early stages of design
40MPP06	Accurate and timely material supply throughout the Project, especially if the Hull Block outfitting is applied
52ARM02	Presence of a Risk Management Team
52ARM04	Project Risk Management breakdown
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions
61WOR08	Work planning suitable for the personnel with special conditions (aged, disabled, etc.)
62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support
63WPM05	Employee circulation
70QAC01	Effectiveness of the Quality Assurance System
81CMC02	Bid/Proposal preparation team and its work standardization
81CMC03	Shipbuilding Contract preparations; Availability of Contracting Group at the Shipyard
81CMC04	Participation of relevant departments in Shipbuilding Contract negotiations

Table 4.2: Proposed 6 Effects to be investigated and tested for improvement in Shipyard 200 (in priority order).

Process/ subprocess	Effect Nr.	Effect
MNG	14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"
MNG	22IEN02	Hazardous waste management
DES	21IFL16	Regular cleaning of work areas
DES	62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support
CON	81CMC02	Bid/Proposal preparation team and its work standardization
CON	81CMC03	Shipbuilding Contract preparations; Availability of Contracting Group at the Shipyard

When the six Effects listed in Table 4.2 are tested for improvement, i.e., their Magnitudes were changed to "1" in all processes/subprocesses they exist, the Productivity Numbers were changed to new values as shown in Figure 4.12.

INITIAL PRODUCTIVITY NUMBERS (see Figure 4.3.)**:**

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.60	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.13	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

INTERACTIVELY CHANGED PRODUCTIVITY NUMBERS AFTER SIX IMPROVEMENTS WERE TESTED (see Table 4.2.):

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.30	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	12.02	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

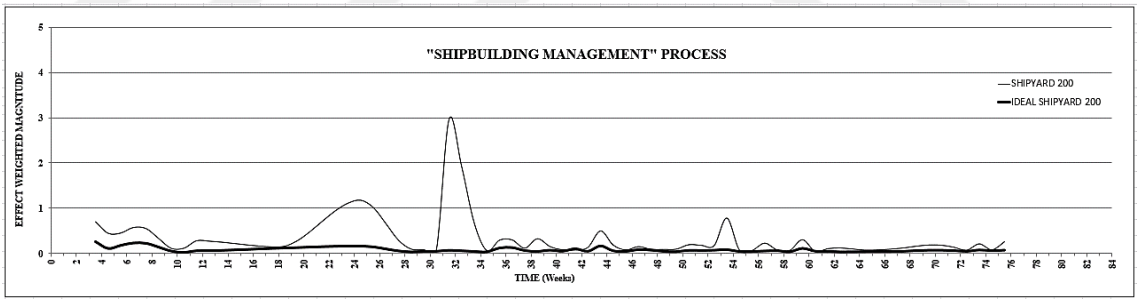
SHIPBUILDING MANAGEMENT :	4.24	IMPROVEMENT TARGET :	1.26	DPN :	3.36
CONTRACTING :	2.46	IMPROVEMENT TARGET :	0.90	DPN :	2.72
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.38	IMPROVEMENT TARGET :	1.05	DPN :	3.22
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.16	IMPROVEMENT TARGET :	0.22	DPN :	5.31
SHIP LAUNCHING :	0.10	IMPROVEMENT TARGET :	0.10	DPN :	0.92
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.65
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.10	IMPROVEMENT TARGET :	0.05	DPN :	2.24

Figure 4.12: Key numerical output on the dashboard of Shipyard 200, before and after six improvements were applied.

As shown in Figure 4.12, the Dimensionless Productivity Number "**U**" of Shipyard 200 changed to 3.30 from the initial 3.60 as a result of the change in the shipyard's current Productivity Number from 13.13 to 12.02. The six improvements showed changes in the Productivity Numbers and accordingly DPNs of the Shipbuilding Management process, Contracting, Outfitting before Ship Launching, Ship Launching and STW, Harbor and Sea Trials subprocesses as a chain reaction. Despite two of the improvements initiated from the Ship Design process (Table 4.2, Effects 21 IFL 16 and 62WPP23), the productivity numbers of the Ship Design process were not changed. This shows more Effects need to be improved in the Ship Design process for further tests on improvement actions. In Figures 4.13 to 4.15, the changes in the graphs of some processes/subprocesses were given as a sample of the visual output benefit of this methodology.

For the Shipbuilding Management process, the change in one peak on the shipyard curve is obvious after six improvements applied but the curve shows that more improvements are necessary to be tested to reduce other peaks.

INITIAL GRAPH (see Figure 4.5):



INTERACTIVELY CHANGED GRAPH AFTER SIX IMPROVEMENTS WERE APPLIED:

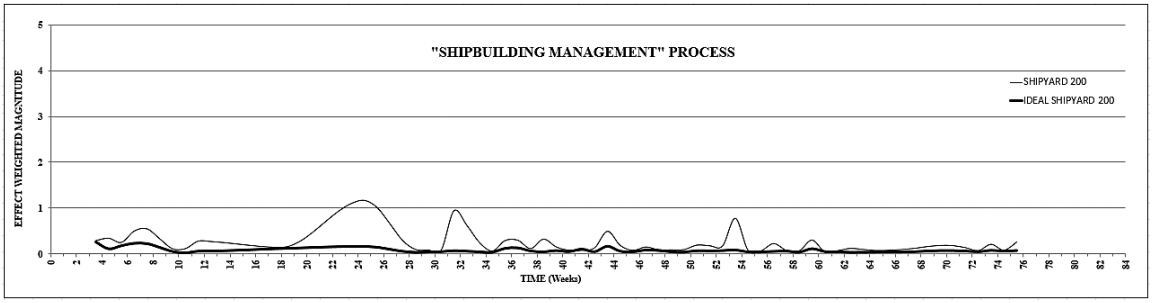
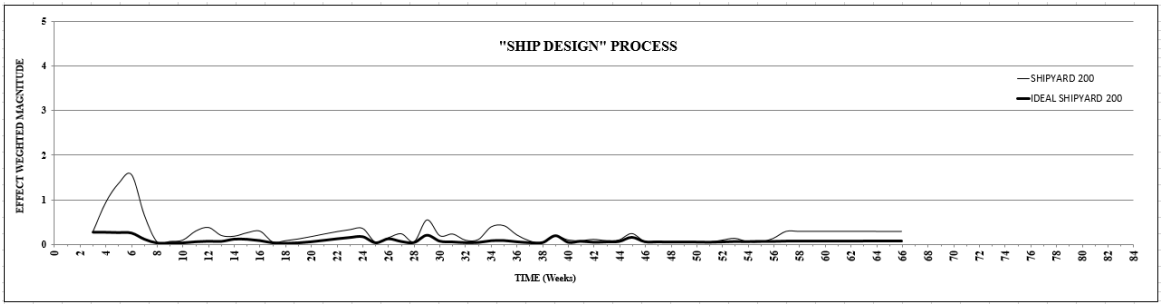


Figure 4.13: Shipyard 200 Productivity Status Dashboard graphs of Shipbuilding Management process before and after six improvements applied.

INITIAL GRAPH (see Figure 4.5):



INTERACTIVELY CHANGED GRAPH AFTER SIX IMPROVEMENTS WERE APPLIED:

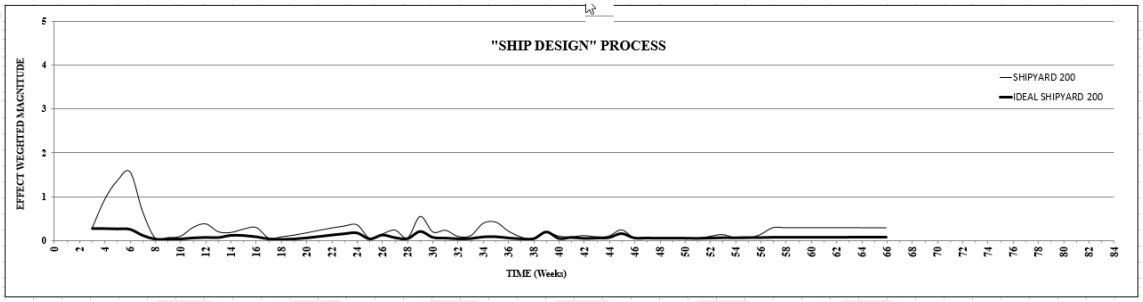
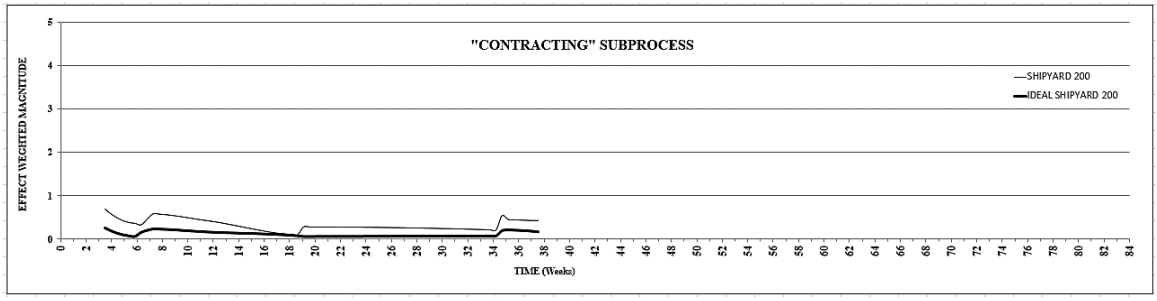


Figure 4.14: Shipyard 200 Productivity Status Dashboard graphs of Ship Design process before and after six improvements were applied.

For the Ship Design process, as also seen on the Productivity Numbers no change occurred on the shipyard curve. The curve shows that improvements in the Effects around Week 6 are still more necessary to be tested.

For the Contracting subprocess, there exists a change in one peak on the shipyard curve at the very beginning after six improvements were applied. This is due to the timewise positions of the two Effects tested for improvement, a very early phase of contracting works. The shipyard curve aligns with the Ideal shipyard curve there. The curve also shows that more improvements may need to be tested for more alignment with the Ideal shipyard curve.

INITIAL GRAPH (see Figure 4.6):



INTERACTIVELY CHANGED GRAPH AFTER SIX IMPROVEMENTS WERE APPLIED:

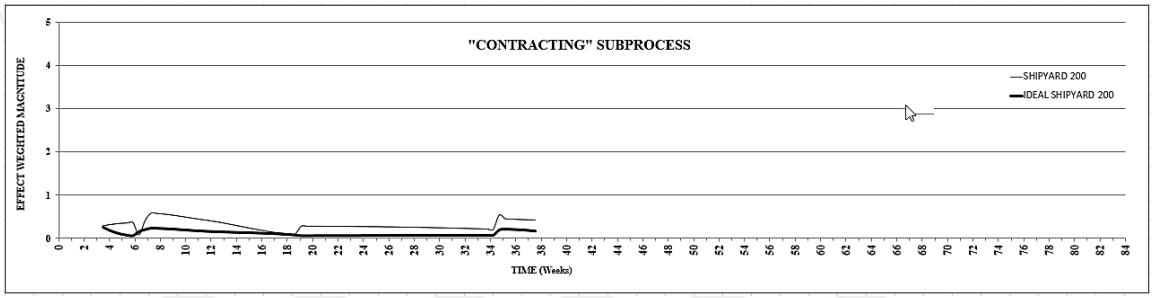


Figure 4.15: Shipyard 200 Productivity Status Dashboard graphs of Contracting subprocess before and after six improvements applied.

As a result, the Productivity Number table and visual graphs on the Shipyard 200 Dashboard show that the aimed methodology works successfully and the analogy to propeller shafting alignment was appropriate.

4.1.2. Shipyard 300

A Shipyard Dashboard was prepared to submit the Productivity Numbers, process/subprocess curves and improvement needs priorities summary. General screen-view samples from Shipyard 300 Dashboard is given in Figures 4.16., 4.17. and in Appendix O.

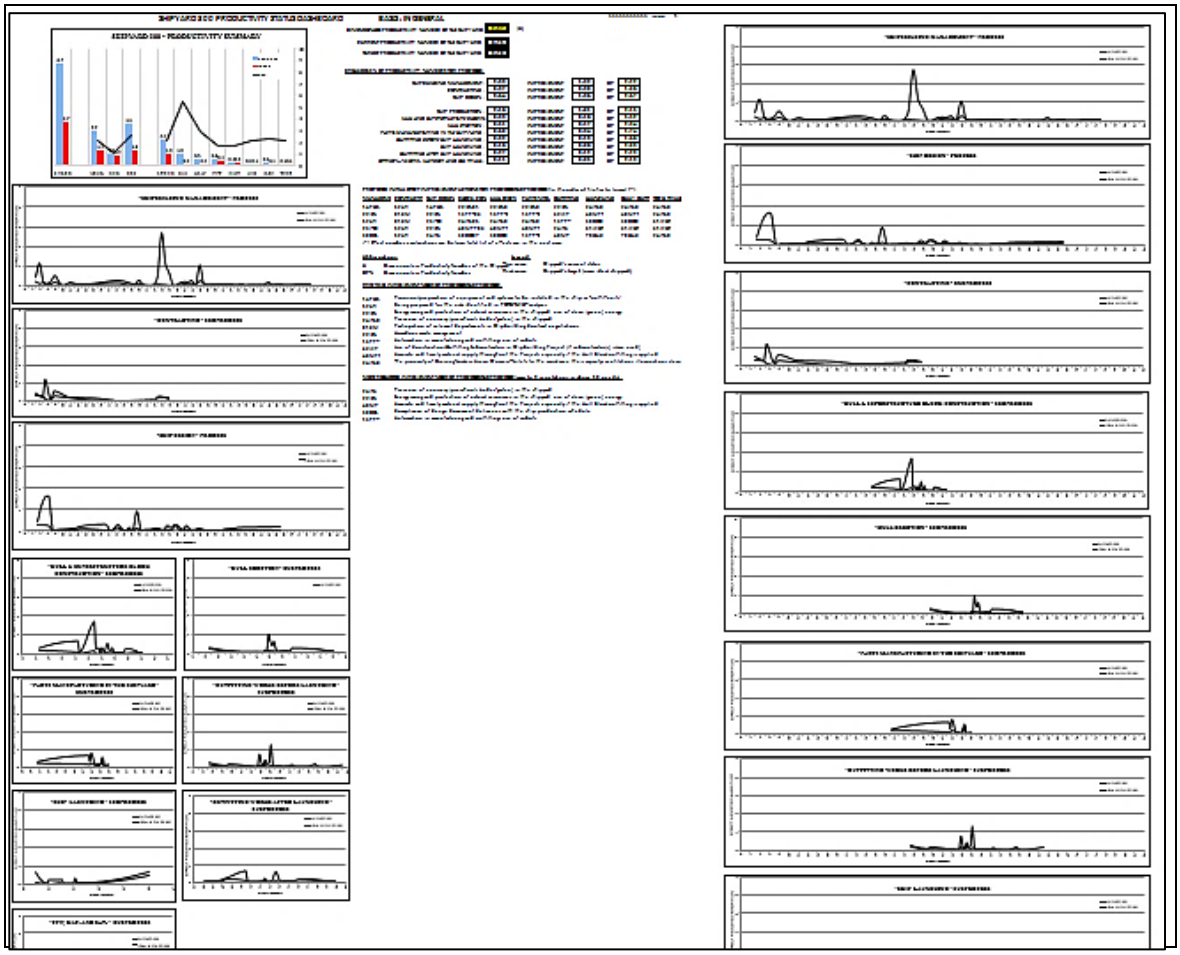


Figure 4.16: Sample screen-view of Shipyard 300 Productivity Status Dashboard (expanded view).

In Figure 4.16., same as the Shipyard 200 Dashboard design (Figure 4.1), the middle-top part of the Dashboard covers the shipyard name, the basis of the Dashboard (i.e. calculations for “in general”, “cost”, “labor” or “time” basis), date and version of the Dashboard, the key numerical output of Productivity Numbers, proposed first five Effect improvement actions for processes/subprocesses (in the order of higher to lower), Effect definitions of first two improvement needs of processes/subprocesses, and most requested improvement needs of processes/subprocesses (max. to 3 repetitions in above 50 needs).

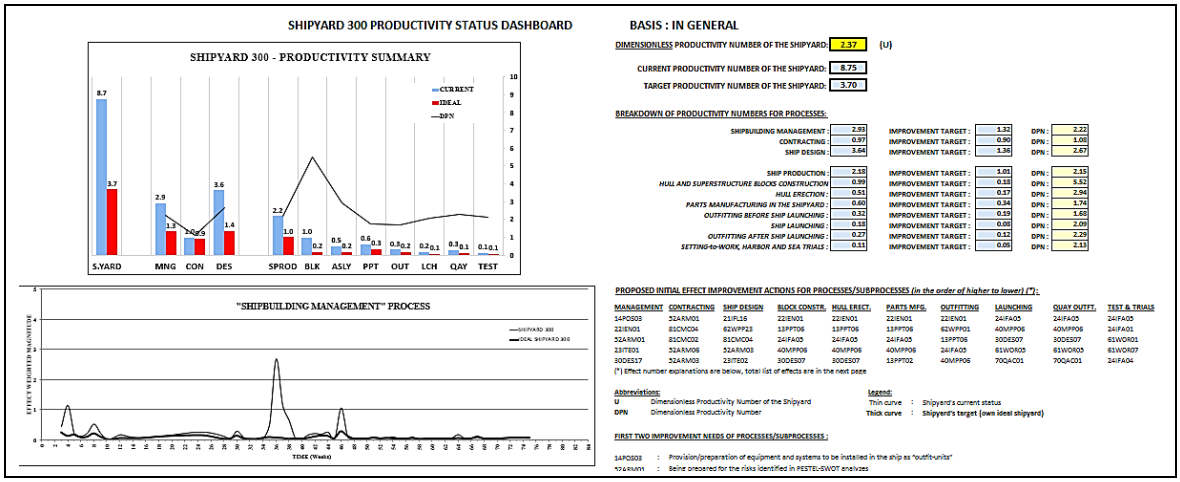


Figure 4.17: Sample screen-view of Shipyard 300 Productivity Status Dashboard, top middle and left parts.

The left part of the Dashboard covers the Productivity Summary graph on top (see Figure 4.17 and 4.19) and then, current-Ideal status graphs of processes/subprocesses in narrowed form, each having their own process/subprocess periods on the time axes.

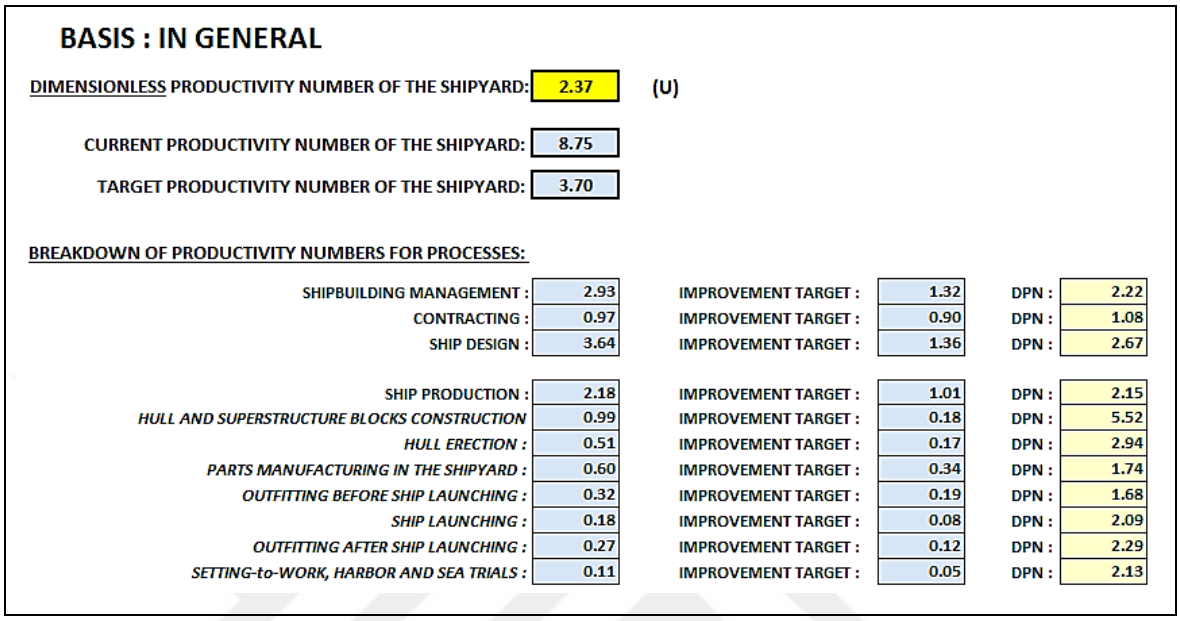
The same graphs are put on the right side of the Dashboard, with all process and subprocess time axes are the total shipbuilding project period, from bid/proposal receipt week (Week 1 in this thesis, see subsection 2.1.2) to the ship delivery week.

Middle-bottom part is reserved for further interactive facilitation after this thesis.

As on the Shipyard 300 Dashboard, the calculated Productivity Numbers, including the Shipyard Dimensionless Productivity Number (**U**) are given in Figure 4.18. The Productivity Numbers are different from Shipyard 200 (Figure 4.3) since Shipyard 300 was a completely separate shipyard during the survey and numerical analyses.

On "In General" basis, which can be changed to Cost or Labor or Time basis for different evaluations based on their weights as given in Figure N.2., the current Productivity Number of the Shipyard was calculated as 8.75.

Target Productivity Number of the Shipyard, which is the "Ideal" version of Shipyard 200, was calculated as 3.70.



BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	2.37	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	8.75				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.70				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	2.93	IMPROVEMENT TARGET :	1.32	DPN :	2.22
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	3.64	IMPROVEMENT TARGET :	1.36	DPN :	2.67
SHIP PRODUCTION :	2.18	IMPROVEMENT TARGET :	1.01	DPN :	2.15
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.99	IMPROVEMENT TARGET :	0.18	DPN :	5.52
HULL ERECTION :	0.51	IMPROVEMENT TARGET :	0.17	DPN :	2.94
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.32	IMPROVEMENT TARGET :	0.19	DPN :	1.68
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.29
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

Figure 4.18: Key numerical output on the dashboard of Shipyard 300.

Their ratio gives the Dimensionless Productivity Number "**U**" of the Shipyard as 2.37 which should be "1" if the Shipyard 300 reaches its Ideal version. To achieve this, some improvements are needed in the processes/subprocesses.

In a rough evaluation of comparing Current and Target Productivity numbers and Dimensionless Productivity Numbers (**U**) of Shipyard 200 and Shipyard 300, one can say that Shipyard 300 is a more productive shipyard than Shipyard 200. But it should be remembered that the methodology in this thesis is not for benchmarking different shipyards and focuses on a shipyard's own status, namely an internal benchmarking with its own Ideal status. The Dimensionless Productivity Numbers (**U**) of Shipyard only shows the level of effort to be spent internally to achieve the maximum productivity by a shipyard itself.

Processes and subprocesses' current Productivity Numbers, Improvement Target Numbers (process/subprocess Ideal Productivity Number) and Dimensionless Productivity Numbers (DPN) are given in Figure 4.18.

The Hull and Superstructure Blocks Construction subprocess has the highest DPN of 5.52, which shows the maximum difference between the current status and Ideal status of the process. All subprocesses of the Ship Production process have a current Productivity Number of less than 1. Tests during the Numerical Analyses showed that, if the current Productivity Number of a process/subprocess is close or less than "1", improvement attention should not be given to such processes, but to the ones with high current Productivity Numbers along with high DPNs. In this respect, the Ship Design process deserves the first improvement checks with its highest current Productivity Number of 3.64 and DPN of 2.67. The Shipbuilding Management process has a high current Productivity Number of 2.93 which puts it into the second position for improvement checks after the Ship Design process. Then improvement tests for Hull and Superstructure Blocks Construction and Contracting subprocesses may be considered.

The Ship Production process is the compilation of its subprocesses, so any changes in those subprocesses will change the Productivity Numbers (current and target) and its DPN, so the Ship Production process can not be manipulated on its own on the Dashboard.

Visual outputs, the current and Ideal status graphs of processes and subprocesses help to gain some insight as shown in Figures 4.19 to 4.23. When the Weighted Magnitude of an Effect is changed, for example for an improvement test, these linked graphs also revise themselves due to the change in the area under the respective process/subprocess curve and the Productivity Number.

In Figure 4.19, the Productivity Summary graph of the dashboard of Shipyard 300 is shown. It shows the current Productivity Numbers, Ideal Productivity Numbers and DPN on the shipyard and process/subprocess basis.

In Figure 4.20, the Shipbuilding Management and Ship Design processes' curves of Shipyard 300 are shown throughout the process periods (Weeks 1-84 for Shipbuilding Management, Weeks 1-80 for Ship Design (see Table 3.15). The thin curves show the current status while the thick black curves show the Ideal Shipyard 300. For Shipbuilding Management, the three peaks above the y=1 line show that some Effects around Week 4

(52ARM01 with WM=1.15, the third in priority order), around Week 36 (14POS03 with WM=2.93, the highest in priority order) and Week 46 (22IEN01 with WM=2.32, the second in the priority order), are to be checked for improvements first.

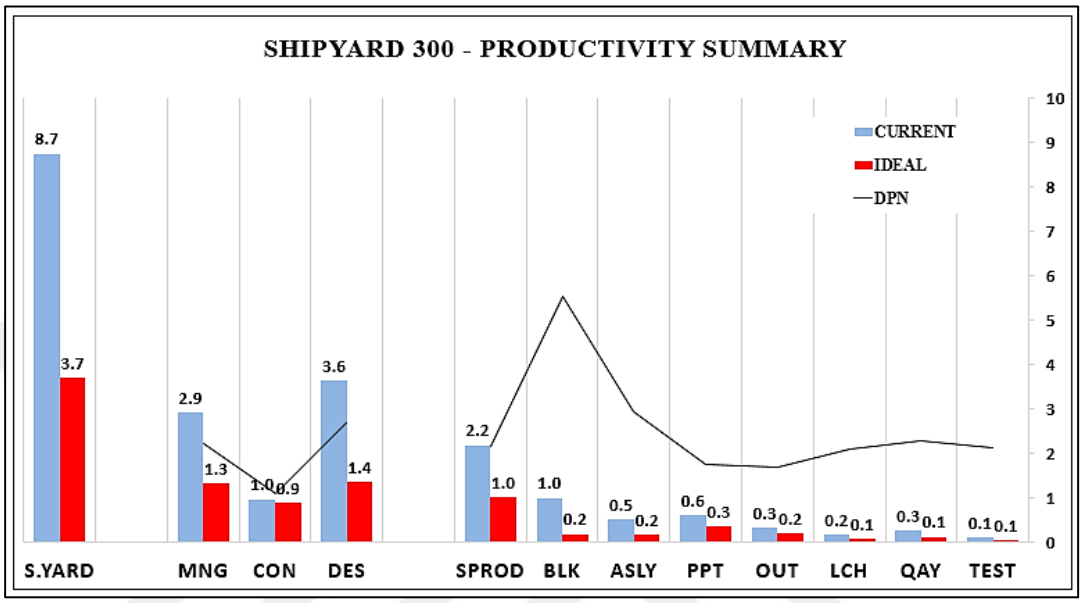


Figure 4.19: Productivity Summary graph of the dashboard of Shipyard 300.

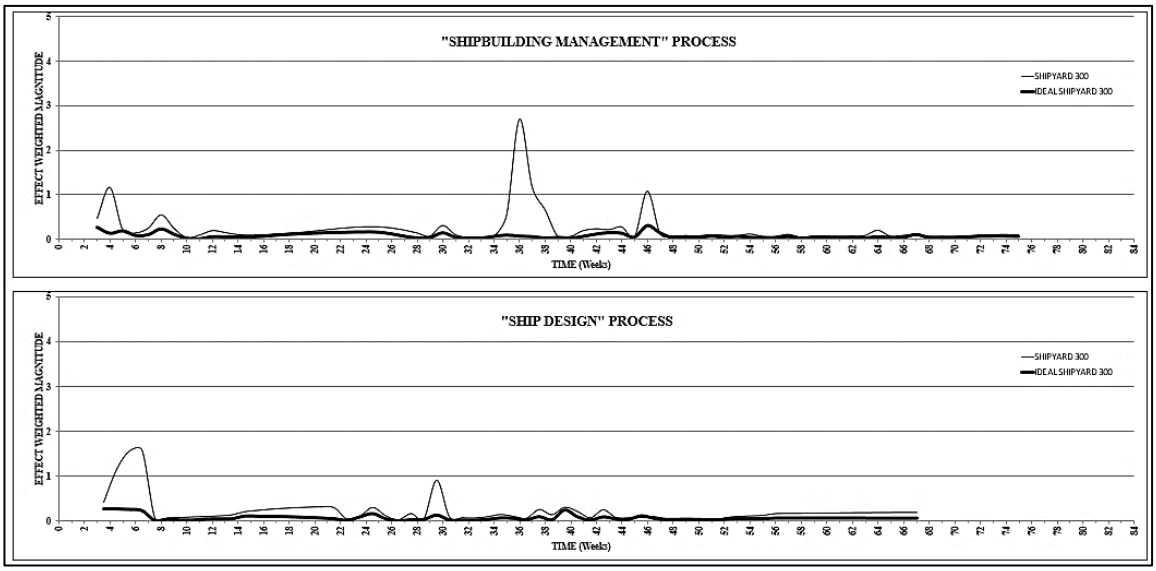


Figure 4.20: Shipyard 300 – Shipbuilding Management and Ship Design processes' graphs.

Again, in Figure 4.20, for the Ship Design one peak is above y=1 and it shows some Effects around Week 7 are to be checked (81CMC04 with WM=1.68, the third in priority order) for improvements first. The Effect number 21IFL16 has the highest Weighted Magnitude (WM) of 2.40 with the timewise position on the 40th week and in the first place for improvement but due to other Effects around it, it may have a lesser need for improvement when interactively tested. As Effect improvements are applied, the thin curve approaches the thick Ideal Shipyard curve.

Due to the "centroid" of timewise distribution application in the methodology, the Effect curves end earlier than the process/subprocess finish weeks. But, those end points are almost through the end of the processes and unless differently emphasized by the survey participants, during Effect Magnitude and timewise distribution type decision during the survey, this does not cause a problem in general.

In Figure 4.21, the graphs of the Contracting, Hull & Superstructure Block Construction, and Hull Erection subprocesses have peaks above the y=1 line. Improvement tests for them may be applied after some improvement tests in the Ship Design and Shipbuilding Management processes.

In Figure 4.22, Outfitting before Ship Launching subprocesses may also wait on hold for improvement since it has a low current Productivity Number of 0.32 and with a relatively low DPN of 1.18. Despite they are below the y=1 line, the peaks of the Parts Manufacturing in the Shipyard, Ship Launching, and Outfitting after Ship Launching subprocesses may be investigated mainly to make internal improvements (which may also have adverse results on other processes/subprocesses) and tested after the prior improvement tests.

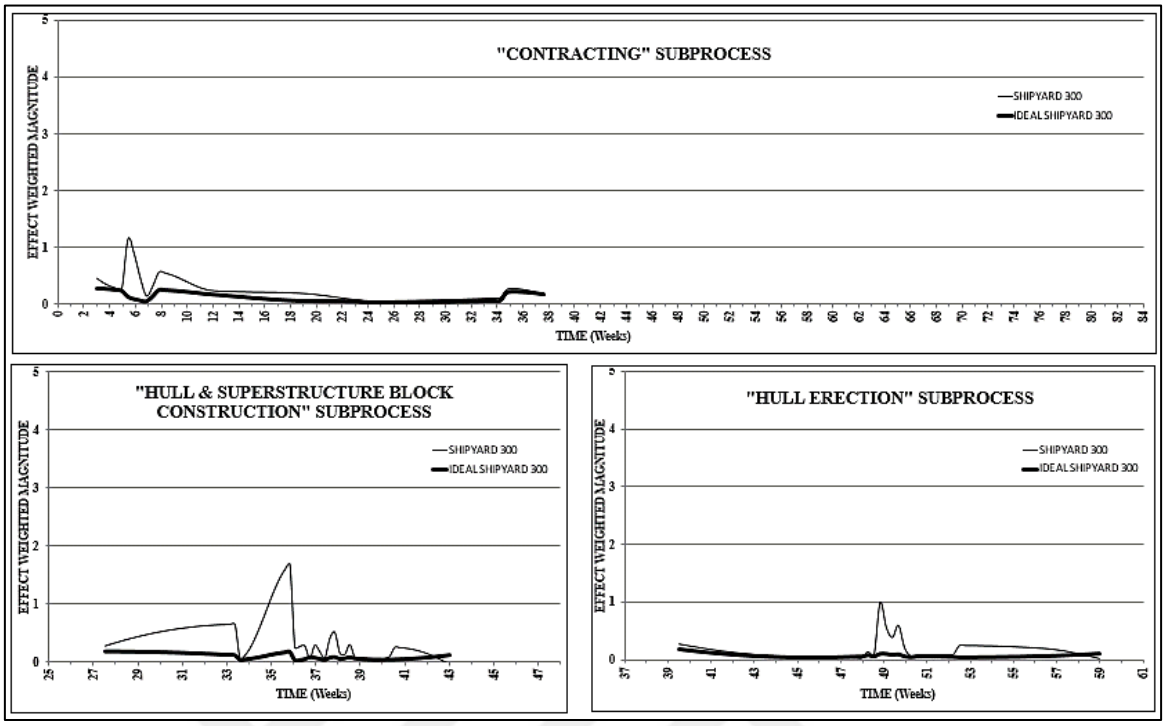


Figure 4.21: Shipyard 300 – Contracting, Hull & Superstructure Block Construction and Hull Erection subprocesses' graphs.

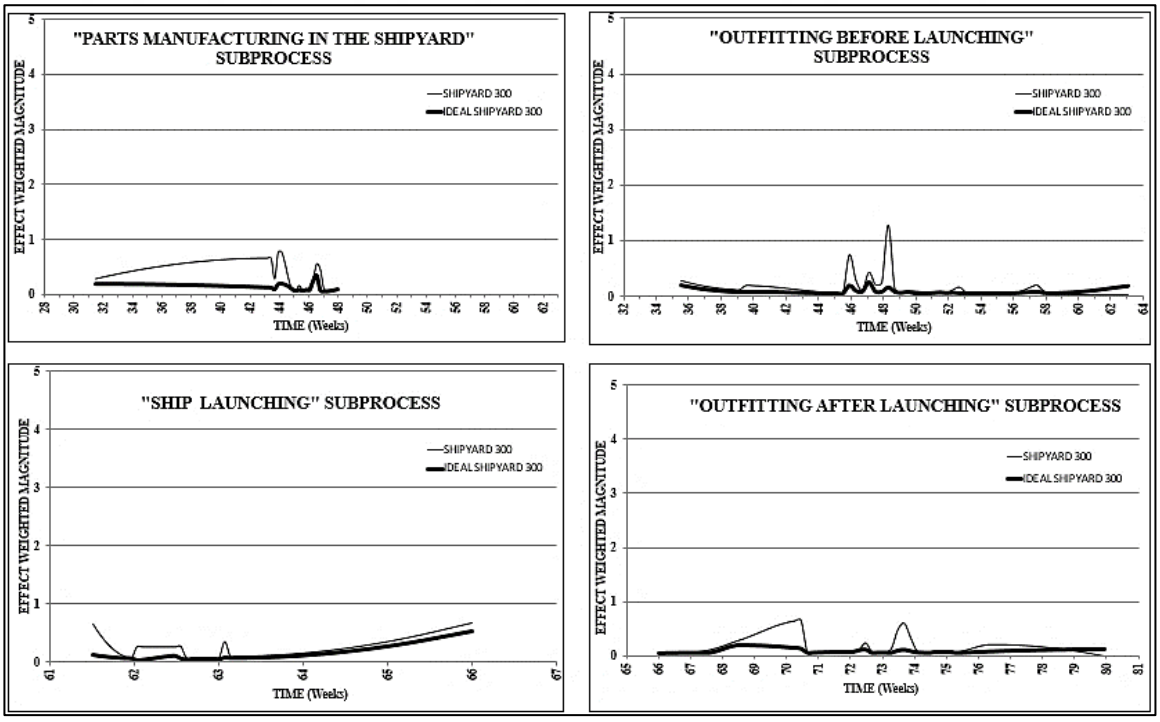


Figure 4.22: Shipyard 300 – Parts Manufacturing in the Shipyard, Outfitting before Launching, Ship Launching, and Outfitting after Ship Launching subprocesses' graphs.

In Figure 4.23, the graph of the Setting-to-Work, Harbor and Sea Trials subprocess is presented. Since the curves are well below y=1, any improvement actions for this subprocess may not be considered at an initial evaluation stage.

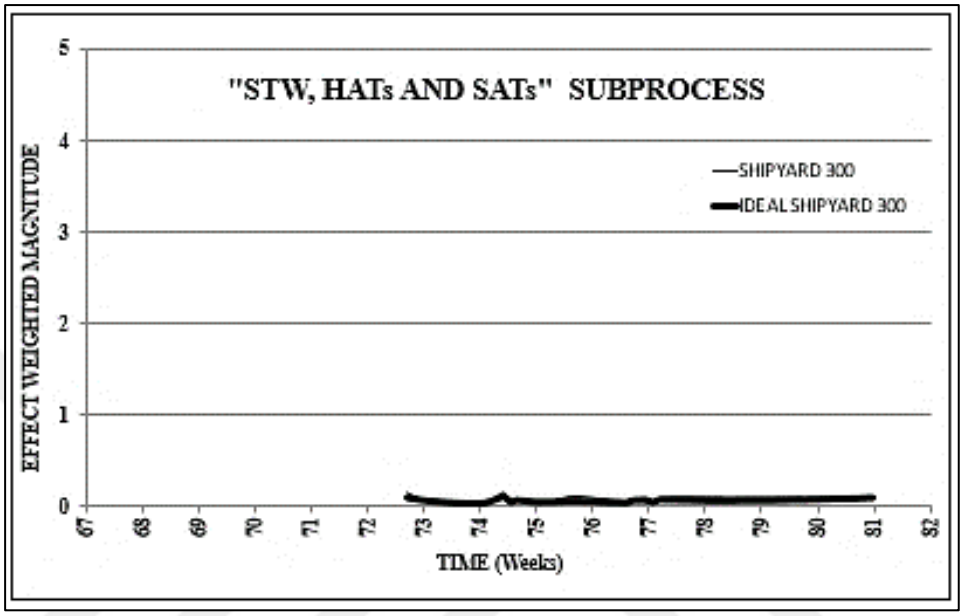


Figure 4.23: Shipyard 300 – Setting-to-Work, Harbor and Sea Trials subprocess graph.

As previously stated, the second research aim was to obtain improvement area priority lists of the processes and, test the effects of the improvements on productivity leading to a continuous improvement cycle. In this respect, along with the Productivity Number calculations, priority lists for needed improvements on the Effects of the process/subprocesses were obtained by the order of the Weighted Magnitudes of the Effects.

For Shipyard 300, the initial five Effects to be tested for improvement in process/subprocess and for the entire shipbuilding process (i.e., to reduce the dimensionless Productivity Number **U** of the Shipyard 300) are listed in the priority order Figure 4.24 and 23 of them are named in the Effect number order in Table 4.3.

MANAGEMENT	CONTRACTING	SHIP DESIGN	BLOCK CONSTR.	HULL ERECT.
14POS03	52ARM01	21IFL16	22IEN01	22IEN01
22IEN01	81CMC04	62WPP23	13PPT06	13PPT06
52ARM01	81CMC02	81CMC04	24IFA05	24IFA05
23ITE01	52ARM06	52ARM03	40MPP06	40MPP06
30DES17	52ARM03	23ITE02	30DES07	30DES07

PARTS MFG.	OUTFITTING	LAUNCHING	QUAY OUTFT.	TEST & TRIALS
22IEN01	22IEN01	24IFA05	24IFA05	24IFA05
13PPT06	62WPP01	40MPP06	40MPP06	24IFA01
24IFA05	13PPT06	30DES07	30DES07	61WOR01
40MPP06	24IFA05	61WOR05	61WOR05	61WOR07
13PPT02	40MPP06	70QAC01	70QAC01	24IFA04

Figure 4.24: Shipyard 300 – Proposed initial five Effects for improvement testing for processes/subprocesses (in the order of higher to lower priority).

Table 4.3: Subjects of the first 23 Effects in Figure 4.24 (in Effect nr. Order).

Effect nr.	Effect
13PPT02	Automation in pipe manufacturing; pipe installation in hull blocks, in the ship
13PPT06	Automation in manufacturing and outfitting, use of robots
14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"
21IFL16	Regular cleaning of work areas
22IEN01	Energy saving and protection of natural resources in the shipyard; use of clean (green) energy
23ITE02	Existence of information integration for shipyard automation systems
24IFA01	The proximity of Dressing-Lockers Areas, Showers-Toilets to the work area; their capacity, ventilation, illumination, cleanliness
24IFA04	The distance between the work area and the car parking lot; adverse weather protection on the walking line; electric vehicle charging facility
24IFA05	Presence of a nursery (preschool, kindergarten) in the shipyard
30DES07	Compliance of design document deliveries with the ship production schedule
30DES17	Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers
40MPP06	Accurate and timely material supply throughout the Project, especially if the Hull Block outfitting is applied
52ARM01	Being prepared for the risks identified in PESTEL-SWOT analyzes
52ARM03	Regular and comprehensive Risk Management in projects
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions
61WOR01	Status of employees (Shipyard own personnel, temporary yard personnel, subcontractor's personnel)
61WOR05	Availability of Quick Workgroups for recurring tasks
61WOR07	Backup of critical personnel
62WPP01	Use of Construction/Outfitting Subcontractors in Shipbuilding Project (If subcontractor(s) is/are used)

Table 4.3: Subjects of the first 23 Effects in Figure 4.24 (in Effect nr. Order).

Effect nr.	Effect
62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support
70QAC01	Effectiveness of the Quality Assurance System
81CMC02	Bid/Proposal preparation team and its work standardization
81CMC04	Participation of relevant departments in Shipbuilding Contract negotiations

As it happened for Shipyard 200 above, the 50 Effects shown in Figure 4.24 have the highest Effect Weighted Magnitudes in their respective process/subprocess. Again, in simple thinking, when the Magnitudes of these Effects are changed to "1" from the current Magnitudes, a substantial improvement can be obtained in the Shipyard. But this is not the case. Due to the repeating Effects (see subsection 3.1.1 and Appendix B) and the use of process/subprocess weights calculations which cause chain reactions in the calculation of Productivity Numbers. Accordingly, it doesn't mean that the improvements of the first five Effects provide a substantial improvement in the Shipyard. Each first two Effects are better tested, starting with the process having the highest current Productivity Number, the Ship Design process of Shipyard 300, followed by the Shipbuilding Management process, Hull and Superstructure Blocks Construction subprocess, and Contracting subprocess as listed in Table 4.4.

Table 4.4: Proposed 6 Effects to be investigated, tested for improvement in Shipyard 300 (in priority order).

Process/ subprocess	Effect Nr.	Effect
DES	21IFL16	Regular cleaning of work areas
DES	62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support
MNG	14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"
MNG, BLK	22IEN01	Energy saving and protection of natural resources in the shipyard; use of clean (green) energy
BLK	13PPT06	Automation in manufacturing and outfitting, use of robots
CON	52ARM01	Being prepared for the risks identified in PESTEL-SWOT analyzes

When the six Effects listed in Table 4.4 are tested for improvement, i.e., their Magnitudes were changed to "1" in all processes/subprocesses they exist, the Productivity Numbers were changed to new values as shown in Figure 4.25.

As shown in Figure 4.25, the Dimensionless Productivity Number "**U**" of Shipyard 300 changed to 2.11 from the initial 2.37 as a result of the change in the shipyard's current Productivity Number from 8.75 to 7.80. The six improvements showed changes in the Productivity Numbers and accordingly DPNs of the Shipbuilding Management, Hull and Superstructure Blocks Construction, Hull Erection, and Outfitting before Ship Launching subprocesses in a chain reaction. Despite two of the improvements being initiated from the Ship Design process (Table 4.4, Effects 21 IFL 16 and 62WPP23) and Contracting subprocess (Table 4.4, Effect 52ARM01), their productivity numbers were not changed. This shows more Effects need to be improved in the Ship Design process for further tests on improvement actions. This is also checked from the Ship Design graph of the Dashboard as shown in Figure 4.26.

The Ship Design process curve shows that improvements on the Effects around Week 7 are still more necessary to be tested. Therefore, the third Effect in a row for the Ship Design process (Figure 4.20, 81CMC04) was added to the improvement test (The first two improvement actions of the Ship Design process (Table 4.4, Effects 21 IFL 16 and 62WPP23), can be kept in the test since they are beneficial to whole shipbuilding process with less cost). After this new improvement test for the Effect 81CMC04 was applied, the following results were received as in Figure 4.27.

As shown in Figure 4.27, the Dimensionless Productivity Number "**U**" of Shipyard 300 changed to 1.89 from the initial 2.37 as a result of the change in the shipyard's current Productivity Number from 8.75 to 6.98. This was a better improvement than the result of the previous six improvements. The seven improvements showed changes in the Productivity Numbers and accordingly DPNs of the Shipbuilding Management, Ship Design, Hull and

Superstructure Blocks Construction, Hull Erection, and Outfitting before Ship Launching subprocesses in a chain reaction. Despite one of the first six improvements was initiated from the Contracting subprocess (Table 4.4, Effect 52ARM01), its productivity number was not changed. This shows more Effects need to be improved in the Contracting subprocess for further tests on improvement actions. It was also noticed that Shipyard 300 was close to aligning with its Ideal version, to become a very productive shipyard.

INITIAL PRODUCTIVITY NUMBERS (see Figure 4.18.)**:**

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	2.37	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	8.75	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.70	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	2.93	IMPROVEMENT TARGET :	1.32	DPN :	2.22
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	3.64	IMPROVEMENT TARGET :	1.36	DPN :	2.67
SHIP PRODUCTION :	2.18	IMPROVEMENT TARGET :	1.01	DPN :	2.15
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.99	IMPROVEMENT TARGET :	0.18	DPN :	5.52
HULL ERECTION :	0.51	IMPROVEMENT TARGET :	0.17	DPN :	2.94
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.32	IMPROVEMENT TARGET :	0.19	DPN :	1.68
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.29
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

INTERACTIVELY CHANGED PRODUCTIVITY NUMBERS AFTER SIX IMPROVEMENTS WERE TESTED (see Table 4.4.):

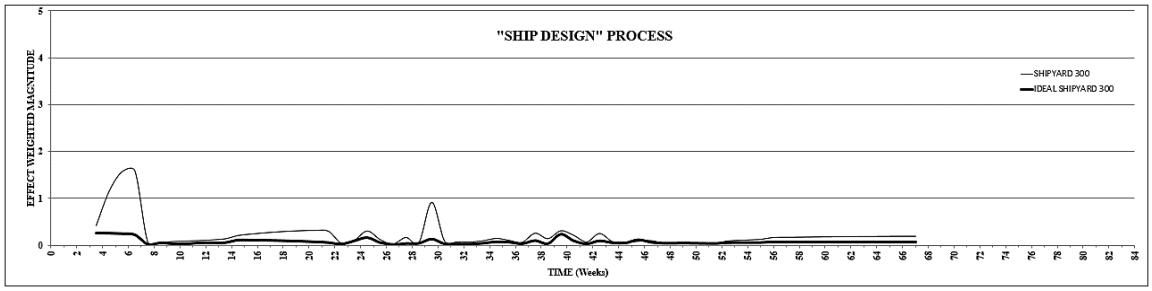
DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	2.11	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	7.80	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.70	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	2.13	IMPROVEMENT TARGET :	1.32	DPN :	1.62
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	3.64	IMPROVEMENT TARGET :	1.36	DPN :	2.67
SHIP PRODUCTION :	2.03	IMPROVEMENT TARGET :	1.01	DPN :	2.00
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.79	IMPROVEMENT TARGET :	0.18	DPN :	4.41
HULL ERECTION :	0.48	IMPROVEMENT TARGET :	0.17	DPN :	2.75
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.19	DPN :	1.43
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.28
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

Figure 4.25: Key numerical output on the dashboard of Shipyard 300, before and after six improvements were applied.

INITIAL GRAPH (see Figure 4.20):



INTERACTIVELY CHANGED GRAPH AFTER SIX IMPROVEMENTS WERE APPLIED (actually no changes are visible!):

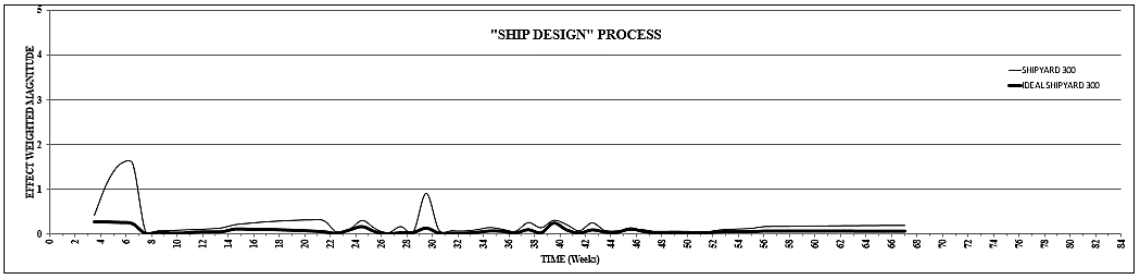


Figure 4.26: Shipyard 300 Productivity Status Dashboard graphs of Ship Design process before and after six improvements were applied.

INITIAL PRODUCTIVITY NUMBERS (see Figure 4.18.)**:**

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	2.37	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	8.75	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.70	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	2.93	IMPROVEMENT TARGET :	1.32	DPN :	2.22
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	3.64	IMPROVEMENT TARGET :	1.36	DPN :	2.67
SHIP PRODUCTION :	2.18	IMPROVEMENT TARGET :	1.01	DPN :	2.15
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.99	IMPROVEMENT TARGET :	0.18	DPN :	5.52
HULL ERECTION :	0.51	IMPROVEMENT TARGET :	0.17	DPN :	2.94
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.32	IMPROVEMENT TARGET :	0.19	DPN :	1.68
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.29
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

INTERACTIVELY CHANGED PRODUCTIVITY NUMBERS AFTER SEVEN IMPROVEMENTS WERE TESTED (see Table 4.4.):

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	1.89	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	6.98	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.70	

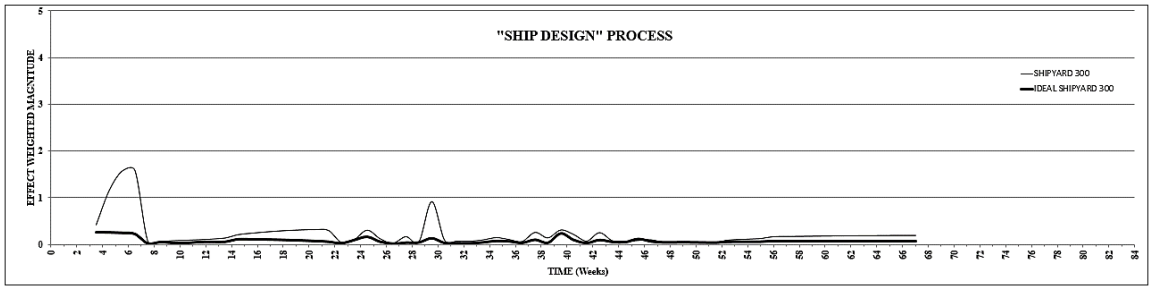
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	2.03	IMPROVEMENT TARGET :	1.32	DPN :	1.54
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	2.93	IMPROVEMENT TARGET :	1.36	DPN :	2.15
SHIP PRODUCTION :	2.03	IMPROVEMENT TARGET :	1.01	DPN :	2.00
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.79	IMPROVEMENT TARGET :	0.18	DPN :	4.41
HULL ERECTION :	0.48	IMPROVEMENT TARGET :	0.17	DPN :	2.75
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.19	DPN :	1.43
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.28
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

Figure 4.27: Key numerical output on the dashboard of Shipyard 300, before and after seven improvements were applied.

In Figures 4.28 to 4.31, the changes in the graphs of some processes/subprocesses again were given as a sample of the visual output benefit of this methodology.

INITIAL GRAPH (see Figure 4.20):



INTERACTIVELY CHANGED GRAPH AFTER SEVEN IMPROVEMENTS WERE APPLIED:

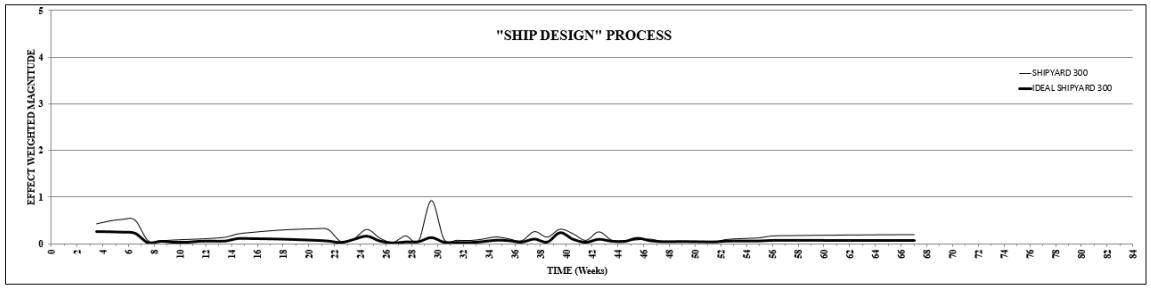


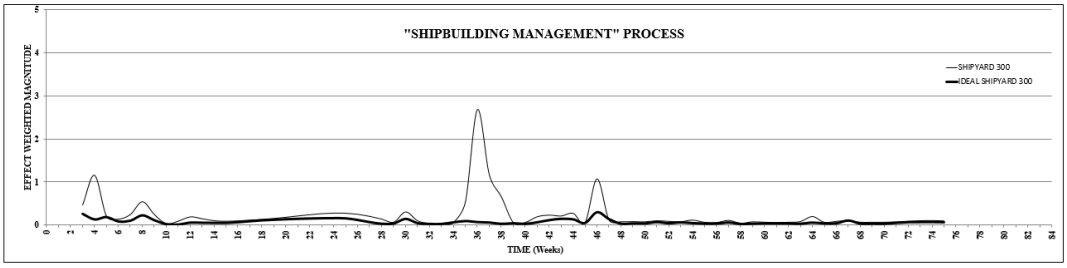
Figure 4.28: Shipyard 300 Productivity Status Dashboard graphs of Ship Design process before and after seven improvements were applied.

For the Ship Design process, the major peak at Week 7 was reduced after its third Effect improvement was applied. The curve shows that more improvements may be tested to reduce the peak at Week 29.

For the Shipbuilding Management process, changes in four peaks on the shipyard curve are obvious after the seven improvements were applied. The curve shows that more improvements may be tested to reduce peaks at Weeks 36 to 39.

For the Hull and Superstructure Blocks Construction subprocess, the change in one peak on the shipyard curve is obvious after the seven improvements were applied. The curve shows that more improvements may be tested to reduce other peaks.

INITIAL GRAPH (see Figure 4.20):



INTERACTIVELY CHANGED GRAPH AFTER SEVEN IMPROVEMENTS WERE APPLIED:

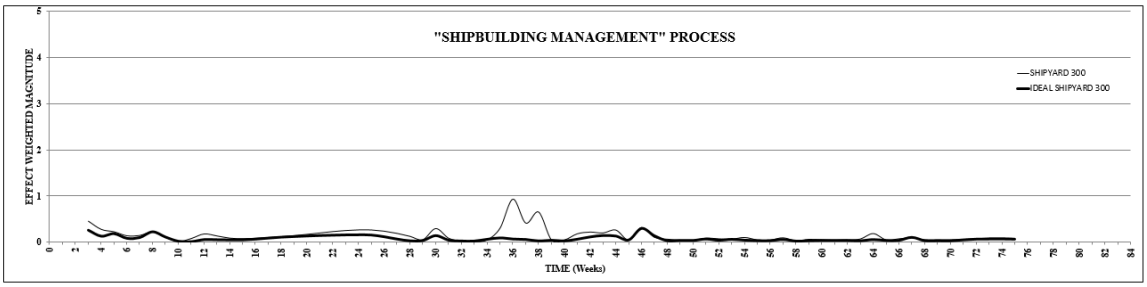
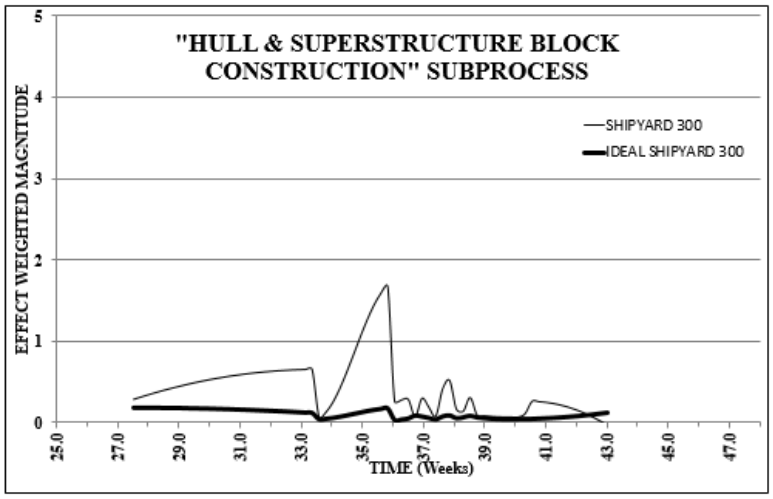


Figure 4.29: Shipyard 300 Productivity Status Dashboard graphs of Shipbuilding Management process before and after seven improvements were applied.

INITIAL GRAPH (see Figure 4.21):



INTERACTIVELY CHANGED GRAPH AFTER SEVEN IMPROVEMENTS WERE APPLIED:

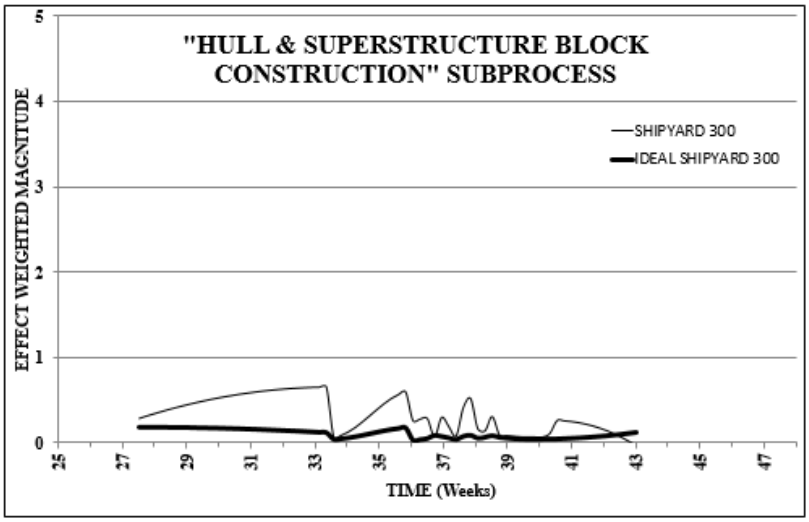
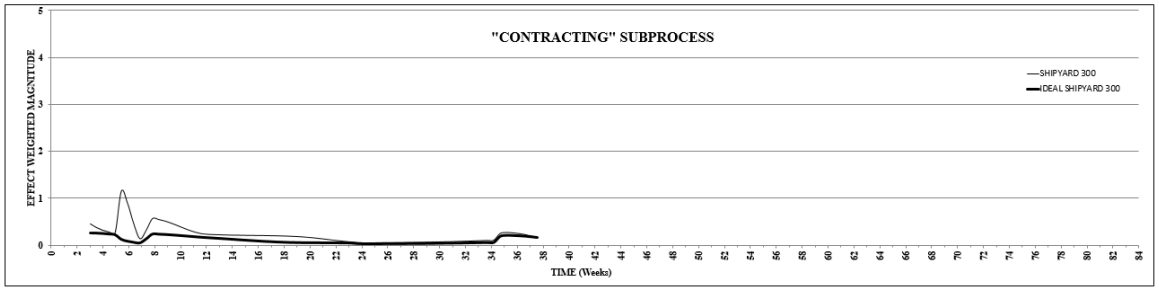


Figure 4.30: Shipyard 300 Productivity Status Dashboard graphs of Hull and Superstructure Blocks Construction subprocess before and after seven improvements were applied.

INITIAL GRAPH (see Figure 4.21):



INTERACTIVELY CHANGED GRAPH AFTER SEVEN IMPROVEMENTS WERE APPLIED:

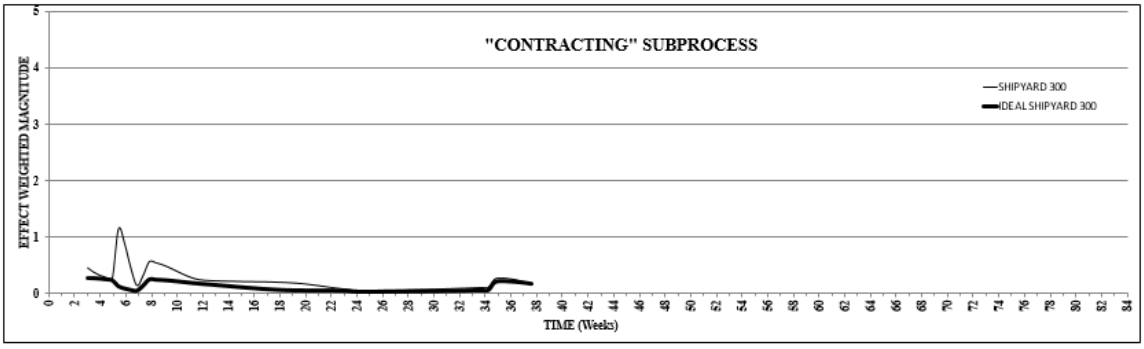


Figure 4.31: Shipyard 300 Productivity Status Dashboard graphs of Contracting subprocess before and after seven improvements were applied.

For the Contracting subprocess, no changes were observed on the shipyard curve after the seven improvements were applied. The curve shows that more improvements may be tested to reduce peaks at Weeks 6 and 8.

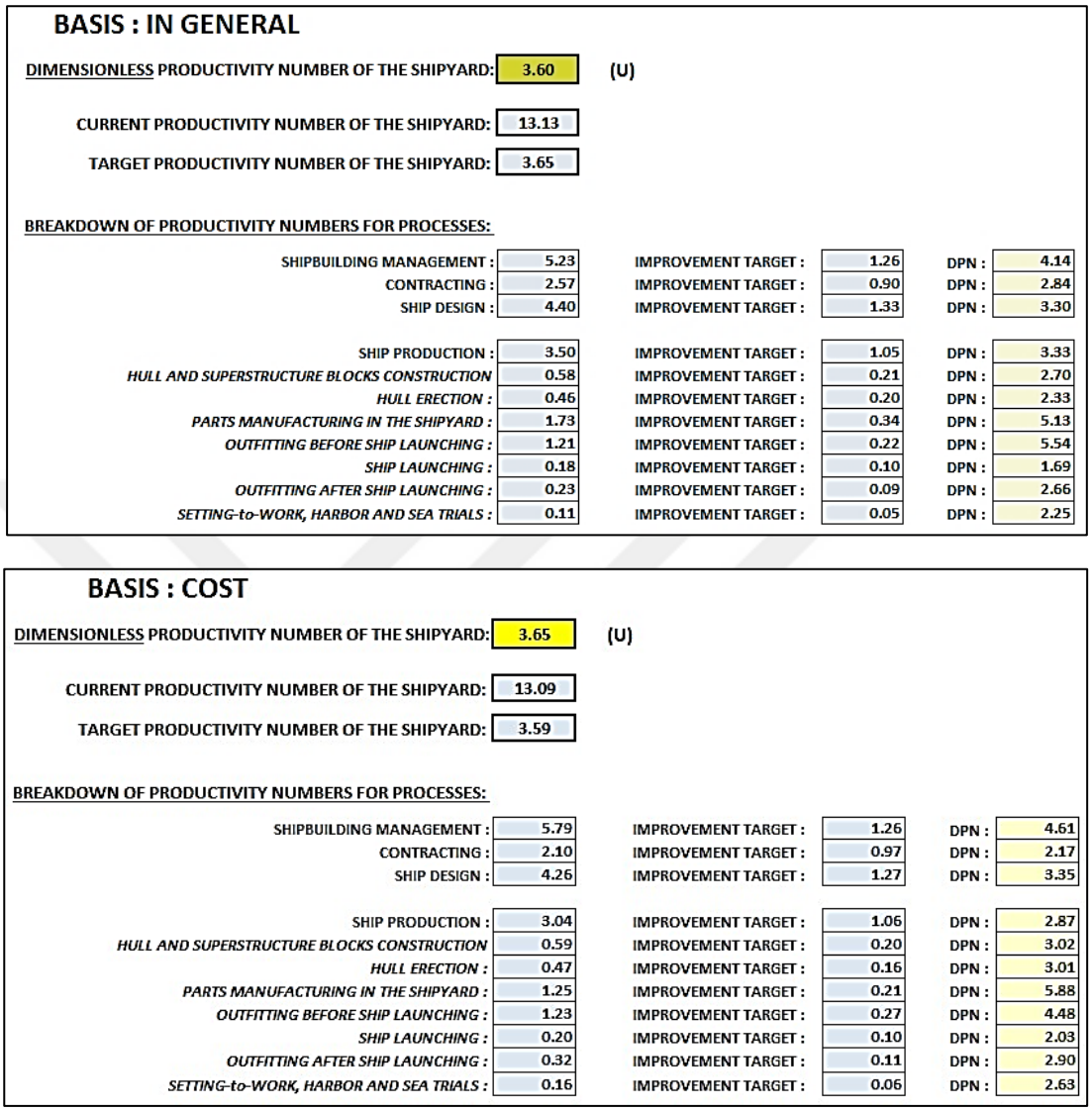
As a result, the Productivity Number table and visual graphs on the Shipyard 300 Dashboard show that the aimed methodology works successfully for another shipyard and the analogy to propeller shafting alignment was still found appropriate.

4.1.3. Productivity Status Evaluations from Cost and Labor Basis

In addition to the productivity status evaluation on "in general" basis, the methodology also covered the "cost", "labor" and "time" basis evaluation choices on the Dashboard depending on the emphasis preference of a shipyard's management,

The Productivity Number calculations were explained in subsection 3.1.4. and weight information from the calculations on Management:Basis Information section of the Questionnaires are presented in Tables N.1. and N.2. As it was mentioned in subsection 3.1.4., the Management:Basis Information section of the Questionnaire had pairwise comparison questions and resulting weights differ in final productivity calculations for the Shipyard and Ideal Shipyard on process and subprocess basis. These different weights were gathered in Figure N.1. and N.2. for the hypothetical Shipyards 200 and 300 respectively. The hypothetical Shipyard 200 Key numerical output and Productivity Graphs on the Dashboard for the four different weight basis are presented in Figures 4.32 to 4.35, followed by an evaluation of the results.

As seen in Figures 4.32 to 4.35, and as tabulated in Table 4.5, depending on the calculated process/subprocess weights from the Shipyard 200 survey, the Dimensionless Productivity Number of the Shipyard ("U") is the highest on Time basis (U=3.75) compared to the Labor basis (U=3.47), while in General the **U** of the Shipyard 200 is 3.60 and almost at the middle of both. This shows that, Shipyard 200 status can be continued to be evaluated on the General basis. However, to have an insight on the decision on improvements if the cost, labor or time has a special emphasis for the shipyard management, then the Effects related to Time basis should have priority since the Dimensionless Productivity Number of the Shipyard is the highest of all, the Current Productivity Number of the shipyard is second (13.11) to the highest (13.13) while the Ideal Shipyard 200 has the lowest Productivity Number (i.e., the Target) with regard to sectoral weights. Then the Effects related to Labor basis should be investigated since the Ideal Shipyard 200 has the highest Productivity Number (i.e., the highest above y=1) with regard to sectoral weights.



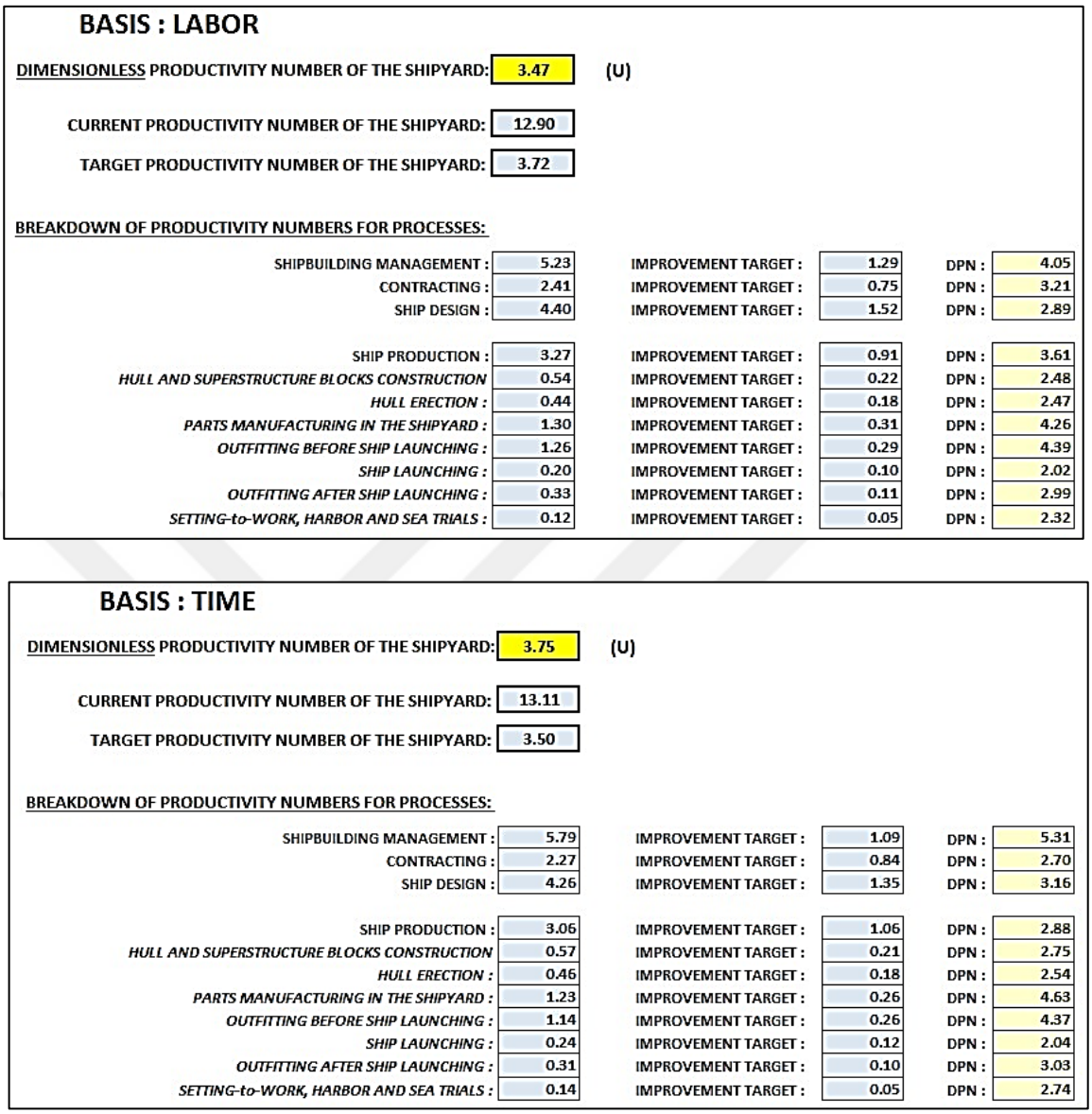
BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.60	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.13				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

BASIS : COST

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.09				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.59				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.79	IMPROVEMENT TARGET :	1.26	DPN :	4.61
CONTRACTING :	2.10	IMPROVEMENT TARGET :	0.97	DPN :	2.17
SHIP DESIGN :	4.26	IMPROVEMENT TARGET :	1.27	DPN :	3.35
SHIP PRODUCTION :	3.04	IMPROVEMENT TARGET :	1.06	DPN :	2.87
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.59	IMPROVEMENT TARGET :	0.20	DPN :	3.02
HULL ERECTION :	0.47	IMPROVEMENT TARGET :	0.16	DPN :	3.01
PARTS MANUFACTURING IN THE SHIPYARD :	1.25	IMPROVEMENT TARGET :	0.21	DPN :	5.88
OUTFITTING BEFORE SHIP LAUNCHING :	1.23	IMPROVEMENT TARGET :	0.27	DPN :	4.48
SHIP LAUNCHING :	0.20	IMPROVEMENT TARGET :	0.10	DPN :	2.03
OUTFITTING AFTER SHIP LAUNCHING :	0.32	IMPROVEMENT TARGET :	0.11	DPN :	2.90
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.16	IMPROVEMENT TARGET :	0.06	DPN :	2.63

Figure 4.32: Key numerical outputs on the dashboard of Shipyard 200 In General (see Figure 4.3) and on Cost basis.



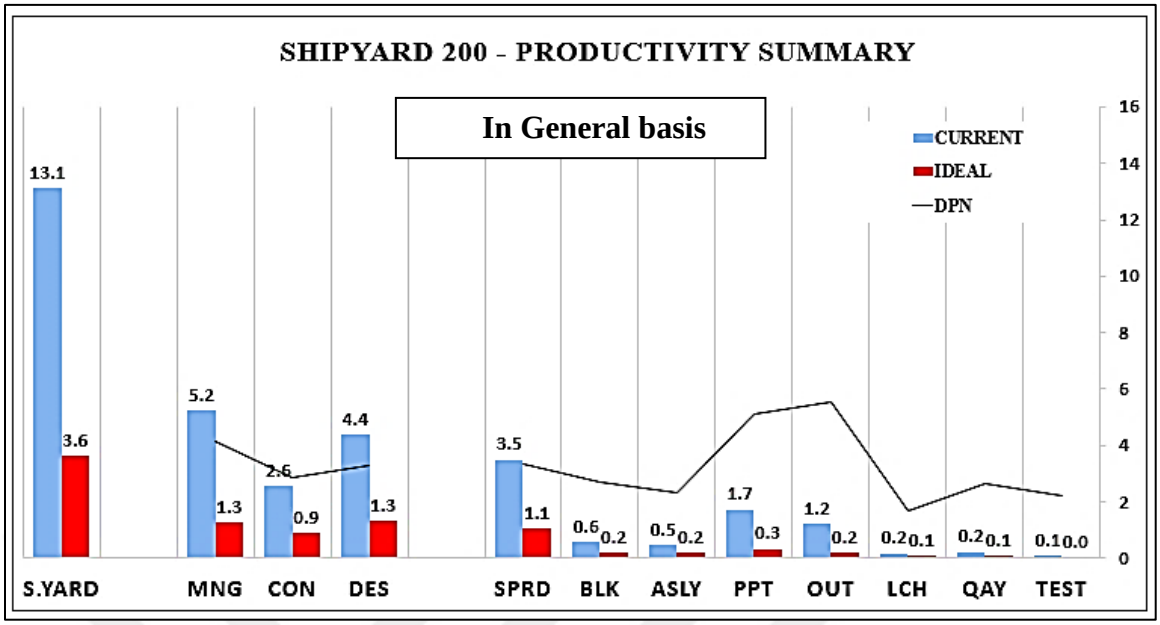
BASIS : LABOR

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.47	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	12.90				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.72				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.29	DPN :	4.05
CONTRACTING :	2.41	IMPROVEMENT TARGET :	0.75	DPN :	3.21
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.52	DPN :	2.89
SHIP PRODUCTION :	3.27	IMPROVEMENT TARGET :	0.91	DPN :	3.61
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.54	IMPROVEMENT TARGET :	0.22	DPN :	2.48
HULL ERECTION :	0.44	IMPROVEMENT TARGET :	0.18	DPN :	2.47
PARTS MANUFACTURING IN THE SHIPYARD :	1.30	IMPROVEMENT TARGET :	0.31	DPN :	4.26
OUTFITTING BEFORE SHIP LAUNCHING :	1.26	IMPROVEMENT TARGET :	0.29	DPN :	4.39
SHIP LAUNCHING :	0.20	IMPROVEMENT TARGET :	0.10	DPN :	2.02
OUTFITTING AFTER SHIP LAUNCHING :	0.33	IMPROVEMENT TARGET :	0.11	DPN :	2.99
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.12	IMPROVEMENT TARGET :	0.05	DPN :	2.32

BASIS : TIME

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.75	(U)			
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.11				
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.50				
BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:					
SHIPBUILDING MANAGEMENT :	5.79	IMPROVEMENT TARGET :	1.09	DPN :	5.31
CONTRACTING :	2.27	IMPROVEMENT TARGET :	0.84	DPN :	2.70
SHIP DESIGN :	4.26	IMPROVEMENT TARGET :	1.35	DPN :	3.16
SHIP PRODUCTION :	3.06	IMPROVEMENT TARGET :	1.06	DPN :	2.88
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.57	IMPROVEMENT TARGET :	0.21	DPN :	2.75
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.18	DPN :	2.54
PARTS MANUFACTURING IN THE SHIPYARD :	1.23	IMPROVEMENT TARGET :	0.26	DPN :	4.63
OUTFITTING BEFORE SHIP LAUNCHING :	1.14	IMPROVEMENT TARGET :	0.26	DPN :	4.37
SHIP LAUNCHING :	0.24	IMPROVEMENT TARGET :	0.12	DPN :	2.04
OUTFITTING AFTER SHIP LAUNCHING :	0.31	IMPROVEMENT TARGET :	0.10	DPN :	3.03
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.14	IMPROVEMENT TARGET :	0.05	DPN :	2.74

Figure 4.33: Key numerical outputs on the dashboard of Shipyard 200 on Labor and on Time basis.



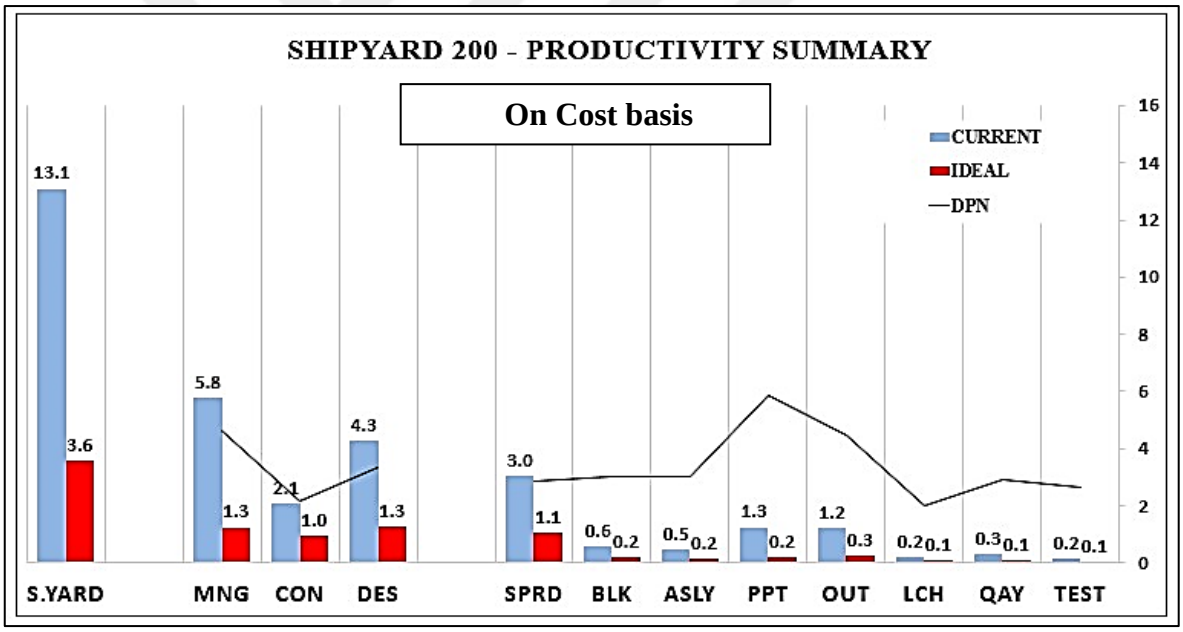


Figure 4.34: Productivity Summary graph of the dashboard of Shipyard 200 In General (see Figure 4.4) and on Cost basis.

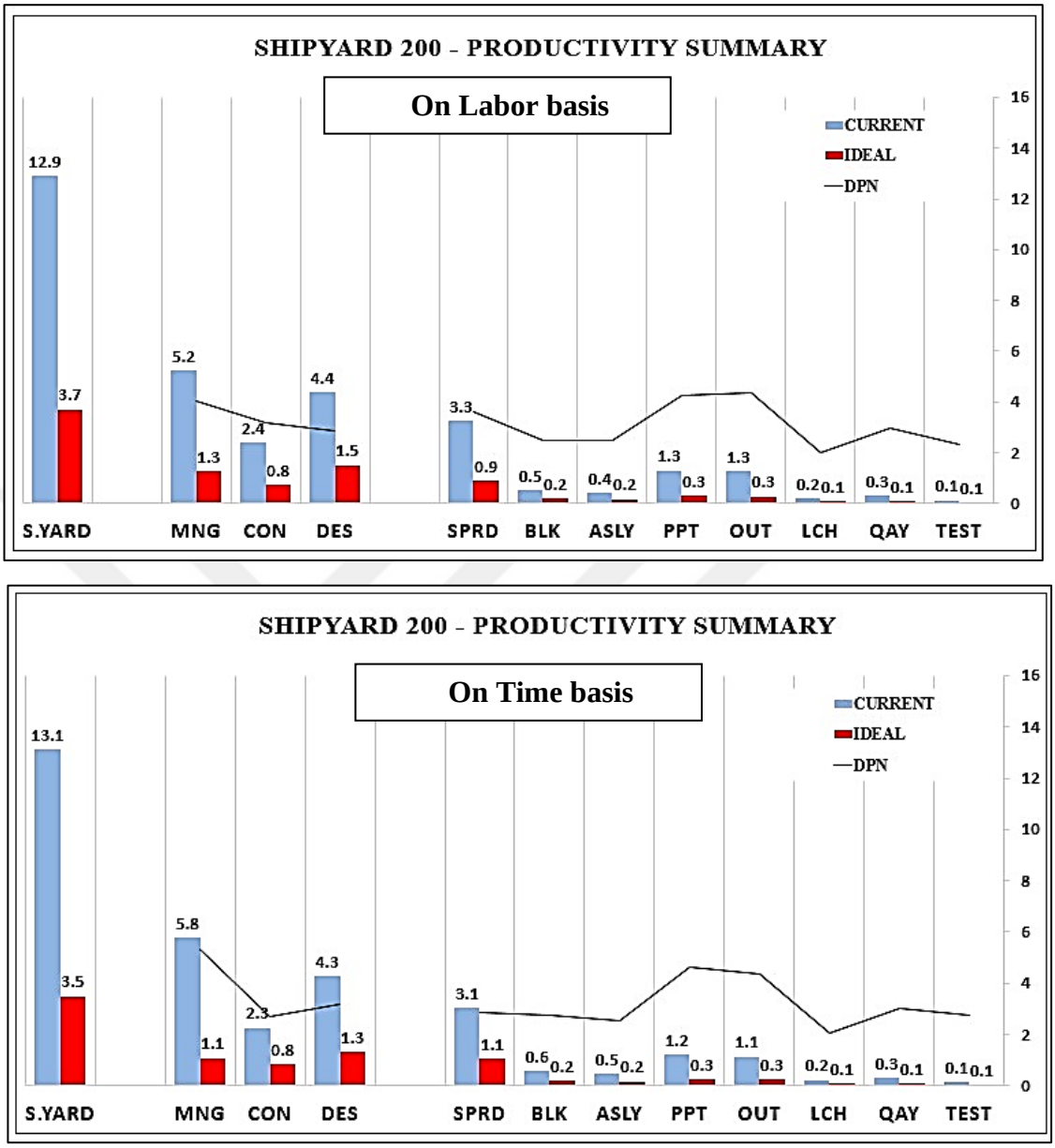


Figure 4.35: Productivity Summary graph of the dashboard of Shipyard 200 on Labor and on Time basis.

As given in Table 4.5, the calculations based on the responses from Shipyard 200 survey showed that, for the respondents, for the Shipbuilding Management process (sampled process in here), the cost (w=0.238) and time (w=0.238) issues are more important than the general (w=0.215) and labor (w=0.215) aspects. The productivity numbers of the Shipbuilding Management process also guides for prioritization in Effects related to Time aspects.

Table 4.5: Shipyard 200 and its Shipbuilding Management process Key Numbers at four different basis.

BASIS =>	GENERAL	COST	LABOR	TIME
Dimensionless Productivity Number of the Shipyard ("U")	3.60	3.65	3.47 (lowest)	3.75 (highest)
Current Productivity Number of the Shipyard	13.13 (highest)	13.09	12.90 (lowest)	13.11
Target Productivity Number of the Shipyard	3.65	3.59	3.72 (highest)	3.50 (lowest)
MNG Process Shipyard Weights (w**) from Survey results out of 1.000 (see Figure N.1)**	0.215	0.238	0.215	0.238
Dimensionless Productivity Number of the MNG Process (DPN)	4.14	4.61	4.05 (lowest)	5.31 (highest)
Current Productivity Number of the MNG Process	5.23 (low)	5.79 (high)	5.23 (low)	5.79 (high)
Target Productivity Number of the MNG Process	1.26	1.26	1.29 (highest)	1.09 (lowest)

This "basis" dimension of the developed methodology in this thesis adds an advantage for further detailed investigations on the Effects to be prioritized in improvements.

4.2. Further Results and Discussions

After the positive results were obtained for the main objective of the research, developing a new methodology with dimensionless metrics to evaluate the shipyard productivity and prioritize the improvement needs that are compatible with the entire shipbuilding process, there remain a few more results to be presented and discussed. These are additional findings of the research, reliability and validity of the research and comparison to earlier work.

4.2.1. Additional Findings and Discussions

Intuitive information may result in incorrect improvement decisions by the management. By the use of the methodology developed in this thesis, priorities of improvement needs for a shipyard can be defined much more effectively. In this study, the use of weights for Effects proved its superiority in decision-making. As an example; the calculations during this study resulted in a priority list of six improvement actions for Shipyard 200 as given in Tables 4.2.

and 4.6. The priorities of the respondents' given in Table 4.6. were before weight assignment to the Effect Magnitudes and may be a reference for incorrect managerial decisions.

Table 4.6: Comparison of improvement priorities for Shipyard 200.

Process/ subprocess	Effect Nr.	Effect	Priority rank in this study	Priority from respondents
MNG	14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"	1st of MNG	38th of MNG
MNG	22IEN02	Hazardous waste management	2nd of MNG	22nd of MNG
DES	21IFL16	Regular cleaning of work areas	1st of DES	25th of DES
DES	62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support	2nd of DES	49th of DES
CON	81CMC02	Bid/Proposal preparation team and its work standardization	1st of CON	17th of CON
CON	81CMC03	Shipbuilding Contract preparations; Availability of Contracting Group at the Shipyard	2nd of CON	18th of CON

In Table 4.7, improvement priorities based on non-weighted Effect Magnitudes as received and averaged (geometric average) from the respondents of Shipyard 200 are presented. Please note that 63WPM05 repeats, so five Effects will be tested.

Table 4.7: Improvement priorities based on non-weighted Effect Magnitudes, for Shipyard 200.

Process/ subprocess	Effect Nr.	Effect	Priority rank in this study	Priority from respondents
MNG	51APL05	Project scheduling simulations	63rd of MNG	1st of MNG
MNG	63WPM05	Employee circulation	22nd of MNG	2nd of MNG
DES	24IFA05	Nursery (preschool)	16th of DES	1st of DES
DES	51APL04	Scheduling techniques	55th of DES	2nd of DES
CON	63WPM05	Employee circulation	8th of CON	1st of CON
CON	52ARM01	Preparation for the risks identified in PESTEL-SWOT analyzes	16th of CON	2nd of CON

When the Effects listed in Table 4.7 were tested in this methodology, the resulting Productivity Numbers are given in Figure 4.36.

It can be seen in Figure 4.36. that the improvement action lists without weighted Effects result in a very minor improvement in the productivity of a shipyard. As it can be seen in

Figure 4.37, almost no change occurred in the Shipbuilding Management graph when the respondents' non-weighted Effect magnitudes were applied.

INITIAL PRODUCTIVITY NUMBERS (see Figure 4.3.)**:**

BASIS : IN GENERAL

DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.60	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.13	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

INTERACTIVELY CHANGED PRODUCTIVITY NUMBERS AFTER RESPONDENTS' FIVE IMPROVEMENTS WERE TESTED

BASIS : IN GENERAL

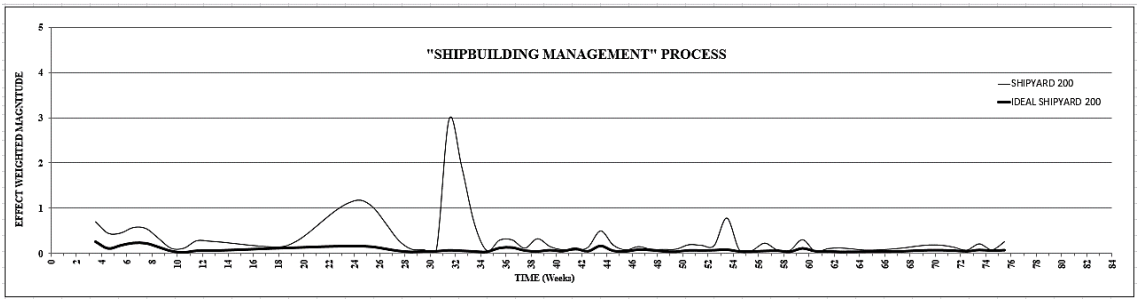
DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.58	(U)
CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD:	13.05	
TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD:	3.65	

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

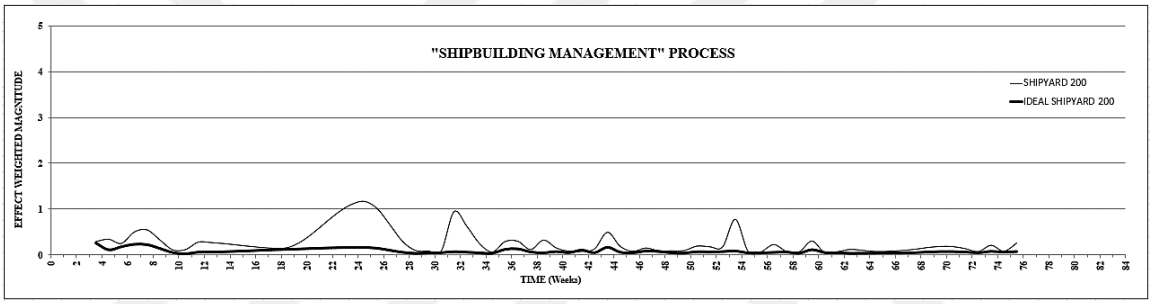
SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.51	IMPROVEMENT TARGET :	0.90	DPN :	2.78
SHIP DESIGN :	4.35	IMPROVEMENT TARGET :	1.33	DPN :	3.26
SHIP PRODUCTION :	3.47	IMPROVEMENT TARGET :	1.05	DPN :	3.31
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

Figure 4.36: Shipyard 200 Productivity Numbers Status before and after respondents' five improvements were applied.

INITIAL GRAPH (see Figure 4.5):



INTERACTIVELY CHANGED GRAPH AFTER SIX IMPROVEMENTS WERE APPLIED EARLIER BY THIS METHODOLOGY (see Figure 4.13):



INTERACTIVELY CHANGED GRAPH AFTER FIVE IMPROVEMENTS OF THE RESPONDENTS WERE APPLIED WITHOUT WEIGHTS

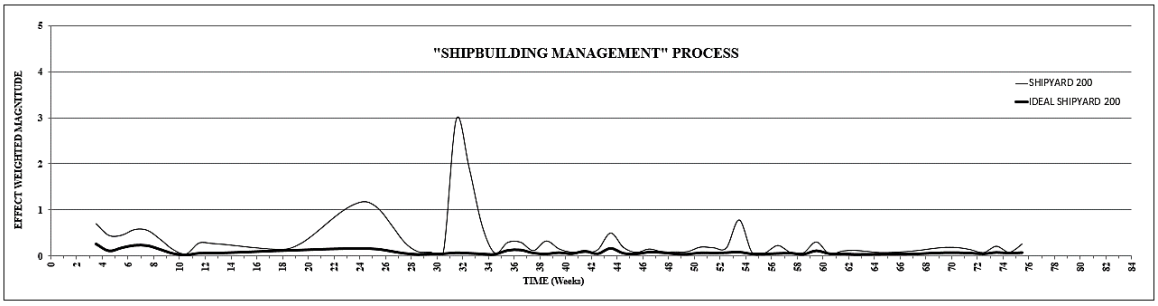


Figure 4.37: Shipyard 200 Productivity Status Dashboard graphs of Shipbuilding Management process before (top) and after six (middle) and respondents' five (bottom) improvements were applied.

The shipyard surveys helped to observe the common improvement needs of the surveyed shipyards, as given in Table 4.8, despite both shipyards were hypothetical.

Table 4.8: Common improvement needs of Shipyard 200 and Shipyard 300 (in Effect nr. Order).

Effect nr.	Effect
Production - Parts Manufacturing in the Shipyard	
13PPT02	Automation in pipe manufacturing; pipe installation in hull blocks, in the ship
13PPT06	Automation in manufacturing and outfitting, use of robots
Production - Outfitting before Launching	
14POS03	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"
Infrastructure - Layout	
21IFL16	Regular cleaning of work areas
Infrastructure - Environment	
22IEN01	Energy saving and protection of natural resources in the shipyard; use of clean (green) energy
Infrastructure - Technology	
23ITE02	Existence of information integration for shipyard automation systems
Infrastructure - Amenities	
24IFA04	The distance between the work area and the car parking lot; adverse weather protection on the walking line; electric vehicle charging facility
24IFA05	Presence of a nursery (preschool, kindergarten) in the shipyard
Design & Production Engineering	
30DES07	Compliance of design document deliveries with the ship production schedule
Materials & Procurement	
40MPP06	Accurate and timely material supply throughout the Project, especially if the Hull Block outfitting is applied
Shipbuilding Management - Risk Management	
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions
Work Force - Performance & Practices	
62WPP23	Manufacturers' installation, start-up, testing and troubleshooting support
Quality	
70QAC01	Effectiveness of the Quality Assurance System
Contracting - Main Contract	
81CMC02	Bid/Proposal preparation team and its work standardization
81CMC04	Participation of relevant departments in Shipbuilding Contract negotiations

The list in Table 4.8. shows the common problems and updated needs in shipbuilding such as more automation and more convenient ship production techniques such as outfitted-blocks, better planning, better material flow; clean work environment, modern information technologies, better amenities for "happy worker", and an awareness on environmental issues such as green energy use.

The data gathered from surveys provided additional information. For example, the list in Table 4.9 is a 15-item summary from the actual shipyards on their weighing the Effects of a shipbuilding process. The list was prepared in the priority order, and used geometric means of cleaned data. This list may not be generalized due to the very low sample size but gives

an opinion. It is observed that 14 of the 15 Effects are related to pure shipbuilding issues and the last one is a management and labor-related Effect.

Table 4.9: Common Effect priorities of Shipyard 5 and Shipyard 12.

Priority order	Effect nr.	Effect
1.	12PSE01	Hull & Superstructure blocks erection
2.	15PLA01	Ship launching
3.	82CSC01	Subcontracts preparation team and its work standardization
4.	22IEN01	Energy saving and protection of natural resources; use of clean (green) energy
5.	14POS01	Manufacturing and assembly of the outfit infrastructure elements
6.	13PPT01	Metal joining techniques
7.	23ITE02	Information integration for shipyard automation systems
8.	40MPP06	Correct material supply
9.	16POQ02	Minimum outfitting effort requirement after launching
10.	22IEN02	Hazardous waste management
11.	70QAC01	Effectiveness of the Quality Assurance System
12.	16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching
13.	81CMC02	Bid/Proposal preparation standardization
14.	23ITE06	Technical investments
15.	61WOR01	Staff status of employees (shipyard's own etc.)

It should be remembered that the methodology in this thesis is not for benchmarking different shipyards with their own, unique conditions and facts, rather focuses on a shipyard's own status, namely an internal benchmarking with its own Ideal status. The Dimensionless Productivity Numbers (**U**) of Shipyard only shows the level of effort to be spent internally to achieve the maximum productivity by a shipyard itself.

4.2.2. Reliability and Validity of the Research

A scientific method is evaluated by both reliability and validity, results of scientific research should be reliable and valid. If, under the same conditions the results can be reproduced and the measure is consistent, the results may be referred to as reliable. If the results of the method represent the purposed measure, the accuracy of the measure is

referred to as valid. Reliability and validity are both closely related, but they mean different things. If a measurement is valid usually it can be reliable and accurate results are generally correctly reproducible, but the opposite may not be correct.

The above general definitions of reliability and validity do not fully comply with this study. Despite the tools, and methods referenced in this study being from known, established theories and applications the methodology developed, a novel methodology was developed with a lack of previous similar methods and in an environment where even gathering the initial data was hard. Therefore, in this thesis, it was not claimed that the developed methodology is the best or unique technique to measure a shipyard's productivity or prioritize improvement needs.

Two evaluations were considered for the reliability and validity of this research, the first one is based on a brief verbal evaluation and the second one is based on statistical analyses.

Tangen (2004) cites Olesen (1992) where it was suggested that there exist five aspects as listed below in the evaluation of the validity of a research. If they are satisfied, good validity of the research can be said;

(i) Internal logic,
(ii) Truth,
(iii) Acceptance,
(iv) Applicability,
(v) Novelty value.

(i) From the internal logic aspect; this study is based on known and accepted theories, and the starting point, hypothesis, and the results are connected. The research question originated from practice and theory such as spline curves, propeller shafting alignment, etc.

(ii) From the truth aspect; the results of this study can be used to explain a real case such as productivity improvement in a shipyard by the use of the methodology.

(iii) From the acceptance aspect; it is currently unknown if researchers accept the methodology and professionals use the methodology used in this thesis.

(iv) From the applicability aspect; this novel methodology is open for further improvement and success as it is used repeatedly.

(v) From the novelty value aspect; a new way of looking at and solution to shipyard productivity measurement and improvements is introduced.

The above verbal evaluations provide insight in the validity of the methodology in this study but also statistical analyses of the data of the test cases are necessary to evaluate the reliability and validity of scientific research, to make inferences about the population from the data gathered from samples (Nişel, 2023).

The main concerns for the reliability of this study are representativity and generalizability. Sample size with respect to population size forms the "size of data". This is one of the factors affecting reliability. The second factor is the "content of the data", the degree of the heterogeneity of the sampled population data and target population definition.(Nişel, 2023).

This study deals with two different populations. The first one is the shipyards building new ships in the world. For this, each shipyard to be surveyed forms a sample. The second population is the employees of each shipbuilding process/subprocess dealt with in this methodology. The participants (respondents) of surveys in each shipyard, working at 10 different shipbuilding processes/subprocesses form the sample of these processes/subprocesses.

As mentioned in subsection 3.2.2., the calculated sample size for the 514 shipyards all around the world was 220 shipyards and this was a very high sample size to be tested within the study time frame. To have a smaller sample size, 45 shipyards were planned and 42 were applied for surveys. The achieved result was the surveys at two actual shipyards with reduced question content (first survey phase), and at two hypothetical shipyards with more content (second survey phase). This resulted in surveys at four shipyards, a small sample size.

For the second population, the shipbuilding process/subprocess employees, calculated sample sizes were almost not possible to achieve as mentioned in subsection 3.2.2. Only in Shipyard 12, which is an active real shipyard that was surveyed, the population, targeted and actual sample sizes were realized (due to the outsourced status of other employees) for three processes. In one each process of the two hypothetical shipyards the targeted and realized sample sizes matched.

Except for the three subprocesses of Shipyard 12, where the number of population is equal to the sample size so that the data from the samples represents the population, the other sample sizes were deemed as small. During the Descriptive Statistics studies and data cleaning, it was also noticed that, due to the small sample size, there exist non-normality, low kurtosis, and high skewness problems in the data to be worked for inferential statistics. Data cleaning helped to reduce non-normality, and skewness problems up to a level, but further cleaning would cause loss of data for test cases. On the other side, all population parameters to meet the Effect magnitudes, Effect weights, and Effect timewise distribution-type information needed for this study were not known, and not available in the literature. Since this study is on the development of a new methodology this seemed normal, but the non-availability of population parameters also affected the statistical inference works and the generalizability of the results negatively.

The lack of request for the second survey phase, at least by the actual shipyards that participated in the first phase, resulted in the non-repetition possibility of the same survey after a few weeks. This was needed to measure the reliability of the data obtained during the surveys, and also to measure the validity of the data and the developed methodology. Therefore, the reliability measure of the gathered data remained with executed Descriptive Statics and central tendency, variation, skewness, and kurtosis information (Nişel, 2023) which were obtained as explained previously in this subsection. Validity shows the accuracy of the method and must be proved. Again, the lack of an actual shipyard to measure the accuracy of the developed method, only the results of two hypothetical shipyard surveys provided information performance of the method, as explained in Section 4. With regard to factors affecting validity (Nişel, 2023),

- target population definition was correct,

- sampling was on a random basis within shipyards also taking care of bias problems,
    - bias problem was also considered in the selection of experts for the hypothetical shipyards with the provision of as much as limited information (see Table 3.13)
- to prevent computational mistakes, double-checks were made in calculations, interpretation of the results was always tried to be refrained while the correct method of analysis was observed.

Misinterpretation of the results was always tried to be refrained while the correct method of analysis was observed. In this respect, statistical analyses in this study were decided to follow some estimations and non-parametric methods, considering the available sample size and, data which probably have some unequal variance and still in an approximate normality level.

In this study, especially the dispersion of the shipyard into two phases and small sample size brought some questions to be investigated. Some of these questions were translated into hypotheses to be tested as follows:

(i) Were the responses of the participants internally consistent?

In eight internal consistency checks, only in case low inconsistency (Cronbach's alpha of 0.72) was observed. It can be stated that internal consistency among the survey respondents exists.

(ii) Can we assume that there is no significant difference between the actual shipyards (Shipyards 5 and 12) and hypothetical shipyards (Shipyards 200 and 300) responses?

In one test statistics among four surveyed shipyards, insignificance in differences was found between one actual and one hypothetical shipyard and also between the two hypothetical shipyards. It can be said that some equalities are significant among the shipyards..

(iii) Were the Sector Weights calculated for actual shipyards (Shipyards 5 and 12 together) different than those of hypothetical shipyards (Shipyards 200 and 300 together)?

In one test statistics among the surveyed actual and hypothetical shipyards on the Shipbuilding Management process, insignificance in difference was found between actual and hypothetical shipyards. It can be said that some equalities are significant on the process basis among the shipyards..

(iv) Can the calculated Sector Weight values represent the whole Shipyards in the World?

Since lack of data on population parameters, only Confidence Intervals were specified for the calculated and normalized Sector weights. Only further surveys help of the improvement in the sample size and respectively the Sector data.

In the above facts and based on the shipyard-based results provided in subsection 4.1., it can be concluded that, since it is a novel methodology and started with small sample sizes, its reliability from the statistical aspect, and validity are at a satisfactory level for further studies, surveys and improvement.

4.2.3. Comparison to Earlier Work

As previously mentioned in subsections 1.2 and 2.3, currently there exists no similar method in the same coverage as presented in this study. Though some studies like Baihaqi et al (2022) and Rubesa et al. (2023) were found to similar approaches as noticed during the Literature Review. Within the content of one reference, First Marine International (2005) there exists some information on the improvement priorities in shipyards. In Table 4.10., a comparison is shown with the findings in this study and in First Marine International (2005) report. It should be noted that the First Marine International (2005) study prioritizes the U.S. Shipbuilding industry improvement needs while the priorities from this study are the sector weight priorities. Therefore, the prioritizations are on two different issues but in some areas, they match such as dimensional accuracy control in hull construction, design methods, Just-in-Time (JIT) arrival of the supplies, use of modular outfit-units, storage and warehousing, dynamic schedule management (continuous monitoring and feedback), performance measurements and efficiency calculations, outfitting after hull assembly and material/Parts Lists of workpackages/workmanship drawings.

Table 4.10: List of Effects' group/subgroups sector weights in priority order.

Effect/ Group Nr.	Effect/Group	Prioritization Rank	
		Normalized Sector Weight (this study)	Improvement needs (FMI,2005)
12PSE01	Hull & Superstructure blocks erection (Hull Construction)	1	15
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching	2	16
14POS01	Manufacturing and assembly of the outfit infrastructure elements	3	9
40MPP06	Correct material supply	4	11
13PPT02	Manufacturing and installation of piping systems in the ship	5	12
11PSB09	Block Blasting-Painting	6	16
14POS05	Paint manufacturer	7	16, 18
70QAC04	Dimensional accuracy control in hull construction	8	7
30DES01	Design methods	9	8
40MPP07	Just-in-Time (JIT) arrival of the supplies	10	9
14POS03	Use of modular "outfit-units"	11	9, 18
14POS06	External hull works, outfitting and painting	12	16, 18
14POS02	Equipment to be taken into the block before the hull erection	13	5
21IFL07	Storage, warehousing	14	16
51APL14	Production management - Field Engineering	15	2, 19
51APL06	Dynamic schedule management : Continuous monitoring and feedback	16	20
51APL11	Performance measurements, Efficiency calculations	17	20
14POS04	Outfitting after hull assembly	18	18
40MPP00	MATERIALS & PROCUREMENT	19	11
61WOR00	WORK FORCE : ORGANIZATION	20	13
30DES10	Material/Parts Lists of workpackages/workmanship drawings	21	20
30DES11	Plate & profile Part numbering system	22	10
30DES14	Outfitting workmanship documents, installation instructions	23	14
30DES06	"Design for Production"	24	1
51APL04	Scheduling techniques	25	3,4,6
30DES05	Design for Hull Block Outfitting	26	5

4.3. Summary

After the numerical analyses with the data gathered from shipyard surveys to obtain Productivity Numbers, priority lists of improvement needs and to observe the statistical significance of the methodology, results were achieved on the analyses.

Two separate Dashboards were finalized for the hypothetical Shipyard 200 and Shipyard 300. Visual presentation of the calculated Productivity Numbers and visual identification of process/subprocess productivity statuses, along with the summarized priority lists of needed improvements are presented.

Dimensionless Productivity Numbers "**U**" of Shipyard 200 and Shipyard 300 are presented with their current and target productivity numbers. The same are presented for processes and subprocesses.

Visual outputs, the current and Ideal status graphs of processes and subprocesses help to gain some insight. When the Weighted Magnitude of an Effect is changed, for example for an improvement test, these linked graphs also revise themselves due to the change in the area under the respective process/subprocess curve and the Productivity Number.
These fulfilled the first research aim successfully.

The second research aim was to obtain improvement area priority lists of the processes and, test the effects of the improvements on productivity leading to a continuous improvement cycle. In this respect, along with the Productivity Number calculations, priority lists for needed improvements on the Effects of the process/subprocesses were obtained by the order of the Weighted Magnitudes of the Effects. Tests on prioritized Effects on process/subprocess basis were held to observe the changes in the Productivity Numbers and graphs. All provided satisfactory results and guidance.

It was shown that intuitively defined priorities for improvements may be misleading, and weighted magnitudes lead to more powerful improvement results.

Common improvement needs of hypothetical Shipyard 200 and Shipyard 300 and also common Effect priorities of actual Shipyard 5 and Shipyard 12 were listed and briefly evaluated.

Despite small sample sizes, the reliability and validity of the study at some satisfactory level is explained by the results of internal consistency and hypothesis tests.

As a result, the Productivity Number tables and visual graphs on the Shipyard 200 Dashboard and Shipyard 300 Dashboard show that the aimed methodology works successfully and the analogy to propeller shafting alignment is appropriate.

5. CONCLUSION

In shipyard management, robust numerical data to show the productivity status and target of a shipyard for the entire shipbuilding process, preferably accompanied by the same for the major shipbuilding processes, and also improvement suggestions to achieve the targets are needed tools. This thesis is focused on "shipyard productivity" and also "productivity improvement" for shipbuilding and proposes a new and handy methodology to calculate a dimensionless "Productivity Number" system for a shipyard. It helps to identify a shipyard's productivity status for the entire and major shipbuilding processes and also provides prioritized lists of needed improvements along with chain reaction indications.

The main research question and the hypothesis were on developing a new methodology, preferably with dimensionless metrics, to evaluate the shipyard productivity and prioritize the improvement needs that are compatible with the entire shipbuilding process.

In this thesis, the developed methodology provided a positive response to the main research question and resulted in the fulfillment of the hypothesis. Dimensionless Productivity Number "**U**" of two (hypothetical) Shipyards are presented with their current and target productivity numbers. The same are presented for their shipbuilding processes and subprocesses.

As per the other research questions, as given in subsection 1.2.3., the following were realized.

Three major shipbuilding processes namely Shipbuilding Management, Ship Design, and Ship Production formed the basis of measurement. Ship Production covered the Contracting, Hull and Superstructure Blocks Construction, Hull Erection, Parts Manufacturing in the Shipyard, Outfitting before Ship Launching, Ship Launching, Outfitting after Ship Launching (Quay outfitting), and Setting-to-Work (STW), Harbor (HATs) and Sea Trials (SATs) subprocesses. Suppliers and Subcontractors, the important stakeholders of shipbuilding are not to be surveyed at their own premises but surveyed from the shipyard's

perspective and also their work within the shipyard premises. In this way, highly varied inputs from the use of subcontractors are leveled as much as possible.

The analogy of propeller shafting alignment to the actual status of a shipyard and its Ideal version worked very well. The Effects with an important impact on ship production project schedule, 185 in number, from the start of contracting works until the end of sea trials, are distributed among ship production, shipbuilding management, and ship design processes with unique magnitude, weight, and timing characteristics. To gather data on the Effects' characteristics, comprehensive surveys at two shipyards with the participation of 21 respondents and surveys among 26 experienced participants simulating employees of two imaginary shipyards were realized. Despite the lack of interest in the shipyards applied, obtained survey results provided shipyard-specific and generalized sector data during the application of the mathematical model.

The results provided the Dimensionless Productivity Number of the subject shipyard, along with the current and target productivity numbers in a dashboard style, supported with simple graphs. Current and target Productivity Numbers of the shipbuilding processes and subprocesses, all are dimensionless are provided with. The results are changeable on the "general" or based on their importance on the time, cost, or labor basis. Improvement needs lists on Shipbuilding Management and Ship Design processes and Ship Production subprocesses are provided as prioritized. They are double-checked by Pareto Analysis. It is possible to manually test alternative improvements and to see the positive and negative effects of them on all processes and subprocesses.

Despite small sample sizes, the reliability and validity of the study at some satisfactory level is explained by the results of internal consistency and hypothesis tests.

To represent the output of a shipyard, the CGT system-based metrics are still globally favored shipyard productivity measures. During a comprehensive literature review, 21 different methods as adopted from business and industrial management areas or developed originally starting from 1980 had been observed in 62 papers & references which strictly cover overall shipyard efficiency or productivity measurements and/or evaluations. The

methodology presented in this thesis, named as "**Dimensionless Productivity Number (DPN) Method**" is believed to be the 22nd method in this row and due to its simplicity in gathering data from the shipyards, it may be found interesting.

In this respect, a methodology was developed, needed test data were obtained partly, calculations, and numerical analyses were made. The Productivity Number table and visual graphs on the Shipyard Dashboards, developed within this study showed that, the aimed methodology works successfully, much better than intuitive improvement decisions, and the analogy to propeller shafting alignment was appropriate.

5.1. Implications of the Findings on Practice

In this thesis, the focus is on a single shipyard's productivity, but shipbuilding is a labor and technology-intensive heavy industry branch with about 400 active shipyards, hundred thousands jobs, and about USD 120 billion output globally as of 2022. The competition is high and there exists already an imbalance of workshare among three Asian nations and the rest, on the high advantage of the Asian side. Shipyards must increase their productivity for better competitive positions and higher profitability. The methodology presented in this thesis may add value for the shipyards that may utilize it.

For the provision of jobs, for the high revenues from newly built and exported ships, the introduction of new technologies to local industries and to protect its interests by maritime power, a competitive shipbuilding capability is important for a nation. Productive, competitive, and therefore possibly busy shipyards help sustainability in the domestic maritime industry and development in academia and other research entities. On the shipyard level, high productivity leads to high profitability and competitiveness, resulting in a high-performance shipyard along with satisfied employees.

This new method assists in shipyard's top management to observe the status of the shipyard, also by visual assistance. The model provided a dimensionless "Productivity Number" system for a shipyard to benchmark with its own "Ideal" conditions. The Effects to be improved in shipbuilding management, ship design, and ship production become visible.

Improvement needs and related investment priorities in the shipyard can be defined more easily. Alternative decisions can be tested, and their effects can be recognized before final managerial decisions. Application of this method at any shipyard, for any type of ship, and at any time, before, during, and after the production is possible. Shorter delivery periods through improvements on prioritized needs can be reached.

Also named as “Ghost Rival method”, this methodology may be found interesting by other industrial sectors that produce customer-defined products for long periods such as ship equipment manufacturers or aircraft industries, etc.

5.2. Recommendations for Future Research

This thesis is believed that it brings a new perspective for further research. It can be extended by more theoretical works and data gathering. The following are planned and also recommended for future studies;

- further surveys at shipyards and utilization of the methodology, developing more data on "Sector Weights of Effects affecting Shipbuilding”,
- possible integration of the dashboard to a common CAD software for easier manipulation on improvement decisions on a visuality basis,
- inclusion of shipbuilding subcontractors’ and suppliers’ performance measure at their premises into the methodology.

During the Literature Review, it was noticed that there are some recent studies close to this study. It may be possible that they also benefit from this thesis after reviewing the methodology and using the data provided in the Appendices.

REFERENCES

ABS – American Bureau of Shipping, (2019). *Guidance Notes on Propulsion Shafting Alignment.* American Bureau of Shipping.

Açık, A., Ertürk, E. , & Sağlam, B. B., (2017) Efficiency evaluation of Turkish shipbuilding industry using Data Envelopment Analysis (in Turkish). *Dokuz Eylül University Maritime Faculty Journal, 9*(2), 234-251.

Adarme, W. J., Serna, M. D. A., Buritica, N.C., (2011). Key performance measures for supply chain management from the Colombian shipyard. In T. Bleceker, C. Jahn & W. Kersten (Eds.), *Maritime Logistics in the Global Economy: Current Trends and Approaches*, Josef Eul Verlag GmbH.

Arnold, T., Chapman, S., & Clive, L. (2008). *Introduction to materials management* (6th Ed.). Pearson Prentice Hall.

Bahihaqi, I., Lazakis, I. & Kurt, R.E., (2022). Assessing performance measurement indicators for ship manufacturing industry through value engineering and risk assessment (Venra) model. In C. Guedes Soares & T. A. Santos (Eds.) *Trends in maritime technology and engineering: Proceedings of the 6th international conference on maritime technology and engineering (MARTECH 2022)* (pp. 25-32). CRC Press. https://doi.org/10.1201/9781003320272-3

Baykal, R., (2017). *İstanbul'un Fethi'nden Günümüze Tersanelerimiz ve Denizcilik Kuruluşlarımız* [Our shipyards and maritime institutions, from conquest of İstanbul to today]. İTÜ Vakfı.

Beier, K.P., (1989). *Computer-aided hull design and production (3rd Ed.).* [Course notes, the University of Michigan].

Benzaquen, J., (2017). Total Factor Productivity. *International Journal of Productivity and Performance Management, 66*(2), 231-250. https://doi.org/10.1108/IJPPM-11-2015-0171

Bernolak, I.,(1997). Effective measurement and successful elements of company productivity: The basis of competitiveness and world prosperity. *International Journal of Production Economics, 52*(1–2),203-213. https://doi.org/10.1016/S0925-5273(97)00026-1

Bethlehem Steel Corporation Sparrows Point yard, A&P Appledore Ltd. & J. J. Henry Co., Inc., (1985). *Design for production manual vol. 1.* (NSRP 0236). U.S. National Shipbuilding Research Program.

Bilen, Ü., (2022). *Shipyard productivity evaluation with key performance indicators.* [Doctoral thesis, İstanbul Technical University]. https://tez.yok.gov.tr/UlusalTezMerkezi/ giris.jsp

Bilen Doğan, Ü., & Helvacıoğlu, İ. H., (2017). Customized project management methods and their applications in shipbuilding projects. *Istanbul Technical University GİDB Dergi, 10*, 3-20.

Bilen, Ü., Helvacıoğlu, Ş. & Helvacıoğlu, İ. H., (2022, September 26-29). *Evaluation of small and medium sized shipyards productivity with Key Performance Indicators* [Conference Paper]. SNAME Maritime Convention, Houston, TX, United States. https://doi.org/10.5957/SMC-2022-120

Birmingham, R., Hall, S., & Kattan, R. (1997). Shipyard technology development strategies. *Journal of Ship Production*, *13*(4), 290-300. https://doi.org/10.5957/jsp.1997.13.4.290

Brodda, J., (1990, April 21-24). *Shipyard modelling-approach to obtain comprehensive understanding of functions and activities* [Conference Paper,1B-1] NSRP 1990 Ship Production Symposium, Milwaukee, WI, United States.

Bruce, G. J., (1992). Shipbuilding performance measurement in unstable conditions. *Proceedings of the Ship Production Symposium,* ADA455880, 7B3,1-7.

Bruce, G. J., (2006). A review of the use of Compensated Gross Tonnes for shipbuilding performance measurement. *Journal of Ship Production*, *22*(2), 99-104. https://doi.org/10.5957/jsp.2006.22.2.99

Čagalj, A., (2009). Productivity in shipbuilding. *Journal Brodogradnja (Shipbuilding), 60*:2, 141-146.

Çağlar, M. & Nisel, R.N., (2017). Impact of marketing and R&D expenditures on financial performance: a research in manufacturing industry. *Research Journal of Business and Management (RJBM), 4*(3), 359-371.

Ceballos, B., Lamata, M.T. & Pelta, D.A., (2016). A comparative analysis of multi-criteria decision-making methods. *Progress in Artificial Intelligence, 5*, 315-322. https://doi.org/10.1007/s13748-016-0093-1

Çelebi, U. B. & Bilgili, L., (2018). An innovative Theory of Constraints based approach for improvement of shipyard project management. *Dokuz Eylül University Maritime Faculty Journal*, *10*(1), 1–17. https://doi.org/10.18613/deudfd.428151

Chang, K.-H., (2015). *e-Design: Computer-Aided Engineering Design*. Academic Press.

Chao, S-L., & Yeh, Y-H., (2020). Comparing the productivity of major shipyards in China, South Korea, and Japan–an application of a metafrontier framework. *Maritime Business Review*, *5*(2), 193-210. https://doi.org/10.1108/MABR-12-2019-0060

Charnes, A., Cooper, W. W. & Rhodes, E. L., (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*, 429-444.

Chen, T., (2017). New fuzzy method for improving the precision of productivity predictions for a factory. *Neural Computing & Applications, 28*(11), 3507–3520. https://doi.org/10.1007/s00521-016-2270-3

Chudasama, K.GM., (2016). Efficiency appraisal of Indian shipyards using Data Envelopment Analysis. *International Journal of Research in Social Sciences, 6*(12), 223-241.

Gordon, S., (2023, January 12). 2022:Shipbuilding review. *Clarksons.* https://insights.clarksons.net/2022-shipbuilding-review

Cobb, C. W. & Douglas, P. H., (1928). A theory of production. *American Economic Review*, *18* (Supplement), 139–165.

Cochran, W.G., (1977). *Sampling Techniques* (3rd Ed.). John Wiley & Sons.

Cook, W. D., & Zhu, J. (2005). *Modeling performance measurement: Applications and implementation issues in DEA*. Springer.

Cook, W. D., Tone, K. & Zhu, J. (2014) Data envelopment analysis : prior to choosing a model. *Omega, 44*), 1-4. http://dx.doi.org/10.1016/j.omega.2013.09.004

Craggs, J., Bloor, D., Tanner, B. & Bullen, H., (2003). Methodology used to calculate naval CGT factors. *Journal of Ship Production, 19*(1), 22–28. https://doi.org/10.5957/jsp.2003.19.1.22

Craggs, J., Bloor, D., Tanner, B. & Bullen, H., (2004). Naval Compensated Gross Tonnage coefficients and shipyard learning. *Journal of Ship Production, 20*(2), 107–113. https://doi.org/10.5957/jsp.2004.20.2.107

Colin, E. C. & Pinto, M. M.O., (2009). Benchmarking shipbuilders' turnover of main assets." *Journal of Ship Production 25*(4), 175-181. https://doi.org/10.5957/jsp.2009.25.4.175

Daniel, L., Adachi A. & Lee, S., (2022). *Shipbuilding market developments, First semester 2022-Monitoring developments in ship supply, demand, prices and costs.* [OECD Science, Technology and Industry Policy Paper, No.132]. OECD Publishing. https://doi.org/10.1787/e511558d-en.

de Boor, C., (1972). On calculating with B-Splines., *Journal of Approximation Theory, 6*(1), 50-62.

DNVGL, (2018). *Calculation methods for shaft alignment.* (DNVGL-CG-0283). DNV-GL.

Doerry, N., (2009, May 20-21). *Using the design structure matrix to plan complex design projects* [Conference Paper]. ASNE Intelligent Ships Symposium (ISS) VIII, Philadelphia, PA, United States.

Drucker, P. F. (1974). *Management: Tasks, responsibilities, practices.* HarperCollins.

ECORYS SCS Group. (2009). *Study on competitiveness of the European shipbuilding industry.* [ENTR/06/054]. https://ec.europa.eu/docsroom/documents

Fareza, R. M., (2020). *Study of shipbuilding competitiveness: Benchmarking analysis as a tool to measure shipyards' competitiveness with a focus on Asian yards* [Master thesis, Delft University of Technology]. https://repository.tudelft.nl

First Marine International (FMI). (2005). *First Marine International findings for the global shipbuilding industrial base benchmarking study Part 1: Major shipyards*. www.nsrp.org/wp-content/uploads/2015/08/FMI-Global_Industrial_benchmarking-mid-tieryards.pdf (5 March 2021).

Fitzgerald, S., Dimitrov, D. & Rumrill, P., (2001). The basics of nonparametric statistics. *Work 16*, 287-292.

Forrester, W. J. (1958). Industrial Dynamics-a major breakthrough for decision makers. *Harvard Business Review,7-8,* 37-66.

Foster, J., (2009). *How to get ideas* (2nd Ed.). Berrett-Koehler.

Franek, J., & Kresta, A., (2014). Judgment scales and consistency measure in AHP. *Procedia Economics and Finance, 12,* 164–173. https://doi.org/10.1016/s2212-5671(14)00332-3

Frankel, E. G., (1983). Impact of technological change on shipbuilding productivity. *Proceedings of the 1983 SPC/IREAPS Technical Symposium on Improving Shipbuilding Productivity,* Vol. II. 641-679.

Fritsch, F.N. & Carlson, R.E., (1980). Monotone piecewise cubic interpolation. *SIAM Journal on Numerical Analysis, 17*(2), 238-246.

Fritsch, F.N. & Carlson, R.E., (1985). Monotone piecewise bicubic interpolation. *SIAM Journal on Numerical Analysis, 22*(2), 386-400.

Fritsch, F.N. & Carlson, R.E., (1989). An algorithm for monotone piecewise bicubic interpolation. *SIAM Journal on Numerical Analysis, 26*(1), 230-238.

Gasparotti, C. & Rusu, E., (2018). An Overview on the shipbuilding market in the current period and forecast. *EuroEconomica. 3*(37), 254-271.

GİSBİR-Turkish Shipbuilders Association, (2016). Türk gemi inşa sanayinin rekabet gücünün artırılması. [Improving competitiveness of Turkish shipbuilding industry]. Türkiye Gemi İnşa Sanayicileri Birliği.

GİSBİR-Turkish Shipbuilders Association, (2020a). 2019-2020 Sektör raporu [2019-2020 Sector Report]. Türkiye Gemi İnşa Sanayicileri Birliği. https://www.gisbir.org/tr/

GİSBİR-Turkish Shipbuilders Association, (2020b). *Members*. [Information booklet]. Türkiye Gemi İnşa Sanayicileri Birliği. https://www.gisbir.org/tr/katalog_2020.

GİSBİR-Turkish Shipbuilders Association, (2023). 2022-2023 Sektör raporu [2022-2023 Sector Report]. Türkiye Gemi İnşa Sanayicileri Birliği. https://www.gisbir.org/tr/

Goldratt, E. M. & Cox, J., (1984). *The Goal: A process of ongoing improvement*. North River Press.

Gourdon, K., (2019). *An analysis of market-distorting factors in shipbuilding: The role of government interventions*. [OECD Science, Technology and Industry Policy Papers, No. 67]. OECD Publishing. https://doi.org/10.1787/b39ade10-en

Gourdon, K. & Steidl, C., (2019). *Global value chains and the shipbuilding industry.* [OECD Science, Technology and Industry Working Paper, 2019/08]. OECD Publishing https://dx.doi.org/10.1787/7e94709a-en (20 April 2021).

Gourdon K., Daniel, L., Adachi, T. & Berger, E., (2023). *New approaches to shipbuilding capacity assessment*. [OECD Science, Technology and Industry Policy Paper, No. 140].OECD Publishing.

Guofu,S., Xiaobing, L., Yizhuang, X. & Nailong, Y., (2017). Measurement and evaluation model of shipbuilding production efficiency. *International Journal of Economic Behavior and Organization*, 5(6), 149-161. https://doi.org /10.11648/j.ijebo.20170506.15

Hadjina, M., Matulja, T. & Rubeša, R., (2015). Methodology for the ship exploitation feedback inclusion for improving the ship design and production process based on adjusted QFD method. *Pomorstvo*, *29*(2), 107-114.

HD Hyundai, (2023). *HHI Shipbuilding group performance record.* [Information booklet]. HD Hyundai. https://english.hhi.co.kr/img/filedown/HHI_PerformanceRecord_220511.pdf

Hellgren, S., (2016). *The Bayesian model for cruise shipbuilding: A process for production efficiency and organization* [Doctoral thesis, Aalto University]. https://aaltoarkisto.finna.fi/?lng=en-gb

Hellgren, S., Hanninen, M., Banda, O. A. V. & Kujala, P., (2017). Modelling of a cruise shipbuilding process for analyzing the effect of organization on production efficiency. *Journal of Ship Production and Design*, *33*(2), 101-121. https://doi.org/10.5957/jspd.2017.33.2.101

Hoffman, J. D., (2001). *Numerical methods for Engineers and Scientists* (2nd Ed.). Marcel Dekker.

Hopman, J.J., Pruyn, J.F.J. & Hekkenberg, R.G., (2010). *Determination of the Compensated Gross Tonnage factors for super yachts.* Delft University of Technology. https://repository.tudelft.nl

Hopp, W. J., & Spearman, M. L., (2011). *Factory Physics* (3rd.Ed.). Waveland.

Hossain, K.A., (2023). Evaluation of global and local shipbuilding market. *Science, Technology & Public Policy*, *7*(2),52-68. https://doi.org/10.11648/j.stpp.20230702.12

Huijgens, L. J. G., (2016). *Quantification of manufacturing complexity in shipbuilding projects* [Master thesis, Delft University of Technology]. https://repository.tudelft.nl

Infomarine On-Line. *Shipyards directory*. https://www. shipyards.gr (18 June 2021).

JASP Team, (2020). JASP (Version 0.16.4)[Computer software].

Kafalı, M. & Özkök, M., (2015). Evaluation of shipyard selection criteria for shipowners using a fuzzy technique. *Journal of Marine Engineering & Technology*, *14*(3), 146-158. https://doi.org/10.1080/20464177.2015.1118787

Kim, Y., Woo, J. H., Jeong, Y-K. & Shin, J. G., (2018). 2018 Computational shipyard dynamics." *Journal of Ship Production and Design*, *34*(4), 355-367. https://doi.org/10.5957/JSPD.170029

Kırdağlı, M., (2010). Tersanelerde verimliliği etkileyen parametrelerin Fuzzy AHP yöntemi ile analizi [Fuzzy AHP analysis of parameters affecting efficiency in shipyards]. [Doctoral thesis, Istanbul Technical University]. https://tez.yok.gov.tr/UlusalTezMerkezi/giris.jsp

Koçak, S. T., Dikilitaş, A., Kayıhan, Y., Tiryaki, C. & Güngör, A., (2022). Classification of contractual risks in shipbuilding projects. In İ. H. Helvacıoğlu, S. Ilgın, B. Sözer, B. Başoğlu (Eds.). *Contract Management for Shipbuilding and Repair: Technical Perspective and Settlement of Legal Disputes* (pp. 61-90). Vedat Kitapçılık.

Koçak, S. T. & Yercan, F., (2021). Comparative cost-effectiveness analysis of Arctic and international shipping routes: a fuzzy analytic hierarchy process. *Transport Policy 114*, 147-164. https://doi.org/10.1016/j.tranpol.2021.08.015

Koenig, P. C., (2002). Technical and economic breakdown of value added in shipbuilding. *Journal of Ship Production, 18*(1), 13-18. https://doi.org/10.5957/jsp.2003.19.1.32

Koenig, P. C., Narita, H. & Baba, K., (2003). Shipbuilding productivity Rates of change in East Asia. *Journal of Ship Production, 19*(1), 32-37.

Kolinski,A., (2013). The role of production efficiency regarding ecological aspects. In P. Golinska (Ed.), *EcoProduction and Logistics* (pp. 93-102). Springer Verlag. https://doi.org/10.1007/978-3-642-23553-5_6

Krishnan, S. N., (2012). A scientific approach to measure shipbuilding productivity. *Maritime Affairs: Journal of the National Maritime Foundation of India, 8*.1, 136-149. https://doi.org/10.1080/09733159.2012.690565

Lamb, T., (1985, September 11-13). *Engineering management for zone construction of ships* [Symposium Paper]. NSRP Ship Production Symposium, Long beach, CA, United States.

Lamb, T., (1986). *Engineering for ship production, a textbook*. The University of Michigan. https://apps.dtic.mil/sti/pdfs/ADA452843.pdf

Lamb, T., (1988). Group Technology in shipbuilding. *Journal of Ship Production, 4*:01, 30-50. https://doi.org/10.5957/jsp.1988.4.1.30

Lamb, T., (1998). Design for production - Shipbuilding productivity and competitiveness. [PowerPoint presentation] https://www.scribd.com/ presentation (27 April 2019).

Lamb, T., (2002). Comparison of shipbuilding practices and productivity worldwide. In F. Perez (Ed.), *Advanced Shipbuilding and Shipping-Competitive Ship Production-37th WEGEMT Summer School* (pp.187-229). ETSI Navales.

Lamb, T. & Hellesoy, A., (2022). A shipbuilding productivity predictor. *Journal of Ship Production, 18*:02, 79-85. https://doi.org/10.5957/jsp.2002.18.2.79

Lamb, T., (2007, October 22-26). *Worldwide shipbuilding productivity status and trends* [Presentation]. X. COPINAVAL Pan American Conference of Naval Engineering, Maritime Transport and Port Engineering, Sao Paulo, Brazil. https://www.scribd.com/presentation/501221402/Worldwide-Shipbuiding-Productivity (19 February 2021)

Lange, P., Weller, R., & Zachmann, G. (2017). GDS: Gradient based density spline surfaces for multiobjective optimization in arbitrary simulations. *Proceedings of the 2017 ACM SIGSIM Conference on Principles of Advanced Discrete Simulation*. pp.185-196. Association for Computing Machinery http://dx.doi.org/10.1145/3064911.3064917

Lee, J., (2013). Directions for the sustainable development of Korean small and medium sized shipyards. *The Asian Journal of Shipping and Logistics*, 29:3, 335-360. https://doi.org/10.1016/j.ajsl.2013.12.003

Lee, T-E, Song, J-S., Im, J-C., Park, J. C., Jeong, D. S. & Lee, K. R., (1996). Search-based heuristic algorithms for basic planning in a large shipyard. *Journal of Ship Production*, 12:4, 211-219.

Liker, J. K. & Lamb, T., (2002). What is Lean ship construction and repair? *Journal of Ship Production, 18*:03, 121-142. https://doi.org/10.5957/jsp.2002.18.3.121

Marine Vessel Traffic. (2021, June 18) *Shipyards list with details and live maps.* https://www.marinevesseltraffic.com/shipyards.

Mayo, G., Shoghli, O. & Morgan, T., (2018). *Manpower and Efficiency Study of the Manns Harbor Shipyard.* University of North Carolina at Charlotte. https://connect.ncdot.gov/projects/research/RNAProjDocs/2018- Final Report.pdf

Michalski, J.P., (2004). Parametric method of preliminary prediction of the ship building costs. *Polish Maritime Research, 11*(S1), 16-19.

Ministry of Transportation-Türkiye, (2023). Tersane ve kıyı yapıları istatistikleri [Shipyards and shore facilities]. [Infographic].

Moyst, H. & Das, B., (2005). Factors affecting ship design and construction lead time and cost. *Journal of Ship Production, 21*. 186-194. https://doi.org/10.5957/jsp.2005.21.3.186.

Moyst, H. & Das, B., (2008). A linear programming approach to optimization of ship design and construction phases. *Journal of Ship Production, 24*:01, 1-6. https://doi.org/10.5957/jsp.2008.24.1.1

Nam, D. & Öz, C. S., (2020). İş güvenliği kültürü ile güvenli davranış arasındaki ilişki: gemi inşa sanayinde bir araştırma [The relationship between occupational safety culture and safety

behavior: a research in shipbuilding industry]. *Journal of Management and Labour*, *4*:2, 153-166.

Nişel, R.N., (2023, January 21). *Data analysis from the perspective of scientific research* [Seminar]. Piri Reis University. İstanbul, Türkiye.

OECD., (1984). *New Compensated Gross Tonnage coefficients*. OECD Publishing.

OECD., (2001). *Measuring productivity-measurement of aggregate and industry level productivity growth*. OECD Publishing.

OECD Council Working Party on Shipbuilding, (2007). *Compensated Gross Ton (CGT) system.* OECD. http://www.oecd.org

OECD., (2016). *Peer review of the Japanese shipbuilding industry*. OECD. http://www.oecd.org

OECD., (2021). *Peer review of the Turkish shipbuilding industry*. OECD. http://www.oecd.org

OECD., (2023a). Analysis of the marine equipment industry and its challenges. OECD. http://www.oecd.org

OECD., (2023b). Developments of ship demand, supply, prices and costs-second semester 2022. OECD. http://www.oecd.org/sti/ind/shipbuilding.htm.

OTA-U.S. Office of Technology Assessment, (1983). *An assessment of maritime technology and trade*. (OTA-O-220). U.S. Office of Technology Assessment

Park, S.ho., (2010). Efficiency and productivity of seven large-sized shipbuilding firms in Korea. *Journal of Korea Port Economic Association, 26*(4), 188~206.

Parkinson, J.R., (1959). Productivity in shipbuilding. *The Journal of Industrial Economics,7*(3), 189-198.

Passow, E., (1974). Piecewise monotone spline interpolation. *Journal of Approximation Theory, 12*:3, 240-241.

Pawan, G., (2016). *NURBS Demo - evaluator for non-uniform rational B-Splines*. http://nurbscalculator.in (19 December 2021).

Pires, F. C .M. & Lamb, T., (2008). Establishing performance targets for shipbuilding policies. *Maritime Policy & Management, 35*:5, 491-502. https://doi.org/10.1080/03088830802352129

Pires, F. C. M., Lamb, T. & Souza, C., (2009). Shipbuilding performance benchmarking." *Int. Journal of Business Performance Management, 11*:3, 216-235. https://doi.org/10.1504/IJBPM.2009.024372

Porter, M. E., (1985). *Competitive advantage: Creating and sustaining superior performance*. The Free Press.

Proctor, T., (2005). *Creative problem solving for managers developing skills for decision making and innovation*. (2nd. Ed.). Routledge.

Prokopenko, J., (1987). *Productivity management: A practical handbook* (2nd Ed.). International Labour Office.

Pruyn, J.F.J. & Hekkenberg, R.G. & van Hooren, C.M., (2010). Determination of the Compensated Gross Tonnage factors for superyachts. *International Shipbuilding Progress, 57*, 127-146. https://doi.org/10.3233/ISP-2010-0066

Rabar, D., (2015). Setting key performance targets for Croatian shipyards. *Croatian Operational Research Review, 6*:1, 279-291. https://doi.org/10.17535/crorr.2015.0022

RAND Corporation, (2005a). *Outsourcing and outfitting practices.* RAND Europe.

RAND Corporation, (2005b). *Differences between military and commercial shipbuilding.* RAND Europe.

Ray, S. C. & Chen, L., (2015). Data Envelopment Analysis for performance evaluation: a child's guide. In S.C. Ray, S. C. Kumbhakar, P. Dua (Eds.) *Benchmarking for Performance Evaluation A Production Frontier Approach*. Springer India https://doi.org/10.1007/978-81-322-2253-8_2

Roque, P. R. Z., (2019). *A systematic approach to measure shipbuilding productivity* [Master thesis, University of Instituto Superior Técnico]. https://scholar.tecnico.ulisboa.pt/

Roque, P. & Gordo, J., (2021). A measurement of shipbuilding productivity. In C. Guedes Soares, (Ed.). *Developments in Maritime Technology and Engineering Vol.1: Proceedings of the 5th international conference on maritime technology and engineering (MARTECH 2020)* (pp. 801-810). CRC Press. https://doi.org/10.1201/9781003216582

Ross, J.R., (2001). Plant and facilities engineering with waste and energy management. In Salvendy, G. (Ed.), *Handbook of Industrial Engineering-Technology and Operations Management* (3rd Ed.).(pp. 1548-1584). John Wiley & Sons.

Rubeša, R., Rijeka, T. Š., Hadjina, M., Matulja, T., & Bolf, D., (2023). The shipyard technological level evaluation methodology. *Brodogradnja, 74*(3), 91–106. https://doi.org/10.21278/brod74305

Saaty, R. W., (1987). The Analytic Hierarchy Process-What it is and how it is used. *Math Modelling 9* (3-5), 161-176. https://doi.org/10.1016/0270-0255(87)90473-8

Saaty, T. L., (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology, 15,* 234-281.

Saaty, T. L., (1980). *The Analytic Hierarchy Process*. McGraw-Hill.

Saaty, T. L. & Vargas, L. G., (2012). *Models, methods, concepts & applications of the Analytic Hierarchy Process* (2nd Ed.). Springer. https://doi.org/10.1007/978-1-4614-3597-6

Saaty, T. L. & Özdemir, M. S., (2003). Why the magic number seven plus or minus two. *Mathematical and Computer Modelling, 38,* 233-244. https://doi.org/10.1016/S0895-7177(03)90083-5

SAJN The Shipbuilders' Association of Japan, (2022). *Shipbuilding statistics*. https://www.sajn.or.jp/files/view/articles_doc/src/f72b16554a3d850d7fa5c0ab96d49f52.pdf

Santos, J., Negas, E. R., & Santos, L. C., (2013). Introduction to data envelopment analysis. In *Efficiency Measures in the Agricultural Sector* (pp. 37–50). Springer Netherlands.

Sea Europe Shipyards & Maritime Equipment Association, (2020). *Annual report.* Sea Europe.

Sharma, V., (2014, December 27). *Productivity & monitoring in shipbuilding industry* [Conference Paper]. PMI Academic Research Conference, Mumbai, India.

Schoenberg, I. J., (1969). Cardinal interpolation and spline functions. *Journal of Approximation Theory*, *2*:2, 167-206.

Shephard, R.W., (1970). *Theory of cost and production functions.* Princeton University Press.

Shin, J. G., Kim, Y., Jeong, Y-K., Woo, J. H. & Ryu, C. (2020). Model-based computational shipyard dynamics and its applications. *Journal of Ship Production and Design, 36*:1, 87-95. https://doi.org/10.5957/jspd.2020.36.1.87

Singh, H., Motwani, J & Kumar, A.,(2000). A review and analysis of the state-of-the-art research on productivity measurement. *Industrial Management & Data Systems, 100*(5), 234-241. https://doi.org/10.1108/02635570010335271

Skyquest, (2023). *Global shipbuilding market size, share, growth analysis, by type (Vessel,Container), by End User (Transport Companies and Military) - Industry forecast 2023-2030).* Skyquest. https://www.skyquestt.com/report/shipbuilding-market

SNAME Society of Naval Architects and Marine Engineers, (1980). *Ship Design and Construction*. SNAME.

SNAME Society of Naval Architects and Marine Engineers, (2003). *Ship Design and Construction*. SNAME.

SNAME Society of Naval Architects and Marine Engineers, (2007). *Practices and procedures for the alignment of marine propulsion shafting systems*. (Technical & Research Bulletin 3-51). SNAME.

SRS1 Software, LLC.,(2014). *SRS1 Cubic Spline for Excel*. https://www.srs1software.com/SRS1CubicSplineForExcel.aspx (24 December 2022).

Sulaiman, E. J. S. & Sulistiyono Susilo, S., (2017). Factors affecting shipbuilding productivity. *Int. J. of Civil Engineering and Technology*, *8*:7, 961-975.

Stanic, V., Fafandjel, N. & Matulja, T., (2017). A methodology for improving productivity of the existing shipbuilding process using modern production concepts and the AHP method." *Journal Brodogradnja (Shipbuilding), 68*:3, 37-56.

Storch, R. L., Hammon, C. P. & Bunch, H. M., (1988). *Ship Production*. Cornell Maritime Press

Storch, R. L., Hammon, C. P., Bunch, H. M. & Moore, C. M., (1995). *Ship Production* (2nd Ed.) Cornell Maritime Press.

Tangen, S., (2004). *Evaluation and revision of performance measurement systems*. [Doctoral thesis, Royal Institute of Technology, Stockholm, Sweden].

The University of Michigan, (1995). *Short course on design for production integration* .[Course notes, Ver. 11/95]

Timoshenko, S. & Goodier, J.N., (1951). *Theory of Elasticity* (2nd Ed.). McGraw-Hill

Todd, F. B., (1980). The role of industrial engineering in shipyard production services. *Managing Ship Production* (Glasgow: University of Strathclyde, WEGEMT, 1980).

Trustteddocks.com. (2021, June 18) *Shipyards*. https://www.trusteddocks. com/catalog

Turan, E. & Cengiz, H. (2015). Turkish shipbuilding industry– challenges and potential. *Journal Brodogradnja (Shipbuilding), 66*:4, 87-101.

U.K. Department for Transport (DfT). (2023). *Shipping fleet statistics 2022*. (Table FLE0501: World fleet registered trading vessels of 100 gross tons and over, gross tonnage on selected registers: 1999 to 2022) [Data set]. U.K. Department for Transport. https://www.gov.uk/government/statistics/shipping-fleet-statistics-2022

UNCTAD, (2019). *Ships built by country of building, annual, 2014-2017*. (Data set). Conference on Trade and Development Stat. https://unctadstat.unctad.org/datacentre/us_shipbuilding_48736318800883

U.S. National Research Council. (1982). *Productivity improvements in U.S. naval shipbuilding.* National Research Council.

Varela, R., Murphy, H., & Linden M. van der., (2017). *Shipbuilding and ship repair workers around the world: Case studies 1950-2010.* Amsterdam University Press.

Walpole, R.E., Myers, R.H., Myers, S.L. & Ye,K., (2012). *Probability & statistics for engineers & scientists* (9th Ed.). Prentice Hall.

Weiers, B.J., (1984). *The productivity problem in United States shipbuilding.* (DOT-TSC-OST-84-2). U.S. Department of Transportation.

Wilmington, R., (2023). *Outlook 2023, A Special Report*. Lloyd'sList . https://lloydslist.com/special-reports/2022/outlook-2023

Woo, J. H., Zhu, H., Lee, D.K., Chung, H. & Jeong, Y., (2021). Assessment framework of smart shipyard maturity level via Data Envelopment Analysis. *Sustainability, 13,* 1964. https://doi.org/10.3390/su13041964

Xue, L., Shi, G. F., Dai, D. S., & Xu, Y. Z., (2020). Two-stage efficiency structure analysis model of shipbuilding based on driving factors: the case of Chinese shipyard. *Open Journal of Social Sciences, 8*, 182-200. https://doi.org/10.4236/jss.2020.82015

Yamane, T., (1967). *Statistics:An introductory analysis* (2nd Ed.). Harper and Row.

Yang, Y., Tang, W., & Ma, J., (2011). Analysis of shafting alignment for container vessels based on improved transition matrix method. *Procedia Engineering, 15,* 5373–5377. https://doi.org/10.1016/j.proeng.2011.08.996

Yıldırım, H. (2018). *Shipbuilding maturity and capability model (S-MCM)* [Doctoral thesis, Piri Reis University]. https://tez.yok.gov.tr/UlusalTezMerkezi/giris.jsp

Zakaria, N. M. G., Iqbal, K. S. & Hossain, K. A., (2010). Evaluation of the performance of contemporary shipbuilding industries in Bangladesh. *Journal of Naval Architecture and Marine Engineering, 7*:2, 73-82. https://doi.org/10.3329/ jname.v7i2.5407

Zhangpeng, G. & Flynn, M. (2006), Productive shipyards. *Lloyd's Shipping Economist*, *28*:6, 37-38.

APPENDIX A. EFFECTS

Table A.1: List of Effects based on groups and subgroups.

Nr.	EFFECT
11PSB00	**PRODUCTION : HULL BLOCKS (PSB)**
11PSB01	Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard
11PSB02	Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard
11PSB03	The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing
11PSB04	The use of CNC profile processing machine in the hull & superstructure blocks manufacturing
11PSB05	The use of roll/press/bender for sheet metal and profile bending processes
11PSB06	The use of welding robots in the hull & superstructure semi-block assembly stages
11PSB07	Categorization of block panel/assembly lines according to their difficulties
11PSB08	Use of jigs in the hull & superstructure blocks production
11PSB09	Block Blasting-Painting
11PSB10	Completion of outfitted or non-outfitted hull & superstructure blocks
12PSE00	**PRODUCTION : HULL ERECTION (PSE)**
12PSE01	Hull & Superstructure blocks erection
13PPT00	**PRODUCTION : PARTS MANUFACTURING (PPT)**
13PPT01	Metal joining techniques
13PPT02	Manufacturing and installation of piping systems in the ship
13PPT03	Cast parts and their machining
13PPT04	Use of high-tech materials
13PPT05	Production of parts and molds from 3D Printers
13PPT06	Manufacturing and installation automation, use of robots
14POS00	**PRODUCTION : OUTFITTING before Launching (POS)**
14POS01	Manufacturing and assembly of the outfit infrastructure elements
14POS02	Equipment to be taken into the block before the hull erection
14POS03	Use of modular "outfit-units"
14POS04	Outfitting after hull assembly
14POS05	Paint manufacturer
14POS06	External hull works, outfitting and painting
14POS07	Embarkation of the equipment on board
14POS08	Protection of the ship and equipment on board
14POS09	Provision of adequate capacity of compressed air, electricity, water, steam
15PLA00	**PRODUCTION : LAUNCHING (PLA)**
15PLA01	Ship launching

Table A.1: List of Effects based on groups and subgroups (continued).

Nr.	EFFECT
16POQ00	**PRODUCTION : OUTFITTING after Launching (POQ)**
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching
16POQ02	Minimum outfitting effort requirement after launching
21IFL00	**INFRASTRUCTURE : LAYOUT (IFL)**
21IFL01	Meteorological conditions
21IFL02	Shipyard closed/covered areas
21IFL03	Length of outfitting quay(s)(berth, pier)
21IFL04	Sea level at outfitting quay(s)(berth, pier)
21IFL05	Waiting (parking) area of the completed hull & superstructure blocks
21IFL06	Appropriate layout for material flow and workflow
21IFL07	Storage, warehousing
21IFL08	Work equipment, machine park proficiency
21IFL09	Minimum mobility requirement in the workstation area
21IFL10	Minimum worker movement distances
21IFL11	Sidewalks, walking zones
21IFL12	Minimum material movement distances
21IFL13	Transport of loads heavier than 23 kgs
21IFL14	Use of the hull-side elevator
21IFL15	Ventilation, air conditioning, illumination in working areas
21IFL16	Cleaning of work areas
22IEN00	**INFRASTRUCTURE : ENVIRONMENT (IEN)**
22IEN01	Energy saving and protection of natural resources; use of clean (green) energy
22IEN02	Hazardous waste management
23ITE00	**INFRASTRUCTURE: TECHNOLOGY (ITE)**
23ITE01	Utilizing up-to-date information technologies in shipbuilding
23ITE02	Information integration for shipyard automation systems
23ITE03	External integration of Shipyard Information System network
23ITE04	Research & Development (R&D) investments
23ITE05	Computer systems investments
23ITE06	Technical investments
24IFA00	**INFRASTRUCTURE : AMENITIES (IFA)**
24IFA01	Dressing-Lockers, Showers-Toilets
24IFA02	Dining-Resting areas
24IFA03	Proximity to public transport
24IFA04	Parking lots
24IFA05	Nursery (preschool, kinder-garten)
30DES00	**DESIGN & PRODUCTION ENGINEERING (DES)**
30DES01	Design methods
30DES02	Design method for design from scratch
30DES03	Level of difference between the design of the proposed ship and design of the contracted ship
30DES04	Conformance of the design to shipyard

Table A.1: List of Effects based on groups and subgroups (continued).

Nr.	EFFECT
30DES05	Design for Hull Block Outfitting
30DES06	"Design for Production"
30DES07	Compliance of design document deliveries with the ship production schedule
30DES08	Quality of design documents
30DES09	Easy-to-understand production design documentation
30DES10	Material/Parts Lists of work packages/workmanship drawings
30DES11	Plate & profile Part numbering system
30DES12	Sheet metalwork/Workpiece documents, numerical (digital) data
30DES13	Hot-works management
30DES14	Outfitting workmanship documents, installation instructions
30DES15	Clash detection in design
30DES16	Easy access of shipbuilding field workers to the ship's 3-dimensional design model
30DES17	Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers
30DES18	Equipment/system installation and operating instructions
30DES19	Consideration of Ship Acceptance Test requirements at early stages of design
30DES20	Technical Coordination with the Classification Society and the Buyer
30DES21	Project Configuration Management
30DES22	Ship weight management
40MPP00	**MATERIALS & PROCUREMENT (MPP)**
40MPP01	Selection of subcontractors/ manufacturers for the project
40MPP02	Contract/Purchase Form standardization in procurements
40MPP03	Long-term cooperation with subcontractors, manufacturers, suppliers
40MPP04	Local content
40MPP05	Geolocation
40MPP06	Correct material supply
40MPP07	Just-in-Time (JIT) arrival of the supplies
40MPP08	Delays in manufacturers' deliveries
40MPP09	Product Acceptance Inspections, Factory Acceptance Tests (FAT)
40MPP10	Supply of flawless products
40MPP11	Buyer furnished material-equipment-systems
40MPP12	Ship spares and First-outfit material procurement management
40MPP13	Preventive maintenance in the storage and on board
40MPP14	Storage/transport of heavy equipment/systems
51APL00	**SHIPBUILDING MANAGEMENT : PLANNING & BUDGETING (APL)**
51APL01	Shipbuilding Project Schedule groups
51APL02	Scope of the Shipbuilding Projects Labor Planning
51APL03	Integration of schedules
51APL04	Scheduling techniques
51APL05	Project scheduling simulations
51APL06	Dynamic schedule management : Continuous monitoring and feedback
51APL07	Dynamic schedule management : Progress and Budget evaluation
51APL08	Accurate time-schedules
51APL09	Accurate labor planning
51APL10	Job-order system
51APL11	Performance measurements, Efficiency calculations
51APL12	Job standardization; Visible indication of job performance metrics and values at the workstation

Table A.1: List of Effects based on groups and subgroups (continued).

Nr.	EFFECT
51APL13	Density of the Change Requests, Rework
51APL14	Production management - Field Engineering
51APL15	Project Progress Meetings, Reports
51APL16	Waiting times
51APL17	Unnecessary overproduction of parts
51APL18	Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period
51APL19	Work sharing
51APL20	Budget tracking methodology
51APL21	Cost control per unit time
51APL22	Tracking and management of operating costs, indirect costs
51APL23	Buy-Rent, Buy-Repair decisions, Service subcontracting decisions
51APL24	Speed of decision making to revise schedules to meet customer demands
52ARM00	**SHIPBUILDING MANAGEMENT : RISK MANAGEMENT (ARM)**
52ARM01	Preparation for the risks identified in PESTEL-SWOT analyzes
52ARM02	Risk management team
52ARM03	Project Risk management
52ARM04	Project Risk management breakdown
52ARM05	Change management
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions
61WOR00	**WORK FORCE : ORGANIZATION (WOR)**
61WOR01	Staff status of employees (shipyard's own etc.)
61WOR02	Number of experienced, permanent employees
61WOR03	Trained and experienced employees
61WOR04	Trained and experienced employee of the subcontractors
61WOR05	Quick Workgroups for repetitive tasks
61WOR06	Leveraging the learning curve
61WOR07	Backup of critical personnel
61WOR08	Work planning suitable for the personnel with special conditions
62WPP00	**WORK FORCE : PERFORMANCE & PRACTICES (WPP)**
62WPP01	Use of Subcontractors (If subcontractor(s) is/are used)
62WPP02	Hull & Superstructure Blocks construction subcontractor (if any)
62WPP03	Hull Steel Outfitting Subcontractors (if any)
62WPP04	Hull Outfitting Subcontractors (Equipment, if any)
62WPP05	Blasting-Painting Subcontractors (if any)
62WPP06	Pipe Manufacturing Subcontractor (if any)
62WPP07	Pipe Installation Subcontractor (if any)
62WPP08	Insulation Subcontractor (if any)
62WPP09	Deck Covering Subcontractor (if any)
62WPP10	Main Propulsion System Installation Subcontractor (if any)
62WPP11	Ship Service Systems Subcontractors (if any)
62WPP12	Ship Electrical System Installation Subcontractor (if any)
62WPP13	Cable Trays Installation Subcontractor (if any)
62WPP14	Cable Pulling Subcontractor (if any)
62WPP15	Ship Electronics/Navigation Systems Installation Subcontractor (if any)
62WPP16	HVAC Ducts Manufacturing Subcontractor (if any)

Table A.1: List of Effects based on groups and subgroups (continued).

Nr.	EFFECT
62WPP17	HVAC Ducting Installation Subcontractor (if applicable)
62WPP18	HVAC System Installation Subcontractor (if any)
62WPP19	Ship Launching Subcontractor
62WPP20	Tank Cleaning/Preparation Subcontractor (if any)
62WPP21	General Service Subcontractor (ship cleaning etc., if any)
62WPP22	Staging/Scaffolding Construction/Dismantling Subcontractor (if any)
62WPP23	Manufacturers' technical support
63WPM00	**WORKFORCE : MOTIVATION (WPM)**
63WPM01	Believing in being a good shipyard, motivation
63WPM02	Efficient, productive work
63WPM03	Wages, salaries
63WPM04	Promotions
63WPM05	Employee circulation
63WPM06	Job descriptions, work sharing
63WPM07	Occupational safety
63WPM08	Protective clothing, safety equipment
63WPM09	Work ergonomics
63WPM10	Improvement suggestions
63WPM11	Negative work psychology
63WPM12	Compliance with working hours
70QAC00	**QUALITY (QAC)**
70QAC01	Effectiveness of the Quality Assurance System
70QAC02	Quality Assurance certification status
70QAC03	Quality control
70QAC04	Dimensional accuracy control in hull construction
70QAC05	Welding quality
70QAC06	Stopping the production in case of faulty production detection
70QAC07	Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management
70QAC08	Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)
70QAC09	Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment
70QAC10	Yard Trial - Preliminary check of Sea Trials (SAT) preparations
70QAC11	Availability of a Quick Defects Repair Team
81CMC00	**CONTRACTING : MAIN CONTRACT (CMC)**
81CMC01	Pre-review of an incoming query
81CMC02	Bid/Proposal preparation standardization
81CMC03	Shipbuilding Contract preparations
81CMC04	Participation in Shipbuilding Contract negotiations
81CMC05	The governing law for the contracts
82CSC00	**CONTRACTING : SUBCONTRACTS (CSC)**
82CSC01	Subcontractor Contracts preparations
82CSC02	Participation in Subcontractor Contract negotiations

APPENDIX B. EFFECTS' DISTRIBUTION LIST

Table B.1: Effects 'distribution (repeat) to processes and subprocesses.

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
11PSB00	**PRODUCTION : HULL BLOCKS (PSB)**										
11PSB01	Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard				+						
11PSB02	Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard				+						
11PSB03	The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing				+						
11PSB04	The use of CNC profile processing machine in the hull & superstructure blocks manufacturing				+						
11PSB05	The use of roll/press/bender for sheet metal and profile bending processes				+						
11PSB06	The use of welding robots in the hull & superstructure semi-block assembly stages				+						
11PSB07	Categorization of block panel/assembly lines according to their difficulties				+						
11PSB08	Use of jigs in the hull & superstructure blocks production				+						
11PSB09	Block Blasting-Painting				+						
11PSB10	Completion of outfitted or non-outfitted hull & superstructure blocks				+						
12PSE00	**PRODUCTION : HULL ERECTION (PSE)**										
12PSE01	Hull &Superstructure blocks erection					+					

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
13PPT00	**PRODUCTION : PARTS MANUFACTURING (PPT)**										
13PPT01	Metal joining techniques				+	+	+				
13PPT02	Manufacturing and installation of piping systems in the ship						+	+			
13PPT03	Cast parts and their machining						+				
13PPT04	Use of high-tech materials						+				
13PPT05	Production of parts and molds from 3D Printers						+				
13PPT06	Manufacturing and installation automation, use of robots				+	+	+	+			
14POS00	**PRODUCTION : OUTFITTING before Launching (POS)**										
14POS01	Manufacturing and assembly of the outfit infrastructure elements				+		+	+			
14POS02	Equipment to be taken into the block before the hull erection				+			+			
14POS03	Use of modular "outfit-units"	+						+			
14POS04	Outfitting after hull assembly							+			
14POS05	Paint manufacturer				+			+		+	
14POS06	External hull works, outfitting and painting					+		+		+	
14POS07	Embarkation of the equipment on board							+		+	
14POS08	Protection of the ship and equipment on board							+	+	+	
14POS09	Provision of adequate capacity of compressed air, electricity, water, steam					+		+		+	+
15PLA00	**PRODUCTION : LAUNCHING (PLA)**										
15PLA01	Ship launching								+		
16POQ00	**PRODUCTION : OUTFITTING after Launching (POQ)**										
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching									+	
16POQ02	Minimum outfitting effort requirement after launching									+	
21IFL00	**INFRASTRUCTURE : LAYOUT (IFL)**										

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
21IFL01	Meteorological conditions	+			+	+	+	+	+	+	+
21IFL02	Shipyard closed/covered areas	+			+	+	+	+	+		
21IFL03	Length of outfitting quay(s)(berth, pier)	+								+	
21IFL04	Sea level at outfitting quay(s)(berth, pier)	+								+	
21IFL05	Waiting (parking) area of the completed hull & superstructure blocks	+			+	+					
21IFL06	Appropriate layout for material flow and workflow	+			+	+	+	+	+	+	
21IFL07	Storage, warehousing	+			+	+	+	+	+	+	
21IFL08	Work equipment, machine park proficiency	+			+	+	+	+	+	+	+
21IFL09	Minimum mobility requirement in the workstation area	+			+	+	+	+	+		
21IFL10	Minimum worker movement distances	+			+	+	+	+			
21IFL11	Sidewalks, walking zones	+			+	+	+	+	+	+	+
21IFL12	Minimum material movement distances	+			+		+	+	+		
21IFL13	Transport of loads heavier than 23 kgs	+			+	+	+	+	+	+	+
21IFL14	Use of the hull-side elevator	+				+		+		+	
21IFL15	Ventilation, air conditioning, illumination in working areas	+			+	+	+	+	+		
21IFL16	Cleaning of work areas	+	+		+	+	+	+	+	+	+
22IEN00	**INFRASTRUCTURE : ENVIRONMENT (IEN)**										
22IEN01	Energy saving and protection of natural resources; use of clean (green) energy	+			+	+	+	+			
22IEN02	Hazardous waste management	+			+	+	+	+	+	+	
23ITE00	**INFRASTRUCTURE: TECHNOLOGY (ITE)**										
23ITE01	Utilizing up-to-date information technologies in shipbuilding	+									
23ITE02	Information integration for shipyard automation systems	+	+								
23ITE03	External integration of Shipyard Information System network	+	+								
23ITE04	Research & Development (R&D) investments	+	+								
23ITE05	Computer systems investments	+	+								
23ITE06	Technical investments	+			+	+	+	+	+	+	

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
24IFA00	**INFRASTRUCTURE : AMENITIES (IFA)**										
24IFA01	Dressing-Lockers, Showers-Toilets	+	+		+	+	+	+	+	+	+
24IFA02	Dining-Resting areas	+	+		+	+	+	+	+	+	+
24IFA03	Proximity to public transport	+	+		+	+	+	+	+	+	+
24IFA04	Parking lots	+	+		+	+	+	+	+	+	+
24IFA05	Nursery (preschool, kinder-garten)	+	+		+	+	+	+	+	+	+
30DES00	**DESIGN & PRODUCTION ENGINEERING (DES)**										
30DES01	Design methods		+								
30DES02	Design method for design from scratch		+								
30DES03	Level of difference between the design of the proposed ship and design of the contracted ship		+	+							
30DES04	Conformance of the design to shipyard		+								
30DES05	Design for Hull Block Outfitting		+								
30DES06	"Design for Production"		+								
30DES07	Compliance of design document deliveries with the ship production schedule		+		+	+	+	+	+	+	
30DES08	Quality of design documents		+		+	+	+	+	+	+	+
30DES09	Easy-to-understand production design documentation		+		+	+	+	+	+	+	
30DES10	Material/Parts Lists of work packages/workmanship drawings		+		+	+	+	+		+	
30DES11	Plate & profile Part numbering system		+		+		+				
30DES12	Sheet metalwork/Workpiece documents, numerical (digital) data		+		+		+				
30DES13	Hot-works management		+		+	+	+	+			
30DES14	Outfitting workmanship documents, installation instructions		+					+		+	
30DES15	Clash detection in design		+								
30DES16	Easy access of shipbuilding field workers to the ship's 3-dimensional design model		+		+	+		+		+	
30DES17	Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers	+	+								

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
30DES18	Equipment/system installation and operating instructions		+					+		+	+
30DES19	Consideration of Ship Acceptance Test requirements at early stages of design	+	+	+							+
30DES20	Technical Coordination with the Classification Society and the Buyer	+	+								
30DES21	Project Configuration Management	+	+								
30DES22	Ship weight management	+	+								
40MPP00	**MATERIALS & PROCUREMENT (MPP)**										
40MPP01	Selection of subcontractors/ manufacturers for the project	+	+	+							
40MPP02	Contract/Purchase Form standardization in procurements	+	+	+							
40MPP03	Long-term cooperation with subcontractors, manufacturers, suppliers	+	+	+							
40MPP04	Local content	+	+	+							
40MPP05	Geolocation	+									
40MPP06	Correct material supply	+	+		+	+	+	+	+	+	+
40MPP07	Just-in-Time (JIT) arrival of the supplies	+									
40MPP08	Delays in manufacturers' deliveries	+									
40MPP09	Product Acceptance Inspections, Factory Acceptance Tests (FAT)	+	+								
40MPP10	Supply of flawless products	+									+
40MPP11	Buyer furnished material-equipment-systems	+	+					+		+	+
40MPP12	Ship spares and First-outfit material procurement management	+	+								
40MPP13	Preventive maintenance in the storage and on board	+									
40MPP14	Storage/transport of heavy equipment/systems	+			+	+	+	+	+	+	
51APL00	**SHIPBUILDING MANAGEMENT : PLANNING & BUDGETING (APL)**										
51APL01	Shipbuilding Project Schedule groups	+	+	+							
51APL02	Scope of the Shipbuilding Projects Labor Planning	+	+		+	+	+	+	+	+	+
51APL03	Integration of schedules	+	+								
51APL04	Scheduling techniques	+	+								
51APL05	Project scheduling simulations	+									

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
51APL06	Dynamic schedule management : Continuous monitoring and feedback	+	+		+	+	+	+	+	+	+
51APL07	Dynamic schedule management : Progress and Budget evaluation	+									
51APL08	Accurate time-schedules	+	+	+	+	+	+	+	+	+	+
51APL09	Accurate labor planning	+	+		+	+	+	+	+	+	+
51APL10	Job-order system	+			+	+	+	+	+	+	+
51APL11	Performance measurements, Efficiency calculations	+	+		+	+	+	+	+	+	+
51APL12	Job standardization; Visible indication of job performance metrics and values at the workstation	+	+		+	+	+	+	+	+	
51APL13	Density of the Change Requests, Rework	+	+		+	+	+	+		+	
51APL14	Production management - Field Engineering	+	+		+	+	+	+	+	+	+
51APL15	Project Progress Meetings, Reports	+	+		+	+	+	+	+	+	+
51APL16	Waiting times	+	+		+	+	+	+	+	+	+
51APL17	Unnecessary overproduction of parts	+			+		+				
51APL18	Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period	+									
51APL19	Work sharing	+	+		+						
51APL20	Budget tracking methodology	+	+								
51APL21	Cost control per unit time	+	+								
51APL22	Tracking and management of operating costs, indirect costs	+	+								
51APL23	Buy-Rent, Buy-Repair decisions, Service subcontracting decisions	+									
51APL24	Speed of decision making to revise schedules to meet customer demands	+	+								
52ARM00	**SHIPBUILDING MANAGEMENT : RISK MANAGEMENT (ARM)**										
52ARM01	Preparation for the risks identified in PESTEL-SWOT analyzes	+		+							
52ARM02	Risk management team	+		+							
52ARM03	Project Risk management	+	+	+							
52ARM04	Project Risk management breakdown	+		+							
52ARM05	Change management	+	+	+							
52ARM06	Identification of the risks which may result in delay the	+	+	+							

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
	delivery of the ship or prevent the delivery; taking precautions										
61WOR00	**WORK FORCE : ORGANIZATION (WOR)**										
61WOR01	Staff status of employees (shipyard's own etc.)	+	+		+	+	+	+	+	+	+
61WOR02	Number of experienced, permanent employees	+	+		+	+	+	+	+	+	+
61WOR03	Trained and experienced employees	+	+		+	+	+	+	+	+	+
61WOR04	Trained and experienced employee of the subcontractors	+	+								
61WOR05	Quick Workgroups for repetitive tasks	+	+		+	+	+	+	+	+	+
61WOR06	Leveraging the learning curve	+			+	+		+		+	+
61WOR07	Backup of critical personnel	+	+		+	+	+	+	+	+	+
61WOR08	Work planning suitable for the personnel with special conditions	+	+		+	+	+	+	+	+	+
62WPP00	**WORK FORCE : PERFORMANCE & PRACTICES (WPP)**										
62WPP01	Use of Subcontractors (If subcontractor(s) is/are used)	+						+			
62WPP02	Hull & Superstructure Blocks construction subcontractor (if any)	+			+						
62WPP03	Hull Steel Outfitting Subcontractors (if any)	+				+		+			
62WPP04	Hull Outfitting Subcontractors (Equipment, if any)	+			+			+		+	+
62WPP05	Blasting-Painting Subcontractors (if any)	+			+						
62WPP06	Pipe Manufacturing Subcontractor (if any)	+					+				
62WPP07	Pipe Installation Subcontractor (if any)	+			+			+		+	+
62WPP08	Insulation Subcontractor (if any)	+			+			+		+	
62WPP09	Deck Covering Subcontractor (if any)	+								+	
62WPP10	Main Propulsion System Installation Subcontractor (if any)	+				+		+		+	+
62WPP11	Ship Service Systems Subcontractors (if any)	+						+		+	+
62WPP12	Ship Electrical System Installation Subcontractor (if any)	+						+		+	+
62WPP13	Cable Trays Installation Subcontractor (if any)	+						+		+	
62WPP14	Cable Pulling Subcontractor (if any)	+						+		+	

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
62WPP15	Ship Electronics/Navigation Systems Installation Subcontractor (if any)	+								+	+
62WPP16	HVAC Ducts Manufacturing Subcontractor (if any)	+					+	+			
62WPP17	HVAC Ducting Installation Subcontractor (if applicable)	+						+		+	
62WPP18	HVAC System Installation Subcontractor (if any)	+						+		+	+
62WPP19	Ship Launching Subcontractor	+							+		
62WPP20	Tank Cleaning/Preparation Subcontractor (if any)	+						+		+	+
62WPP21	General Service Subcontractor (ship cleaning etc., if any)	+						+	+	+	+
62WPP22	Staging/Scaffolding Construction/Dismantling Subcontractor (if any)	+				+		+	+	+	
62WPP23	Manufacturers' technical support	+	+					+		+	+
63WPM00	**WORKFORCE : MOTIVATION (WPM)**										
63WPM01	Believing in being a good shipyard, motivation	+	+	+	+	+	+	+	+	+	+
63WPM02	Efficient, productive work	+	+		+	+	+	+	+	+	+
63WPM03	Wages, salaries	+	+	+	+	+	+	+	+	+	+
63WPM04	Promotions	+	+	+	+	+	+	+	+	+	+
63WPM05	Employee circulation	+	+	+	+	+	+	+	+	+	+
63WPM06	Job descriptions, work sharing	+	+	+	+	+	+	+	+	+	+
63WPM07	Occupational safety	+			+	+	+	+	+	+	+
63WPM08	Protective clothing, safety equipment	+	+		+	+	+	+	+	+	+
63WPM09	Work ergonomics	+	+		+	+	+	+	+	+	+
63WPM10	Improvement suggestions	+	+	+	+	+	+	+	+	+	+
63WPM11	Negative work psychology	+	+		+	+	+	+	+	+	+
63WPM12	Compliance with working hours	+	+		+	+	+	+	+	+	+
70QAC00	**QUALITY (QAC)**										
70QAC01	Effectiveness of the Quality Assurance System	+	+		+	+	+	+	+	+	+
70QAC02	Quality Assurance certification status	+	+								
70QAC03	Quality control	+	+		+	+	+	+	+	+	
70QAC04	Dimensional accuracy control in hull construction		+		+	+					
70QAC05	Welding quality				+	+	+	+			

Table B.1: Effects 'distribution (repeat) to processes and subprocesses (cont'd).

Nr.	EFFECT	Processes and subprocesses									
		MNG	DES	SHIP PRODUCTION							
				CON	BLK	ASLY	PPT	OUT	LCH	QAY	TEST
70QAC06	Stopping the production in case of faulty production detection	+			+	+	+	+	+	+	
70QAC07	Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management	+									+
70QAC08	Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)	+									+
70QAC09	Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment	+	+								+
70QAC10	Yard Trial - Preliminary check of Sea Trials (SAT) preparations	+									+
70QAC11	Availability of a Quick Defects Repair Team	+									+
81CMC00	**CONTRACTING : MAIN CONTRACT (CMC)**										
81CMC01	Pre-review of an incoming query			+							
81CMC02	Bid/Proposal preparation standardization	+	+	+							
81CMC03	Shipbuilding Contract preparations	+		+							
81CMC04	Participation in Shipbuilding Contract negotiations	+	+	+							
81CMC05	The governing law for the contracts			+							
82CSC00	**CONTRACTING : SUBCONTRACTS (CSC)**										
82CSC01	Subcontractor Contracts preparations			+							
82CSC02	Participation in Subcontractor Contract negotiations			+							

APPENDIX C. EFFECT SUB-DETAILS AND MAGNITUDE CHOICES

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices.

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
11PSB00	**PRODUCTION : HULL BLOCKS (PSB)**		
11PSB01	**Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard**		
11PSB01.(1)	*Primer paint status of purchased plates (steel or else) when arrive at the Shipyard*	1	They always arrive as the shop primer applied
		2	Mostly the shop primer is applied. There is also a primer paint system in the plate storage area
		3	In half of the projects, plates arrive as the shop primer paint has been applied. There is also a primer paint system in the plate storage area
		4	Sometimes the plates arrive as shop primer applied. There is also a primer paint system in the plate storage area
		5	They arrive in the shipyard as unprimed. Shop primer is not applied at all (or sometimes it is applied manually or with a gun-spray)
11PSB01.(2)	*Distance of sheet plate storage area to plate cutting machine(s)*	1	Very close (approximately 100 meters and below)
		2	Close (approximately 100 - 200 meters)
		3	Medium distance (approximately 300 - 400 meters)
		4	Remote (approximately 400 - 500 meters)
		5	Too far (more than 500 meters)
11PSB01.(3)	*Method of separation of the plates in the plate storage area*	1	Always according to material types and thicknesses
		2	Generally, according to material types and thicknesses
		3	Only according to their thicknesses
		4	Only by material type
		5	Without any separation on material type and thickness
11PSB01.(4)	*Plates' transfer method from storage area to the hull fabrication shop (magnetic crane, roller, etc.)*	1	By the crane (magnetic etc.) and roller/conveyor systems
		2	By a crane (magnetic etc.)
		3	By the roller/conveyor system
		4	By a forklift, tractor trailer, truck etc.
		5	By a hand carriage etc.

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
11PSB02	**Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard**		
11PSB02.(1)	*Primer paint status of purchased profiles when they arrive at the Shipyard*	1	They always arrive as the shop primer applied
		2	Mostly the shop primer is applied. There is also a primer paint system in the shipyard
		3	In half of the projects, plates arrive as the shop primer paint has been applied. There is also a primer paint system in the shipyard
		4	Sometimes the profiles arrive as shop primer applied. There is also a primer paint system in the shipyard
		5	They arrive in the shipyard as unprimed. Primer paint is not applied at all (or sometimes it is applied manually or with a gun-spray
11PSB02.(2)	*Distance of profile stowage to profile processing machine(s)*	1	Very close (approximately 100 meters and below)
		2	Close (approximately 100 - 200 meters)
		3	Medium distance (approximately 300 - 400 meters)
		4	Remote (approximately 400 - 500 meters)
		5	Too far (more than 500 meters)
11PSB02.(3)	*Method of separation of the profiles at the profile stowage*	1	Always according to material types, shapes and thicknesses
		2	Generally, according to material types, shapes and thicknesses
		3	Only according to their material types
		4	Only by shape
		5	Without any separation on material type, shape and thickness.
11PSB03	**The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing**		
11PSB03.(1)	*Number of CNC plasma cutting machines and whether they all use the same type of nesting-cutting software*	1	There are at least 2 (two) CNC plasma cutting machines; at least 2 (two) machines use the data from the same type of nesting-cutting software
		2	There is at least 1 (one) CNC plasma machine, but in projects, most of the time plates arrive in the Shipyard as already cut
		3	There are at least 2 (two) CNC plasma cutting machines; they receive data from different types of nesting-cutting software
		4	There is 1 (one) CNC flame cutting machine
		5	There is no CNC flame cutting machine; in all projects, plates arrive in the Shipyard as already cut
11PSB03.(2)	*Beveling on the plates by the CNC machine*	1	Always
		2	Bevels are cut by CNC plasma cutting machine. However, in projects, mostly plates arrive in the Shipyard as their bevels cut
		3	Bevels are cut by CNC plasma cutting machine. However, sometimes in projects, plates arrive in the Shipyard with their bevels cut
		4	Bevels are sometimes cut by CNC plasma cutting machine and sometimes by hand grinding after they are cut
		5	Bevels of the plates are cut manually by hand grinding after they are cut

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
11PSB03.(3)	*Availability of a submerged type of plasma or laser or pressure water plate cutting machine to cut thin plates with reduced deformation/distortion*	1	At least 2 (two) of the CNC plasma cutting machines are submerged type; In addition, there is at least 1 (one) laser beam or water jet cutting machine
		2	There is 1 (one) submerged type CNC plasma cutting machine. In addition, there are at least 1 (one) laser beam or water jet cutting machine.
		3	There is 1 (one) laser beam or water jet cutting machine
		4	There is 1 (one) submerged type CNC plasma cutting machine
		5	There is no submerged type of plate cutting machine, laser beam or water jet cutting machine
11PSB04	**The use of CNC profile processing machine in the hull & superstructure blocks manufacturing**		
11PSB04.(1)	*Number of CNC plasma cutting machines and whether they all use the same type of nesting-cutting software*	1	There are at least 2 (two) CNC profile processing machines; at least 2 (two) machines receive data from the same type of profile processing software
		2	There are at least 2 (two) CNC profile processing machines; they receive data from different types of profile processing software
		3	There is 1 (one) CNC profile processing machine
		4	There is no CNC profile processing machine; for the projects, the profiles arrive in the Shipyard already processed
		5	There is 1 (one) non-CNC profile processing machine
11PSB04.(2)	*Beveling on the profiles by the CNC profile processing machine*	1	Always
		2	Bevels are opened by the profile processing machine. However, in projects, mostly shipbuilding profiles arrive in the Shipyard with their bevels cut
		3	Bevels are opened by the CNC profile processing machine. However, in projects, sometimes shipbuilding profiles arrive in the Shipyard with their bevels cut
		4	Bevels are sometimes opened by CNC profile processing machine, sometimes by hand by grinding
		5	Bevels of the profiles are opened manually by grinding
11PSB05	**The use of roll/press/bender for sheet metal and profile bending processes**		
11PSB05.(1)	*The number of rolls/presses/benders for sheet metal and profile bending processes; using sheet/profile bending software*	1	There are at least 2 (two) 3-roll variable-axis plate bending and profile bending machines. These machines receive data from the same type of plate/profile bending software
		2	Sheets and/or profiles arrive in the Shipyard as bended
		3	There are at least 2 (two) 3-roll variable-axis plate bending and profile bending machines. These machines receive data from different types of plate/profile bending software
		4	There is 1 (one) 3-roll variable-axis plate bending and profile bending machine
		5	Plate bending and profile bending machines are not available

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
11PSB06	**The use of welding robots in the hull & superstructure semi-block assembly stages**		
11PSB06.(1)	*The use of sheet metal and profile welding robots in the hull & superstructure semi-block assembly stages*	1	There are at least 2 (two) plate welding robots and at least 2 (two) profile welding robots
		2	In projects, panels arrive in the shipyard as their welds are completed
		3	1 (one) plate welding robot and 1 (one) profile welding robot are available
		4	There is at least 1 (one) plate welding robot or at least 1 (one) profile welding robot
		5	Plate and profile welding robots are not available
11PSB07	**Categorization of block panel/assembly lines according to their difficulties**		
11PSB07.(1)	*Categorization of block panel/assembly lines according to their difficulties (i.e., eggbox, curved, flat etc.)*	1	This is applied for all hull and superstructure panels/blocks
		2	Only flat and curved panel/block distinction is made, superstructure blocks are manufactured at a separate line
		3	Only flat and curved panel/block distinction is made
		4	Only the forward block and the aft block are manufactured at a separate line, such a distinction is not made in other panels/blocks
		5	No such distinction is made
11PSB08	**Use of jigs in the hull & superstructure blocks production**		
11PSB08.(1)	*Use of jigs in the hull & superstructure blocks production; use of easily adjustable jigs (e.g., pin-jigs)*	1	They are pin-jig (adjustable) type and a flat-bed truck/heavy lift crawler can get under
		2	They are pin-jig (adjustable) type but a flat-bed truck/heavy lift crawler cannot get under
		3	They are solid-welded type and a flat-bed truck/heavy lift crawler can get under
		4	They are solid-welded type but a flat-bed truck/heavy lift crawler cannot get under
		5	Jigs are generally not used for blocks
11PSB09	**Block Blasting-Painting**		
11PSB09.(1)	*Dimensions and facilities of the Block Blasting-Painting hall*	1	There is at least 1 (one) completely closed blasting & painting facility with automatic cleaning system and high-quality ventilation system. In there at least 2 (two) ship blocks can be simultaneously blasted & primered and painted as until the final coat or at a level close to the final coat
		2	There is at least 1 (one) completely closed blasting & painting facility with automatic cleaning system and high-quality ventilation system. In there at least 2 (two) ship blocks can be simultaneously blasted & primered
		3	There is at least 1 (one) completely closed blasting & painting facility. In there at least 2 (two) ship blocks can be simultaneously blasted & primed
		4	There is at least 1 (one) blasting &painting facility. In there 1 (one) ship block can be blasted & primed
		5	There is no separate blasting & painting facility, it is done in a temporary facility or outdoors

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
11PSB10	**Completion of outfitted or non-outfitted hull & superstructure blocks**		
11PSB10.(1)	*Weights of outfitted or non-outfitted hull & superstructure blocks when completed*	1	Above 600 tons
		2	Up to 600 tons
		3	Up to 300 tons
		4	Up to 150 tons
		5	Up to 50 tons
11PSB10.(2)	*Distance between the hull erection area and the location where the hull & superstructure blocks are parked*	1	Very close (around 100 m.)
		2	Close (around 100-200 m.)
		3	Medium distance (around 200-300 m.)
		4	Remote (around 300-500 m.)
		5	Too far (more than 500 m.)
11PSB10.(3)	*Method of transferring hull & superstructure blocks to the hull erection area*	1	Since the hull block construction area is next to the erection area, they are lifted and transferred only by the crane
		2	By a rail system
		3	On a flat-bed truck/heavy-lift crawler
		4	By a sea/river/canal transport vessel
		5	On a trailer
12PSE00	**PRODUCTION : HULL ERECTION (PSE)**		
12PSE01	**Hull & Superstructure blocks erection**		
12PSE01.(1)	*Speed of block erection welding*	1	Since accuracy control is carried out continuously and correctly during block construction, welding for block erections is made very quickly
		2	(Left blank)
		3	Since measurement controls are partially carried out during the block construction, welding for block erections is made in an acceptable time period
		4	(Left blank)
		5	Measurement controls are not carried out during the block construction, welding for block erections take long time
12PSE01.(2)	*Use of allowance for block erection edge hull/deck plating*	1	Since accuracy control is carried out continuously and correctly during the block construction, no allowance is used for the erection the blocks
		2	Since accuracy control is carried out continuously and correctly during the block construction, less than 20 mm. allowance is used for the erection the blocks
		3	Between 20- and 50-mm. allowance is used.
		4	(Left blank)
		5	More than 50 mm. allowance is used. Additional plating or filling by weld is used when necessary
12PSE01.(3)	*Block erection welding method*	1	Erection welding is made from the outside using a welding robot, using methods such as ceramic welding
		2	Erection welding is made by welding from one side, using methods such as ceramic welding
		3	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	(Left blank)
		5	Erection welding is made on both sides, inside and outside of the hull
13PPT00	**PRODUCTION : PARTS MANUFACTURING (PPT)**		
13PPT01	**Metal joining techniques**		
13PPT01.(1)	*Application of most recent metal joining techniques (friction stir welding etc.) in shipbuilding and other thin sheet metal welding & other joining works*	1	Totally agree
		2	(Left blank)
		3	Implemented at medium level, it is not competitive
		4	(Left blank)
		5	Old technology is used, it is not competitive
13PPT02	**Manufacturing and installation of piping systems in the ship**		
13PPT02.(1)	*Automation in pipe fabrication*	1	Pipe fabrication is done in the fully automated pipe workshop (pipe stacking, bending, welding, testing) of the Shipyard
		2	Pipe fabrication is carried out by subcontractors with full automation (pipe stacking, bending, welding, testing) in their own facilities
		3	Pipe fabrication is done in the shipyard's pipe workshop, with limited automation
		4	Pipe fabrication is done in the shipyard's pipe workshop, which has no automation
		5	Pipe fabrication is done by subcontractors with limited or no automation
13PPT02.(2)	*Pipe installation in hull blocks, in the ship*	1	Piping installation in the hull blocks and assembly onboard is carried out by the shipyard personnel in line with the time schedule
		2	Piping installation in the hull blocks and assembly onboard is carried out by the subcontractor's personnel in line with the time schedule
		3	Piping installation and assembly onboard is carried out by the shipyard personnel in line with the time schedule
		4	Piping installation and assembly onboard is carried out by the subcontractor's personnel in line with the time schedule
		5	Piping installation and assembly onboard is carried out by the shipyard or subcontractor's personnel in line with occasional delays
13PPT03	**Cast parts and their machining**		
13PPT03.(1)	*Application of modern techniques for the production, processing and coating (galvanizing etc.) of cast parts*	1	Subcontractors carry out the production and processes at the desired quality, flawlessly and on time
		2	Shipyard owns modern facilities that produce small-sized (valves, etc.) parts at the desired quality and flawlessly; subcontractors produce large casting parts (rudder horn, etc.) and deliver them at the desired quality and on time
		3	Shipyard owns modern facilities that produce parts at the desired quality and flawlessly
		4	Subcontractors produce the parts, partially at the desired quality and generally deliver on time

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		5	Shipyard owns non-modern facilities which produce the parts, partially at the desired quality
13PPT04	**Use of high-tech materials**		
13PPT04.(1)	*Availability of manufacturing technologies suitable for the use of materials such as high-strength steels, thin sheet metal, aluminum and composites in shipbuilding and outfitting*	1	Fully available in the shipyard
		2	Not available in the shipyard. Such manufacturing is done by competent Subcontractors
		3	Available on a limited basis in the shipyard
		4	(Left blank)
		5	Not available in he shipyard
13PPT05	**Production of parts and molds from 3D Printers**		
13PPT05.(1)	*Manufacturing of parts and molds from industrial type 3D Printers*	1	It is applied intensively in the shipyard. There are at least 2 (two) industrial type 3-D printers
		2	It is intensively implemented by the subcontractors
		3	It is applied on a limited basis in the shipyard. There is at least 1 (one) industrial type 3-D printer
		4	There is at least 1 (one) industrial type 3-D printer in the shipyard. However, no parts have been manufactured to date.
		5	There are no production activities using 3-D printers
13PPT06	**Manufacturing and installation automation, use of robots**		
13PPT06.(1)	*Use of robotic technologies in manufacturing and outfitting*	1	It is used extensively in the shipyard
		2	(Left blank)
		3	It is applied to a limited extent in the shipyard.
		4	(Left blank)
		5	It is not implemented in the shipyard.
13PPT06.(2)	*Manufacturing/outfitting with only robots and automated systems in the second/night shift*	1	Yes
		2	Left blank)
		3	Partially
		4	Left blank)
		5	No
14POS00	**PRODUCTION : OUTFITTING before Launching (POS)**		
14POS01	**Manufacturing and assembly of the outfit infrastructure elements**		
14POS01.(1)	*Manufacturing and assembly of the outfit infrastructure elements(welded parts, hangers, carcasses, etc.) during the hull & superstructure blocks assembly*	1	All welded parts (foundations, flats, carcasses, etc.), pipe hangers, HVAC system ducting hangers, cable way/tray hangers, pipes and pipe elements, cable ways/trays , HVAC system ducts, partition bulkheads and ceiling covering carcasses, profiles, deck fittings (bollards, cleats etc.) are installed during the block construction
		2	All welded parts (foundations, flats, carcasses, etc.), pipe hangers, HVAC system ducting hangers, cable way/tray hangers, pipes are installed during the block construction
		3	All welded parts (foundations, flats, carcasses, etc.), pipe hangers, HVAC system ducting hangers, cable

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
			way/tray hangers are installed during the block construction
		4	All welded parts (foundations, flats, carcasses, etc.) are installed during the block construction
		5	No hot-works, outfitting during the block construction, all are welded and installed on the hull after the block erection
14POS02	**Equipment to be taken into the block before the hull erection**		
14POS02.(1)	*Equipment outfit level of the hull & superstructure blocks after block assembly, before hull erection*	1	Ship service equipment units that can be installed during the block construction (pump units with mounted pipes, compressor units, fresh water makers, etc.) are prepared separately in the form of pallets before/during the block construction phase in the shipyard or come from subcontractors. After the paint underneath, behind them and insulation, etc., they are installed in the block before block erection
		2	Ship service equipment that can be installed during the block construction (pump units with mounted pipes, compressor units, fresh water makers, etc.) arrive in the shipyard from the subcontractors before/during the block construction phase. After the paint underneath, behind them and insulation, etc., they are installed in the block before block erection
		3	Ship service equipment that can be installed during the block construction (pump units with mounted pipes, compressor units, fresh water makers, etc.) arrive in the shipyard from the subcontractors before/during the block construction phase. They are taken into the blocks with no preparation underneath and behind; they are installed temporarily or permanently in the block before block erection
		4	A very limited number of equipment arrive in the shipyard from the subcontractors before/during the block construction phase. They are taken into the blocks with or without preparation underneath and behind; then they are installed temporarily or permanently in the block before block erection
		5	No equipment is installed during the block construction period
14POS03	**Use of modular "outfit-units"**		
14POS03.(1)	*Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"*	1	It is very high
		2	It is between high and medium
		3	It is at a medium level
		4	It is at a medium-low level
		5	It is very low
14POS04	**Outfitting after hull assembly**		
14POS04.(1)	*Outfitting after hull assembly*	1	All welded parts (foundations, flats, carcasses, etc.), pipe hangers, HVAC system ducting hangers, cable way/tray hangers, pipes and pipe elements, cable ways/trays , HVAC system ducts, partition bulkheads and ceiling covering carcasses, profiles, deck fittings (bollards, cleats etc.) were previously installed during the block construction. Their installation is finalized at this stage

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		2	(Left blank)
		3	Some of the welded parts are mounted in the block during the block construction phase. At this stage, the standard ceiling carcass and bulkhead fixtures are mounted, followed by mounting of pipe hangers, HVAC system ducting hangers, cable ways/tray hangers, pipes and pipefittings, cable ways/trays, HVAC system ducts on these standard carcasses and fixtures
		4	(Left blank)
		5	All welded parts (foundations, flats, carcasses, etc.), pipe hangers, HVAC system ducting hangers, cable way/tray hangers, pipes and pipe elements, cable ways/trays , HVAC system ducts, partition bulkheads and ceiling covering carcasses, profiles, deck fittings (bollards, cleats etc.) are installed in this stage
14POS05	**Paint manufacturer**		
14POS05.(1)	*Support of the paint manufacturer and Paint Inspector*	1	The paint manufacturer works in full harmony with the shipyard. The paint inspector is knowledgeable and careful, and warns for all possible paint defects in advance
		2	The paint manufacturer works in harmony with the shipyard. The paint inspector notifies at paint defect detection
		3	The paint manufacturer responds to after-sales requests within normal time. The paint inspector usually arrives with a delay
		4	The paint manufacturer responds slowly to after-sales requests. However, the support of the paint inspector increases the paint quality
		5	The paint manufacturer responds slowly to after-sales requests. The paint inspector usually arrives with a delay
14POS05.(2)	*Easy application of paints*	1	Paints are easy to apply, dry quickly, accept touch-ups, and are resistant to adverse environmental conditions
		2	Paints are easy to apply, dry in a normal time, accept touch-up, and are resistant to adverse environmental conditions
		3	(Left blank)
		4	Paints are applied with normal difficulty, dry in a normal time, accept touch-up, but are not resistant to adverse environmental conditions
		5	Paints are not easy to apply, dry slowly, hardly accept touch-ups, and are not resistant to adverse environmental conditions
14POS06	**External hull works, outfitting and painting**		
14POS06.(1)	*Availability of sufficient mobile platforms or staging/scaffolding for hull works, outfitting and painting*	1	There are abundant number of mobile platforms (cobra etc.) at ample capacity. Scaffolding is not required for works at external hull and painting before ship launching
		2	(Left blank)
		3	Scaffolding is being established for external hull works. 1 (one) mobile platform (cobra etc.) is available for external painting before ship launching
		4	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		5	Scaffolding is being established for external hull works and for external painting before ship launching. There is no mobile platform
14POS07	**Embarkation of the equipment onboard**		
14POS07.(1)	*Cutting and welding of patches to be opened for embarking equipment onboard*	1	Since the equipment within the weight limits are installed in the blocks and the blocks are outfitted before hull erection, there is no need for cutting and welding of patches after the hull erection
		2	The equipment within the weight limits are largely installed in the blocks and the blocks are outfitted before hull erection. Remaining equipment are embarked onboard from soft-patches or cutting a limited number of patches after the hull erection
		3	A limited number of equipment are installed in the blocks before hull erection. Remaining equipment are embarked onboard from soft-patches; patch cutting is not done much
		4	Since the equipment are not installed before the hull erection, the equipment are embarked onboard from soft-patches; patch cutting is not done much
		5	Since the equipment are not installed before the hull erection, the equipment are embarked onboard from cut patches, then welded
14POS07.(2)	*Embarkation of heavy machinery, equipment onboard*	1	Since the machinery within the weight limits are installed in the blocks and the blocks are outfitted before hull erection, there is no need for cutting and welding of patches after the hull erection
		2	Heavy weight machinery such as main engine etc. are embarked onboard from soft-patches or by cutting a limited number of patches. The shipyard's own crane capacity is sufficient
		3	(Left blank)
		4	Heavy weight machinery such as main engine etc. are embarked onboard from soft-patches or by cutting a limited number of patches. The shipyard's own crane capacity may not be sufficient, then the crane is provided from outside
		5	Heavy weight machinery such as main engine etc. are embarked onboard from cut patches. The shipyard's own crane capacity may not be sufficient, then the crane is provided from outside
14POS07.(3)	*Management of equipment embarkation order via soft/cut patches*	1	Since the equipment & machinery within the weight limits are installed in the blocks and the blocks are outfitted before hull erection, there is no need for additional management
		2	Before embarkation of equipment & machinery onboard, a sequence plan is prepared, taking into account the location, infrastructure preparation and rigger capacity, and field engineers supervise the implementation
		3	Before embarkation of equipment & machinery onboard, a sequence plan is prepared, taking into account the location, infrastructure preparation and rigger capacity, and the riggers implement
		4	(Left blank)
		5	No planning or management is done, they are taken onboard randomly

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
14POS07.(4)	*Protection of the ship at open patches area in bad weather*		Since the outfitting of the ship is done in a closed area, it is not affected by adverse weather conditions
		2	(Left blank)
		3	Portable roofs etc. are prepared in advance for each patch to be opened and kept on top of the patches
		4	(Left blank)
		5	No preliminary preparations are made, temporary measures are tried to be taken in case of rainy weather
14POS08	**Protection of the ship and equipment onboard**		
14POS08.(1)	*Watertightness integrity checks and precautions before launching; launching securing/safety measures for equipment which are not fixed onboard*	1	Totally agree
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree
14POS08.(2)	*Protective measures against adverse environmental conditions, ingress of dust/sand and precipitation into the ship*	1	Totally agree. The shipyards has standard instructions for this
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree
14POS08.(3)	*Taking precautions against hit/ramming damage during material-equipment transfers within the ship*	1	Totally agree. The shipyards has standard instructions for this
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree
14POS08.(4)	*Taking precautions against damage to the ship of fluids, electric and compressed air lines/circuits used in construction*	1	Totally agree. The shipyards has standard instructions for this
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree
14POS08.(5)	*Taking precautions against entry of rodent in the ship*	1	Totally agree. The shipyards has standard instructions for this
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree
14POS08.(6)	*Watertightness integrity checks and precautions after launching, temporary cathodic protection (submerged anodes), fire safety measures*	1	Totally agree. The shipyards has standard instructions for this
		2	Precautions are taken at good level
		3	Precautions are taken at adequate level
		4	Precautions are taken at partial level
		5	Strongly disagree

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
14POS08.(7)	*Periodical maintenance of the material-equipment-systems installed onboard, after launching*	1	Totally agree. The shipyards has standard instructions and a maintenance team for this. Manufacturers' personnel also perform maintenance when necessary
		2	A good level of maintenance is provided
		3	Adequate level of maintenance is provided
		4	Maintenance is partially carried out
		5	Strongly disagree
14POS09	**Provision of adequate capacity of compressed air, electricity, water, steam**		
14POS09.(1)	*During the construction of the ship, availability of sufficient amount and capacity of compressed air, electrical power & lighting and water as required; provision of sea water, feed (distilled) water, steam if needed ; availability of their supply lines to reach all parts of the ship*	1	Fully available
		2	Available at good level
		3	Available at sufficient levels
		4	Partially available
		5	Strongly disagree
14POS09.(2)	*Active status of the compressed air, electricity-lighting, water and if needed, sea water, feed water, steam etc. lines*	1	Periodic checks are carried out at least once a year or more frequently. What is necessary is replaced immediately. In case of need for repair, urgent and permanent quality repair is provided
		2	Periodic checks are carried out at least every 2 (two) years. What is necessary is replaced immediately. In case of need for repair, urgent and permanent quality repair is provided
		3	Periodic checks are carried out at intervals greater than 2 (two) years. What is necessary is replaced immediately. In case of need for repair, urgent and permanent quality repair is provided
		4	Periodic control is rarely encountered. In case of need for repair, urgent and permanent quality repair is provided
		5	Periodic control is rarely encountered. If repair is needed, repair is provided
14POS09.(3)	*Power electricity supplied*	1	Sufficient capacity transformer(s) etc. infrastructure is available. In case of a power outage, generator(s) of sufficient capacity are activated in less than 45 (forty-five) seconds
		2	Sufficient capacity transformer(s) etc. infrastructure is available. In case of a power outage, generator(s) of sufficient capacity are activated for more than 45 (forty-five) seconds
		3	Sufficient capacity transformer(s) etc. infrastructure is available. In case of a power outage, generator(s) are activated in less than 45 (forty-five) seconds, but with limited capacity
		4	Transformer etc. infrastructure may remain limited. In case of power outage, the generator(s) are activated
		5	A generator is not available
15PLA00	**PRODUCTION : LAUNCHING (PLA)**		
15PLA01	**Ship launching**		
15PLA01.(1)	*Launching infrastructure*	1	There is an infrastructure to launch at least 4 (four) ships within 1 (one) month, as constructed in parallel
		2	There is an infrastructure to launch 3 (three) ships within 1 (one) month, as constructed in parallel

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	There is an infrastructure to launch 2 (two) ships within 1 (one) month, as constructed in parallel
		4	Parallel construction is carried out, but more than 1 (one) month is required for consecutive launchings
		5	The ship construction and launching infrastructure is for a single ship at a time
15PLA01.(2)	*Launching method as generally applied in the shipyard*	1	Ship construction and outfitting activities are carried out in a closed, air-conditioned dry-dock; the ship is undocked and transferred to the outfitting quay before setting-to-work activities commence
		2	Ship construction and outfitting activities are carried out in a closed, air-conditioned floating dock; the ship is undocked and transferred to the outfitting quay before setting-to-work activities commence
		3	Synchronized lift system or pulling to the dock/platform or lowering method with a high lifting capacity crane
		4	Balloon launching
		5	Classical end-launching or side-launching
15PLA01.(3)	*Launching preparation and launching team*	1	Ship launching activities are carried out only by the shipyard's team responsible for this task. (The team's other duty may be ship docking)
		2	(Left blank)
		3	Ship launching activities are carried out by a Subcontractor
		4	(Left blank)
		5	Ship launching activities are carried out a team assigned from the shipyard employees during the launching period
15PLA01.(4)	*Dry dock availability for launching safety and hull (external) works after launching*	1	Since the ship construction and outfitting activities are carried out in a dry or floating dock before launching, there is no need for an additional dock. If a next ship construction begins in this dock, there is also another dry- or floating dock of sufficient capacity for post-launching works
		2	There is a dry- or floating dock in the shipyard with sufficient capacity
		3	(Left blank)
		4	There is a dry or floating dock in the shipyard. When its capacity is inadequate, it is rented from outside
		5	There is no dry or floating dock in the shipyard, it is rented from outside
16POQ00	**PRODUCTION : OUTFITTING after Launching (POQ)**		
16POQ01	**Works, installations on the shell, external hull and exterior paint during the outfitting after launching**		
16POQ01.(1)	*Ship's environment during the outfitting works on the hull (external) after her launching (in/on covered graving/floating docks)*	1	Since the ship's outfitting is largely completed before launching, there is no need for these activities after launching
		2	It is done in the covered dry- or covered floating dock
		3	It is done in the dry-dock
		4	It is done in the floating dock

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		5	In a periodically rented floating dock in the shipyard or at another shipyard; or in a dry-dock of another shipyard
16POQ01.(2)	*Facilities for hull (external) outfitting after her launching*	1	Since the ship's outfitting is largely completed before launching, there is no need for these activities after launching
		2	There are mobile platforms (cobra etc.) in the number and capacity that will not require scaffolding for works and external painting on the external hull
		3	Scaffolding is installed for works on the hull. 1 (one) mobile platform (cobra etc.) is available for external painting
		4	(Left blank)
		5	Scaffolding is installed for works and painting on the external hull. No mobile platform (cobra etc.) is available
16POQ02	**Minimum outfitting effort requirement after launching**		
16POQ02.(1)	*Minimum outfitting effort requirement after launching (Outfitting is mostly completed before the ship is launched and Setting-to-Work(STW) activities are about to start)*	1	It is completely done in this way
		2	(Left blank)
		3	Partially executed at this level
		4	(Left blank)
		5	A lot of outfitting work is done after launching, while the ship is afloat
21IFL00	**INFRASTRUCTURE : LAYOUT (IFL)**		
21IFL01	**Meteorological conditions**		
21IFL01.(1)	*Annual general meteorological conditions at the site of the shipyard*	1	12 months temperate climate, little wind
		2	(Left blank)
		3	It has the characteristics of 4 seasons, moderately cold, hot, rain and wind, normal humidity
		4	(Left blank)
		5	Most of the year can be very cold or very hot, very rainy, high humidity, high wind speeds
21IFL01.(2)	*Physical damage received from adverse weather conditions*	1	Yes
		2	(Left blank)
		3	To a lesser extent
		4	(Left blank)
		5	No
21IFL01.(3)	*Operational delay happened due to adverse weather conditions*	1	Yes
		2	(Left blank)
		3	To a lesser extent
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
21IFL01.(4)	*Infrastructure improvements against the adverse weather conditions*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
21IFL01.(5)	*Shipyard's own emergency response means against adverse weather conditions*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
21IFL02	**Shipyard closed/covered areas**		
21IFL02.(1)	*The ratio of the covered work area to the whole work area of the shipyard, to protect work areas from the sun and precipitation*	1	100% - 76% covered
		2	75% -51% covered
		3	50% - 26% covered
		4	25% - 1% covered
		5	Fully open
21IFL02.(2)	*The ratio of the covered part being closed on all four sides and having only ventilation*	1	Between 100% and 76%
		2	Between 75% -51%
		3	Between 50% and 26%
		4	Between 25% and 1%
		5	Not available
21IFL02.(3)	*The ratio of the covered part being closed on all four sides and having heating and/or air conditioning system*	1	Between 100% and 76%
		2	Between 75% -51%
		3	Between 50% and 26%
		4	Between 25% and 1%
		5	Not available
21IFL03	**Length of outfitting quay(s)(berth, pier)**		
21IFL03.(1)	*Compliance of the total length of the outfitting quay (berth, pier) to the number of ships to be outfitted simultaneously*	1	For 4 or more ships
		2	For 3 ships
		3	For 2 ships
		4	For one ship
		5	The outfitting quay is short; service is received from other nearby docks/piers
21IFL04	**Sea level at outfitting quay(s) (berth, pier)**		
21IFL04.(1)	*Regular measurement of sea depth at outfitting quays (berth(s)/pier(s))*	1	At most three times a month and sufficient time before ship launching
		2	Two or three times a year and sufficient time before ship launching
		3	Only in sufficient time before ship launching
		4	Only when a ship with high draft will be moored
		5	Never

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
21IFL05	**Waiting (parking) area of the completed hull & superstructure blocks**		
21IFL05.(1)	*Adequacy of the waiting (parking) area of the completed hull & superstructure blocks*	1	Completed blocks do not wait, they immediately move on to the block erection phase. Planning is made accordingly
		2	There is a waiting area that is adequate and protected against rain
		3	There is sufficient waiting area
		4	The waiting area sometimes become inadequate and short-term queues may occur
		5	The waiting area is inadequate, and a queue may occur in the hull shop or on the transfer route
21IFL06	**Appropriate layout for material flow and workflow**		
21IFL06.(1)	*Suitability of the layout of the material storage, processing area and output storage areas for the material flow and workflow*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
21IFL07	**Storage, warehousing**		
21IFL07.(1)	*Adequacy of storage and warehousing facilities; their suitability for different material types*	1	There are indoor and outdoor storage area(s) of sufficient volume and equipped with the necessary shelves
		2	There are adequate indoor and outdoor storage area(s)
		3	There are open storage area(s) of sufficient volume
		4	There exists insufficient storage space for shipbuilding materials
		5	There is no shipbuilding material storage area
21IFL07.(2)	*Air-conditioned storage area in the shipyard*	1	Available
		2	It is not needed, not available
		3	(Left blank)
		4	(Left blank)
		5	(Left blank)
21IFL07.(3)	*Shelf-life material storage*	1	Available. Shelf-life is monitored very closely.
		2	Available
		3	It is not needed
		4	Not available
		5	(Left blank)
21IFL07.(4)	*Corrosive/flammable/explosive material storage area*	1	Available. Security checks are carried out very strictly
		2	Available. Safety checks are carried out
		3	It is not needed, not available
		4	(Left blank)
		5	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
21IFL07.(5)	*Storage space for hand tools, work equipment etc.*	1	There are indoor and outdoor storage area(s), sufficient volume of necessary cabinets, shelves, etc. equipped with amenities
		2	There are indoor storage area(s), sufficient volume of necessary cabinets, shelves, etc. equipped with amenities
		3	There are outdoor storage area(s) with sufficient volume
		4	Hand tools etc. work equipment is stored in a central storage in the Shipyard outside working hours
		5	The work equipment, hand tools etc. storage space is inadequate or unavailable.
21IFL07.(6)	*Shipyard general material warehouses*	1	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; equipped with amenities, material finding-retrieving automation system from the shelves (via barcode, RFID, etc.) and easy transfer means to field of work
		2	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; equipped with barcode, RFID amenities and easy transfer means to field of work
		3	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; transfer means to field of work is at an acceptable level
		4	There are indoor and outdoor storage area(s) with sufficient volume
		5	The storage space for shipbuilding materials is insufficient, transportation is difficult, or is not available.
21IFL07.(7)	*Shipbuilding material storage area where we carry out our activities*	1	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; equipped with amenities, material finding-retrieving automation system from the shelves (via barcode, RFID, etc.) and easy transfer means to field of work
		2	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; equipped with barcode, RFID amenities and easy transfer means to field of work
		3	There are indoor and outdoor storage area(s) with sufficient volume, necessary cabinets, shelves; transfer means to field of work is at an acceptable level
		4	There are indoor and outdoor storage area(s) with sufficient volume
		5	The storage space for shipbuilding materials is insufficient, transportation is difficult, or is not available
21IFL08	**Work equipment, machine park proficiency**		
21IFL08.(1)	*Adequacy of workbench, machine park, hand tools we use*	1	Always in sufficient numbers, capacity and durability. The replacement and supply of missing items are done as soon as possible
		2	In a relatively sufficient number and capacity. The missing ones are being replaced and supplied
		3	Hand tools are insufficient in number and capacity
		4	Benches and machines are insufficient in number and capacity
		5	Hand tools, benches and machines are insufficient in number and capacity

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
21IFL08.(2)	*Supply of fast-consumables, spares and accessories for workbenches, machine park, hand tools which we use in our work*	1	There is constant stock control and supply to ensure that always there exists a sufficient number of long-lasting consumables, spares and accessories
		2	(Left blank)
		3	Consumables, spares and accessories are provided when needed
		4	(Left blank)
		5	Provision of consumables, spares and accessories takes a very long time
21IFL08.(3)	*Machine, tools etc. maintenance & repair*	1	There are at least 2 (two) teams in the Shipyard for continuous maintenance and repair. They both perform regular planned maintenance and have rapid repair capabilities
		2	There is 1 (one) team in the Shipyard for continuous maintenance and repair. They both perform regular planned maintenance and have rapid repair capabilities
		3	Planned maintenance is carried out at certain periods throughout the year. There is 1 (one) team at the Shipyard for repairs. They have the ability to repair quickly
		4	There is 1 (one) team to carry out maintenance and repair. They work sequentially, according to demand
		5	There is no planned maintenance; each operator maintains his own machine tool. Manufacturer company personnel are invited for repair
21IFL09	**Minimum mobility requirement in the workstation area**		
21IFL09.(1)	*Suitability of the layout of workbenches and machines in workstations for the workers to move easily in the shortest distances during work*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
21IFL10	**Minimum worker movement distances**		
21IFL10.(1)	*Suitability of the layout of the shipyard for the employees to move in the shortest distance*	1	Totally Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
21IFL11	**Sidewalks, walking zones**		
21IFL11.(1)	*Well-maintained sidewalks and marked walking areas in the shipyard*	1	Yes
		2	It usually exists and is well-maintained
		3	It usually exists but is neglected
		4	Very limited
		5	No, there are no sidewalks
21IFL12	**Minimum material movement distances**		
21IFL12.(1)	*Arrangement of the layout of the workbenches, machines, warehouses, etc. in*	1	Totally Yes
		2	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
	the work area according to the movement of materials over the shortest distances	3	Partially
		4	(Left blank)
		5	No
21IFL13	**Transport of loads heavier than 23 kgs**		
21IFL13.(1)	*Number and capacities of cranes for lifting loads heavier than 23 kgs in the shipyard*	1	Very adequate and functional. Causes no delays or disruptions
		2	Usually, sufficient. Sometimes delays and disruptions may occur
		3	(Left blank)
		4	Insufficient in number and may cause delays
		5	Insufficient in terms of number and lifting capacity
21IFL13.(2)	*In addition to cranes, methods to reduce the use of cranes*	1	There are conveyors and carriers for material transportation
		2	(Left blank)
		3	There are conveyors or carriers for material transportation
		4	(Left blank)
		5	There is no possibility other than a crane for material transportation
21IFL14	**Use of the hull-side elevator**		
21IFL14.(1)	*Use of side elevator(s) for entry and exit during construction on ships to high-depth ships and ships with high superstructures*	1	Yes. Additionally, easy entry and exit lines to the ship are opened
		2	An elevator is installed or easy entry and exit lines are opened to the ship
		3	Sometimes
		4	(Left blank)
		5	No
21IFL15	**Ventilation, air conditioning, illumination in working areas**		
21IFL15.(1)	*Ventilation, air-conditioning means in closed areas*	1	Fixed or portable ventilation-air conditioning systems are available in all closed areas. There are dust and smoke extraction systems on all benches and machines
		2	Fixed or mobile ventilation-air conditioning systems are partially available in closed areas. Dust and smoke extraction systems are available on benches and machines
		3	Fixed or mobile ventilation-air conditioning systems are partially available in closed areas. Dust and smoke extraction systems on benches and machines are partially or not available at all
		4	There is insufficient ventilation. Bench, machine-top dust and smoke extraction systems are available
		5	There is insufficient ventilation. There are no bench, machine-top dust or smoke extraction systems
21IFL15.(2)	*Ventilation and air-conditioning means in semi-open areas to the atmosphere (under the porch, warehouse with large doors, inside the ship etc.)*	1	Fixed or mobile ventilation-air conditioning systems are available or installed immediately if necessary
		2	It is installed immediately if needed
		3	(Left blank)
		4	It is installed when needed but with insufficient capacities
		5	Not available, not provided

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
21IFL15.(3)	*Natural light and electrical illumination in indoor areas*	1	The work areas have the highest possible level of natural lighting, but also have the means to prevent the negative effects of intense sunlight
		2	Natural light is insufficient in the work areas, electrical lighting is sufficient
		3	The work areas have natural and electrical lighting, but intense sunlight can have a negative effect
		4	Electrical lighting is insufficient in the work areas
		5	Natural light and electrical lighting are insufficient in the work areas
21IFL15.(4)	*Ventilation and air-conditioning means in closed social areas (dressing room, WC-shower, cafeteria-mess hall etc.)*	1	Fixed or portable ventilation-air conditioning systems are available
		2	Fixed or portable ventilation-air conditioning systems are partially available
		3	Fixed or portable ventilation systems are available
		4	There is insufficient ventilation
		5	Not available
21IFL15.(5)	*Natural light and electrical illumination in closed social areas (dressing room, WC-shower, cafeteria-mess hall etc.)*	1	The social areas have the highest possible level of natural lighting, but also have the means to prevent the negative effects of intense sunlight
		2	Natural light is insufficient in the social areas, electrical lighting is sufficient
		3	The social areas have natural and electrical lighting, but intense sunlight can have a negative effect
		4	Electrical lighting is insufficient in the social areas
		5	Natural light and electrical lighting are insufficient in the social areas
21IFL16	**Cleaning of work areas**		
21IFL16.(1)	*Regular cleaning of work areas*	1	Regular cleaning is carried out by cleaning teams twice every day, in the middle of the day and at the end of work/at night
		2	Regular cleaning is carried out by cleaning teams at the end of every shift or at night
		3	Regular cleaning is carried out by cleaning teams every day during working hours
		4	Employees clean their areas; The cleaning team comes several times during the week
		5	Cleaning is done once a week or at longer intervals
22IEN00	**INFRASTRUCTURE : ENVIRONMENT (IEN)**		
22IEN01	**Energy saving and protection of natural resources; use of clean (green) energy**		
22IEN01.(1)	*Energy (power electricity) savings at the shipyard*	1	Shipyard's existing and current comprehensive directives regarding energy saving measures are complied with, and application checks are constantly carried out. In the work area(s), instantaneous electricity consumption can be seen from the digital billboard etc. Measurement and recording of energy savings are carried out at a reliable level on a regular, frequent basis and on location (warehouse, unit area, etc.) basis. Managerial evaluations are made periodically, and measures are developed

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		2	Shipyard's existing and current comprehensive directives regarding energy saving measures are complied with, and application checks are constantly carried out. Measurement and recording of energy savings are carried out at a reliable level on a regular, frequent basis and on location (warehouse, unit area, etc.) basis. Managerial evaluations are made periodically, and measures are developed
		3	Shipyard's existing and current comprehensive directives regarding energy saving measures are complied with, and application checks are carried out periodically. Some measuring and recording operations regarding energy savings are carried out on a location (warehouse, unit area, etc.) basis. Managerial evaluations are made
		4	Shipyard's existing and current comprehensive directives regarding energy saving measures are complied with, and application checks are carried out periodically
		5	There are no measures or practices that will save energy in the shipyard
22IEN01.(2)	*Energy saving (lighting, ventilation)*	1	Lighting systems were changed to LED type lighting. During night shifts, lighting and, if possible, ventilation and air conditioning devices are not operated, especially in work areas that have robot-like automation and do not require humans
		2	(Left blank)
		3	Lighting systems were changed to LED type lighting
		4	(Left blank)
		5	No savings measures are implemented
22IEN01.(3)	*Fossil fuel savings*	1	Transport vehicles are largely electric vehicles. However, there are a small number of fossil fuel vehicles to prevent disruption of operations in case of shortage
		2	All of the transportation vehicles are electric vehicles
		3	Approximately 50%-75% of the transportation vehicles are electric vehicles
		4	Approximately 25% of the transportation vehicles are electric vehicles
		5	Electric vehicles are not available
22IEN01.(4)	*Saving on water*	1	There exists a rainwater storage facility in the shipyard, and the water circuits are fed from there to the maximum extent. When there is a decrease in fresh water resources in the region, the shipyard has a sea water desalinization plant to feed its fresh water system
		2	(Left blank)
		3	There exists a rainwater storage facility in the shipyard, and the water lines are fed from there as much as possible
		4	(Left blank)
		5	There is no rainwater storage facility in the shipyard. Little attention is paid to saving water

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
22IEN01.(5)	*Use of clean energy*	1	There are internal "Green Energy" resources serving the shipyard
		2	Shipyard provides and fed by external "Green Energy"
		3	(Left blank)
		4	(Left blank)
		5	There are no "Green Energy" sources serving to the shipyard
22IEN02	**Hazardous waste management**		
22IEN02.(1)	*Hazardous waste management*	1	There are storage areas around the work areas, and they are collected regularly and sent to the shipyard main storage/disposal centers. If grid is used in the blasting operations, there is a screening and reuse facility, and the residues are treated as hazardous waste
		2	There are mass storage areas in the shipyard and waste is regularly sent to disposal centers. There is a blast grid screening and reuse facility, and the residues are treated as hazardous waste
		3	There are storage areas around work areas, they are collected regularly and sent to the shipyard main storage/disposal centers
		4	There are mass storage areas in the shipyard and waste is regularly sent to disposal centers
		5	No special precautions are taken for hazardous, environmentally harmful solid wastes and fluids
23ITE00	**INFRASTRUCTURE: TECHNOLOGY (ITE)**		
23ITE01	**Utilizing up-to-date information technologies in shipbuilding**		
23ITE01.(1)	*Industry 4.0 and Internet-of-Things (IOT), Industry 5.0, Artificial Intelligence applications in the Shipyard*	1	Industry 4.0 and IoT applications are currently being implemented in the shipyard (e.g., instant employee and material location, continuous communication with supply chain elements, etc.), and infrastructure preparation for Industry 5.0 (autonomous transport vehicles for the shipyard, etc.) is ongoing. For these applications, studies are continuing with domestic and foreign engineering companies, research and development organizations and universities
		2	In order to benefit from these practices, the shipyard continues to work with domestic and foreign engineering companies, research and development organizations and universities on a contractual basis
		3	(Left blank)
		4	There are preliminary evaluation studies for these applications in the shipyard
		5	There is no work for these applications in the shipyard.
23ITE02	**Information integration for shipyard automation systems**		
23ITE02.(1)	*Existence of information integration for shipyard automation systems*	1	In the shipyard, automated units of all interrelated benches, machines, vehicles, storage systems, etc., including the computer systems of the management, design, planning, purchasing etc. departments constantly transfer information and data over a network

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		2	In the shipyard, automated units of only necessary interrelated benches, machines, vehicles, storage systems, etc., including the computer systems of the management, design, planning, purchasing etc. departments constantly transfer information and data over a network
		3	In the shipyard, automated units of only necessary interrelated benches, machines, vehicles, storage systems, etc., including the computer systems of the management, design, planning, purchasing etc. departments transfer information and data over a network only when necessary
		4	In the shipyard, infrastructure and installation work is still ongoing that automated units of interrelated machines, machines, vehicles, storage systems, etc., including the computer systems of the management, design, planning, purchasing etc. departments transfer information and data over a network
		5	There is no automation information network in the shipyard; Each unit uses information and data within itself
23ITE03	**External integration of Shipyard Information System network**		
23ITE03.(1)	*External integration of Shipyard Information System network*	1	There is a computer network integration for outside the shipyard. This external network is integrated with the customer and suppliers
		2	There is a computer network integration for outside the shipyard and under development due to some deficiencies. This external network is integrated with the customer and suppliers
		3	(Left blank)
		4	There is a computer network within the shipyard. External communication is provided via internet, e-mail, cloud systems, etc.
		5	There is no computer network within the shipyard. Internal and external communication is provided via internet, e-mail, cloud systems etc.
23ITE03.(2)	*Computer network security*	1	Shipyard's computer systems are reliable, and their hardware and software are constantly kept up to date. Cybersecurity measures are constantly kept up to date.
		2	(Left blank)
		3	Shipyard's computer systems are generally reliable, but there are times that they malfunction. Hardware and software are updated from time to time upon request
		4	(Left blank)
		5	The reliability and keeping up-to-date of Shipyard's computer systems is not at a satisfactory level
23ITE04	**Research & Development (R&D) investments**		
23ITE04.(1)	*Research & Development (R&D) investments*	1	Resources are allocated in the budget every year for R&D; Cooperation continues uninterruptedly with domestic and international engineering companies, research and development organizations and universities. Employees always have the opportunity to make suggestions to the management for R&D needs
		2	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	In some years, resources are allocated in the budget for R&D; Cooperation is carried out with domestic and international engineering companies, research and development organizations and universities, as needed
		4	(Left blank)
		5	R&D budget, investments and studies are not available
23ITE05	**Computer systems investments**		
23ITE05.(1)	*Computer systems investments*	1	Every year, resources are allocated in the budget for computer systems, projected and implemented. Employees always have the opportunity to make suggestions to the management regarding needs
		2	(Left blank)
		3	If needed, resources are allocated in the budget for computer systems, projected and implemented
		4	(Left blank)
		5	Resources are not allocated for computer systems unless absolutely necessary, or they are very limited
23ITE06	**Technical investments**		
23ITE06.(1)	*Technical infrastructure and superstructure investments (Machinery, automation, building-facility-public works etc.)*	1	Every year, resources are allocated in the budget for technical infrastructure and superstructure, projected and implemented. Employees always have the opportunity to make suggestions to the management regarding needs
		2	(Left blank)
		3	If necessary, resources are allocated in the budget for technical infrastructure and superstructure, projected and implemented
		4	(Left blank)
		5	Unless necessary, resources are not allocated for technical infrastructure and superstructure, or they are very limited
24IFA00	**INFRASTRUCTURE : AMENITIES (IFA)**		
24IFA01	**Dressing-Lockers, Showers-Toilets**		
24IFA01.(1)	*The proximity of Dressing-Lockers Areas, Showers-Toilets to the work area; their capacity, ventilation, illumination, cleanliness*	1	Yes
		2	It is relatively close in distance, has adequate capacity, is airy and well lit. Cleaning is done regularly throughout the day
		3	It is relatively close in distance, has sufficient capacity, and has normal ventilation and lighting. Cleaning is not done regularly
		4	Relatively close distance, limited capacity; Lighting and ventilation may be considered inadequate. Cleaning is not done regularly
		5	Their distance is far, their capacity, maintenance and cleanliness are not good
24IFA02	**Dining-Resting areas**		
24IFA02.(1)	*Presence of a hygienic and satisfactory (taste, calorie, quality) mess hall with sufficient seating capacity, in close proximity*	1	Totally agree
		2	Food is not satisfactory
		3	Not enough seating capacity

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
	and where you can get food in the shortest waiting time	4	Waiting time is long or distance is far (more than 5 minutes walking)
		5	Totally no
24IFA02.(2)	*For breaks, availability of a resting and refreshment area with sufficient seating capacity and quick service, very close to the work areas*	1	Totally agree. Additional facilities such as a ping-pong table and internet computer are also available
		2	Totally agree
		3	Seating capacity is insufficient and/or service is not fast
		4	It is far away (more than 3 minutes on foot)
		5	Not available
24IFA02.(3)	*Availability of a canteen with sufficient products in close proximity to the work areas*	1	Totally agree
		2	Product varieties are insufficient
		3	It is far away (more than 3 minutes on foot)
		4	Not available
		5	(Left blank)
24IFA03	**Proximity to public transport**		
24IFA03.(1)	*Distance to the work area and public transportation facilities at the start and end of the working hours*	1	Very close (up to 500 meters)
		2	(Left blank)
		3	Close (between 500 - 1000 meters)
		4	(Left blank)
		5	Very distant (more than 1 km)
24IFA04	**Parking lots**		
24IFA04.(1)	*Protection against adverse weather conditions in the walking line between the parking lot and the dressing areas*	1	Protection against rain, wind and sun for approximately 100% of the distance
		2	Top cover against rain and sun for approximately 100% of the distance
		3	Protection against rain, wind and sun for approximately 50% of the distance
		4	Top cover protection against rain and sun for approximately 50% of the distance
		5	No protection is available
24IFA04.(2)	*Presence of an electric vehicle charging station in the parking lot*	1	There are in sufficient numbers
		2	There are, but insufficient numbers
		3	In the process of being established
		4	(Left blank)
		5	Not available
24IFA04.(3)	*The distance between the place where we carry out our work and the parking lot*	1	It is within the shipyard and very close. (up to 500 meters)
		2	It is outside the shipyard but very close. (up to 500 meters)
		3	It is outside the shipyard and close (between 500 - 1000 meters)
		4	It is outside the shipyard and is far away (between 500 - 1000 meters)
		5	Parking is not available

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
24IFA05	**Nursery (preschool, kinder-garten)**		
24IFA05.(1)	*Presence of a nursery (preschool, kinder-garten) in the shipyard*	1	Yes
		2	It exists but it is not good
		3	(left blank)
		4	Since only men work in the shipyard or the number of female workers is lower than legal requirement for a nursery, there is no need for it
		5	Although there is a need, it does not exist
30DES00	**DESIGN & PRODUCTION ENGINEERING (DES)**		
30DES01	**Design methods**		
30DES01.(1)	*Speedy completion of the ship's preliminary and contract design phases*	1	Shipyard's design team uses standard design packages that they have prepared before and are available in the design archive, completely suitable for the shipyard and the project
		2	Shipyard's design subcontractor uses standard design packages that they have prepared before and are available in their design archives, and are completely suitable for our shipyard and the project
		3	Shipyard's design team and/or design subcontractor can adapt existing designs in the design archives to be completely suitable for the shipyard and the project, with minimal changes, in a very short time (maximum 10 (ten) days)
		4	Shipyard's design team carries out a new design work for each project
		5	Shipyard's design subcontractor carries out new design work for each project
30DES01.(2)	*Speedy completion of ship detail design*	1	Shipyard's design team uses standard detail design packages that they have previously prepared and are available in the design archive, completely suitable for the shipyard and the project. In this context, equipment/system supplies are made by the Shipyard under the long-term contracts with equipment/system manufacturers, and equipment/system differences at different shipbuilding projects are avoided
		2	Shipyard's design subcontractor uses standard detail design packages that they have previously prepared and are available in the design archive, completely suitable for the shipyard and the project. In this context, equipment/system supplies are made by the Shipyard under the long-term contracts with equipment/system manufacturers, and equipment/system differences at different shipbuilding projects are avoided
		3	Equipment/system procurements are made by the Shipyard. Shipyard's design team and/or design subcontractor can adapt existing designs in the design archives to be fully suitable for the shipyard and the project in a short time

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	Part of the equipment/system procurements are made by the Customer. Shipyard's design team carries out a new detail design work for each project
		5	Part of the equipment/system supplies are made by the Customer. Shipyard's design subcontractor carries out a new detailed design work for each project
30DES01.(3)	*Ship's first-steel-cut only after the detail design reaches a certain maturity*	1	Steel cutting for the hull construction does not start until the detail design reaches 70% level
		2	(Left blank)
		3	Steel cutting for the hull construction does not start until the detail design reaches 30-40% level
		4	(Left blank)
		5	Steel cutting for the hull construction starts as soon as possible after the shipbuilding contract enters into force. Design progress is not waited
30DES01.(4)	*Automated design processes according to Class rules*	1	The design team always ensures that the classification society plan (design) approval period is kept short by fully using the design software of the relevant classification society rules
		2	(Left blank)
		3	The design team uses design software belonging to the relevant classification society rules from time to time, as needed
		4	(Left blank)
		5	The design team does not use design software that belongs to the relevant classification society rules
30DES01.(5)	*Design for the 2nd ship and beyond*	1	The design team ensures document organization that will avoid confusion in the design documents during the production on a ship-by-ship basis, with minimal design effort
		2	(Left blank)
		3	(Left blank)
		4	The design team prepares a separate set of design documents for each ship
		5	The design team ensures document organization that will avoid confusion in the design documents during the production on a ship-by-ship basis, with minimal design effort. But sometimes confusions happen.
30DES02	**Design method for design from scratch**		
30DES02.(1)	*"From scratch" design methods used in preliminary design and contract design (design synthesis, set-based design, design spiral methods)*	1	Shipyard's design team carries out concurrent design according to the design stages; uses design synthesis, set-based design and design spiral methods
		2	Shipyard's design subcontractor carries out concurrent design according to the design stages; uses design synthesis, set-based design and design spiral methods
		3	(Left blank)
		4	Shipyard's design team carries out preliminary and contract design using the design spiral method
		5	Shipyard's design subcontractor carries out preliminary and contract design using the design spiral method
30DES03	**Level of difference between the design of the proposed ship and design of the contracted ship**		
30DES03.(1)		1	No difference occurs

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
	Level of difference between the design of the proposed ship and design of the contracted ship	2	(Left blank)
		3	Some differences occur, but are tolerable in terms of the proposed project schedule and cost
		4	(Left blank)
		5	Many differences emerge. It creates negativities in terms of the proposed project schedule and cost
30DES04	**Conformance of the design to shipyard**		
30DES04.(1)	*Conformance of the design to the infrastructure, superstructure and workforce capabilities of the shipyard*	1	Shipyard's design team has knowledge of all infrastructure and superstructure facilities and workforce capabilities of the shipyard; these capabilities are not exceeded in design. A producibility review meeting is held within the Shipyard before each project contract.
		2	Shipyard's design subcontractor has knowledge of all infrastructure and superstructure facilities and workforce capabilities of the shipyard; these capabilities are not exceeded in design. A producibility review meeting is held before each project contract
		3	Shipyard's design team has knowledge of all infrastructure and superstructure facilities and workforce capabilities of the shipyard. There is no need for any other work.
		4	Shipyard's design subcontractor has knowledge of all infrastructure and superstructure facilities and workforce capabilities of the shipyard. There is no need for any other work.
		5	The shipyard usually appoints different design subcontractors for projects, and information about the shipyard's infrastructure and superstructure facilities and workforce capabilities is provided when the design subcontractor requests
30DES05	**Design for Hull Block Outfitting**		
30DES05.(1)	*Compliance of the design documentation to the Hull Block Outfitting methodology*	1	Even if only 1 (one) ship is to be built, upon request of the Shipyard, design documentation is prepared in accordance with the on-block outfitting methodology
		2	In case more than one ship of the same type is to be constructed, upon request of the Shipyard, design documentation is prepared in accordance with the on-block outfitting methodology
		3	Design documentation is not prepared specifically for the application of on-block outfitting, but prepared as suitable for installation of welded parts and bilge piping during the block construction
		4	Design documentation is not prepared specifically for the application of on-block outfitting, but prepared as suitable for installation of welded parts during the block construction
		5	In preparing the design documentation, any outfitting during the block construction is not taken into account
30DES05.(2)	*Design Team's making Transition Design; using of the Work Package systematic*	1	Even if only 1 (one) ship is to be built, upon request of the Shipyard, design documentation is prepared in accordance with the Work Package systematic
		2	In case of construction of more than one ship of the same type, design documentation is prepared in accordance with the Work Package systematic upon request of the Shipyard

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	(Left blank)
		4	(Left blank)
		5	Design documentation is not prepared in the Work Package systematic
30DES06	**"Design for Production"**		
30DES06.(1)	*Paying attention to the production/ manufacturing, outfitting practices in the design (design for production)*	1	The design team reflects standard practices that facilitate easier manufacturing, construction and outfitting, and additional practices of the Shipyard in this direction, into the design
		2	(Left blank)
		3	The design team reflects standard practices that facilitate easier manufacturing, construction and outfitting into the design as much as possible
		4	(Left blank)
		5	Applications that facilitate easier manufacturing, construction and outfitting are not taken into account in the design
30DES07	**Compliance of design document deliveries with the ship production schedule**		
30DES07.(1)	*Compliance of design document deliveries with the ship production schedule*	1	Yes, no delays or problems are encountered
		2	(Left blank)
		3	Design document deliveries may occasionally fall behind the shipbuilding schedule and delay procurement and ship production activities
		4	(Left blank)
		5	Design document deliveries fall behind the shipbuilding schedule and delay procurement and ship production activities
30DES08	**Quality of design documents**		
30DES08.(1)	*Error-free design documents, sufficiency of the information given in the documents*	1	Totally agree
		2	Highly agree
		3	Partially agree
		4	A little agree
		5	Strongly disagree
30DES08.(2)	*Class plan approval time lengths for design documents*	1	It is very short; the Classification Society does not require changes
		2	(Left blank)
		3	It is in the normal period; the Classification Society requests changes in some documents
		4	(Left blank)
		5	It is too slow, causing delays in the project/ship production
30DES09	**Easy-to-understand production design documentation**		
30DES09.(1)	*Easily understandable production design documentation*	1	Totally agree
		2	Highly agree
		3	Partially agree
		4	A little agree
		5	Do not agree

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
30DES10	**Material/Parts Lists of work packages/workmanship drawings**		
30DES10.(1)	*Submission of material/parts lists along with the workmanship drawings*	1	Always, very accurately
		2	(Left blank)
		3	It is at a satisfactory level
		4	(Left blank)
		5	It is often incomplete and inaccurate
30DES10.(2)	*Workmanship drawings and associated material/parts lists numbering system*	1	They have the same document number, drawing or list revisions can be easily tracked
		2	They have different document numbers, but drawing or list revisions can be easily tracked
		3	(Left blank)
		4	They have the same document number, but revisions on the drawing or list cannot be easily tracked
		5	Different document numbers are used. There are problems in revisions and follow-up
30DES11	**Plate & profile Part numbering system**		
30DES11.(1)	*Plate & profile/ Part numbering system*	1	There is a system that works successfully. No problems are encountered, including the tracking of wasted parts
		2	There is a system that works successfully. However, there is a problem in tracking wasted parts
		3	(Left blank)
		4	The numbering (marking) system is problematic. Wasted parts tracking is difficult
		5	A numbering system is implemented which works well or poorly, wasted parts are not tracked
30DES12	**Sheet metalwork/Workpiece documents, numerical (digital) data**		
30DES12.(1)	*Sheet metalwork/workpiece documents, numerical (digital) data*	1	They are completely sufficient, internally compatible, complete and easy-to-understand
		2	(Left blank)
		3	Usually in adequate, normal content
		4	(Left blank)
		5	They are insufficient, incomplete and difficult to understand
30DES13	**Hot-works management**		
30DES13.(1)	*Main foundations (Main Engine, Rudder etc.)*	1	All main foundations are installed during the block construction, including the first ship. Design documentation & data are received accordingly
		2	(Left blank)
		3	On the first ship, all possible main foundations are installed during the block construction. If there is a delay in design documentation, in data, the block is kept waiting
		4	(Left blank)
		5	On the first ship, all possible foundations are installed during the block construction. If there is a delay in design documentation, in data, the block is not kept waiting and their installations are done on-board

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
30DES13.(2)	*Equipment, system foundations*	1	Ship service equipment groups (pump groups with mounted pipes, compressor groups, fresh water makers, etc.) are prepared with their other fixed equipment and on their foundations in the form of pallets during the block construction process in the shipyard. For other detached, late-arriving equipment, there exists a method of determining and drilling foundation installation holes at an early stage (company template or preparing a template at the arrival to the warehouse, etc.)
		2	Although pallet application is not made, equipment-system foundation installations are made in the block to the maximum extent during the block construction. For equipment, there exists a method of determining and drilling foundation installation holes at an early stage (company template or preparing a template at the arrival to the warehouse, etc.)
		3	(Left blank)
		4	Equipment-system foundation installations are largely made on the hull, after block erection. For equipment, there exists a method of determining and drilling foundation installation holes at an early stage (company template or preparing a template at the arrival to the warehouse, etc.)
		5	Equipment-system foundation installations are largely made on the hull, after block erection. Foundation drilling is done on-board
30DES13.(3)	*Other welded parts (hot works), small foundations*	1	Ship service equipment groups (pump groups with mounted pipes, compressor groups, fresh water makers, etc.) are prepared with their welded parts and small foundations in the form of pallets during the block construction process in the shipyard. Necessary works out of the pallets such as welded part, small foundation installations are done on-block. For other detached, late-arriving equipment, on-board assembly is carried out
		2	Although pallet application is not made, welded parts and small foundations are installed on-block as much as possible. For other detached, late-arriving equipment, on-board assembly is carried out
		3	(Left blank)
		4	(Left blank)
		5	Welded part and small foundation installations are largely made on-board
30DES13.(4)	*Deck/Bulkhead penetrations*	1	Including the first ship of its class, the deck/bulkhead penetrations are cut during plate cutting stage of block construction. Design documentation, numerical cutting data comes accordingly
		2	(Left blank)
		3	Except for the first ship of its class, the deck/bulkhead penetrations are cut during plate cutting stage of block construction. Design documentation, numerical cutting data comes accordingly. For the first ship, they are cut on-board

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	(Left blank)
		5	In all ships, deck/bulkhead penetrations are cut on-board
30DES14	**Outfitting workmanship documents, installation instructions**		
30DES14.(1)	*Content adequacy of outfitting workmanship documents, installation instructions*	1	They are completely sufficient, complete and easy-to-understand
		2	(Left blank)
		3	Usually has adequate, normal content
		4	(Left blank)
		5	They are insufficient, incomplete and difficult to understand
30DES15	**Clash detection in design**		
30DES15.(1)	*Clash detection during the piping-cable trays-ducting design*	1	Design team continuously performs clash detection in 3-D design
		2	The design team performs clash detection in the 3-D design at intervals (once a week, etc.)
		3	Design team continuously performs clash detection in 2-D design
		4	The design team performs clash detection in 2-D design at intervals (once a week, etc.)
		5	The design team does not perform clash detection
30DES16	**Easy access of shipbuilding field workers to the ship's 3-dimensional design model**		
30DES16.(1)	*Making the ship's 3-dimensional design model available to the field workers*	1	Yes. The field team is provided with an updated 3-Dimensional ship model, which they can use on a tablet and/or with Augmented Reality (VR) glasses
		2	Yes. The field team is provided with an updated 3-Dimensional ship model that they can use on a computer near the construction site
		3	Yes. The field team is provided with an updated 3-Dimensional ship model that they can use on a computer in their office or in a nearby design office
		4	A printed design document with images taken from the 3-D model is provided to the field team
		5	No
30DES16.(2)	*Providing ship's 3-dimensional design to the field workers in such a way that measurements can be taken on*	1	Yes
		2	(Left blank)
		3	Partial measurements can be taken with some effort
		4	(Left blank)
		5	No
30DES16.(3)	*Providing a tablet application to the field team that will simultaneously display the relevant 3-dimensional ship design model when hovering over a 2-D workmanship drawing*	1	Yes
		2	(Left blank)
		3	(Left blank)
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
30DES17	**Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers**		
30DES17.(1)	*Design and Subcontractor/Manufacturer management*	1	There are personnel who provide technical coordination between the companies that produce the equipment/systems to be used on the ship and the Design team continuously. This personnel work within a Systems Engineering approach by ensuring continuous technical coordination between the Shipyard and the companies that produce the equipment/systems during the construction-outfitting period of the ship, and by following the production in the companies
		2	There are personnel who provide technical coordination between the companies that produce the equipment/systems to be used on the ship and the Design team continuously
		3	There are personnel who provide technical coordination between the companies that produce the equipment/systems to be used on the ship and the Design team continuously. Additionally, there are shipyard personnel who provide technical coordination between the Shipyard and the companies that produce the equipment/systems during the construction-outfitting period of the ship
		4	There are shipyard personnel who provide technical coordination between the Shipyard and the companies that produce the equipment/systems during the construction-outfitting period of the ship
		5	Both the Design team and the Shipyard coordinate with the companies that produce the equipment/systems to be used on the ship, in case of need
30DES17.(2)	*Ship's 3-dimensional design model software material database/library*	1	Includes standardized materials, equipment and systems used by the shipyard
		2	It largely includes the standardized materials, equipment and systems used by the shipyard, and the deficiencies are quickly uploaded to the database
		3	It partially includes the materials, equipment and systems used by the shipyard; the missing parts are quickly uploaded to the database
		4	(Left blank)
		5	The design team does not take this issue into consideration in the design, the shipyard supplies materials, equipment and systems in accordance with the design
30DES18	**Equipment/system installation and operating instructions**		
30DES18.(1)	*Content adequacy of the equipment/system installation and operating instructions*	1	They are completely sufficient, complete and easy-to-understand
		2	(Left blank)
		3	They usually have adequate, normal content
		4	(Left blank)
		5	They are insufficient, incomplete and difficult to understand

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
30DES19	**Consideration of Ship Acceptance Test requirements at early stages of design**		
30DES19.(1)	*Consideration of Ship Acceptance Test requirements at the early stages of design*	1	They are listed and taken into account from the beginning of the design, and discussions are held with the Classification Society and manufacturers on necessary issues
		2	They are listed and taken into account from the beginning of the design
		3	(Left blank)
		4	Considered as the design progresses
		5	They are taken into account when preparing Test & Trial Procedures
30DES20	**Technical Coordination with the Classification Society and the Buyer**		
30DES20.(1)	*Online/digital Class plan approval process*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
30DES20.(1)	*Technical coordination of the Design Team with the Buyer*	1	Provided regularly and continuously. The Buyer has permanent Project Control personnel at the Shipyard
		2	(Left blank)
		3	Coordination is achieved through online meetings with the Buyer, electronic correspondence and Project Progress Meetings. The Buyer has Project Control personnel who come to the Shipyard periodically
		4	(Left blank)
		5	The Buyer does not have Project Control personnel at the Shipyard. Coordination with the Buyer is achieved through correspondence and Project Progress Meetings.
30DES21	**Project Configuration Management**		
30DES21.(1)	*Integration of the design computer system (CAx) with a PLM (Product Life Cycle Management) and Shipyard PLM/ERP system*	1	Yes, it is applied in all projects, including the design and main subcontractors
		2	Yes, it is applied in all projects, including the design subcontractor
		3	The design subcontractor has its own PLM system, and the Shipyard has its own PLM/ERP system. Data transfer can be partially provided in projects
		4	There is no PLM system for design. The shipyard has an ERP system
		5	PLM and ERP systems are not available
30DES21.(2)	*Availability of a work breakdown structure, design document and material numbering systematic standard as applied for design-material-construction, beginning from the contracting stage*	1	Yes, it is applied in all projects
		2	(Left blank)
		3	Separate systematics are applied for the design and material management
		4	(Left blank)
		5	It is tried to be carried out with the information coming from the design team

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
30DES21.(3)	*From the beginning of the contract phase, implementation of Project Configuration Management for the design, material-equipment-systems and the software installed on onboard systems*	1	Yes, it is applied in all projects
		2	(Left blank)
		3	Partially implemented
		4	(Left blank)
		5	Not implemented. Each unit has its own list system
30DES21.(4)	*Revision tracking of design documents in the field*	1	There is a staff (or team) specifically following up. It is implemented without any problems
		2	(Left blank)
		3	It is followed by the relevant factory/workshop and field teams themselves. Problems are encountered from time to time
		4	(Left blank)
		5	There is no regular application, problems often arise
30DES22	**Ship weight management**		
30DES22.(1)	*Ship weight calculation and monitoring team of the Design Team*	1	There is a Weight Engineer/personnel assigned to the design team, and this personnel also carries out ship weight management throughout the project. Equipment-system weights are obtained from manufacturers
		2	(Left blank)
		3	There is no special assignment in the design team, but weight calculation checks are made throughout the project. Equipment-system weights are tried to be obtained from manufacturers
		4	(Left blank)
		5	There is no special assignment in the design team, only weight calculations are made, no updates are made
30DES22.(2)	*Recording of weights entering and leaving the ship*	1	Hull & superstructure blocks are weighed after their construction and outfitting; every material, equipment and system entering or leaving the ship is weighed and recorded at the entrance of the ship. Applications such as barcode and RFID are used during the weight registration process
		2	Hull & superstructure blocks are weighed after their construction and outfitting; every material, equipment and system entering or leaving the ship is weighed and recorded at the entrance of the ship
		3	Hull & superstructure blocks are weighed after their construction and outfitting; material, equipment and system entering or leaving the ship is not weighed
		4	(Left blank)
		5	Hull & superstructure blocks, materials, equipment and systems entering and leaving the ship are not weighed
30DES22.(3)	*Equipment-System weights*	1	If the equipment-system is to be newly produced, the weight foreseen in the weight calculation is contractually dictated to the subcontractor/manufacturer. It is produced accordingly. Weight measurement is made at the factory (during the factory acceptance test, etc.)
		2	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	EFFECT *and its sub-details*	Magn.	Question choices
		3	No weight is dictated for the equipment-systems; Weight measurement is made at factory (during the factory acceptance test, etc.)
		4	(Left blank)
		5	No weight dictation or measurement is made for equipment and systems
40MPP00	**MATERIALS & PROCUREMENT (MPP)**		
40MPP01	**Selection of subcontractors/ manufacturers for the project**		
40MPP01.(1)	*Availability of a database of all possible domestic and international subcontractors, suppliers in the shipyard*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP01.(2)	*Determination of subcontractors, manufacturers and suppliers with scientific methods*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP01.(3)	*Final selection on the determined candidates after financial, technical, quality etc. inspections*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP02	**Contract/Purchase Form standardization in procurements**		
40MPP02.(1)	*Use of standardized subcontracts, forms in purchasing activities*	1	Totally Yes. These have been prepared together with manufacturers with whom the shipyard have long-term cooperation. Agreements can also be reached quickly for new manufacturers
		2	Yes. However, when necessary, the shipyard can directly reference the manufacturer's documents and reach an agreement quickly
		3	Partially
		4	(Left blank)
		5	No
40MPP03	**Long-term cooperation with subcontractors, manufacturers, suppliers**		
40MPP03.(1)	*Long-term cooperation agreements with subcontractors, manufacturers, suppliers*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
40MPP04	**Local content**		
40MPP04.(1)	*Priority in local content*	1	Totally Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP05	**Geolocation**		
40MPP05.(1)	*Closer distance of the shipyard to land, rail, sea and air transportation points*	1	All available within the approx. 20 km. radius
		2	All available within the approx. 20 - 50 km. radius
		3	All available within the approx. 50 - 150 km. radius
		4	(Left blank)
		5	Only the land route and the port are close
40MPP05.(2)	*Closer distance of the shipyard to the shipbuilding side-industry and other related manufacturers*	1	All available within the approx. 20 km. radius
		2	All available within the approx. 20 - 50 km. radius
		3	All available within the approx. 50 - 150 km. radius
		4	Partially present within the 150 km. radius.
		5	Available further than 150 km. radius
40MPP06	**Correct material supply**		
40MPP06.(1)	*Accurate and timely material supply throughout the Project*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
40MPP06.(2)	*Ensuring the timely, trouble-free material flow for the projects where the Hull Block outfitting method is applied*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
40MPP07	**Just-in-Time (JIT) arrival of the supplies**		
40MPP07.(1)	*Just-in-Time (JIT) arrival of the supplies*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	Never
40MPP08	**Delays in manufacturers' deliveries**		
40MPP08.(1)	*None of the deliveries delay*	1	It is 100% correct
		2	About 75% correct
		3	About 50% correct
		4	About 25% correct

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		5	There is always a delay
40MPP09	**Product Acceptance Inspections, Factory Acceptance Tests (FAT)**		
40MPP09.(1)	*Checking the production status of our orders that were in production, long before FATs*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP09.(2)	*Evaluation and pre-checks with the manufacturers before FATs*	1	Always applied
		2	(Left blank)
		3	Partially applied
		4	(Left blank)
		5	Not applied; problems are usually encountered
40MPP09.(3)	*Implementation of a careful quality control process at the arrival of all products to the shipyard*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP10	**Supply of flawless products**		
40MPP10.(1)	*Supply of flawless products (products with no problems until the end of the ship's Warranty period)*	1	It is 100% correct
		2	About 75% correct
		3	About 50% correct
		4	About 25% correct
		5	There are constant malfunctions and defects
40MPP11	**Buyer furnished material-equipment-systems**		
40MPP11.(1)	*Timely arrival of Buyer (Ship Owner, etc.) furnished materials-equipment-systems*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
40MPP11.(2)	*Always of the required quality and design suitable for the ship*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
40MPP11.(3)	*Delivery of the correct documentation for installation, integration and operation*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
40MPP12	**Ship spares and First-outfit material procurement management**		
40MPP12.(1)	*Proper procurement management of ship spares and first-outfit material*	1	Yes; They are delivered to the ship on time and has the quality desired by the Buyer
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP13	**Preventive maintenance in the storage and onboard**		
40MPP13.(1)	*Preventive maintenance of equipment and systems in the storage and on board*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
40MPP14	**Storage/transport of heavy equipment/systems**		
40MPP14.(1)	*Supervision of a field engineer in the yard during the storage and transportation of equipment/systems which weigh more than 1 ton*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL00	**SHIPBUILDING MANAGEMENT : PLANNING & BUDGETING (APL)**		
51APL01	**Shipbuilding Project Schedule groups**		
51APL01.(1)	*Shipbuilding Project Schedule groups (e.g., Design, Procurement, Construction &Outfitting, Test & Trials Schedules etc.)*	1	It covers the preparation, control and updating activities of Project Master Time Schedule and at least the following; - Design Time Schedule, - Procurement Time Schedule, - Shipbuilding (Production) Detailed Time Schedule, - Test & Trials Time Schedule
		2	It covers the preparation, control and updating activities of Project Master Time Schedule and at least the following; - Procurement Time Schedule, - Shipbuilding (Production) Detailed Time Schedule, - Test & Trials Time Schedule. Design Time Schedule is prepared separately by the Design subcontractor
		3	It covers the preparation, control and updating activities of Project Master Time Schedule and Shipbuilding (Production) Detailed Time Schedule. Other time schedules are prepared if necessary
		4	It covers the preparation, control and updating activities of the Project Master Time Schedule. Other time schedules are prepared if necessary
		5	Time schedules are prepared if necessary

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
51APL02	**Scope of the Shipbuilding Projects Labor Planning**		
51APL02.(1)	*Scope of the Shipbuilding Projects Labor Planning (compliance with standard times; Job-order system)*	1	It is prepared, controlled and updated together with time schedules, including details such as Standard Times and Job Order preparation
		2	It is prepared, controlled and updated separately, including details such as Standard Times and Job Order preparation
		3	Generally applied, Job Orders are prepared
		4	Generally applied. Job Order application is not available
		5	Workforce planning is done internally by the relevant shipyard unit when necessary
51APL03	**Integration of schedules**		
51APL03.(1)	*Time-Labor-Material schedules working in an integrated digital environment*	1	It is provided through a fully integrated software in terms of Time-Labour-Material. All relevant units can access the schedules electronically; those authorized can provide up-to-date feedback
		2	It is provided through a fully integrated software in terms of Time and Labor. Procurement schedule is not integrated. All relevant units can access the schedules electronically; those authorized can provide up-to-date feedback
		3	It is partially provided through an integrated software in terms of Time-Labour-Material. All relevant units can access the schedules electronically; those authorized can provide up-to-date feedback
		4	It is provided through a fully integrated software in terms of Time-Labour-Material. Only the Planning department can access the schedules electronically
		5	Time-Labour-Material scheduling is not integrated, it is independent
51APL04	**Scheduling techniques**		
51APL04.(1)	*Planning techniques used in Time Scheduling*	1	Critical Chain (CCM), Critical Path (CPM) or more advanced techniques are used
		2	Critical Path (CPM) method is used
		3	Critical Path (CPM) and PERT methods are used
		4	PERT method is used
		5	Gantt type charts are used for scheduling on MS Excel etc. Software
51APL05	**Project scheduling simulations**		
51APL05.(1)	*Simulations in project scheduling*	1	Time Schedules and Work Flows can be simulated completely on a 3-dimensional shipyard production model; actions are taken according to the results
		2	(Left blank)
		3	Time Schedules and Workflows can be partially simulated, and action is taken according to the results
		4	(Left blank)
		5	Not implemented
51APL06	**Dynamic schedule management : Continuous monitoring and feedback**		
51APL06.(1)	*Dynamic schedule management : Continuous monitoring and feedback*	1	Monitoring and feedback is provided on a daily basis. Corrective measures are quickly put into effect
		2	Monitoring and feedback is provided weekly. Corrective measures are quickly put into effect

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	EFFECT *and its sub-details*	Magn.	Question choices
		3	Monthly monitoring and feedback is provided. Corrective measures are quickly put into effect
		4	Monitoring and feedback are provided at long intervals
		5	No monitoring, feedback or evaluation
51APL07	**Dynamic schedule management : Progress and Budget evaluation**		
51APL07.(1)	*Dynamic schedule management : Progress and Budget evaluation*		Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL08	**Accurate time-schedules**		
51APL08.(1)	*Accuracy of time schedules*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL09	**Accurate labor planning**		
51APL09.(1)	*Accuracy of labor planning*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL10	**Job-order system**		
51APL10.(1)	*Availability of a Job-order system, job-orders' preparation by expert personnel*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL10.(2)	*Continuous correctness of the start-end dates, job-sequences and descriptions in the Job-Orders*	1	Totally Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL11	**Performance measurements, Efficiency calculations**		
51APL11.(1)	*Performance measurements on the basis of workstation/worksite; their evaluation with scientific methods and the implementation of efficiency improvements measures*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
51APL12	**Job standardization; Visible indication of job performance metrics and values at the workstation**		
51APL12.(1)	*Ensured and documented work standardization for the work to be done at each workstation*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL12.(2)	*Visibly posted indication of job performance metrics, values at each workstation*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL12.(3)	*Measuring the own performance of the staff working at each workstation*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL13	**Density of the Change Requests, Rework**		
51APL13.(1)	*Density of the Change Requests, Rework*	1	No change requests are received
		2	Change requests are approximately 25%
		3	Change requests occur at approximately 50% level
		4	Change requests occur at approximately 75% level
		5	Change requests happen very frequently
51APL14	**Production management - Field Engineering**		
51APL14.(1)	*Sufficient number of production management, field engineering personnel*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL14.(2)	*Constant coordination of Production management, field engineering personnel with Planning Team*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL14.(3)	*Production management, field engineering personnel daily meetings with their own staff and at least weekly meetings with other branches; having a regular reporting and measurement/statistics system*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
51APL15	**Project Progress Meetings, Reports**		
51APL15.(1)	*Holding periodic progress meetings of the projects regularly with the participation of the relevant units in the shipyard*	1	Yes, weekly
		2	(Left blank)
		3	Yes, bi-weekly
		4	Yes, once a month
		5	No
51APL15.(2)	*Publishing a progress, resource utilization report before or immediately after each meeting*	1	Yes, published weekly
		2	(Left blank)
		3	Yes, published bi-weekly
		4	Yes, published once a month
		5	No
51APL16	**Waiting times**		
51APL16.(1)	*Waiting times during work (due to the preceding employee's work; material; information from manufacturer, etc.)*	1	It never happens, there is always a constant flow
		2	Have to wait for approximately 25% of the work period
		3	Have to wait for approximately 50% of the work period
		4	Have to wait for approximately 75% of the work period
		5	Always wait a long time
51APL16.(2)	*Effective use of available capacity by shifting to another job during the waiting period*	1	Never happens, work continues as uninterrupted
		2	With the immediate intervention of the activity manager, effective time use is maintained by switching to other activities
		3	(Left blank)
		4	Workers use initiative to switch to another task and try to continue using the work time effectively
		5	No shifting, stay on hold
51APL17	**Unnecessary overproduction of parts**		
51APL17.(1)	*Unnecessary overproduction of parts*	1	No part production within the activities
		2	(Left blank)
		3	Occasionally more parts are produced than necessary
		4	In approximately 50% of the work, more parts than necessary are produced
		5	Often, more parts are produced than necessary
51APL18	**Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period**		
51APL18.(1)	*Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period*	1	No
		2	(Left blank)
		3	(Left blank)
		4	(Left blank)
		5	Yes
51APL19	**Work sharing**		
51APL19.(1)	*Creativity of the Shipyard management for work-sharing (other shipyards,*	1	Yes
		2	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
	subcontractors, etc.) when works start to exceed capacity	3	Partially
		4	(Left blank)
		5	No
51APL20	**Budget tracking methodology**		
51APL20.(1)	*Availability of a continuous budget tracking methodology*	1	Applied separately for each project and for the entire Shipyard
		2	(Left blank)
		3	Applied partially
		4	(Left blank)
		5	Not applied
51APL21	**Cost control per unit time**		
51APL21.(1)	*Availability of a unit time-cost control systematic*	1	Applied on an hourly basis
		2	Applied on a daily basis
		3	Applied on a weekly or bi-weekly basis
		4	Applied on a monthly basis
		5	It is applied for periods longer than one month
51APL22	**Tracking and management of operating costs, indirect costs**		
51APL22.(1)	*Tracking and management of operating costs, indirect costs*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL23	**Buy-Rent, Buy-Repair decisions, Service subcontracting decisions**		
51APL23.(1)	*Using scientific methods for Buy-Rent, Buy-Repair decisions, Service subcontracting decisions*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
51APL24	**Speed of decision making to revise schedules to meet customer demands**		
51APL24.(1)	*Speed of decision making to revise schedules to meet customer demands*	1	Very high
		2	(Left blank)
		3	Moderate
		4	(Left blank)
		5	Low
52ARM00	**SHIPBUILDING MANAGEMENT : RISK MANAGEMENT (ARM)**		
52ARM01	**Preparation for the risks identified in PESTEL-SWOT analyzes**		
52ARM01.(1)	*Being prepared for the risks identified in PESTEL-SWOT analyzes*	1	Yes
		2	(Left blank)

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	Partially
		4	(Left blank)
		5	No
52ARM02	**Risk management team**		
52ARM02.(1)	*Presence of a Risk Management Team*	1	Applied by the Risk Management group
		2	There is only one Risk Manager/staff; She/he does it
		3	Project Management team does it
		4	Only Project Manager does it
		5	Not done much or at all
52ARM03	**Project Risk management**		
52ARM03.(1)	*Conducting Risk Management studies before the contract signing period*	1	Risk identification, Risk analysis-evaluation, Risk mitigation studies are carried out
		2	Risk identification, Risk analysis-evaluation studies are carried out
		3	Risk identification studies are carried out
		4	Risk identification studies are carried out
		5	Risk studies are not carried out
52ARM03.(2)	*Risk Management after the contract signing period*	1	Risk Mitigation Plan is implemented; Risk Monitoring continues throughout the project
		2	Risk Mitigation Plan is implemented; Risk Monitoring continues throughout the project
		3	Risk Analysis-Evaluation and Risk Mitigation studies are carried out; Risk Monitoring continues throughout the project
		4	Risk Monitoring continues throughout the project
		5	Risk Monitoring is not done
52ARM04	**Project Risk management breakdown**		
52ARM04.(1)	*Project Risk Management breakdown*	1	They are managed under separate headings such as Main Contract Risks, Subcontract Risks, Design and Performance Risks, Ship Construction Risks, Other Technical and Infrastructure Risks, Financial Risks, Workforce Risks.
		2	It is managed under basic headings such as Contract Risks, Design and Performance Risks, Ship Construction Risks, Other Technical and Infrastructure Risks, Financial Risks.
		3	Managed under the headings Contract Risks and Technical Risks
		4	Managed under the title of contract
		5	Risk Management is not done
52ARM05	**Change management**		
52ARM05.(1)	*Systematized "Change Management"*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
52ARM06	**Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions**		
52ARM06.(1)	*Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR00	**WORK FORCE : ORGANIZATION (WOR)**		
61WOR01	**Staff status of employees (shipyard's own etc.)**		
61WOR01.(1)	*Status of employees (Shipyard own personnel, temporary yard personnel, subcontractor's personnel)*	1	The shipyard carries out its activities with 50%-75% permanent (long term contracted, own) employees. The remaining personnel are outsourced and/or temporarily hired (short term contracted) personnel
		2	The shipyard carries out its activities with 25%-50% permanent (long term contracted, own) employees. The remaining personnel are outsourced and/or temporarily hired (short term contracted) personnel
		3	The shipyard carries out its activities entirely with the permanent (long term contracted, own) employees
		4	The shipyard carries out its activities only with permanent staff in managerial positions, and the rest are entirely outsourced
		5	The shipyard carries out its activities only with permanent staff in managerial positions, and the rest are entirely temporarily hired (short term contracted) personnel
61WOR02	**Number of experienced, permanent employees**		
61WOR02.(1)	*Number of experienced, permanent employees (permanent retention of key personnel in the Shipyard's own staff)*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR03	**Trained and experienced employees**		
61WOR03.(1)	*Special effort to maintain positions of the trained and experienced employees in the Shipyard*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR03.(2)	*Existence of a training center at the shipyard*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
61WOR04	**Trained and experienced employee of the subcontractors**		
61WOR04.(1)	*In subcontractor selection, giving importance to status of trained and experienced employees*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR05	**Quick Workgroups for repetitive tasks**		
61WOR05.(1)	*Availability of Quick Workgroups for recurring tasks*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR06	**Leveraging the learning curve**		
61WOR06.(1)	*Leveraging the learning curve (In the construction of serial ships, immediately shifting the workers of the first ship to the next ship)*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR07	**Backup of critical personnel**		
61WOR07.(1)	*Backup of critical personnel*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
61WOR08	**Work planning suitable for the personnel with special conditions**		
61WOR08.(1)	*Work planning suitable for the older personnel approaching retirement*	1	Totally agree
		2	Agree
		3	Partially agree
		4	A little agree
		5	Strongly disagree
61WOR08.(2)	*Work planning suitable for disabled personnel*	1	Totally agree
		2	Agree
		3	Partially agree
		4	A little agree
		5	Strongly disagree

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP00	**WORK FORCE : PERFORMANCE & PRACTICES (WPP)**		
62WPP01	**Use of Subcontractors (If subcontractor(s) is/are used)**		
62WPP01.(1)	*Use of Construction/Outfitting Subcontractors in Shipbuilding Project (If subcontractor(s) is/are used)*	1	It is about half and half. Shipyard permanent personnel take part in matters that require permanent expertise
		2	Approximately one quarter of the services are subcontracted. Shipyard permanent personnel take part in matters that require permanent expertise
		3	No subcontractors are used, all activities are carried out by Shipyard permanent staff
		4	No subcontractors are used, all activities are carried out by the Shipyard's permanent and temporary personnel
		5	Subcontractors are used in every possible activity
62WPP02	**Hull & Superstructure Blocks construction subcontractor (if any)**		
62WPP02.(1)	*Knowledge and experience level of employees of Hull & Superstructure Blocks construction subcontractor (even if not implemented)*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP02.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP02.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP02	**Hull Erection Subcontractor (if any) workers' experience, knowledge and work performance**		
62WPP02.(1)	*Experience, knowledge and work performance of the workers of the Subcontractors (if any) working on the Hull Erection*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP02.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP02.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP03	**Hull Steel Outfitting Subcontractors (if any)**		
62WPP03.(1)	*Experience, knowledge and work performance of the workers of the Subcontractors (if any) working on the Outfitting (Steel) activities before launching in the shipyard and/or in their own facilities*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP03.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP03.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP04	**Hull Outfitting Subcontractors (Equipment, if any)**		
62WPP04.(1)	*Experience, knowledge and work performance of the workers of the Subcontractors (if any) working on the Hull Outfitting (Equipment) activities before launching in the shipyard and/or in their own facilities*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP04.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP04.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP05	**Blasting-Painting Subcontractors (if any)**		

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP05.(1)	*Experience, knowledge and work performance of the Blasting-Painting Subcontractor (if any)*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP05.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP05.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP06	**Pipe Manufacturing Subcontractor (if any)**		
62WPP06.(1)	*Experience, knowledge and work performance of the Pipe Manufacturing Subcontractor (if any) working in the shipyard and/or in its own facilities*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP06.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP06.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP07	**Pipe Installation Subcontractor (if any)**		
62WPP07.(1)	*Experience, knowledge and work performance of the Pipe Installation Subcontractor (if any)*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP07.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP07.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP08	**Insulation Subcontractor (if any)**		
62WPP08.(1)	*Experience, knowledge and work performance of the Insulation Subcontractor (if any)*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP08.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP08.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP09	**Deck Covering Subcontractor (if any)**		
62WPP09.(1)	*Experience, knowledge and work performance of the Deck Covering Subcontractor (if any)*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP09.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP09.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		5	Very low
62WPP10	**Main Propulsion System Installation Subcontractor (if any)**		
62WPP10.(1)	*Main Propulsion System Installation Subcontractor (if any) workers' experience, knowledge and work performance, also in terms of hull alignment*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP10.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP10.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP11	**Ship Service Systems Subcontractors (if any)**		
62WPP11.(1)	*Ship Service Systems Subcontractors (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP11.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP11.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP12	**Ship Electrical System Installation Subcontractor (if any)**		
62WPP12.(1)	*Ship Electrical System Installation Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP12.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP12.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP13	**Cable Trays Installation Subcontractor (if any)**		
62WPP13.(1)	*Cable Trays Installation Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP13.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP13.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP14	**Cable Pulling Subcontractor (if any)**		
62WPP14.(1)	*Cable Pulling Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP14.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP14.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP15	**Ship Electronics/Navigation Systems Installation Subcontractor (if any)**		
62WPP15.(1)	*Ship Electronics/Navigation Systems Installation Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP15.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP15.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP16	**HVAC Ducts Manufacturing Subcontractor (if any)**		
62WPP16.(1)	*Experience, knowledge and work performance of the HVAC Ducts Manufacturing Subcontractor (if any) working in the shipyard and/or their own facilities*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP16.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP16.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP17	**HVAC Ducting Installation Subcontractor (if applicable)**		
62WPP17.(1)	*HVAC Ducting Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP17.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP17.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP18	**HVAC System Installation Subcontractor (if any)**		
62WPP18.(1)	*HVAC System Installation Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP18.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP18.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP19	**Ship Launching Subcontractor**		
62WPP19.(1)	*Ship Launching Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP19.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP19.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP20	**Tank Cleaning/Preparation Subcontractor (if any)**		
62WPP20.(1)	*Tank Cleaning/Preparation Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP20.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP20.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP21	**General Service Subcontractor (ship cleaning etc., if any)**		
62WPP21.(1)	*General Service Subcontractor (if any, for ship cleaning etc.) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP21.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
62WPP21.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP22	**Staging/Scaffolding Construction/Dismantling Subcontractor (if any)**		
62WPP22.(1)	*Staging/Scaffolding Construction/Dismantling Subcontractor (if any) workers' experience, knowledge and work performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP22.(2)	*On-time delivery performance*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP22.(3)	*Delivery with quality*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
62WPP23	**Manufacturers' technical support**		
62WPP23.(1)	*Manufacturers' installation, start-up, testing and troubleshooting support*	1	Very high
		2	Between High and Medium levels
		3	At a medium level
		4	Between Medium and Low levels
		5	Very low
63WPM00	**WORKFORCE : MOTIVATION (WPM)**		
63WPM01	**Believing in being a good shipyard, motivation**		
63WPM01.(1)	*Believing in being a good shipyard, motivation*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
63WPM02	**Efficient, productive work**		
63WPM02.(1)	*Efficient, productive work*	1	Totally agree
		2	Agree
		3	Partially agree

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	Agree at a low level
		5	Strongly disagree
63WPM03	**Wages, salaries**		
63WPM03.(1)	*Wages/salaries match with employees' education level, experience, job responsibilities, and performance*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM03.(2)	*Timely payment of the wages/salaries*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM03.(3)	*Payment of performance incentives in addition to wages/salaries*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM04	**Promotions**		
63WPM04.(1)	*Promotion system and its suitability with the educational level, experience, job responsibility and performance*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM05	**Employee circulation**		
63WPM05.(1)	*Low employee circulation*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM06	**Job descriptions, work sharing**		
63WPM06.(1)	*Clear definitions of jobs and responsibilities; known by employees*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM06.(2)	*Fair distribution of work among personnel, creating a fair solution when a problem is encountered, ensuring task sharing*	1	Yes
		2	(Left blank)
		3	Partially

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	(Left blank)
		5	No
63WPM06.(3)	*Providing on-the-job training regarding our job role responsibilities at and after employment*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM06.(4)	*Regular in-house trainings provided by shipyard employees to share their knowledge and experience*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM07	**Occupational safety**		
63WPM07.(1)	*Regularly checking work safety during work, avoiding normalizations of risk areas*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM07.(2)	*Not allowing fatalistic approach in terms of occupational safety*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM07.(3)	*Reachability of the first aid team and the fire brigade to our work area in a short time in the event of an occupational accident*	1	In less than 5 minutes
		2	(Left blank)
		3	(Left blank)
		4	In 5 to 10 minutes
		5	More than 10 minutes
63WPM07.(4)	*Regular repetition of occupational safety trainings*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM07.(5)	*Recent occupational accident happened in our work area*	1	Never happened
		2	Has not happened for more than 12 months
		3	Has not happened for more than 6 months
		4	Has not happened for more than 3 months
		5	It has not happened for more than 1 month

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
63WPM08	**Protective clothing, safety equipment**		
63WPM08.(1)	*Protective workwear*	1	Provided unlimitedly by the shipyard. Their cleaning is provided regularly by the shipyard
		2	Provided unlimitedly by the shipyard
		3	Provided by the shipyard with certain quotas throughout the year. Cleaning is provided by the Shipyard
		4	Provided by the shipyard with certain quotas throughout the year.
		5	The shipyard does not provide them, the employees buy them themselves and keep it clean
63WPM08.(2)	*Heavy-duty work clothing for outdoor workers*	1	Provided unlimitedly by the shipyard. Their cleaning is provided regularly by the shipyard
		2	Provided unlimitedly by the shipyard
		3	Provided by the shipyard with certain quotas throughout the year. Cleaning is provided by the Shipyard
		4	Provided by the shipyard with certain quotas throughout the year.
		5	The shipyard does not provide them, the employees buy them themselves and keep it clean
63WPM08.(3)	*Safety equipment*	1	Provided unlimitedly by the shipyard. Their cleaning is provided regularly by the shipyard
		2	Provided unlimitedly by the shipyard
		3	Provided by the shipyard with certain quotas throughout the year. Cleaning is provided by the Shipyard
		4	Provided by the shipyard with certain quotas throughout the year.
		5	The shipyard does not provide them, the employees buy them themselves and keep it clean
63WPM09	**Work ergonomics**		
63WPM09.(1)	*Ergonomic working measures against physical fatigue and injury at our workstations taken by the Shipyard management*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM09.(2)	*Periodical measurements and evaluations on the workstation ergonomics by the shipyard management*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM09.(3)	*Use of exoskeleton (robotic prosthesis) by personnel carrying heavy loads*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
63WPM10	**Improvement suggestions**		
63WPM10.(1)	*Systematic reception, evaluation, and implementation of employees' suggestions for improvement*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM10.(2)	*The managers of our field of activity always prevent the formation of bottlenecks and constantly develop solutions*	1	Totally agree
		2	Agree
		3	Partially agree
		4	Agree at a low level
		5	Strongly disagree
63WPM11	**Negative work psychology**		
63WPM11.(1)	*When negative, bad working conditions occur, be able to report the situation to the management without the fear of losing the job, etc.*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM11.(2)	*Employees doing their jobs by fully examining the design documents and by examining the relevant norm-standard rule when necessary. The absence of a "nothing happens" approach of the employees*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM11.(3)	*Lack of employees who act as if "they do know their job" in case actually they don't*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM12	**Compliance with working hours**		
63WPM12.(1)	*Strict adherence to working hours*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM12.(2)	*Deployment of the storage(s), a rest-refreshment area, a small workshop to the nearest place(s), inside the containers if necessary, in order to have the least distance from the work area*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
63WPM12.(3)	*Employees not leaving work early (daily)*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
63WPM12.(4)	*Employees not using too many casual leave*	1	They don't use
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	Densely used
63WPM12.(5)	*Implementation of annual leaves as previously planned*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC00	**QUALITY (QAC)**		
70QAC01	**Effectiveness of the Quality Assurance System**		
70QAC01.(1)	*Effectiveness of the Quality Assurance System*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC02	**Quality Assurance certification status**		
70QAC02.(1)	*Availability of necessary Quality Assurance certificates*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC03	**Quality control**		
70QAC03.(1)	*Application of Total Quality principles; Quality Control on individual basis*	1	The shipyard has a Quality Assurance Department. Each production-installation unit also has its own quality control group, and they carry out continuous inspection, measurement and evaluation from the beginning of the process. Each employee also carries out her/his own quality control
		2	(Left blank)
		3	The shipyard has a Quality Assurance department. Each employee also carries out her/his own quality control

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		4	(Left blank)
		5	The shipyard has a Quality Assurance Department. Quality Control is provided by this department's staff
70QAC04	**Dimensional accuracy control in hull construction**		
70QAC04.(1)	*Inclusion of critical dimensions in Hull & Superstructure Block construction drawings according to a systematic (e.g., Accuracy Control) and continuous control during manufacturing*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC04.(2)	*Dimensional accuracy at Block erection edges*	1	Perfect block construction is ensured by using visual devices to compare the 3-dimensional ship product model and the block, measuring with lasers, etc.
		2	(Left blank)
		3	Correct construction with no or little deviation is ensured by constant measurements
		4	(Left blank)
		5	Only basic measurements are made during the block constructions; edge allowance is used against any defects during the block erection
70QAC05	**Welding quality**		
70QAC05.(1)	*Controlling critical welds with non-destructive testing (NDT)*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC05.(2)	*Detection of very few weld defects by the Classification Society surveyors*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC06	**Stopping the production in case of faulty production detection**		
70QAC06.(1)	*Stopping the production/process in case of faulty production/outfitting detection*	1	Production is stopped; the source of the defect is investigated, and production is not carried out until it is corrected
		2	(Left blank)
		3	Production is stopped for a short time; the source of the defect is investigated, and partial production continues until it is corrected
		4	(Left blank)
		5	Production does not stop and continues if the defect is within tolerance; If not, the defective product is replaced.

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
70QAC07	**Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management**		
70QAC07.(1)	*Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management internal directive on responsibilities*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC08	**Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)**		
70QAC08.(1)	*Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC09	**Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment**		
70QAC09.(1)	*Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC10	**Yard Trial - Preliminary check of Sea Trials (SAT)preparations**		
70QAC10.(1)	*Yard Trial - Preliminary check of Sea Trials (SAT)preparations*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
70QAC11	**Availability of a Quick Defects Repair Team**		
70QAC11.(1)	*Availability of a Quick Defects Repair Team*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
81CMC00	**CONTRACTING : MAIN CONTRACT (CMC)**		
81CMC01	**Pre-review of an incoming query**		
81CMC01.(1)	*Pre-review, breakdown and distribution of an incoming query, tender documentation*	1	The query/tender documents arrived in the shipyard are quickly examined by the Business Development team, while they are divided into sections for the relevant shipyard departments by a software
		2	The query/tender documents arrived in the shipyard are quickly examined by the Business Development team, and they are divided into sections for the relevant shipyard departments

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	**EFFECT** *and its sub-details*	Magn.	Question choices
		3	(Left blank)
		4	The query/tender documents arrived in the shipyard are quickly examined by a temporarily appointed team, and they are divided into sections for the relevant shipyard departments by the same team
		5	The query/tender documents arrived in the shipyard are copied and distributed to the relevant shipyard departments
81CMC02	**Bid/Proposal preparation standardization**		
81CMC02.(1)	*Bid/Proposal preparation team and its work standardization*	1	There is a proposal preparation team with standardized practices and standard contract templates with their annexes. In project cost estimation, material, labor quantities and costs are associated with these standard contract templates
		2	(Left blank)
		3	Partial standardization available
		4	(Left blank)
		5	No standardization exists
81CMC03	**Shipbuilding Contract preparations**		
81CMC03.(1)	*Shipbuilding Contract preparations; Availability of Contracting Group at the Shipyard*	1	Yes
		2	(Left blank)
		3	There is no Contracting Group in the shipyard, the relevant Project Management carries out this task along with the outsourced legal support
		4	There is no Contracting Group in the shipyard, the relevant Project Management carries out this task and legal support is outsourced when needed
		5	It is carried out by the relevant Project Management based on the draft Contract proposed by the Buyer
81CMC04	**Participation in Shipbuilding Contract negotiations**		
81CMC04.(1)	*Participation of relevant departments in Shipbuilding Contract negotiations*	1	Shipyard senior management representative, Contracting Group, Risk Management Group, Project Management, relevant System Engineers, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) representatives participate in all stages of the contract negotiations
		2	(Left blank)
		3	Contracting Group, Risk Management Group, Project Management, relevant System Engineers participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions
		4	Contracting Group, Project Management, relevant System Engineers participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions

Table C.1: List of Effects, sub-details and survey questionnaire second division Effect Magnitude (Magn.) question choices (cont'd).

Nr.	EFFECT *and its sub-details*	Magn.	Question choices
		5	Project Management participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions
81CMC05	**The governing law for the contracts**		
81CMC05.(1)	*Correct determination of the governing law to which the contracts will be subject to at the beginning of draft contract preparation period*	1	Yes
		2	(Left blank)
		3	Partially
		4	(Left blank)
		5	No
82CSC00	**CONTRACTING : SUBCONTRACTS (CSC)**		
82CSC01	**Subcontractor Contracts preparations**		
82CSC01.(1)	*Subcontract preparation team and its work standardization*	1	Exists
		2	(Left blank)
		3	There is no Contracting Group in the shipyard, the relevant Project Management carries out this task along with the outsourced legal support
		4	There is no Contracting Group in the shipyard, the relevant Project Management carries out this task and legal support is outsourced when needed
		5	It is carried out by the relevant Project Management based on the draft Contract proposed by the Subcontractor
82CSC02	**Participation in Subcontractor Contract negotiations**		
82CSC02.(1)	*Participation of relevant departments in Subcontract negotiations*	1	Shipyard senior management representative, Contracting Group, Risk Management Group, Project Management, relevant System Engineers, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) representatives participate in all stages of the contract negotiations
		2	(Left blank)
		3	Contracting Group, Risk Management Group, Project Management, relevant System Engineers participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions
		4	Contracting Group, Project Management, relevant System Engineers participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions
		5	Project Management participate in all stages of Contract negotiations; Shipyard senior management, Administrative Group, Financial Group (Finance and Accounting), Technical Group (Design, Production, Quality) join during their relevant sessions

Questions on the Basis Information

Following information will support, but will not be used as to declare the Shipyard's identity in the Thesis. *In this purpose, "Apprixomate" values can be used below.*

I. Basic information of the Shipyard

1. Total years that the Shipyard builds ships : .....
2. Total area of the Shipyard (square meters) : ..... (approximately)
3. Ratio of the closed area of the Shipyard to the total area (%) : ..... (approximately)
4. Total number of Shipyard employees (registered to the Shipyard) : ..... (approximately)
5. Whether if the Shipyard builds both commercial and naval ships : ..... ("Yes", or "only Commercial", "only Naval")

II. Information on the ship type/class that be taken as the reference by the Shipyard in this Survey

The ship type/class will be taken as the reference by the Shipyard in this Survey should be the one best known to the Shipyard (maximum use of yard means-capabilities), with least production time and serial in production if possible.

1. The ship type/class will be taken as the reference in this Survey : ..... (e.g. chemical tanker, Ro-Ro etc.)
2. Approximate DWT / (Approx. Full Load Displacement if Naval Ship) : ..... (please specify unit)
3. Approximate Gross Tonnage : ..... (please specify unit)
4. Approximate Length overall : ..... (please specify unit)
5. Approximate max. Beam : ..... (please specify unit)
6. Approximate Summer loaded draft : ..... (please specify unit)
7. Main propulsion engines fuel type (MDO, LNG, Hybrid etc.) : .....
8. Number of delivered reference ships until 1 January 2022 : .....
9. Number of reference ships under construction as of 1 January 2022 : .....

III. Information on the production of the ship type/class that be taken as the reference by the Shipyard in this Survey

1. Total time (in weeks) between the "Start of the Shipbuilding Contract Negotiations" and "Ship Delivery & Acceptance" for the first of the reference ships : .....
2. Time information of the shipbuilding major stages as tabulated below for the first of the reference ships :

Major Stage	Total duration (weeks)	Within the total project duration as specified in Question III.1 above	
		Week started	Week completed
Management *(From the week of shipbuilding contract negotiations starts until the delivery of the ship)*		1	
Contracting *(Shipbuilding Contract and main subcontractor contracts period)*		1	
Ship Design *(From the week the Design Team started the project)*			
Hull & Superstructure Blocks Construction *(First plate cutting to the dispatch of the last superstructure block to the hull assembly)*			
Hull Erection *(From placing the second block on to the slipway until the end of the erection of the last superstructure block)*			
Parts manufacturing in the Shipyard *(From the beginning of the first pipe manufacturing to the last pipe manufacturing)*			
Outfitting before Launching *(If applied, during the block production; if not, starting with the first erected blocks on the slipway)*			
Ship Launching *(From the start of launching preparations to the first week after launching)*			
Outfitting after Launching			
Setting-to-Work (STW), Harbor and Sea Trials (HAT-SAT)			

Figure D.1: Questions on the Basis Information.

APPENDIX E. SURVEY PARTICIPANTS STATISTICS

Table E.1: Questions asked to survey participants in the Questionnaire for participant' statistics.

IV. Participants' Information

IV.a. Start and Finish dates of filling-in this Questionnaire Form

Start date	Finish date
...../...../202....	...../...../202....

IV.b. Participants : *(please complete for each Employee seperately)*

	Age	Gender	Speciality	Current title in the shipyard	Time in this Shipyard
Example:	*26*	*M*	*CNC operator*	*Top Level Manager, General Manager/Managing Director, Director, Group Manager, Manager, Chief Engineer, Group Leader, Group Chief, Chief, Leader, Senior Engineer/Designer, Engineer, Expert Technician, Specialist, Technician, Master Foreman, Foreman, Operator, Worker etc.*	*9 months (please specify "Month" if less than 12 months, "Year" if longer)*
Employee :					

	Education (last completed)	Experience in Shipbuilding Sector	Number of previous work places			
			Shipyard	Ship design house	Shipbuilding side industry firm	Other
Example:	*Ph.D., Master's Deg., Bachelor's Deg., Vocational School, Vocational High School, High School, Middle School, Elementary School*	*14 years (please specify "Month" if less than 12 months, "Year" if longer)*	*2*	*1*	*1*	*2*
Employee :						

Table E.2: Survey participants summary.

	Number of Participants
SHIPYARD NR. 5	4
SHIPYARD NR. 12	17
SHIPYARD NR. 200	12
SHIPYARD NR. 300	14
TOTAL	**47**

Table E.3: Distribution of survey participants on process responses basis.

	Shipbuilding Management	Contracting	Hull&Superstructure Blocks Construction	Hull-Erection	Parts Manufacturing in the Shipyard	Outfitting before Launching	Ship Launching	Outfitting after Launching	STW, Harbor & Sea Tests & Trials	Ship Design	
SHIPYARD 5	2	1	1	1	1	1	1	2	1	1	of total 4 respond-ents
SHIPYARD 12	2	2	3	3	3	3	3	3	3	3	of total 17 respond-ents
SHIPYARD 200	5					3				4	total 12 respondents
SHIPYARD 300	5					3				6	total 14 respondents
TOTAL	**14**	**3**	**4**	**4**	**4**	**10**	**4**	**5**	**4**	**14**	

with partially reflected responses rom SY 200 and SY 300, only for Sectoral (average) weight calculations

SHIPYARD 200	7	12	12	12	12	8	12	12	12	8
SHIPYARD 300	9	14	14	14	14	11	14	14	14	8
TOTAL	**30**	**29**	**30**	**30**	**30**	**29**	**30**	**31**	**30**	**30**

Table E.4: Participants' gender distribution.

Characteristics	Frequency	%
Male	42	89.3
Female	2	4.3
Undisclosed	3	6.4
Total	47	100

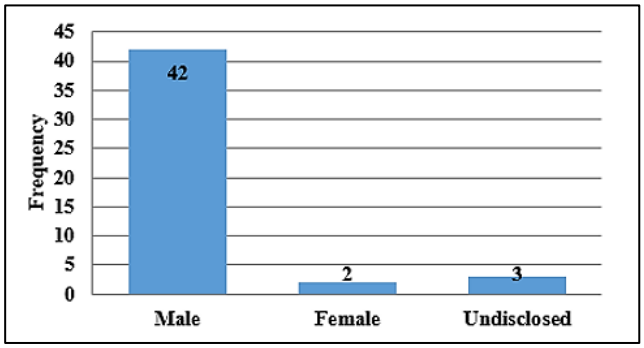


Figure E.1: Participants' gender distribution.

Table E.5: Participants' age distribution.

Characteristics	Frequency	%
20-30	2	4.3
31-40	19	40.4
41-50	16	34.0
51-60	3	6.4
61-70	3	6.4
Undisclosed	4	8.5
Total	47	100

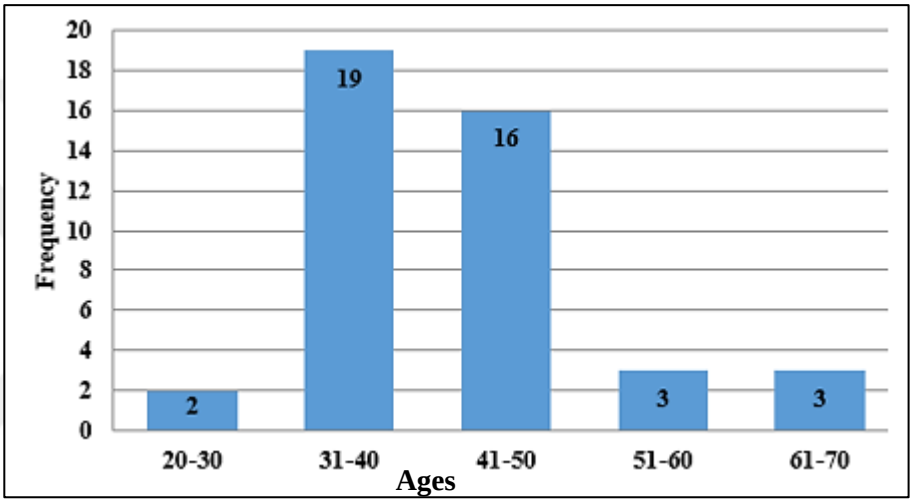


Figure E.2: Participants' age distribution.

Table E.6: Participants' experience in shipbuilding sector (years).

Characteristics	Frequency	%
3-5	1	2
6-10	7	15
11-15	6	13
16-20	15	32
21-25	6	13
25-40	7	15
Undisclosed	5	11
Total	47	100

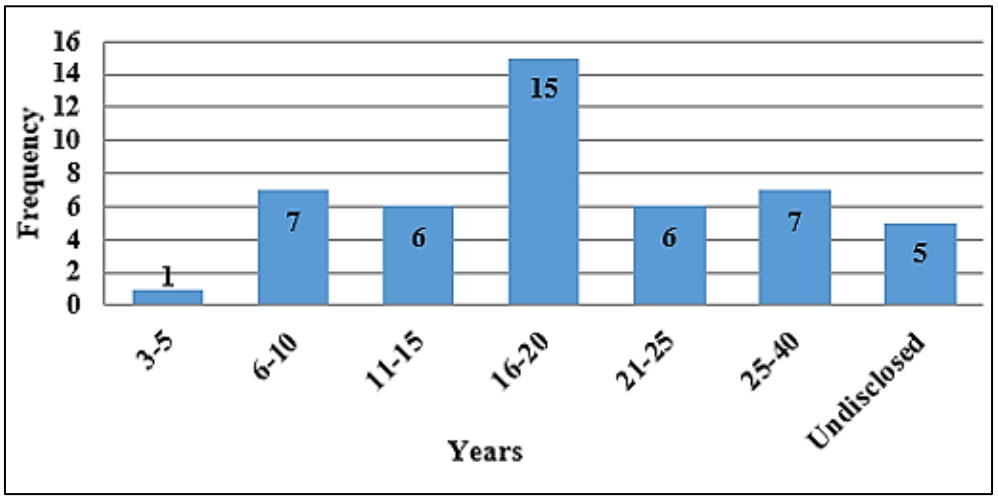


Figure E.3: Participants' experience in shipbuilding sector (years).

Table E.7: Participants' specialties

Characteristics	Frequency	%
Project Management, Contracts, Budgeting	2	4.3
Naval Architecture & Marine Engineering	26	55.3
Naval Architecture & Offshore Technology	1	2.1
Ship Design	4	8.5
Hull Production	1	2.1
Hull Outfitting	2	4.3
Pipe Fitting	2	4.3
Industrial Engineering	1	2.1
Interior Architecture	1	2.1
Undisclosed	7	14.9

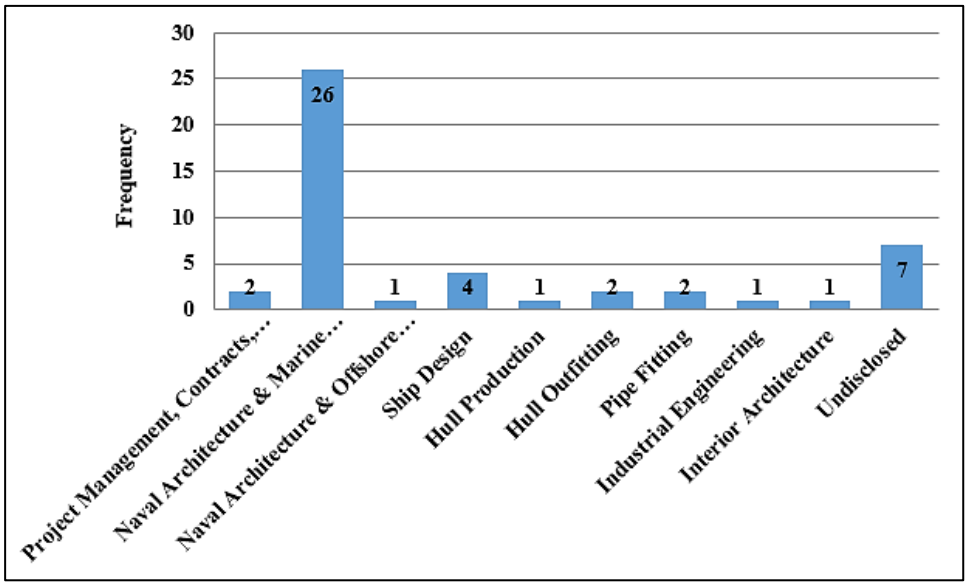


Figure E.4: Participants' specialties

Table E.8: Participants' current job title.

Characteristics	Frequency	%
Manager, Top Level	3	6.3
Manager, General	2	4.2
Manager, Department	11	22.9
Manager, Project	1	2.1
Director	3	6.3
Chief Engineer	2	4.2
Chief, Group/Branch	4	8.3
Leader, Group/Team	5	10.4
Leader, Senior Engineer	6	12.5
Engineer	2	4.2
Technician	2	4.2
Planner	3	6.3
Undisclosed	3	6.3

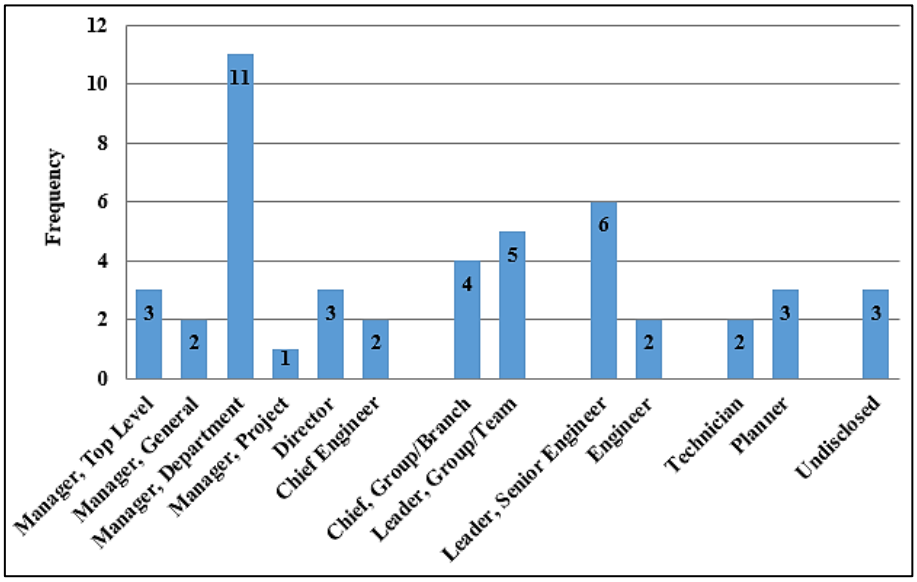


Figure E.5: Participants' current job title

Table E.9: Participants' workplace history.

Characteristics	Frequency		
WORKED at :			
1 x SHIPYARD	11		
2 x SHIPYARDs	10		
3 x SHIPYARDs	11		
4 x SHIPYARDs	1		
5 x SHIPYARDs	1		
6 x SHIPYARDs	1		
1 x DESIGN HOUSE		17	
2 x DESIGN HOUSEs		9	
3 x DESIGN HOUSEs		2	
1 x SIDE IND. FIRM			5
3 x SIDE IND. FIRM			1

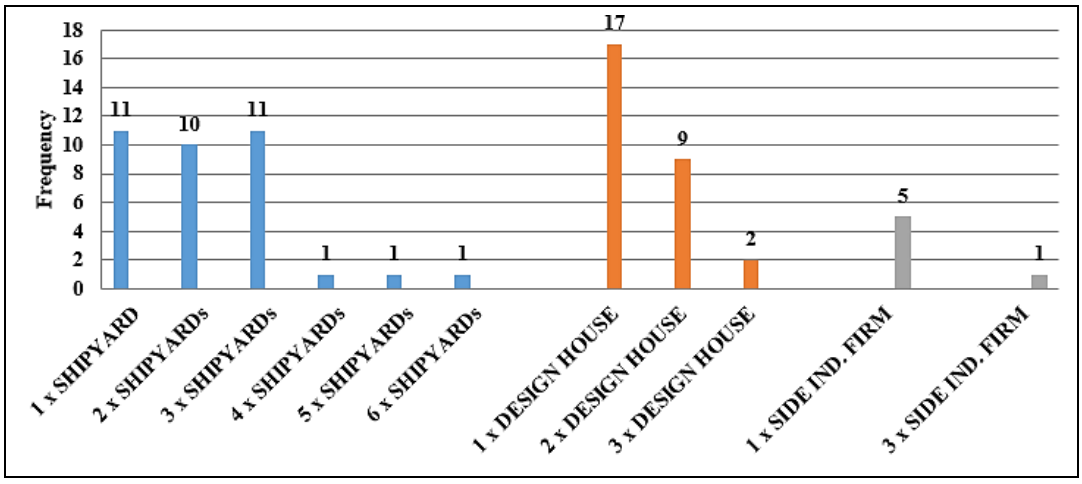


Figure E.6: Participants' workplace history.

Table E.10: Participants' education level (last completed).

Characteristics	Frequency	%
Ph.D.	1	2
Master of Science (M.S.)	12	26
Bachelor's Degree (B.S.)	25	53
Associate Degree	3	6
Undisclosed	6	13

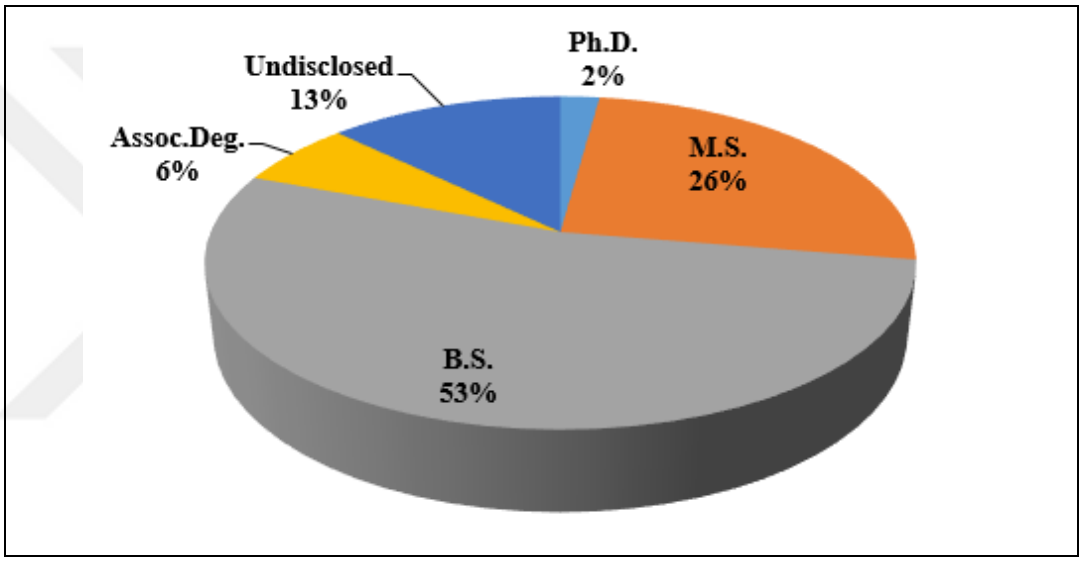


Figure E.7: Participants' education level (last completed).

APPENDIX F. PAIRWISE COMPARISON TEMPLATE

EFFECT WEIGHT CALCULATION TEMPLATE (Pairwise Comparison, Perfect Consistency):

1. DATA :

# of CRITERIA = 6

PAIR-WISE COMPARISON MATRIX (AUTO CALCULATION)

	A	B	C	D	E	F
A	1	7	9	5	0.333333	7
B	0.142857	1	1.285714	0.714286	0.047619	1
C	0.111111	0.777778	1	0.555556	0.037037	0.777778
D	0.2	1.4	1.8	1	0.066667	1.4
E	3	21	27	15	1	21
F	0.142857	1	1.285714	0.714286	0.047619	1
SUM =	4.59683	32.17778	41.37143	22.98413	1.53228	32.17778

2. CALCULATION :

	A	B	C	D	E	F
A	0.2175	0.2175	0.2175	0.2175	0.2175	0.2175
B	0.0311	0.0311	0.0311	0.0311	0.0311	0.0311
C	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242
D	0.0435	0.0435	0.0435	0.0435	0.0435	0.0435
E	0.6526	0.6526	0.6526	0.6526	0.6526	0.6526
F	0.0311	0.0311	0.0311	0.0311	0.0311	0.0311

Criteria Weight = Eigenvector

A	0.218
B	0.031
C	0.024
D	0.044
E	0.653
F	0.031
	1.0000

CALCULATED WEIGHTS

MNG Quest. 1	0.218
MNG Quest. 2	0.031
MNG Quest. 3	0.024
MNG Quest. 4	0.044
MNG Quest. 5	0.653
MNG Quest. 6	0.031
CHECK	

RESPONSE IN THE QUESTIONNAIRE

S.Nr.	Extremely less important	Much less important	Less important	Slightly less important	Equally important	Moderately important	Strongly important	Very strongly important	Extremely important
1									9

MNG Quest. 1	Criteria A importance compared to	7.0000	Criteria B
MNG Quest. 2	Criteria A importance compared to	9.0000	Criteria C
MNG Quest. 3	Criteria A importance compared to	5.0000	Criteria D
MNG Quest. 4	Criteria A importance compared to	0.3333	Criteria E
MNG Quest. 5	Criteria A importance compared to	7.0000	Criteria F
MNG Quest. 6			

S.Nr.	Extremely less important	Much less important	Less important	Slightly less important	Equally important	Moderately important	Strongly important	Very strongly important	Extremely important
2								7	
3									9
4							5		
5				0.3333					
6								7	

Figure F.1: Pairwise comparison calculation template sample for six Effects.

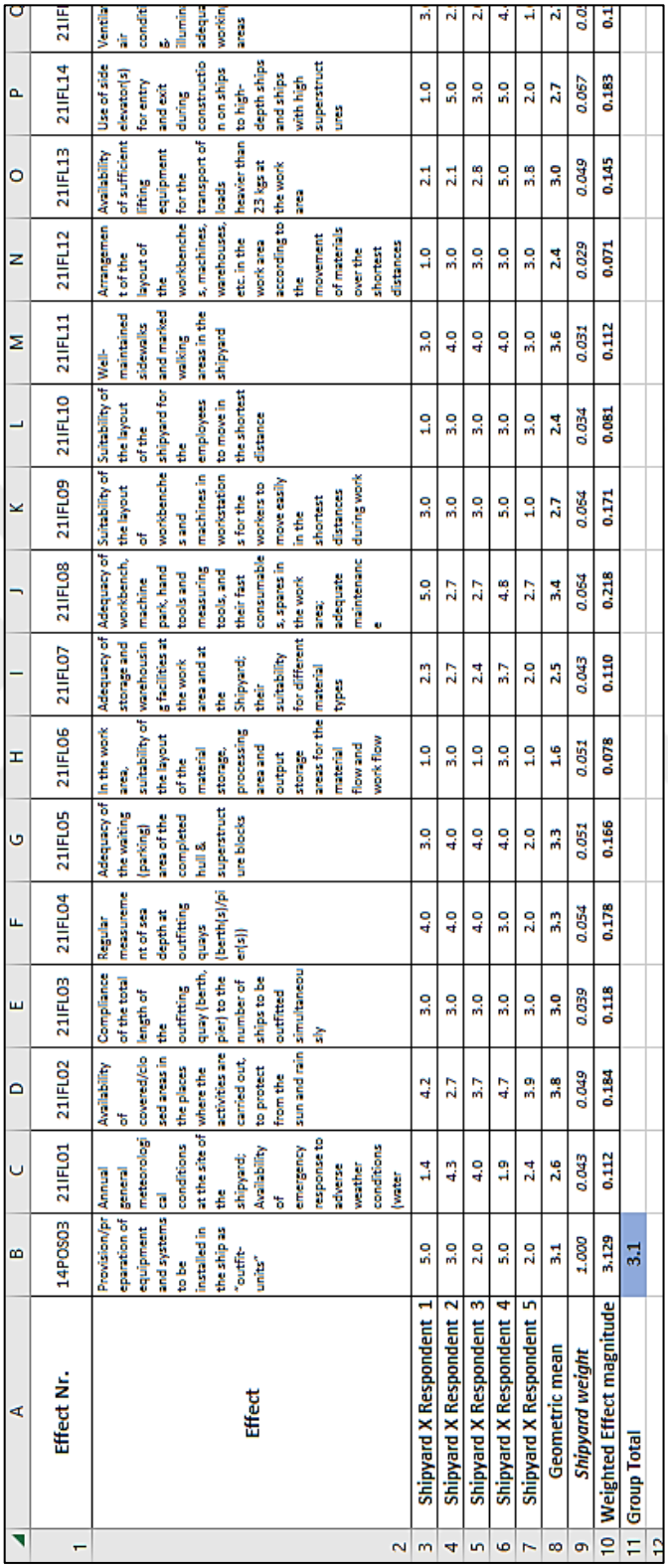
APPENDIX G. EFFECT WEIGHTS RECORDING TEMPLATE

1. SHIPBUILDING MANAGEMENT:

EFFECT NR:	21IF01	21IF02	21IF03	21IF04	21IF05	21IF06	21IF07	21IF08	21IF09	21IF10	21IF11	21IF12	21IF13	21IF14	21IF15	21IF16	22IEN01	22IEN02	23ITE01	23ITE0
RESPONDENTS AND CALCULATED WEIGHTS FROM THEIR QUESTIONNAIRE RESPONSES																				
Shipyard 12-1	0.096	0.096	0.096	0.019	0.096	0.032	0.019	0.032	0.032	0.096	0.032	0.096	0.096	0.032	0.096	0.032	0.250	0.750	0.045	0.1
Shipyard 12-1	0.068	0.014	0.068	0.123	0.123	0.005	0.041	0.068	0.123	0.041	0.095	0.041	0.068	0.068	0.041	0.014	0.250	0.750	0.050	0.0
Shipyard 05-1	0.084	0.028	0.084	0.084	0.009	0.084	0.141	0.197	0.141	0.006	0.004	0.009	0.028	0.009	0.084	0.005	0.500	0.500	0.050	0.1
Shipyard 200Y1	0.275	0.039	0.039	0.039	0.039	0.039	0.039	0.092	0.092	0.055	0.039	0.039	0.039	0.055	0.039	0.039	0.900	0.100	0.216	0.6
Shipyard 200Y2	0.014	0.041	0.014	0.068	0.068	0.068	0.068	0.041	0.095	0.095	0.095	0.068	0.068	0.122	0.041	0.041	0.125	0.875	0.036	0.1
Shipyard 200Y3	0.029	0.088	0.088	0.088	0.088	0.088	0.029	0.088	0.029	0.029	0.029	0.029	0.029	0.088	0.088	0.088	0.500	0.500	0.168	0.1
Shipyard 200Y4	0.099	0.020	0.020	0.020	0.020	0.020	0.020	0.033	0.296	0.020	0.020	0.020	0.296	0.033	0.033	0.033	0.500	0.500	0.063	0.1
Shipyard 200Y5	0.014	0.100	0.100	0.100	0.071	0.071	0.100	0.100	0.014	0.014	0.014	0.014	0.071	0.071	0.071	0.071	0.167	0.833	0.227	0.4
Shipyard 300Y2	0.095	0.014	0.019	0.019	0.014	0.019	0.019	0.014	0.019	0.019	0.014	0.019	0.019	0.666	0.014	0.019	0.875	0.125	0.583	0.0
Shipyard 300Y3	0.019	0.094	0.094	0.094	0.019	0.056	0.094	0.131	0.056	0.056	0.056	0.056	0.056	0.019	0.094	0.006	0.500	0.500	0.192	0.1
Shipyard 300Y4	0.061	0.183	0.061	0.061	0.012	0.012	0.061	0.061	0.020	0.020	0.020	0.020	0.020	0.020	0.183	0.183	0.500	0.500	0.365	0.0
Shipyard 300Y6	0.009	0.063	0.063	0.063	0.063	0.063	0.063	0.080	0.063	0.063	0.063	0.063	0.063	0.063	0.080	0.080	0.500	0.500	0.063	0.1
NUMBER OF ROWS WITH DATA :	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
DESCRIPTIVE STATISTICS :																				
MEAN=	0.072	0.065	0.062	0.065	0.052	0.046	0.058	0.078	0.082	0.043	0.040	0.040	0.071	0.104	0.072	0.051	0.464	0.536	0.190	0.2
MEDIAN=	0.065	0.052	0.065	0.065	0.051	0.048	0.051	0.074	0.059	0.035	0.031	0.034	0.059	0.059	0.076	0.036	0.500	0.500	0.125	0.1
MODE=	0.426	0.061	0.132	0.132	#YOK	0.061	0.061	0.061	0.047	0.047	0.047	0.047	0.047	0.076	0.047	1.000	0.500	0.500	0.063	0.2
GEOMETRIC MEAN=	0.046	0.048	0.051	0.054	0.037	0.035	0.047	0.063	0.055	0.032	0.029	0.032	0.052	0.053	0.060	0.033	0.398	0.456	0.120	0.1
MIN.=	0.009	0.014	0.014	0.019	0.009	0.005	0.019	0.014	0.014	0.006	0.004	0.009	0.019	0.009	0.014	0.006	0.125	0.100	0.036	0.0
MAX.=	0.275	0.183	0.100	0.123	0.123	0.088	0.141	0.197	0.296	0.096	0.095	0.096	0.296	0.666	0.183	0.183	0.900	0.875	0.583	0.6
RANGE=	0.266	0.169	0.086	0.104	0.113	0.084	0.122	0.183	0.282	0.091	0.091	0.087	0.277	0.656	0.169	0.177	0.775	0.775	0.548	0.5
TOTAL=	0.863	0.778	0.746	0.777	0.622	0.557	0.693	0.937	0.980	0.514	0.481	0.475	0.854	1.245	0.864	0.612	5.567	6.433	2.277	2.5
VARIANCE=	0.005	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.008	0.001	0.001	0.001	0.005	0.030	0.002	0.002	0.055	0.055	0.034	0.0
STD.DEV.=	0.073	0.050	0.032	0.035	0.038	0.029	0.038	0.050	0.080	0.030	0.031	0.026	0.075	0.180	0.045	0.050	0.245	0.245	0.194	0.1
SKEWNESS=	2.111	1.151	-0.426	-0.040	0.464	0.006	0.967	1.138	1.956	0.724	0.914	0.905	2.855	3.267	1.282	1.831	0.503	-0.503	1.458	2.1
STANDARD ERROR of SKEWNESS=	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.6
SKWCHECK=	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.249	1.2
CURTOSIS=	5.647	1.500	-1.419	-1.079	-1.027	-1.508	0.432	1.771	4.542	-0.578	-0.285	0.204	8.994	10.998	2.734	3.971	-0.117	-0.117	1.098	5.8
STANDARD ERROR of CURTOSIS=	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.232	1.2

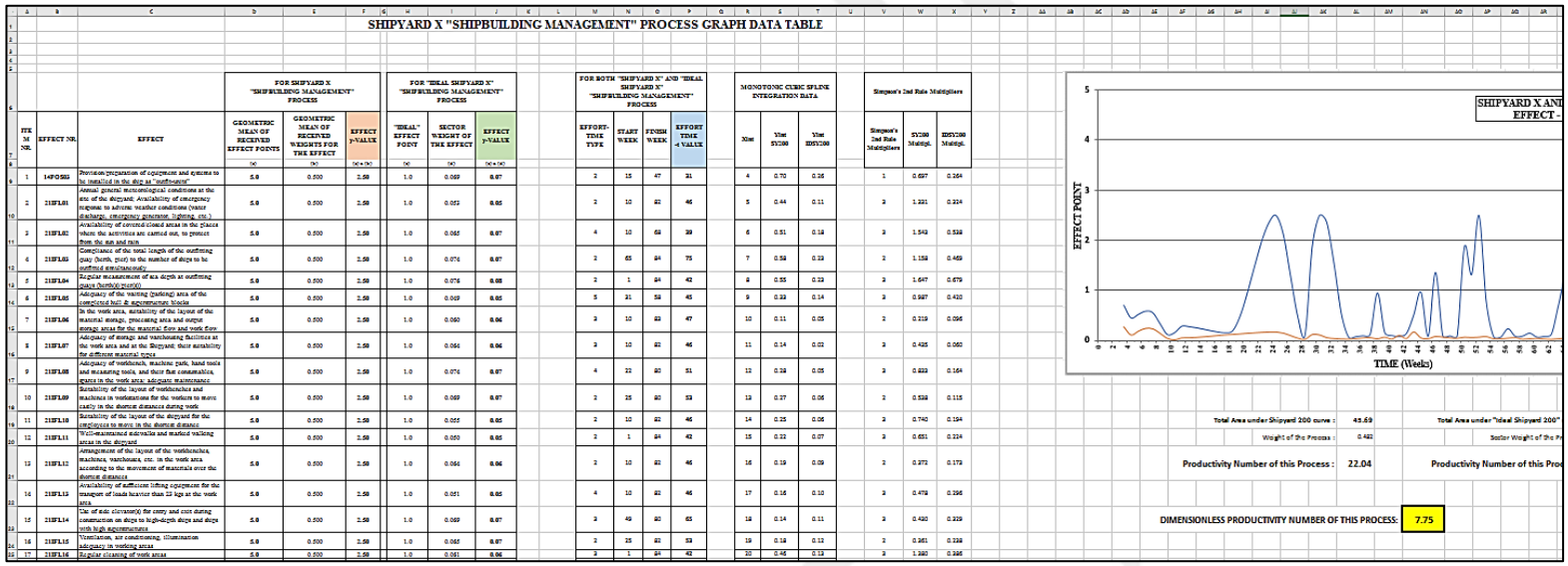
Figure G.1: Effect weights recording template sample.

APPENDIX H. EFFECT MAGNITUDE GATHERING, CURVE-AREA CALCULATION TEMPLATES



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Effect Nr.**	14POS03	21IFL01	21IFL02	21IFL03	21IFL04	21IFL05	21IFL06	21IFL07	21IFL08	21IFL09	21IFL10	21IFL11	21IFL12	21IFL13	21IFL14	21IFl
2	**Effect**	Provision/preparation of equipment and systems to be installed in the ship as "outfit-units"	Annual general meteorological conditions at the site of the shipyard; Availability of emergency response to adverse weather conditions (water	Availability of covered/closed areas in the places where the activities are carried out, to protect from the sun and rain	Compliance of the total length of the outfitting quay (berth, pier) to the number of ships to be outfitted simultaneously	Regular measurement of sea depth at outfitting quays (berth(s)/pier(s))	Adequacy of the walking (parking) area of the completed hull & superstructure blocks	In the work area, suitability of the layout of the material storage, processing area and output storage areas for the material flow and work flow	Adequacy of storage and warehousing facilities at the work area and at the Shipyard; their suitability for different material types	Adequacy of workbench, machine park, hand tools and measuring tools, and their fast consumable s, spares in the work area; adequate maintenance	Suitability of the layout of workbenches and machines in workstations for the workers to move easily in the shortest distances during work	Suitability of the layout of the shipyard for the employees to move in the shortest distance	Well-maintained sidewalks and marked walking areas in the shipyard	Arrangement of the layout of the workbenches, machines, warehousses, etc. in the work area according to the movement of materials over the shortest distances	Availability of sufficient lifting equipment for the transport of loads heavier than 23 kgs at the work area	Use of side elevator(s) for entry and exit during construction ships to high-depth ships and ships with high superstructures	Ventila air condit g, illumin adequ workin areas
3	Shipyard X Respondent 1	5.0	1.4	4.2	3.0	4.0	3.0	1.0	2.3	5.0	3.0	1.0	3.0	1.0	2.1	1.0	3.
4	Shipyard X Respondent 2	3.0	4.3	2.7	3.0	4.0	4.0	3.0	2.7	2.7	3.0	3.0	4.0	3.0	2.1	5.0	2.
5	Shipyard X Respondent 3	2.0	4.0	3.7	3.0	4.0	4.0	1.0	2.4	2.7	3.0	3.0	4.0	3.0	2.8	3.0	2.
6	Shipyard X Respondent 4	5.0	1.9	4.7	3.0	3.0	4.0	3.0	3.7	4.8	5.0	3.0	4.0	3.0	5.0	5.0	4.
7	Shipyard X Respondent 5	2.0	2.4	3.9	3.0	2.0	2.0	1.0	2.0	2.7	1.0	3.0	3.0	3.0	3.8	2.0	1.
8	Geometric mean	3.1	2.6	3.8	3.0	3.3	3.3	1.6	2.5	3.4	2.7	2.4	3.6	2.4	3.0	2.7	2.
9	*Shipyard weight*	*1.000*	*0.043*	*0.049*	*0.039*	*0.054*	*0.051*	*0.051*	*0.043*	*0.054*	*0.054*	*0.034*	*0.031*	*0.029*	*0.049*	*0.057*	*0.0*
10	Weighted Effect magnitude	3.129	0.112	0.184	0.118	0.178	0.166	0.078	0.110	0.218	0.171	0.081	0.112	0.071	0.145	0.183	0.1
11	Group Total	3.1															
12																	

Figure H.1: Effect magnitudes gathering template sample.



SHIPYARD X "SHIPBUILDING MANAGEMENT" PROCESS GRAPH DATA TABLE

ITEM NR.	EFFECT NR.	EFFECT	FOR SHIPYARD X "SHIPBUILDING MANAGEMENT" PROCESS			FOR "IDEAL SHIPYARD X" "SHIPBUILDING MANAGEMENT" PROCESS			FOR BOTH "SHIPYARD X" AND "IDEAL SHIPYARD X" "SHIPBUILDING MANAGEMENT" PROCESS				MONOTONIC CUBIC SPLINE INTERPOLATION DATA			Simpson's 2nd Rule Multipliers		
			GEOMETRIC MEAN OF RECEIVED EFFECT POINTS	GEOMETRIC MEAN OF RECEIVED WEIGHTS FOR THE EFFECT	EFFECT y-VALUE	"IDEAL" EFFECT POINT	SECTOR WEIGHT OF THE EFFECT	EFFECT y-VALUE	EFFORT-TIME TYPE	START WEEK	FINISH WEEK	EFFORT TIME x-VALUE	Xint	Yint SY200	Yint IDSY200	Simpson's 2nd Rule Multipliers	SY200 Multipl.	IDSY200 Multipl.
			(a)	(b)	(a)x(b)	(a)	(b)	(a)x(b)										
1	1SPOS01	Provision/preparation of equipment and systems to be installed in the ship as "earthworks".	5.0	0.500	2.50	1.0	0.069	0.07	2	15	47	31	4	0.70	0.36	1	0.697	0.364
2	2SFL01	Annual general meteorological conditions at the site of the shipyard; Availability of emergency response to adverse weather conditions (water discharge, emergency generator, lighting, etc.)	5.0	0.500	2.50	1.0	0.053	0.05	2	10	82	46	5	0.44	0.11	2	1.221	0.224
3	2SFL02	Availability of covered/closed areas in the places where the activities are carried out, to protect them the sun and rain	5.0	0.500	2.50	1.0	0.065	0.07	4	10	68	39	6	0.51	0.14	2	1.543	0.338
4	2SFL03	Compliance of the total length of the outfitting quay (berth, pier) to the number of ships to be outfitted simultaneously	5.0	0.500	2.50	1.0	0.074	0.07	2	65	94	75	7	0.59	0.23	2	1.158	0.469
5	2SFL04	Regular measurement of sea depth at outfitting quays (berth/pier/etc)	5.0	0.500	2.50	1.0	0.076	0.08	2	1	94	42	8	0.55	0.23	2	1.647	0.679
6	2SFL05	Adequacy of the waiting (parking) area of the completed hull & superstructure blocks	5.0	0.500	2.50	1.0	0.069	0.05	5	21	58	45	9	0.33	0.14	2	0.987	0.420
7	2SFL06	In the work area, suitability of the layout of the material storage, processing area and output storage areas for the material flow and work flow	5.0	0.500	2.50	1.0	0.060	0.06	3	10	82	47	10	0.11	0.05	2	0.319	0.096
8	2SFL07	Adequacy of storage and warehousing facilities at the work area and at the Shipyard; their suitability for the different material types	5.0	0.500	2.50	1.0	0.064	0.06	3	10	82	46	11	0.14	0.03	2	0.425	0.092
9	2SFL08	Adequacy of workbench, machine park, hand tools and measuring tools, and their fast consumables, spares in the work area; adequate maintenance	5.0	0.500	2.50	1.0	0.074	0.07	4	22	80	51	12	0.29	0.05	2	0.833	0.164
10	2SFL09	Suitability of the layout of workbenches and machines in workstations for the workers to move easily in the shortest distances during work	5.0	0.500	2.50	1.0	0.069	0.07	2	25	80	53	13	0.27	0.06	2	0.538	0.115
11	2SFL10	Suitability of the layout of the shipyard for the employees to move in the shortest distance	5.0	0.500	2.50	1.0	0.055	0.05	2	10	82	46	14	0.25	0.06	2	0.740	0.184
12	2SFL11	Well-maintained sidewalks and marked walking areas in the shipyard	5.0	0.500	2.50	1.0	0.050	0.05	2	1	94	42	15	0.22	0.07	2	0.651	0.324
13	2SFL12	Arrangement of the layout of the workbenches, machines, warehouses, etc. in the work area according to the movement of materials over the shortest distances	5.0	0.500	2.50	1.0	0.064	0.06	2	10	82	46	16	0.19	0.09	2	0.572	0.173
14	2SFL13	Availability of sufficient lifting equipment for the transport of loads heavier than 25 kgs at the work area	5.0	0.500	2.50	1.0	0.051	0.05	4	10	82	46	17	0.16	0.10	2	0.479	0.296
15	2SFL14	Use of side elevator(s) for entry and exit during construction on ships to high-depth ships and ships with high superstructures	5.0	0.500	2.50	1.0	0.069	0.07	2	49	80	65	18	0.14	0.11	2	0.420	0.329
16	2SFL15	Ventilation, air conditioning, illumination adequacy in working areas	5.0	0.500	2.50	1.0	0.065	0.07	2	25	82	53	19	0.11	0.12	2	0.361	0.338
17	2SFL16	Regular cleaning of work areas	5.0	0.500	2.50	1.0	0.061	0.06	3	1	94	42	20	0.46	0.13	3	1.380	0.396

Total Area under Shipyard 200 curve : 43.69 | Total Area under "Ideal Shipyard 200"

Weight of the Process : 0.482 | Scaler Weight of the Pr

Productivity Number of this Process : 22.04 | Productivity Number of this Proc

DIMENSIONLESS PRODUCTIVITY NUMBER OF THIS PROCESS: 7.75

Figure H.2: Curve-area calculation template sample.

APPENDIX I. CALCULATED EFFECT WEIGHTS

Table I.1: Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
14POS00	0.073	0.025	0.124	0.350	0.011	0.071	0.031	0.086	0.317	0.095	0.302	0.071
14POS03	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21IFL00	0.073	0.075	0.014	0.050	0.080	0.071	0.031	0.086	0.045	0.095	0.060	0.024
21IFL01	0.084	0.096	0.068	0.275	0.014	0.029	0.099	0.014	0.095	0.019	0.061	0.009
21IFL02	0.028	0.096	0.014	0.039	0.041	0.088	0.020	0.100	0.014	0.094	0.183	0.063
21IFL03	0.084	0.096	0.068	0.039	0.014	0.088	0.020	0.100	0.019	0.094	0.061	0.063
21IFL04	0.084	0.019	0.123	0.039	0.068	0.088	0.020	0.100	0.019	0.094	0.061	0.063
21IFL05	0.009	0.096	0.123	0.039	0.068	0.088	0.020	0.071	0.014	0.019	0.012	0.063
21IFL06	0.084	0.032	0.005	0.039	0.068	0.088	0.020	0.071	0.019	0.056	0.012	0.063
21IFL07	0.141	0.019	0.041	0.039	0.068	0.029	0.020	0.100	0.019	0.094	0.061	0.063
21IFL08	0.197	0.032	0.068	0.092	0.041	0.088	0.033	0.100	0.014	0.131	0.061	0.080
21IFL09	0.141	0.032	0.123	0.092	0.095	0.029	0.296	0.014	0.019	0.056	0.020	0.063
21IFL10	0.006	0.096	0.041	0.055	0.095	0.029	0.020	0.014	0.019	0.056	0.020	0.063
21IFL11	0.004	0.032	0.095	0.039	0.095	0.029	0.020	0.014	0.014	0.056	0.020	0.063
21IFL12	0.009	0.096	0.041	0.039	0.068	0.029	0.020	0.014	0.019	0.056	0.020	0.063
21IFL13	0.028	0.096	0.068	0.039	0.068	0.029	0.296	0.071	0.019	0.056	0.020	0.063
21IFL14	0.009	0.032	0.068	0.055	0.122	0.088	0.033	0.071	0.666	0.019	0.020	0.063
21IFL15	0.084	0.096	0.041	0.039	0.041	0.088	0.033	0.071	0.014	0.094	0.183	0.080
21IFL16	0.006	0.032	0.014	0.039	0.041	0.088	0.033	0.071	0.019	0.006	0.183	0.080
22IEN00	0.073	0.075	0.014	0.050	0.057	0.071	0.094	0.086	0.063	0.032	0.060	0.024
22IEN01	0.500	0.250	0.250	0.900	0.125	0.500	0.500	0.167	0.875	0.500	0.500	0.500
22IEN02	0.500	0.750	0.750	0.100	0.875	0.500	0.500	0.833	0.125	0.500	0.500	0.500
23ITE00	0.218	0.075	0.014	0.050	0.080	0.071	0.094	0.086	0.063	0.032	0.060	0.024
23ITE01	0.050	0.045	0.050	0.216	0.036	0.188	0.063	0.227	0.583	0.192	0.565	0.063
23ITE02	0.250	0.227	0.250	0.031	0.250	0.188	0.188	0.045	0.083	0.192	0.081	0.063
23ITE03	0.050	0.227	0.250	0.043	0.179	0.063	0.188	0.045	0.083	0.038	0.081	0.063
23ITE04	0.150	0.136	0.050	0.648	0.250	0.188	0.188	0.227	0.083	0.192	0.081	0.313
23ITE05	0.250	0.136	0.050	0.031	0.179	0.188	0.188	0.227	0.083	0.192	0.081	0.188
23ITE06	0.250	0.227	0.350	0.031	0.107	0.188	0.188	0.227	0.083	0.192	0.113	0.313
24IFA00	0.015	0.075	0.014	0.050	0.080	0.071	0.094	0.086	0.106	0.019	0.060	0.024
24IFA01	0.398	0.273	0.152	0.119	0.037	0.158	0.100	0.122	0.636	0.385	0.091	0.385
24IFA02	0.398	0.273	0.758	0.017	0.185	0.158	0.100	0.122	0.091	0.385	0.091	0.385
24IFA03	0.080	0.091	0.030	0.017	0.185	0.053	0.100	0.122	0.091	0.077	0.273	0.077
24IFA04	0.080	0.273	0.030	0.017	0.259	0.474		0.610	0.091	0.077	0.273	0.077
24IFA05	0.044	0.091	0.030	0.831	0.333	0.158	0.700	0.024	0.091	0.077	0.273	0.077
30DES00	0.015	0.075	0.124	0.050	0.057	0.071	0.031	0.086	0.035	0.095	0.043	0.071
30DES17	0.097	0.273	0.120	0.636	0.059	0.200	0.200	0.294	0.636	0.366	0.626	0.200

Table I.1: Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
30DES19	0.484	0.273	0.120	0.091	0.176	0.200	0.200	0.059	0.091	0.073	0.089	0.200
30DES20	0.290	0.273	0.120	0.091	0.176	0.200	0.200	0.294	0.091	0.073	0.089	0.200
30DES21	0.032	0.091	0.040	0.091	0.294	0.200	0.200	0.294	0.091	0.122	0.125	0.200
30DES22	0.097	0.091	0.600	0.091	0.294	0.200	0.200	0.059	0.091	0.366	0.070	0.200
40MPP00	0.024	0.075	0.124	0.050	0.057	0.071	0.031	0.086	0.045	0.095	0.043	0.071
40MPP01	0.042	0.123	0.014	0.132	0.017	0.033	0.041	0.047	0.130	0.061	0.284	0.042
40MPP02	0.014	0.041	0.068	0.019	0.122	0.100	0.123	0.009	0.019	0.020	0.041	0.125
40MPP03	0.042	0.025	0.041	0.019	0.003	0.100	0.041	0.047	0.026	0.061	0.041	0.125
40MPP04	0.008	0.025	0.003	0.662	0.122	0.033	0.288	0.047	0.014	0.183	0.057	0.125
40MPP05	0.008	0.025	0.068	0.019	0.087	0.033	0.205	0.047	0.649	0.020	0.095	0.208
40MPP06	0.042	0.123	0.123	0.015	0.087	0.033	0.041	0.047	0.014	0.061	0.057	0.125
40MPP07	0.126	0.123	0.123	0.015	0.087	0.100	0.041	0.236	0.019	0.061	0.057	0.042
40MPP08	0.126	0.025	0.096	0.015	0.052	0.100	0.006	0.236	0.019	0.183	0.057	0.042
40MPP09	0.042	0.041	0.096	0.019	0.052	0.100	0.008	0.047	0.014	0.012	0.095	0.042
40MPP10	0.126	0.123	0.096	0.019	0.087	0.167	0.041	0.047	0.019	0.183	0.041	0.042
40MPP11	0.126	0.123	0.096	0.015	0.052	0.100	0.041	0.047	0.014	0.061	0.041	0.014
40MPP12	0.126	0.123	0.068	0.019	0.087	0.033	0.041	0.047	0.019	0.061	0.041	0.042
40MPP13	0.126	0.041	0.041	0.015	0.087	0.033	0.041	0.047	0.019	0.020	0.057	0.014
40MPP14	0.042	0.041	0.068	0.019	0.052	0.033	0.041	0.047	0.026	0.012	0.041	0.014
51APL00	0.073	0.075	0.124	0.050	0.080	0.071	0.094	0.086	0.045	0.032	0.060	0.071
51APL01	0.016	0.060	0.027	0.233	0.007	0.027	0.035	0.020	0.047	0.017	0.169	0.031
51APL02	0.003	0.060	0.082	0.033	0.022	0.027	0.012	0.020	0.005	0.017	0.024	0.031
51APL03	0.079	0.060	0.027	0.033	0.037	0.082	0.012	0.020	0.005	0.052	0.024	0.031
51APL04	0.003	0.020	0.027	0.033	0.037	0.027	0.012	0.020	0.009	0.017	0.024	0.010
51APL05	0.005	0.020	0.005	0.033	0.051	0.027	0.175	0.020	0.235	0.003	0.056	0.010
51APL06	0.047	0.060		0.033	0.051	0.082	0.175	0.098	0.007	0.052	0.056	0.031
51APL07	0.079	0.060	0.082	0.033	0.051	0.082	0.175	0.098	0.007	0.052	0.056	0.031
51APL08	0.079	0.060	0.027	0.033	0.037	0.027	0.012	0.020	0.005	0.087	0.034	0.031
51APL09	0.047	0.060	0.027	0.033	0.037	0.027	0.012	0.020	0.005	0.087	0.034	0.031
51APL10	0.079	0.020	0.137	0.033	0.051	0.027	0.035	0.020	0.009	0.017	0.034	0.031
51APL11	0.016	0.020	0.005	0.033	0.051	0.082	0.035	0.098	0.009	0.003	0.056	0.031
51APL12	0.005	0.060	0.005	0.033	0.051	0.027	0.035	0.004	0.009	0.052	0.034	0.010
51APL13	0.079	0.020	0.137	0.033	0.037	0.082	0.035	0.098	0.141	0.052	0.034	0.010
51APL14	0.079	0.060	0.009	0.033	0.022	0.082	0.007	0.098	0.007	0.052	0.024	0.010
51APL15	0.016	0.060	0.027	0.033	0.037	0.009	0.035	0.098	0.007	0.017	0.034	0.010
51APL16	0.047	0.020	0.027	0.033	0.051	0.009	0.035	0.098	0.009	0.052	0.034	0.010
51APL17	0.079	0.020	0.005	0.033	0.051	0.082	0.035	0.020	0.422	0.087	0.034	0.010
51APL18	0.005	0.020	0.027	0.033	0.037	0.027	0.012	0.020	0.016	0.006	0.024	0.010
51APL19	0.047	0.020	0.027	0.033	0.037	0.027	0.012	0.020	0.005	0.017	0.034	0.010

Table I.1: Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
51APL20	0.047	0.060	0.082	0.033	0.051	0.027	0.012	0.020	0.009	0.052	0.034	
51APL21	0.002	0.020	0.009	0.033	0.051	0.027	0.012	0.020	0.007	0.052	0.056	0.155
51APL22	0.110	0.060	0.137	0.033	0.051	0.027	0.012	0.020	0.009	0.052	0.024	0.155
51APL23	0.016	0.020	0.027	0.033	0.051	0.027	0.035	0.020	0.009	0.052	0.034	0.155
51APL24	0.016	0.060	0.027	0.033	0.037	0.027	0.035	0.020	0.005	0.052	0.034	0.155
52ARM00	0.073	0.075	0.124	0.050	0.080	0.071	0.094	0.017	0.045	0.032	0.060	0.071
52ARM01	0.100	0.136	0.167	0.583	0.025	0.063	0.045	0.100	0.500	0.150	0.515	0.167
52ARM02	0.100	0.136	0.167	0.083	0.225	0.188	0.227	0.100	0.100	0.050	0.074	0.167
52ARM03	0.100	0.136	0.167	0.083	0.175	0.188	0.227	0.100	0.100	0.150	0.103	0.167
52ARM04	0.100	0.136	0.167	0.083	0.225	0.188	0.227	0.100	0.100	0.150	0.103	0.167
52ARM05	0.300	0.045	0.167	0.083	0.175	0.188	0.227	0.500	0.100	0.050	0.103	0.167
52ARM06	0.300	0.409	0.167	0.083	0.175	0.188	0.045	0.100	0.100	0.450	0.103	0.167
61WOR00	0.073	0.075	0.124	0.050	0.080	0.071	0.094	0.086	0.045	0.032	0.060	0.024
61WOR01	0.037	0.050	0.069	0.500	0.092	0.033	0.060	0.156	0.563	0.033	0.423	0.100
61WOR02	0.005	0.150	0.069	0.071	0.013	0.167	0.020	0.156	0.063	0.100	0.060	0.100
61WOR03	0.111	0.150	0.069	0.071	0.013	0.233	0.020	0.156	0.063	0.167	0.060	0.100
61WOR04	0.184	0.150	0.069	0.071	0.018	0.167	0.180	0.031	0.063	0.100	0.141	0.033
61WOR05	0.184	0.150	0.014	0.071	0.031	0.100	0.180	0.031	0.063	0.167	0.060	0.033
61WOR06	0.184	0.150	0.347	0.071	0.092	0.100	0.180	0.156	0.063	0.100	0.085	0.033
61WOR07	0.184	0.150	0.347	0.071	0.092	0.100	0.180	0.156	0.063	0.233	0.085	0.500
61WOR08	0.111	0.050	0.014	0.071	0.647	0.100	0.180	0.156	0.063	0.100	0.085	0.100
62WPP00	0.073	0.075	0.124	0.050	0.080	0.071	0.094	0.017	0.063	0.032	0.060	0.071
62WPP01				0.250	0.192	0.043	0.052	0.030	0.241		0.193	0.120
62WPP02	0.067	0.031	0.021		0.038	0.043	0.010	0.030	0.034		0.028	0.040
62WPP03	0.067	0.031	0.021	0.036	0.027	0.043	0.010	0.030	0.034		0.028	0.040
62WPP04	0.067	0.031	0.021	0.036	0.027	0.043	0.010	0.030	0.034		0.028	0.040
62WPP05	0.022	0.031	0.021	0.036	0.027	0.043	0.010	0.006	0.034		0.028	0.040
62WPP06	0.067	0.031	0.021	0.036	0.038	0.043	0.010	0.006	0.034		0.028	0.040
62WPP07	0.067	0.031	0.021	0.036	0.038	0.043	0.010	0.006	0.034		0.028	0.040
62WPP08	0.007	0.031	0.021	0.036	0.064	0.043	0.010	0.006	0.034		0.028	0.040
62WPP09	0.067	0.094	0.551	0.036	0.064	0.043	0.017	0.006	0.034		0.021	0.040
62WPP10	0.067	0.031	0.021	0.036	0.021	0.043	0.007	0.150	0.034		0.021	0.040
62WPP11	0.067	0.094	0.021	0.036	0.027	0.043	0.010	0.150	0.034		0.021	0.040
62WPP12	0.067	0.094	0.021	0.036	0.038	0.043	0.007	0.030	0.034		0.039	0.040
62WPP13	0.067	0.031	0.021	0.036	0.038	0.043	0.010	0.030	0.034		0.039	0.040
62WPP14	0.067	0.031	0.021	0.036	0.038	0.043	0.010	0.030	0.034		0.039	0.040
62WPP15	0.067	0.094	0.021	0.036	0.021	0.043	0.006	0.150	0.034		0.039	0.040
62WPP16	0.067	0.031	0.021	0.036	0.038	0.043	0.010	0.030	0.034		0.039	0.040
62WPP17	0.010	0.031	0.021	0.036	0.038	0.043	0.010	0.030	0.034		0.039	0.040
62WPP18	0.010	0.031	0.021	0.036	0.038	0.043	0.010	0.030	0.034		0.039	0.040

Table I.1: Effect weights of Shipbuilding Management (MNG) process, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
62WPP19	0.022	0.031	0.021	0.036	0.021	0.043	0.259	0.150	0.034		0.021	0.040
62WPP20	0.013	0.031	0.021	0.036	0.038	0.043	0.155	0.030	0.034		0.064	0.040
62WPP21	0.007	0.031	0.021	0.036	0.038	0.043	0.155	0.006	0.034		0.064	0.040
62WPP22	0.013	0.031	0.021	0.036	0.021	0.043	0.155	0.006	0.034		0.064	0.040
62WPP23	0.022	0.094	0.021	0.036	0.064	0.043	0.052	0.030	0.034		0.064	0.040
63WPM00	0.073	0.075	0.025	0.050	0.080	0.071	0.094	0.017	0.035	0.032	0.060	0.024
63WPM01	0.021	0.036	0.701	0.214	0.015	0.056	0.037	0.025	0.420	0.064	0.372	0.023
63WPM02	0.064	0.036	0.027	0.071	0.103	0.056	0.007	0.025	0.060	0.064	0.053	0.023
63WPM03	0.150	0.107	0.027	0.071	0.074	0.167	0.037	0.125	0.047	0.191	0.053	0.164
63WPM04	0.150	0.107	0.027	0.071	0.103	0.167	0.037	0.125	0.047	0.064	0.053	0.117
63WPM05	0.064	0.036	0.027	0.071	0.074	0.167	0.110	0.025	0.047	0.013	0.053	0.008
63WPM06	0.107	0.107	0.027	0.071	0.103	0.056	0.110	0.125	0.047	0.021	0.053	0.070
63WPM07	0.150	0.107	0.027	0.071	0.015	0.056	0.110	0.175	0.060	0.191	0.053	0.164
63WPM08	0.107	0.107	0.027	0.071	0.044	0.056	0.110	0.175	0.060	0.191	0.053	0.164
63WPM09	0.007	0.107	0.027	0.071	0.103	0.056	0.110	0.125	0.060	0.064	0.074	0.070
63WPM10	0.004	0.107	0.027	0.071	0.132	0.056	0.110	0.025	0.060	0.013	0.074	0.008
63WPM11	0.064	0.036	0.027	0.071	0.132	0.056	0.184	0.025	0.047	0.064	0.053	0.023
63WPM12	0.107	0.107	0.027	0.071	0.103	0.056	0.037	0.025	0.047	0.064	0.053	0.164
70QAC00	0.073	0.075	0.025	0.050	0.080	0.071	0.094	0.086	0.045	0.095	0.034	0.214
70QAC01	0.111	0.273	0.036	0.385	0.029	0.146	0.043	0.048	0.488	0.111	0.393	0.067
70QAC02	0.111	0.091	0.007	0.077	0.143	0.029	0.130	0.048	0.054	0.111	0.056	0.067
70QAC03	0.111	0.091	0.007	0.077	0.143	0.049	0.130	0.048	0.054	0.111	0.079	0.067
70QAC06	0.111	0.091	0.182	0.077	0.200	0.146	0.217	0.238	0.070	0.111	0.079	0.467
70QAC07	0.111	0.091	0.182	0.077	0.086	0.146	0.043	0.238	0.070	0.111	0.079	0.067
70QAC08	0.111	0.091	0.182	0.077	0.086	0.146	0.043	0.238	0.070	0.037	0.079	0.067
70QAC09	0.111	0.091	0.182	0.077	0.086	0.146	0.043	0.048	0.070	0.037	0.079	0.067
70QAC10	0.111	0.091	0.182	0.077	0.086	0.146	0.043	0.048	0.070	0.333	0.079	0.067
70QAC11	0.111	0.091	0.036	0.077	0.143	0.049	0.304	0.048	0.054	0.037	0.079	0.067
81CMC00	0.073	0.075	0.025	0.050	0.102	0.071	0.031	0.086	0.045	0.285	0.034	0.214
81CMC02	0.652	0.600	0.429	0.778	0.077	0.333	0.714	0.143	0.763	0.143	0.778	0.091
81CMC03	0.130	0.200	0.429	0.111	0.538	0.333	0.143	0.714	0.085	0.429	0.111	0.455
81CMC04	0.217	0.200	0.143	0.111	0.385	0.333	0.143	0.143	0.153	0.429	0.111	0.455

Table I.2: Effect weights of Design (DES) process, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200				Shipyard 300					
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_4	r_1	r_2	r_3	r_4	r_5	r_6
21IFL00	0.031	0.074	0.073	0.074	0.023	0.071	0.015	0.009	0.025	0.116		0.035	0.353	0.031
21IFL16	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23ITE00	0.094	0.053	0.041	0.053	0.117	0.051	0.015	0.138	0.025	0.050		0.021	0.024	0.094
23ITE02	0.375	0.700	0.818	0.818	0.673	0.577	0.089	0.375	0.536	0.139	0.673	0.395	0.648	0.250
23ITE03	0.125	0.100	0.091	0.091	0.135	0.192	0.018	0.125	0.107	0.694	0.135	0.079	0.130	0.250
23ITE04	0.125	0.100			0.096	0.115	0.446	0.375	0.179	0.028	0.096	0.395	0.093	0.250
23ITE05	0.375	0.100	0.091	0.091	0.096	0.115	0.446	0.125	0.179	0.139	0.096	0.132	0.130	0.250
24IFA00	0.031	0.053	0.073	0.053	0.023	0.118	0.011	0.009	0.015	0.070		0.021	0.353	0.031
24IFA01	0.048	0.560	0.138	0.560	0.122	0.283	0.378	0.374	0.211	0.147		0.374	0.273	0.299
24IFA02	0.238	0.080	0.020	0.080	0.610	0.057	0.378	0.374	0.634	0.021		0.374	0.273	0.299
24IFA03	0.238	0.080	0.015	0.080	0.122	0.094	0.076	0.125	0.070	0.049		0.125	0.273	0.299
24IFA04	0.238	0.140	0.414	0.140	0.122	0.283	0.126	0.075	0.042	0.049		0.075	0.091	0.060
24IFA05	0.238	0.140	0.414	0.140	0.024	0.283	0.042	0.053	0.042	0.734		0.053	0.091	0.043
30DES00	0.094	0.369	0.365	0.369	0.117	0.355	0.075	0.046	0.076	0.348		0.106	0.118	0.094
30DES01	0.019	0.231	0.078	0.129	0.079	0.212	0.026	0.050	0.075	0.220	0.227	0.032	0.039	0.050
30DES02	0.019	0.046	0.011	0.026	0.011	0.071	0.132	0.010	0.025	0.024	0.032	0.006	0.008	0.017
30DES03	0.096	0.026	0.009	0.014	0.079	0.042	0.009	0.050	0.075	0.024	0.032	0.158	0.039	0.017
30DES04	0.135	0.026	0.011	0.014	0.011	0.042	0.009	0.151	0.025	0.073	0.032	0.095	0.013	0.050
30DES05	0.019	0.033	0.234	0.388	0.079	0.042	0.009	0.017	0.075	0.031	0.032	0.006	0.039	0.017
30DES06	0.135	0.033	0.026	0.043	0.011	0.030	0.009	0.050	0.075	0.031	0.032	0.006	0.039	0.050
30DES07	0.019	0.014	0.011	0.014	0.011	0.030	0.026	0.050	0.075	0.024	0.032	0.095	0.008	0.050
30DES08	0.135	0.033	0.009	0.014	0.011	0.030	0.079	0.050	0.075	0.031	0.032	0.032	0.013	0.050
30DES09	0.019	0.033	0.011	0.014	0.016	0.030	0.079	0.050	0.025	0.024	0.032	0.032	0.013	0.050
30DES10	0.019	0.033	0.009	0.014	0.016	0.030	0.026	0.050	0.025	0.044	0.032	0.032		0.050
30DES11	0.019	0.033	0.011	0.014	0.079	0.030	0.132	0.050	0.025	0.044	0.032	0.006	0.116	0.050
30DES12	0.019	0.046	0.011	0.014	0.238	0.030	0.079	0.050	0.025	0.024	0.032	0.032	0.013	0.050
30DES13	0.019	0.046	0.016	0.129	0.016	0.042	0.079	0.050	0.025	0.024	0.045	0.032	0.039	0.050
30DES14	0.019	0.033	0.016	0.018	0.016	0.030	0.026	0.050	0.025	0.031	0.032	0.005	0.116	0.050
30DES15	0.019	0.033	0.390	0.018	0.011	0.030	0.026	0.050	0.025	0.073	0.032	0.006	0.116	0.050
30DES16	0.019	0.046	0.016	0.014	0.026	0.071	0.009	0.017	0.025	0.031	0.045	0.006	0.008	0.050
30DES17	0.019	0.033	0.011	0.014	0.016	0.030	0.005	0.017	0.025	0.031	0.045	0.095	0.116	0.050
30DES18	0.019	0.033	0.011	0.014	0.079	0.042	0.026	0.017	0.025	0.044	0.045	0.095	0.013	0.050
30DES19	0.058	0.046	0.011	0.018	0.079	0.030	0.079	0.017	0.025	0.031	0.045	0.011	0.008	0.050
30DES20	0.058	0.033	0.009	0.014	0.079	0.042	0.026	0.050	0.075	0.073	0.045	0.032	0.116	0.050
30DES21	0.019	0.033	0.011	0.014	0.016	0.030	0.026	0.050	0.075	0.031	0.045	0.032	0.116	0.050
30DES22	0.096	0.077	0.078	0.043	0.016	0.030	0.079	0.050	0.075	0.031	0.032	0.158	0.013	0.050
40MPP00	0.094	0.053	0.052	0.053	0.117	0.051	0.025	0.138	0.025	0.050		0.106	0.024	0.094
40MPP01	0.081	0.249	0.125	0.563	0.208	0.494	0.068	0.100	0.136	0.126	0.473	0.102	0.474	0.125
40MPP02	0.016	0.083	0.018	0.063	0.208	0.099	0.023	0.100	0.045	0.126	0.068	0.034	0.095	0.125

Table I.2: Effect weights of Design (DES) process, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200				Shipyard 300					
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_4	r_1	r_2	r_3	r_4	r_5	r_6
40MPP03	0.016	0.249	0.025	0.063	0.208	0.071	0.205	0.033	0.045	0.042	0.068	0.034	0.068	0.125
40MPP04	0.565	0.249	0.025	0.063	0.208	0.071	0.205	0.300	0.045	0.025	0.068	0.015	0.053	0.125
40MPP06	0.081	0.050	0.042	0.063	0.042	0.055	0.205	0.100	0.409	0.014	0.068	0.306	0.053	0.125
40MPP09	0.081	0.050	0.018	0.063	0.042	0.071	0.205	0.300	0.136	0.018	0.095	0.306	0.068	0.125
40MPP11	0.081	0.036	0.624	0.063	0.042	0.071	0.068	0.033	0.136	0.018	0.068	0.102	0.095	0.125
40MPP12	0.081	0.036	0.125	0.063	0.042	0.071	0.023	0.033	0.045	0.631	0.095	0.102	0.095	0.125
51APL00	0.094	0.053	0.052	0.053	0.023	0.051	0.075	0.138	0.227	0.039		0.319	0.017	0.094
51APL01	0.058	0.245	0.044	0.041	0.100	0.287	0.026	0.056	0.056	0.165	0.281	0.050	0.256	0.056
51APL02	0.058	0.049	0.044	0.041	0.020	0.041	0.026	0.056	0.056	0.165	0.040	0.050	0.051	0.056
51APL03	0.058	0.035	0.131	0.124	0.020	0.041	0.026	0.056	0.019	0.165	0.040	0.017	0.037	0.056
51APL04	0.058	0.035	0.044	0.041	0.020	0.041	0.009	0.019	0.056	0.165	0.040	0.017	0.028	0.056
51APL06	0.058	0.049	0.131	0.124	0.014	0.041	0.079	0.056	0.167	0.024	0.031	0.050	0.037	0.056
51APL08	0.058	0.027	0.015	0.041	0.020	0.041	0.079	0.167	0.056	0.024	0.031	0.050	0.028	0.056
51APL09	0.058	0.027	0.015	0.041	0.014	0.041	0.079	0.167	0.056	0.018	0.031	0.151	0.028	0.056
51APL11	0.058	0.035	0.131	0.124	0.100	0.057	0.026	0.056	0.056	0.033	0.040	0.050	0.037	0.056
51APL12	0.058	0.049	0.015	0.014	0.100	0.041	0.009	0.056	0.056	0.033	0.040	0.017	0.051	0.056
51APL13	0.058	0.049	0.006	0.006	0.033	0.041	0.079	0.019	0.056	0.024	0.040	0.151	0.037	0.056
51APL14	0.058	0.035	0.044	0.041	0.100	0.041	0.079	0.056	0.056	0.024	0.040	0.050	0.051	0.056
51APL15	0.058	0.035	0.044	0.041	0.020	0.041	0.079	0.056	0.056	0.033	0.056	0.050	0.085	0.056
51APL16	0.019	0.049	0.015	0.014	0.014	0.041	0.079	0.056	0.019	0.018	0.040	0.151	0.051	0.056
51APL19	0.058	0.035	0.009	0.008	0.020	0.041	0.009	0.056	0.056	0.024	0.040	0.050	0.037	0.056
51APL20	0.058	0.082	0.009	0.008	0.100	0.041	0.079	0.019	0.056	0.018	0.056	0.050	0.085	0.056
51APL21	0.058	0.082	0.131	0.124	0.100	0.041	0.026	0.019	0.056	0.024	0.056	0.017	0.037	0.056
51APL22	0.058	0.049	0.131	0.124	0.100	0.041	0.079	0.019	0.056	0.024	0.056	0.017	0.037	0.056
51APL24	0.058	0.035	0.044	0.041	0.100	0.041	0.132	0.019	0.019	0.024	0.040	0.010	0.028	0.056
52ARM00	0.094	0.074	0.073	0.074	0.023	0.051	0.224	0.046	0.025	0.050		0.106	0.017	0.094
52ARM03	0.333	0.763	0.797	0.797	0.200	0.875	0.143	0.231	0.429	0.778	0.797	0.455	0.797	0.333
52ARM05	0.333	0.153	0.114	0.114	0.600		0.143	0.077	0.143	0.111	0.114	0.455	0.114	0.333
52ARM06	0.333	0.085	0.089	0.089	0.200	0.125	0.714	0.692	0.429	0.111	0.089	0.091	0.089	0.333
61WOR00	0.094	0.053	0.052	0.053	0.023	0.051	0.015	0.046	0.076	0.070		0.035	0.024	0.094
61WOR01	0.045	0.550	0.643	0.643	0.043	0.507	0.055	0.055	0.130	0.268	0.538	0.081	0.517	0.143
61WOR02	0.224	0.061	0.071	0.071	0.214	0.072	0.055	0.055	0.130	0.038	0.077	0.243	0.103	0.143
61WOR03	0.015	0.061	0.071	0.071	0.214	0.072	0.273	0.385	0.130	0.038	0.077	0.243		0.143
61WOR04	0.224	0.079	0.071	0.071	0.009	0.072	0.273	0.275	0.130	0.089	0.077	0.081	0.103	0.143
61WOR05	0.224	0.079	0.071	0.071	0.214	0.101	0.055	0.165	0.043	0.268	0.077	0.027		0.143
61WOR07	0.224	0.061	0.071	0.071	0.300	0.072	0.273	0.055	0.391	0.030	0.077	0.243	0.172	0.143
61WOR08	0.045	0.110			0.006	0.101	0.018	0.011	0.043	0.268	0.077	0.081	0.103	0.143
62WPP00	0.094	0.053	0.052	0.053	0.039	0.051	0.075	0.046	0.227	0.070		0.035	0.017	0.094
62WPP23	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
63WPM00	0.094	0.041	0.041	0.041	0.023	0.051	0.373	0.138	0.025	0.050		0.106	0.039	0.094

Table I.2: Effect weights of Design (DES) process, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200				Shipyard 300					
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_4	r_1	r_2	r_3	r_4	r_5	r_6
63WPM01	0.091	0.064			0.014	0.059	0.119	0.183	0.087	0.052	0.059	0.114		0.091
63WPM02	0.091	0.050			0.097	0.059	0.085	0.183	0.029	0.052	0.059	0.038	0.189	0.091
63WPM03	0.091	0.050	0.059	0.055	0.019	0.059	0.085	0.130	0.146	0.041	0.059	0.114	0.027	0.091
63WPM04	0.091	0.050		0.055	0.019	0.059	0.085	0.130	0.087	0.073	0.059	0.114	0.027	0.091
63WPM05	0.018	0.447	0.533	0.492	0.097	0.412	0.017	0.026	0.029	0.367	0.412	0.038	0.189	0.091
63WPM06	0.091	0.050	0.076	0.055	0.019	0.059	0.085	0.130	0.087	0.122	0.059	0.038	0.027	0.091
63WPM08	0.127	0.064	0.107	0.164	0.097	0.059	0.085	0.009	0.146	0.041	0.059	0.190	0.063	0.091
63WPM09	0.127	0.050	0.107	0.070	0.019	0.059	0.085	0.009	0.087	0.073	0.059	0.013	0.189	0.091
63WPM10	0.091	0.064			0.032	0.059	0.085	0.009	0.010	0.052	0.059	0.038	0.063	0.091
63WPM11	0.091	0.050	0.059	0.055	0.487	0.059	0.119	0.183	0.146	0.052	0.059	0.190	0.189	0.091
63WPM12	0.091	0.064	0.059	0.055	0.097	0.059	0.153	0.009	0.146	0.073	0.059	0.114	0.038	0.091
70QAC00	0.094	0.074	0.052	0.074	0.117	0.051	0.075	0.015	0.025	0.050		0.106	0.017	0.094
70QAC01	0.158	0.649	0.649	0.663	0.111	0.636	0.176	0.238	0.294	0.568	0.614	0.111	0.578	0.200
70QAC02	0.474	0.093	0.072	0.074	0.111	0.091	0.059	0.238	0.294	0.081	0.123	0.333	0.193	0.200
70QAC03	0.053	0.093	0.093	0.095	0.111	0.091	0.059	0.238	0.294	0.081	0.088	0.111	0.083	0.200
70QAC04	0.158	0.072	0.093	0.095	0.333	0.091	0.176	0.238	0.059	0.189	0.088	0.111	0.064	0.200
70QAC09	0.158	0.093	0.093	0.074	0.333	0.091	0.529	0.048	0.059	0.081	0.088	0.333	0.083	0.200
81CMC00	0.094	0.053	0.073	0.053	0.352	0.051	0.025	0.230	0.227	0.039				0.094
81CMC02	0.500	0.900			0.500	0.167	0.167	0.500	0.250	0.750	0.167	0.167	0.167	0.500
81CMC04	0.500	0.100			0.500	0.833	0.833	0.500	0.750	0.250	0.833	0.833	0.833	0.500

Table I.3: Effect weights of Contracting (CON) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12	
	r_1	r_1	r_2
30DES00	0.122	0.143	0.205
30DES03	0.200	0.833	0.875
30DES19	0.800	0.167	0.125
40MPP00	0.024	0.048	0.205
40MPP01	0.625	0.625	0.088
40MPP02	0.125	0.125	0.441
40MPP03	0.125	0.125	0.441
40MPP04	0.125	0.125	0.029
51APL00	0.366	0.143	0.205
51APL01	0.333	0.833	0.250
51APL08	0.667	0.167	0.750
52ARM00	0.041	0.048	0.068
52ARM01	0.056	0.313	0.167
52ARM02	0.167	0.063	0.167
52ARM03	0.278	0.104	0.167
52ARM04	0.167	0.104	0.167
52ARM05	0.056	0.104	0.167
52ARM06	0.278	0.313	0.167
63WPM00	0.041	0.143	0.068
63WPM01	0.114	0.200	0.040
63WPM03	0.795	0.200	0.280
63WPM04			
63WPM05	0.016	0.200	0.280
63WPM06	0.038	0.200	0.280
63WPM10	0.038	0.200	0.120
81CMC00	0.366	0.429	0.205
81CMC01	0.097	0.111	0.130
81CMC02	0.097	0.111	0.130
81CMC03	0.290	0.111	0.652
81CMC04	0.032	0.333	0.043
81CMC05	0.484	0.333	0.043
82CSC00	0.041	0.048	0.041
82CSC01	0.800	0.750	0.833
82CSC02	0.200	0.250	0.167

Table I.4: Effect weights of Hull & Superstructure Block Construction (BLK) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
11PSB00	0.037	0.099	0.356	0.303
11PSB01	0.050	0.290		0.193
11PSB02	0.050	0.290	0.097	0.039
11PSB03	0.050	0.058	0.014	0.193
11PSB04	0.050	0.058	0.014	0.193
11PSB05	0.050	0.041	0.483	0.193
11PSB06	0.150	0.041	0.032	0.064
11PSB07	0.150	0.041	0.019	0.039
11PSB08	0.150	0.041	0.019	0.028
11PSB09	0.150	0.097	0.032	0.039
11PSB10	0.150	0.041	0.290	0.021
12PSE00	0.037	0.099		0.043
13PPT00	0.007	0.099	0.040	0.043
13PPT01	0.500	0.500	0.833	0.750
13PPT06	0.500	0.500	0.167	0.250
14POS00	0.111	0.033	0.051	0.034
14POS01	0.652	0.778	0.745	0.778
14POS02	0.130	0.111	0.106	0.111
14POS05	0.217	0.111	0.149	0.111
21IFL00	0.007	0.014	0.051	0.061
21IFL01	0.102	0.040	0.030	0.040
21IFL02	0.102	0.040	0.451	0.008
21IFL05	0.020	0.280	0.090	0.040
21IFL06	0.102	0.280	0.271	0.008
21IFL07	0.102	0.040	0.030	0.008
21IFL08	0.061	0.040	0.030	0.277
21IFL09	0.061	0.040	0.013	0.198
21IFL10	0.061	0.040	0.013	0.013
21IFL11	0.061	0.040	0.018	0.119
21IFL12	0.102	0.040	0.013	0.119
21IFL13	0.102	0.040	0.018	0.040
21IFL15	0.061	0.040	0.010	0.013
21IFL16	0.061	0.040	0.013	0.119
22IEN00	0.007	0.014	0.071	0.061
22IEN01	0.500	0.500	0.875	0.900
22IEN02	0.500	0.500	0.125	0.100

Table I.4: Effect weights of Hull & Superstructure Block Construction (BLK) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
23ITE00	0.007	0.014	0.051	0.061
23ITE06	1.000	1.000	1.000	1.000
24IFA00	0.007	0.014	0.071	0.061
24IFA01	0.143	0.398	0.154	0.048
24IFA02	0.143	0.398	0.022	0.048
24IFA03	0.143	0.080	0.022	0.238
24IFA04	0.143	0.080	0.031	0.238
24IFA05	0.429	0.044	0.771	0.429
30DES00	0.111	0.099	0.040	0.034
30DES07	0.020	0.257	0.543	0.488
30DES08	0.140	0.257	0.060	0.054
30DES09	0.140	0.257	0.060	0.070
30DES10	0.140	0.051	0.060	0.070
30DES11	0.140	0.051	0.060	0.070
30DES12	0.140	0.051	0.078	0.098
30DES13	0.140	0.037	0.060	0.054
30DES16	0.140	0.037	0.078	0.098
40MPP00	0.111	0.099	0.040	0.034
40MPP06	0.800	0.875	0.875	0.750
40MPP14	0.200	0.125	0.125	0.250
51APL00	0.111	0.020	0.040	0.043
51APL02	0.016	0.053	0.387	0.362
51APL06	0.082	0.053	0.055	0.040
51APL08	0.082	0.011	0.043	0.052
51APL09	0.082	0.053	0.043	0.052
51APL10	0.082	0.053	0.055	0.052
51APL11	0.082	0.053	0.043	0.072
51APL12	0.082	0.053	0.077	0.072
51APL13	0.082	0.267	0.055	0.052
51APL14	0.082	0.053	0.043	0.052
51APL15	0.082	0.011	0.043	0.052
51APL16	0.082	0.018	0.055	0.052
51APL17	0.082	0.267	0.055	0.052
51APL19	0.082	0.053	0.043	0.040
61WOR00	0.111	0.099	0.040	0.043
61WOR01	0.032	0.307	0.498	0.490
61WOR02	0.161	0.307	0.055	0.098
61WOR03	0.161	0.034	0.100	0.054
61WOR05	0.161	0.102	0.055	0.070
61WOR06	0.161	0.102	0.071	0.070

Table I.4: Effect weights of Hull & Superstructure Block Construction (BLK) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
61WOR07	0.161	0.044	0.055	0.054
61WOR08	0.161	0.102	0.166	0.163
62WPP00	0.111	0.099	0.051	0.061
62WPP02	0.200	0.517	0.663	0.636
62WPP04	0.200	0.172	0.074	0.091
62WPP05	0.200	0.103	0.095	0.091
62WPP07	0.200	0.103	0.074	0.091
62WPP08	0.200	0.103	0.095	0.091
63WPM00	0.111	0.099	0.051	0.061
63WPM01	0.027	0.186	0.420	0.327
63WPM02	0.009	0.186	0.047	0.109
63WPM03	0.009	0.037	0.047	0.036
63WPM04	0.009	0.027	0.060	0.047
63WPM05	0.009	0.027	0.047	0.036
63WPM06	0.134	0.027	0.047	0.036
63WPM07	0.134	0.186	0.060	0.065
63WPM08	0.134	0.186	0.047	0.036
63WPM09	0.134	0.027	0.060	0.065
63WPM10	0.134	0.027	0.060	0.065
63WPM11	0.134	0.062	0.060	0.109
63WPM12	0.134	0.027	0.047	0.065
70QAC00	0.111	0.099	0.051	0.061
70QAC01	0.111	0.402	0.692	0.605
70QAC03	0.111	0.080	0.077	0.121
70QAC04	0.333	0.057	0.077	0.067
70QAC05	0.111	0.057	0.077	0.121
70QAC06	0.333	0.402	0.077	0.086

Table I.5: Effect weights of Hull Erection (ASLY) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
12PSE00	0.048	0.289	0.306	0.316
12PSE01	1.000	1.000	1.000	1.000
13PPT00	0.010	0.096	0.034	0.045
13PPT01	0.333	0.500	0.833	0.750
13PPT06	0.667	0.500	0.167	0.250
14POS00	0.048	0.041	0.044	0.035
14POS06	0.667	0.833	0.833	0.875
14POS09	0.333	0.167	0.167	0.125
21IFL00	0.010	0.041	0.061	0.063
21IFL01	0.032	0.111	0.254	0.038
21IFL02	0.095	0.553	0.051	0.008
21IFL05	0.095	0.022	0.085	0.013
21IFL06	0.095	0.022	0.051	0.008
21IFL07	0.095	0.022	0.051	0.008
21IFL08	0.095	0.022	0.051	0.263
21IFL09	0.095	0.016	0.085	0.188
21IFL10	0.095	0.016	0.085	0.013
21IFL11	0.011	0.016	0.085	0.113
21IFL13	0.011	0.037	0.051	0.038
21IFL14	0.095	0.016	0.051	0.188
21IFL15	0.095	0.111	0.051	0.013
21IFL16	0.095	0.037	0.051	0.113
22IEN00	0.010	0.096	0.061	0.063
22IEN01	0.333	0.500	0.875	0.900
22IEN02	0.667	0.500	0.125	0.100
23ITE00	0.010	0.096	0.061	0.063
23ITE06	1.000	1.000	1.000	1.000
24IFA00	0.010	0.096	0.102	0.063
24IFA01	0.143	0.393	0.153	0.048
24IFA02	0.143	0.393	0.031	0.048
24IFA03	0.143	0.079	0.022	0.238
24IFA04	0.143	0.079	0.031	0.238
24IFA05	0.429	0.056	0.764	0.429
30DES00	0.143	0.032	0.034	0.035
30DES07	0.028	0.272	0.586	0.586
30DES08	0.194	0.272	0.065	0.065

Table I.5: Effect weights of Hull Erection (ASLY) subprocess, calculated from shipyard survey responses (raw data) (cont'd).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
30DES09	0.194	0.272	0.084	0.084
30DES10	0.194	0.091	0.065	0.084
30DES13	0.194	0.054	0.084	0.065
30DES16	0.194	0.039	0.117	0.117
40MPP00		0.032	0.034	0.035
40MPP06	0.800	0.875	0.875	0.750
40MPP14	0.200	0.125	0.125	0.250
51APL00	0.143	0.041	0.034	0.045
51APL02	0.020	0.138	0.413	0.398
51APL06	0.098	0.028	0.059	0.044
51APL08	0.098	0.046	0.046	0.057
51APL09	0.098	0.138	0.046	0.057
51APL10	0.098	0.138	0.059	0.057
51APL11	0.098	0.138	0.059	0.080
51APL12	0.098	0.046	0.059	0.080
51APL13	0.098	0.138	0.083	0.057
51APL14	0.098	0.138	0.059	0.057
51APL15	0.098	0.028	0.059	0.057
51APL16	0.098	0.028	0.059	0.057
61WOR00	0.143	0.032	0.044	0.045
61WOR01	0.032	0.307	0.482	0.490
61WOR02	0.161	0.307	0.069	0.098
61WOR03	0.161	0.034	0.096	0.054
61WOR05	0.161	0.102	0.069	0.070
61WOR06	0.161	0.102	0.069	0.070
61WOR07	0.161	0.044	0.054	0.054
61WOR08	0.161	0.102	0.161	0.163
62WPP00	0.143	0.032	0.061	0.063
62WPP03	0.455	0.778	0.763	0.778
62WPP10	0.455	0.111	0.085	0.111
62WPP22	0.091	0.111	0.153	0.111
63WPM00	0.143	0.032	0.061	0.063
63WPM01	0.027	0.741	0.373	0.327
63WPM02	0.009	0.029	0.053	0.109
63WPM03	0.009	0.029	0.041	0.036
63WPM04	0.009	0.029	0.053	0.047
63WPM05	0.009		0.053	0.036
63WPM06	0.134	0.029	0.041	0.036
63WPM07	0.134	0.029	0.053	0.065
63WPM08	0.134	0.029	0.053	0.036

Table I.5: Effect weights of Hull Erection (ASLY) subprocess, calculated from shipyard survey responses (raw data) (cont'd).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
63WPM09	0.134		0.053	0.065
63WPM10	0.134	0.029	0.075	0.065
63WPM11	0.134	0.029	0.075	0.109
63WPM12	0.134	0.029	0.075	0.065
70QAC00	0.143	0.041	0.061	0.063
70QAC01	0.125	0.156	0.593	0.605
70QAC03	0.125	0.022	0.119	0.121
70QAC04	0.375	0.022	0.085	0.067
70QAC05		0.022	0.085	0.121
70QAC06	0.375	0.778	0.119	0.086

Table I.6: Effect weights of Parts Manufacturing in Shipyard (PPT) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
13PPT00	0.042	0.429	0.429	0.423
13PPT01	0.214	0.565	0.565	0.575
13PPT02	0.214	0.081	0.081	0.082
13PPT03	0.071	0.081	0.081	0.064
13PPT04	0.214	0.081	0.081	0.082
13PPT05	0.071	0.113	0.113	0.115
13PPT06	0.214	0.081	0.081	0.082
14POS00	0.042	0.048	0.048	0.047
14POS01	1.000	1.000	1.000	1.000
21IFL00	0.008	0.048	0.048	0.047
21IFL01	0.035	0.426	0.426	0.414
21IFL02	0.105	0.061	0.061	0.046
21IFL06	0.105	0.061	0.061	0.046
21IFL07	0.105	0.061	0.061	0.059
21IFL08	0.105	0.061	0.061	0.046
21IFL09	0.105	0.047	0.047	0.059
21IFL10	0.105	0.047	0.047	0.059
21IFL11	0.012	0.047	0.047	0.059
21IFL12	0.105	0.047	0.047	0.059
21IFL13	0.012	0.047	0.047	0.059
21IFL15	0.105	0.047	0.047	0.046
21IFL16	0.105	0.047	0.047	0.046
22IEN00	0.008	0.048	0.048	0.047
22IEN01	0.333	0.900	0.900	0.900
22IEN02	0.667	0.100	0.100	0.100
23ITE00	0.008	0.048	0.048	0.047
23ITE06	1.000	1.000	1.000	1.000
24IFA00	0.008	0.048	0.048	0.060
24IFA01	0.143	0.636	0.636	0.663
24IFA02	0.143	0.091	0.091	0.074
24IFA03	0.143	0.091	0.091	0.095
24IFA04	0.143	0.091	0.091	0.095
24IFA05	0.429	0.091	0.091	0.074
30DES00	0.126	0.048	0.048	0.047
30DES07	0.023	0.600	0.600	0.558
30DES08	0.163	0.067	0.067	0.062

Table I.6: Effect weights of Parts Manufacturing in Shipyard (PPT) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
30DES09	0.163	0.067	0.067	0.080
30DES10	0.163	0.067	0.067	0.062
30DES11	0.163	0.067	0.067	0.080
30DES12	0.163	0.067	0.067	0.080
30DES13	0.163	0.067	0.067	0.080
40MPP00	0.126	0.048	0.048	0.047
40MPP06	0.800	0.875	0.875	0.875
40MPP14	0.200	0.125	0.125	0.125
51APL00	0.126	0.048	0.048	0.047
51APL02	0.018	0.420	0.420	0.399
51APL06	0.089	0.047	0.047	0.057
51APL08	0.089	0.047	0.047	0.057
51APL09	0.089	0.047	0.047	0.057
51APL10	0.089	0.047	0.047	0.057
51APL11	0.089	0.047	0.047	0.057
51APL12	0.089	0.060	0.060	0.057
51APL13	0.089	0.060	0.060	0.057
51APL14	0.089	0.060	0.060	0.044
51APL15	0.089	0.060	0.060	0.057
51APL16	0.089	0.060	0.060	0.057
51APL17	0.089	0.047	0.047	0.044
61WOR00	0.126	0.048	0.048	0.047
61WOR01	0.038	0.630	0.630	0.583
61WOR02	0.192	0.070	0.070	0.083
61WOR03	0.192	0.070	0.070	0.083
61WOR05	0.192	0.070	0.070	0.083
61WOR07	0.192	0.070	0.070	0.083
61WOR08	0.192	0.090	0.090	0.083
62WPP00	0.126	0.048	0.048	0.047
62WPP06	0.800	0.900	0.900	0.875
62WPP16	0.200	0.100	0.100	0.125
63WPM00	0.126	0.048	0.048	0.047
63WPM01	0.027	0.444	0.444	0.438
63WPM02	0.009	0.049	0.049	0.049
63WPM03	0.009	0.049	0.049	0.049
63WPM04	0.009	0.049	0.049	0.063
63WPM05	0.009	0.049	0.049	0.049
63WPM06	0.134	0.049	0.049	0.049
63WPM07	0.134	0.049	0.049	0.049
63WPM08	0.134	0.049	0.049	0.049

Table I.6: Effect weights of Parts Manufacturing in Shipyard (PPT) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
63WPM09	0.134	0.049	0.049	0.063
63WPM10	0.134	0.049	0.049	0.049
63WPM11	0.134	0.049	0.049	0.049
63WPM12	0.134	0.063	0.063	0.049
70QAC00	0.126	0.048	0.048	0.047
70QAC01	0.125	0.700	0.700	0.750
70QAC03	0.125	0.100	0.100	0.083
70QAC05	0.125	0.100	0.100	0.083
70QAC06	0.625	0.100	0.100	0.083

Table I.7: Effect weights of Outfitting before Ship Launching (OUT) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200			Shipyard 300		
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_1	r_2	r_3
13PPT00	0.041	0.420	0.420	0.429	0.082	0.082	0.397	0.031	0.401	0.109
13PPT02	0.333	0.875	0.875	0.875	0.875	0.875	0.500	0.500	0.500	0.125
13PPT06	0.667	0.125	0.125	0.125	0.125	0.125	0.500	0.500	0.500	0.875
14POS00	0.041	0.047	0.047	0.048	0.082	0.082	0.044	0.155	0.057	0.036
14POS01	0.144	0.488	0.488	0.474	0.235	0.235	0.488	0.161	0.427	0.341
14POS02	0.029	0.070	0.070	0.068	0.034	0.034	0.054	0.054	0.061	0.068
14POS03	0.144	0.070	0.070	0.068	0.078	0.078	0.070	0.054	0.061	
14POS04	0.029	0.054	0.054	0.053	0.078	0.078	0.054	0.032	0.085	
14POS05	0.048	0.070	0.070	0.068	0.034	0.034	0.070	0.161	0.085	0.341
14POS06		0.070	0.070	0.068	0.047	0.047	0.070	0.161	0.085	0.049
14POS07	0.144	0.070	0.070	0.068	0.235	0.235	0.054	0.161	0.085	0.114
14POS08	0.433	0.054	0.054	0.068	0.235	0.235	0.070	0.161	0.047	0.049
14POS09	0.029	0.054	0.054	0.068	0.026	0.026	0.070	0.054	0.061	0.038
21IFL00	0.014	0.060	0.060	0.048	0.082	0.082	0.057	0.006	0.057	0.109
21IFL01	0.032	0.379	0.379	0.387	0.077	0.027	0.347	0.018	0.337	0.151
21IFL02	0.095	0.076	0.076	0.055	0.077	0.081	0.039	0.088	0.037	0.022
21IFL06	0.095	0.054	0.054	0.055	0.077	0.081	0.039	0.088	0.048	0.022
21IFL07	0.095	0.042	0.042	0.055	0.077	0.081	0.050	0.088	0.048	0.030
21IFL08	0.095	0.042	0.042	0.055	0.077	0.081	0.050	0.053	0.048	0.030
21IFL09	0.095	0.042	0.042	0.043	0.077	0.081	0.050	0.088	0.067	0.050
21IFL10	0.095	0.042	0.042	0.043	0.077	0.081	0.069	0.088	0.067	0.151
21IFL11	0.011	0.054	0.054	0.043	0.077	0.081	0.069	0.088	0.067	0.151
21IFL12	0.095	0.042	0.042	0.043	0.077	0.081	0.069	0.088	0.067	0.151
21IFL13	0.011	0.054	0.054	0.043	0.077	0.081	0.050	0.088	0.048	0.151
21IFL14	0.095	0.076	0.076	0.077	0.077	0.081	0.069	0.088	0.067	0.050
21IFL15	0.095	0.042	0.042	0.055	0.077	0.081	0.050	0.088	0.048	0.017
21IFL16	0.095	0.054	0.054	0.043	0.077	0.081	0.050	0.053	0.048	0.022
22IEN00	0.014	0.060	0.060	0.048	0.082	0.082	0.057	0.006	0.057	0.109
22IEN01	0.333	0.900	0.900	0.875	0.250	0.750	0.875	0.833	0.900	0.500
22IEN02	0.667	0.100	0.100	0.125	0.750	0.250	0.125	0.167	0.100	0.500
23ITE00					0.082	0.082	0.057	0.155	0.045	0.109
24IFA00	0.014	0.060	0.060		0.016	0.016	0.079	0.006	0.057	0.326
24IFA01	0.143	0.614	0.614	0.654	0.098	0.040	0.467	0.135	0.626	0.081
24IFA02	0.143	0.088	0.088	0.093	0.294	0.200	0.067	0.135	0.070	0.027

Table I.7: Effect weights of Outfitting before Ship Launching (OUT) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200			Shipyard 300		
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_1	r_2	r_3
24IFA03	0.143	0.088	0.088	0.093	0.294	0.280	0.156	0.027	0.089	0.243
24IFA04	0.143	0.123	0.123	0.093	0.020	0.200	0.156	0.027	0.125	0.081
24IFA05	0.429	0.088	0.088	0.065	0.294	0.280	0.156	0.676	0.089	0.568
30DES00	0.123	0.047	0.047	0.061	0.082	0.082	0.044	0.155	0.045	0.022
30DES07	0.020	0.534	0.534	0.553	0.125	0.150	0.553	0.125	0.534	0.465
30DES08	0.140	0.059	0.059	0.079	0.125	0.050	0.061	0.025	0.059	0.066
30DES09	0.140	0.076	0.076	0.061	0.125	0.050	0.061	0.375	0.059	0.052
30DES10	0.140	0.059	0.059	0.061	0.125	0.150	0.061	0.025	0.059	0.052
30DES13	0.140	0.076	0.076	0.061	0.125	0.150	0.061	0.025	0.076	0.155
30DES14	0.140	0.076	0.076	0.061	0.125	0.150	0.061	0.025	0.059	0.093
30DES16	0.140	0.059	0.059	0.061	0.125	0.150	0.079	0.375	0.076	0.066
30DES18	0.140	0.059	0.059	0.061	0.125	0.150	0.061	0.025	0.076	0.052
40MPP00	0.123	0.047	0.047	0.061	0.082	0.082	0.044	0.155	0.057	0.016
40MPP06	0.455	0.818	0.818	0.778	0.333	0.333	0.797	0.714	0.778	0.333
40MPP11	0.455	0.091	0.091	0.111	0.333	0.333	0.089	0.143	0.111	0.333
40MPP14	0.091	0.091	0.091	0.111	0.333	0.333	0.114	0.143	0.111	0.333
51APL00	0.123	0.060	0.060	0.061	0.082	0.082	0.044	0.006	0.045	0.016
51APL02	0.020	0.441	0.441	0.417	0.038	0.036	0.447	0.027	0.447	0.223
51APL06	0.098	0.049	0.049	0.060	0.038	0.036	0.050	0.136	0.050	0.025
51APL08	0.098	0.049	0.049	0.060	0.038	0.107	0.050	0.136	0.050	0.025
51APL09	0.098	0.049	0.049	0.060	0.115	0.107	0.064	0.136	0.050	0.025
51APL10	0.098	0.063	0.063	0.046	0.191	0.178	0.064	0.136	0.050	0.223
51APL11	0.098	0.063	0.063	0.060	0.038	0.036	0.064	0.005	0.064	0.032
51APL12	0.098	0.063	0.063	0.060	0.268	0.249	0.064	0.136	0.064	0.045
51APL13	0.098	0.049	0.049	0.060	0.004	0.004	0.050	0.005	0.050	0.074
51APL14	0.098	0.063	0.063	0.060	0.191	0.178	0.050	0.136	0.064	0.074
51APL15	0.098	0.063	0.063	0.060	0.038	0.036	0.050	0.136	0.064	0.032
51APL16	0.098	0.049	0.049	0.060	0.038	0.036	0.050	0.009	0.050	0.223
61WOR00	0.123	0.047	0.047	0.061	0.082	0.082	0.044	0.006	0.045	0.016
61WOR01	0.032	0.522	0.522	0.558	0.143	0.111	0.568	0.046	0.568	0.094
61WOR02	0.161	0.075	0.075	0.080	0.143	0.333	0.063	0.231	0.063	0.094
61WOR03	0.161	0.075	0.075	0.080	0.143	0.111	0.063	0.231	0.063	0.031
61WOR05	0.161	0.075	0.075	0.080	0.143	0.111	0.081	0.231	0.081	0.281
61WOR06	0.161	0.104	0.104	0.062	0.143	0.111	0.081	0.015	0.081	0.019
61WOR07	0.161	0.075	0.075	0.062	0.143	0.111	0.063	0.015	0.063	0.013
61WOR08	0.161	0.075	0.075	0.080	0.143	0.111	0.081	0.231	0.081	0.468
62WPP00	0.123	0.047	0.047	0.061	0.082	0.082	0.044	0.006	0.045	0.012
62WPP01	0.089	0.325	0.325	0.375	0.059	0.059	0.356		0.617	0.304
62WPP03	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043

Table I.7: Effect weights of Outfitting before Ship Launching (OUT) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12			Shipyard 200			Shipyard 300		
	r_1	r_1	r_2	r_3	r_1	r_2	r_3	r_1	r_2	r_3
62WPP04					0.059	0.059	0.040		0.024	0.043
62WPP07	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP08	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP10	0.089	0.036	0.036	0.042	0.059	0.059	0.040		0.024	0.043
62WPP11	0.089	0.036	0.036	0.042	0.059	0.059	0.040		0.024	0.043
62WPP12	0.089	0.036	0.036	0.042	0.059	0.059	0.040		0.024	0.043
62WPP13	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP14	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP16	0.018	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP17	0.018	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP18	0.018	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP20	0.018	0.065	0.065	0.042	0.059	0.059	0.040		0.024	0.043
62WPP21	0.018	0.036	0.036	0.042	0.059	0.059	0.051		0.024	0.043
62WPP22	0.018	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
62WPP23	0.089	0.046	0.046	0.042	0.059	0.059	0.040		0.024	0.043
63WPM00	0.123	0.047	0.047	0.061	0.082	0.082	0.044	0.155	0.045	0.109
63WPM01	0.027	0.426	0.426	0.444	0.083	0.020	0.450	0.031	0.414	0.057
63WPM02	0.009	0.047	0.047	0.049	0.083	0.060	0.050	0.156	0.046	0.008
63WPM03	0.009	0.047	0.047	0.049	0.083	0.140	0.050	0.156	0.059	0.057
63WPM04	0.009	0.061	0.061	0.049	0.083	0.140	0.050	0.156	0.059	0.397
63WPM05	0.009	0.047	0.047	0.049	0.083	0.140	0.050	0.006	0.059	0.170
63WPM06	0.134	0.047	0.047	0.049	0.083	0.140	0.050	0.006	0.046	0.057
63WPM07	0.134	0.047	0.047	0.049	0.083	0.140	0.050	0.156	0.046	0.006
63WPM08	0.134	0.047	0.047	0.049	0.083	0.100	0.050	0.156	0.046	0.008
63WPM09	0.134	0.061	0.061	0.049	0.083	0.060	0.050	0.006	0.059	0.170
63WPM10	0.134	0.061	0.061	0.049		0.020		0.006		0.008
63WPM11	0.134	0.061	0.061	0.049	0.083	0.020	0.050	0.006	0.046	0.057
63WPM12	0.134	0.047	0.047	0.063	0.083	0.020	0.050	0.156	0.059	0.006
70QAC00	0.123	0.060	0.060	0.061	0.082	0.082	0.044	0.155	0.045	0.016
70QAC01	0.125	0.733	0.733	0.700	0.250	0.250	0.750	0.089	0.733	0.688
70QAC03	0.125	0.105	0.105	0.100	0.250	0.250	0.083	0.018	0.081	0.098
70QAC05	0.125	0.081	0.081	0.100	0.250	0.250	0.083	0.446	0.081	0.138
70QAC06	0.625	0.081	0.081	0.100	0.250	0.250	0.083	0.446	0.105	0.076

Table I.8: Effect weights of Ship Launching (LCH) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
14POS00	0.035	0.121	0.030	0.417
14POS08	1.000	1.000	1.000	1.000
15PLA00	0.176	0.024	0.004	0.046
15PLA01	1.000	1.000	1.000	1.000
21IFL00	0.012	0.013	0.150	0.046
21IFL01	0.039	0.061	0.081	0.423
21IFL02	0.117	0.183	0.243	0.060
21IFL06	0.117	0.183	0.081	0.060
21IFL07	0.117	0.183	0.081	0.060
21IFL08	0.117	0.061	0.081	0.060
21IFL09	0.117	0.061	0.081	0.060
21IFL11	0.013	0.007	0.081	0.060
21IFL12	0.117	0.183	0.081	0.060
21IFL13	0.013	0.009	0.027	0.060
21IFL15	0.117	0.061	0.081	0.047
21IFL16	0.117	0.009	0.081	0.047
22IEN00	0.012	0.040	0.030	0.046
22IEN02	1.000	1.000	1.000	1.000
23ITE00	0.012	0.017	0.030	0.046
23ITE06	1.000	1.000	1.000	1.000
24IFA00	0.012	0.017	0.006	0.060
24IFA01	0.143	0.065	0.333	0.143
24IFA02	0.143	0.007	0.333	0.143
24IFA03	0.143	0.022	0.111	0.143
24IFA04	0.143	0.324	0.111	0.143
24IFA05	0.429	0.583	0.111	0.429
30DES00	0.106	0.121	0.090	0.046
30DES07	0.067	0.333	0.333	0.818
30DES08	0.467	0.333	0.333	0.091
30DES09	0.467	0.333	0.333	0.091
40MPP00	0.106	0.121	0.090	0.046
40MPP06	0.800	0.250	0.833	0.500
40MPP14	0.200	0.750	0.167	0.500
51APL00	0.106	0.121	0.150	0.046
51APL02	0.022	0.103	0.185	0.529
51APL06	0.109	0.103	0.185	0.059

Table I.8: Effect weights of Ship Launching (LCH) subprocess, calculated from shipyard survey responses (raw data) (cont'd).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
51APL08	0.109	0.021	0.185	0.059
51APL09	0.109	0.015	0.185	0.059
51APL10	0.109	0.103	0.037	0.059
51APL11	0.109	0.310	0.037	0.059
51APL12	0.109	0.103	0.026	0.059
51APL14	0.109	0.034	0.062	0.059
51APL15	0.109	0.103	0.037	
51APL16	0.109	0.103	0.062	0.059
61WOR00	0.106	0.040	0.150	0.046
61WOR01	0.038	0.688	0.221	0.597
61WOR02	0.192	0.076	0.221	0.066
61WOR03	0.192	0.098	0.221	0.066
61WOR05	0.192		0.074	0.066
61WOR07	0.192	0.138	0.044	0.085
61WOR08	0.192		0.221	0.119
62WPP00	0.106	0.121	0.150	0.046
62WPP19	0.714	0.677	0.143	0.818
62WPP21	0.143	0.226	0.714	0.091
62WPP22	0.143	0.097	0.143	0.091
63WPM00	0.106	0.121	0.030	0.060
63WPM01	0.027	0.077	0.025	0.450
63WPM02	0.009	0.011	0.124	0.050
63WPM03	0.009	0.011	0.124	0.050
63WPM04	0.009	0.011	0.124	0.050
63WPM05	0.009	0.011	0.074	0.050
63WPM06	0.134	0.011	0.074	0.050
63WPM07	0.134	0.232	0.173	0.050
63WPM08	0.134	0.077	0.173	0.050
63WPM09	0.134	0.077	0.074	0.050
63WPM10	0.134	0.015	0.025	0.050
63WPM11	0.134	0.387	0.005	0.050
63WPM12	0.134	0.077	0.005	0.050
70QAC00	0.106	0.121	0.090	0.046
70QAC01	0.143	0.455	0.455	0.818
70QAC03	0.143	0.091	0.091	0.091
70QAC06	0.714	0.455	0.455	0.091

Table I.9: Effect weights of Outfitting after Ship Launching (QAY) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
14POS00	0.041	0.055	0.406	0.374
14POS05	0.227	0.070	0.663	0.677
14POS06		0.209	0.095	0.097
14POS07	0.045	0.023	0.074	0.075
14POS08	0.682	0.349	0.074	0.075
14POS09	0.045	0.349	0.095	0.075
16POQ00	0.041	0.018	0.045	0.053
16POQ01	0.200	0.250	0.900	0.900
16POQ02	0.800	0.750	0.100	0.100
21IFL00	0.014	0.018	0.045	0.053
21IFL01	0.044	0.036	0.307	0.313
21IFL03	0.132	0.179	0.044	0.045
21IFL04	0.132	0.108	0.061	0.045
21IFL06	0.132	0.179	0.061	0.045
21IFL07	0.132	0.179	0.044	0.045
21IFL08	0.132	0.179	0.044	0.045
21IFL11	0.015	0.012	0.044	0.063
21IFL13	0.015	0.012	0.044	0.045
21IFL14	0.132	0.007	0.307	0.313
21IFL16	0.132	0.108	0.044	0.045
22IEN00	0.014	0.018	0.045	0.053
22IEN02	1.000	1.000	1.000	1.000
23ITE00	0.014	0.011	0.045	0.053
23ITE06	1.000	1.000	1.000	1.000
24IFA00	0.014	0.018	0.058	0.075
24IFA01	0.067	0.318	0.075	0.075
24IFA02	0.200	0.318	0.015	0.015
24IFA03	0.200	0.318	0.015	0.015
24IFA04	0.200	0.045	0.224	0.224
24IFA05	0.333		0.672	0.672
30DES00	0.123	0.018	0.045	0.042
30DES07	0.032	0.340	0.578	0.600
30DES08	0.161	0.068	0.064	0.067
30DES09	0.161	0.340	0.083	0.067
30DES10	0.161	0.068	0.064	0.067
30DES14	0.161	0.068	0.064	0.067

Table I.9: Effect weights of Outfitting after Ship Launching (QAY) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
30DES16	0.161	0.049	0.064	0.067
30DES18	0.161	0.068	0.083	0.067
40MPP00	0.123	0.166	0.045	0.053
40MPP06	0.455	0.833	0.818	0.818
40MPP11	0.455	0.167	0.091	0.091
40MPP14	0.091		0.091	0.091
51APL00	0.123	0.166	0.045	0.053
51APL02	0.020	0.192	0.403	0.412
51APL06	0.098	0.064	0.058	0.059
51APL08	0.098	0.192	0.058	0.059
51APL09	0.098	0.192	0.058	0.059
51APL10	0.098	0.038	0.058	0.059
51APL11	0.098	0.064	0.058	0.059
51APL12	0.098	0.064	0.081	0.059
51APL13	0.098	0.027	0.081	0.059
51APL14	0.098	0.064	0.045	0.059
51APL15	0.098	0.064	0.045	0.059
51APL16	0.098	0.038	0.058	0.059
61WOR00	0.123	0.277	0.058	0.053
61WOR01	0.032	0.283	0.589	0.589
61WOR02	0.161	0.094	0.065	0.065
61WOR03	0.161	0.094	0.065	0.065
61WOR05	0.161	0.094	0.084	0.084
61WOR06	0.161	0.094	0.065	0.065
61WOR07	0.161	0.057	0.065	0.065
61WOR08	0.161	0.283	0.065	0.065
62WPP00	0.123	0.166	0.045	0.053
62WPP04	0.083	0.067	0.375	0.375
62WPP07	0.083	0.067	0.042	0.042
62WPP08	0.083	0.022	0.042	0.042
62WPP09	0.083	0.022	0.042	0.042
62WPP10	0.083	0.336	0.042	0.042
62WPP11	0.083	0.202	0.042	0.042
62WPP12	0.083	0.202	0.042	0.042
62WPP13	0.083	0.013	0.042	0.042
62WPP14	0.083	0.067	0.042	0.042
62WPP15	0.083		0.042	0.042
62WPP17	0.017		0.042	0.042
62WPP18	0.017		0.042	0.042
62WPP20	0.017		0.042	0.042

Table I.9: Effect weights of Outfitting after Ship Launching (QAY) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
62WPP21	0.017		0.042	0.042
62WPP22	0.017		0.042	0.042
62WPP23	0.083		0.042	0.042
63WPM00	0.123	0.011	0.058	0.042
63WPM01	0.027	0.028	0.426	0.190
63WPM02	0.009	0.083	0.047	0.021
63WPM03	0.009	0.083	0.047	0.021
63WPM04	0.009	0.083	0.061	0.038
63WPM05	0.009	0.083	0.047	0.570
63WPM06	0.134	0.083	0.047	0.021
63WPM07	0.134	0.194	0.061	0.021
63WPM08	0.134	0.194	0.061	0.021
63WPM09	0.134	0.083	0.047	0.027
63WPM10	0.134	0.028	0.047	0.027
63WPM11	0.134	0.028	0.061	0.021
63WPM12	0.134	0.028	0.047	0.021
70QAC00	0.123	0.055	0.058	0.042
70QAC01	0.143	0.231	0.797	0.818
70QAC03	0.143	0.692	0.114	0.091
70QAC06	0.714	0.077	0.089	0.091

Table I.10: Effect weights of Setting-to-Work , Harbor and Sea Trials (TEST) subprocess, calculated from shipyard survey responses (raw data).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
14POS00	0.107	0.427	0.427	0.477
14POS09	1.000	1.000	1.000	1.000
21IFL00	0.107	0.061	0.061	0.068
21IFL01	0.231	0.663	0.663	0.677
21IFL08	0.231	0.074	0.074	0.075
21IFL11	0.077	0.074	0.074	0.075
21IFL13	0.231	0.095	0.095	0.097
21IFL16	0.231	0.095	0.095	0.075
24IFA00	0.036	0.061	0.061	0.068
24IFA01	0.333	0.075	0.075	0.692
24IFA02	0.333	0.015	0.015	0.077
24IFA03	0.111	0.015	0.015	0.077
24IFA04	0.111	0.224	0.224	0.077
24IFA05	0.111	0.672	0.672	0.077
30DES00	0.107	0.061	0.061	0.053
30DES08	0.333	0.818	0.818	0.797
30DES18	0.333	0.091	0.091	0.114
30DES19	0.333	0.091	0.091	0.089
40MPP00	0.107	0.061	0.061	0.053
40MPP06	0.333	0.797	0.797	0.818
40MPP10	0.333	0.089	0.089	0.091
40MPP11	0.333	0.114	0.114	0.091
51APL00	0.107	0.061	0.061	0.068
51APL02	0.120	0.382	0.382	0.488
51APL06	0.120	0.055	0.055	0.070
51APL08	0.120	0.076	0.076	0.054
51APL09	0.120	0.076	0.076	0.070
51APL10	0.040	0.076	0.076	0.054
51APL11	0.120	0.076	0.076	0.070
51APL14	0.120	0.055	0.055	0.054
51APL15	0.120	0.076	0.076	0.070
51APL16	0.120	0.127	0.127	0.070
61WOR00	0.107	0.061	0.061	0.053
61WOR01	0.146	0.451	0.451	0.493
61WOR02	0.146	0.064	0.064	0.070
61WOR03	0.437	0.150	0.150	0.070

Table I.10: Effect weights of Setting-to-Work , Harbor and Sea Trials (TEST) subprocess, calculated from shipyard survey responses (raw data) (continued).

EFFECT Nr.	Shipyard 5	Shipyard 12		
	r_1	r_1	r_2	r_3
61WOR05	0.049	0.090	0.090	0.099
61WOR06	0.049	0.064	0.064	0.099
61WOR07	0.146	0.090	0.090	0.070
61WOR08	0.029	0.090	0.090	0.099
62WPP00	0.107	0.061	0.061	0.053
62WPP04	0.100	0.389	0.389	0.485
62WPP07	0.100	0.056	0.056	0.054
62WPP10	0.100	0.056	0.056	0.054
62WPP11	0.100	0.043	0.043	0.054
62WPP12	0.100	0.043	0.043	0.054
62WPP15	0.100	0.043	0.043	0.054
62WPP18	0.100	0.056	0.056	0.069
62WPP20	0.100	0.130	0.130	0.069
62WPP21	0.100	0.130	0.130	0.054
62WPP23	0.100	0.056	0.056	0.054
63WPM00	0.107	0.061	0.061	0.053
63WPM01	0.100	0.395	0.395	0.414
63WPM02	0.100	0.056	0.056	0.046
63WPM03	0.100	0.056	0.056	0.046
63WPM04	0.100	0.056	0.056	0.059
63WPM05	0.033	0.056	0.056	0.059
63WPM06	0.100	0.056	0.056	0.046
63WPM07	0.100	0.044	0.044	0.046
63WPM08	0.033	0.044	0.044	0.046
63WPM09	0.100	0.056	0.056	0.059
63WPM10	0.100	0.056	0.056	0.059
63WPM11	0.033	0.044	0.044	0.059
63WPM12	0.100	0.079	0.079	0.059
70QAC00	0.107	0.085	0.085	0.053
70QAC01	0.300	0.565	0.565	0.630
70QAC07	0.100	0.081	0.081	0.070
70QAC08	0.100	0.081	0.081	0.090
70QAC09	0.100	0.081	0.081	0.070
70QAC10	0.100	0.081	0.081	0.070
70QAC11	0.300	0.113	0.113	0.070

Table I.11: Weights of Management : Basis information, calculated from shipyard survey responses (raw data).

Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
MBS101	0.563	0.144	0.300	0.500	0.042	0.125	0.300	0.125	0.500	0.170	0.417	0.063
MBS102	0.063	0.029	0.100	0.071	0.042	0.125	0.100	0.125	0.071	0.170	0.083	0.063
MBS103	0.063	0.029	0.100	0.071	0.042	0.125	0.100	0.125	0.071	0.170	0.083	0.063
MBS104	0.063	0.029	0.100	0.071	0.208	0.125	0.100	0.125	0.071	0.034	0.083	0.063
MBS105	0.063	0.144	0.100	0.071	0.292	0.125	0.100	0.125	0.071	0.057	0.083	0.188
MBS106	0.063	0.048	0.100	0.071	0.042	0.125	0.100	0.125	0.071	0.170	0.083	0.188
MBS107	0.063	0.144	0.100	0.071	0.208	0.125	0.100	0.125	0.071	0.057	0.083	0.188
MBS108	0.063	0.433	0.100	0.071	0.125	0.125	0.100	0.125	0.071	0.170	0.083	0.188
MBS201	0.045	0.125	0.300	0.500	0.197	0.083	0.300	0.125	0.500	0.125	0.417	0.045
MBS202	0.136	0.125	0.100	0.071	0.039	0.083	0.100	0.125	0.071	0.125	0.083	0.136
MBS203	0.136	0.125	0.100	0.071	0.039	0.083	0.100	0.125	0.071	0.125	0.083	0.136
MBS204	0.136	0.125	0.100	0.071	0.197	0.250	0.100	0.125	0.071	0.125	0.083	0.136
MBS205	0.136	0.125	0.100	0.071	0.197	0.083	0.100	0.125	0.071	0.125	0.083	0.136
MBS206	0.136	0.125	0.100	0.071	0.066	0.083	0.100	0.125	0.071	0.125	0.083	0.136
MBS207	0.136	0.125	0.100	0.071	0.197	0.250	0.100	0.125	0.071	0.125	0.083	0.136
MBS208	0.136	0.125	0.100	0.071	0.066	0.083	0.100	0.125	0.071	0.125	0.083	0.136
MBS301	0.124	0.125	0.300	0.500	0.115	0.083	0.300	0.125	0.500	0.083	0.300	0.045
MBS302	0.018	0.125	0.100	0.071	0.038	0.083	0.100	0.125	0.071	0.250	0.100	0.136
MBS303	0.041	0.125	0.100	0.071	0.038	0.083	0.100	0.125	0.071	0.250	0.100	0.136
MBS304	0.041	0.125	0.100	0.071	0.115	0.250	0.100	0.125	0.071	0.028	0.100	0.136
MBS305	0.018	0.125	0.100	0.071	0.346	0.083	0.100	0.125	0.071	0.028	0.100	0.136
MBS306	0.371	0.125	0.100	0.071	0.115	0.083	0.100	0.125	0.071	0.250	0.100	0.136
MBS307	0.371	0.125	0.100	0.071	0.115	0.250	0.100	0.125	0.071	0.028	0.100	0.136
MBS308	0.018	0.125	0.100	0.071	0.115	0.083	0.100	0.125	0.071	0.083	0.100	0.136
MBS401	0.389	0.125	0.300	0.500	0.250	0.083	0.288	0.125	0.417	0.068	0.417	0.045
MBS402	0.056	0.125	0.100	0.071	0.050	0.083	0.096	0.125	0.083	0.205	0.083	0.136
MBS403	0.130	0.125	0.100	0.071	0.050	0.083	0.096	0.125	0.083	0.205	0.083	0.136
MBS404	0.130	0.125	0.100	0.071	0.250	0.250	0.288	0.125	0.083	0.023	0.083	0.136
MBS405	0.056	0.125	0.100	0.071	0.250	0.083	0.058	0.125	0.083	0.023	0.083	0.136
MBS406	0.130	0.125	0.100	0.071	0.050	0.083	0.058	0.125	0.083	0.205	0.083	0.136
MBS407	0.056	0.125	0.100	0.071	0.050	0.250	0.058	0.125	0.083	0.068	0.083	0.136
MBS408	0.056	0.125	0.100	0.071	0.050	0.083	0.058	0.125	0.083	0.205	0.083	0.136
MBS501	0.677	0.333	0.143	0.797	0.652	0.200	0.333	0.333	0.745	0.455	0.778	0.600
MBS502	0.097	0.333	0.429	0.114	0.217	0.200	0.333	0.333	0.149	0.091	0.111	0.200
MBS503	0.226	0.333	0.429	0.089	0.130	0.600	0.333	0.333	0.106	0.455	0.111	0.200

Table I.11: Weights of Management : Basis information, calculated from shipyard survey responses (raw data) (continued).

Nr.	Shipyard 5	Shipyard 12		Shipyard 200					Shipyard 300			
	r_1	r_1	r_2	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4
MBS601	0.231	0.333	0.143	0.797	0.714	0.200	0.333	0.333	0.745	0.455	0.714	0.333
MBS602	0.077	0.333	0.429	0.114	0.143	0.200	0.333	0.333	0.149	0.091	0.143	0.333
MBS603	0.692	0.333	0.429	0.089	0.143	0.600	0.333	0.333	0.106	0.455	0.143	0.333
MBS701	0.677	0.333	0.231	0.797	0.652	0.200	0.333	0.333	0.745	0.429	0.714	0.600
MBS702	0.097	0.333	0.077	0.114	0.217	0.200	0.333	0.333	0.149	0.143	0.143	0.200
MBS703	0.226	0.333	0.692	0.089	0.130	0.600	0.333	0.333	0.106	0.429	0.143	0.200
MBS801	0.677	0.333	0.333	0.797	0.714	0.200	0.333	0.333	0.745	0.429	0.652	0.333
MBS802	0.097	0.333	0.333	0.114	0.143	0.200	0.333	0.333	0.149	0.143	0.130	0.333
MBS803	0.226	0.333	0.333	0.089	0.143	0.600	0.333	0.333	0.106	0.429	0.217	0.333
MBS901	0.342	0.167	0.227	0.586	0.094	0.125	0.107	0.167	0.583	0.214	0.459	0.075
MBS902	0.038	0.167	0.045	0.084	0.281	0.125	0.321	0.167	0.083	0.214	0.092	0.025
MBS903	0.114	0.167	0.227	0.065	0.031	0.125	0.107	0.167	0.083	0.214	0.153	0.225
MBS904	0.342	0.167	0.045	0.065	0.031	0.375	0.036	0.167	0.083	0.214	0.153	0.225
MBS905	0.049	0.167	0.227	0.084	0.094	0.125	0.107	0.167	0.083	0.071	0.092	0.225
MBS906	0.114	0.167	0.227	0.117	0.469	0.125	0.321	0.167	0.083	0.071	0.051	0.225
MBS991	0.875	0.500	0.500	0.125	0.833	0.500	0.250	0.833	0.900	0.500	0.500	0.875
MBS992	0.125	0.500	0.500	0.875	0.167	0.500	0.750	0.167	0.100	0.500	0.500	0.125

APPENDIX J. EFFECT MAGNITUDES

Table J.1: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
14POS03	5.0	3.0	2.0	5.0	2.0	3.1	1.000	3.129
21IFL01	1.4	4.3	4.0	1.9	2.4	2.6	0.043	0.112
21IFL02	4.2	2.7	3.7	4.7	3.9	3.8	0.049	0.184
21IFL03	3.0	3.0	3.0	3.0	3.0	3.0	0.039	0.118
21IFL04	4.0	4.0	4.0	3.0	2.0	3.3	0.054	0.178
21IFL05	3.0	4.0	4.0	4.0	2.0	3.3	0.051	0.166
21IFL06	1.0	3.0	1.0	3.0	1.0	1.6	0.051	0.078
21IFL07	2.3	2.7	2.4	3.7	2.0	2.5	0.043	0.110
21IFL08	5.0	2.7	2.7	4.8	2.7	3.4	0.064	0.218
21IFL09	3.0	3.0	3.0	5.0	1.0	2.7	0.064	0.171
21IFL10	1.0	3.0	3.0	3.0	3.0	2.4	0.034	0.081
21IFL11	3.0	4.0	4.0	4.0	3.0	3.6	0.031	0.112
21IFL12	1.0	3.0	3.0	3.0	3.0	2.4	0.029	0.071
21IFL13	2.1	2.1	2.8	5.0	3.8	3.0	0.049	0.145
21IFL14	1.0	5.0	3.0	5.0	2.0	2.7	0.067	0.183
21IFL15	3.6	2.9	2.0	4.4	1.6	2.7	0.051	0.136
21IFL16	5.0	4.0	3.0	5.0	2.0	3.6	0.051	0.182
22IEN01	4.0	5.0	1.0	4.3	2.7	3.0	0.342	1.020
22IEN02	5.0	4.0	3.0	4.0	2.0	3.4	0.449	1.543
23ITE01	5.0	5.0	4.0	4.0	2.0	3.8	0.115	0.440
23ITE02	5.0	4.0	4.0	5.0	2.0	3.8	0.104	0.397
23ITE03	4.1	3.3	3.5		2.8	3.4	0.084	0.284
23ITE04	5.0	5.0	3.0	5.0	3.0	4.1	0.288	1.175
23ITE05	5.0	3.0	3.0	5.0	1.0	3.0	0.124	0.366
23ITE06	5.0	3.0	3.0	5.0	3.0	3.7	0.121	0.447
24IFA01	5.0	3.0	2.0		2.0	2.8	0.097	0.269
24IFA02	4.9	2.9	2.3		1.4	2.6	0.090	0.237
24IFA03	1.0	3.0	5.0		1.0	2.0	0.073	0.143
24IFA04	4.7	4.9	3.7		3.6	4.2	0.189	0.790
24IFA05	4.0	4.0	5.0		4.0	4.2	0.237	1.002
30DES17	1.3	3.5	3.5		1.0	2.0	0.213	0.422
30DES19	4.0	4.0	2.0	5.0	1.0	2.8	0.130	0.360
30DES20	1.0	3.3	3.0	3.0	1.0	2.0	0.180	0.354
30DES21	4.0	3.5	1.5		1.2	2.3	0.199	0.449
30DES22	2.8	1.7	2.6	5.0	2.0	2.6	0.144	0.379
40MPP01	3.0	3.0	3.0	3.0	2.1	2.8	0.033	0.091

Table J.1: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
40MPP02		3.0	2.0	5.0	1.0	2.3	0.049	0.114
40MPP03	5.0	1.0	3.0	5.0	3.0	3.0	0.026	0.078
40MPP04	3.0	5.0	1.0	3.0	1.0	2.1	0.130	0.278
40MPP05	2.0	2.8	2.0		1.5	2.0	0.056	0.113
40MPP06	3.1	3.8	3.0		3.2	3.2	0.038	0.124
40MPP07	3.0	3.0	3.0		1.0	2.3	0.066	0.150
40MPP08	3.0	2.0	2.0	5.0	2.0	2.6	0.040	0.105
40MPP09	3.2	3.0	3.0	3.0	1.0	2.4	0.033	0.080
40MPP10	3.0	2.0	2.0	4.0	2.0	2.5	0.056	0.139
40MPP11	2.8	1.8	3.0	4.0	2.0	2.6	0.043	0.112
40MPP12	1.0	3.0	3.0		1.0	1.7	0.040	0.070
40MPP13	3.0	3.0	3.0		1.0	2.3	0.038	0.087
40MPP14	5.0	1.0	3.0		1.0	2.0	0.036	0.072
51APL01	4.0	3.0	1.0		1.0	1.9	0.019	0.036
51APL02	4.0	3.0	2.0		1.0	2.2	0.021	0.048
51APL03	5.0	3.0	2.0		2.0	2.8	0.030	0.082
51APL04	5.0	4.0	2.0		2.0	3.0	0.024	0.071
51APL05	5.0	5.0	5.0		5.0	5.0	0.031	0.155
51APL06	3.0	3.0	2.0		2.0	2.4	0.075	0.184
51APL07	5.0	3.0	3.0		1.0	2.6	0.075	0.195
51APL08	5.0	3.0	3.0		3.0	3.4	0.024	0.081
51APL09	3.0	3.0	3.0		1.0	2.3	0.024	0.054
51APL10	5.0	3.0	3.0	3.0	2.0	3.1	0.032	0.097
51APL11	5.0	5.0	3.0	3.0	3.0	3.7	0.054	0.201
51APL12	5.0	5.0	3.0	3.0	1.3	3.1	0.023	0.071
51APL13	2.0	2.0	2.0	5.0	3.0	2.6	0.051	0.133
51APL14	3.0	3.0	3.0	3.0	1.0	2.4	0.033	0.080
51APL15	4.0	3.0	1.3	3.5	1.3	2.4	0.033	0.078
51APL16	2.3	2.0	3.0	4.0	2.0	2.6	0.035	0.090
51APL17	3.0	3.0	1.0	4.0	1.0	2.0	0.039	0.081
51APL18	5.0	5.0	1.0	5.0	1.0	2.6	0.024	0.062
51APL19	3.0	3.0	1.0	5.0	1.0	2.1	0.024	0.051
51APL20	3.0	3.0	1.0	3.0	1.0	1.9	0.025	0.049
51APL21	4.0	4.0	3.0	5.0	3.0	3.7	0.025	0.095
51APL22	3.0	5.0	3.0	5.0	1.0	3.0	0.025	0.075
51APL23	5.0	5.0	3.0	3.0	1.0	3.0	0.032	0.094
51APL24	3.0	3.0	3.0	5.0	1.0	2.7	0.030	0.079
52ARM01	5.0	5.0	3.0	5.0	3.0	4.1	0.052	0.210
52ARM02	5.0	4.0	3.0	5.0	3.0	3.9	0.152	0.591

Table J.1: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
52ARM03	4.1	4.0	2.0	5.0	2.0	3.2	0.144	0.460
52ARM04	5.0	4.0	2.0	5.0	3.0	3.6	0.152	0.545
52ARM05	1.0	3.0	1.0	5.0	3.0	2.1	0.199	0.426
52ARM06	3.0	5.0	1.0	5.0	3.0	3.0	0.104	0.309
61WOR01	1.0	4.0	2.0	5.0	2.0	2.4	0.073	0.176
61WOR02	1.0	1.0	1.0	5.0	1.0	1.4	0.055	0.076
61WOR03	1.3	1.5	5.0	5.0	2.0	2.5	0.059	0.145
61WOR04	5.0	1.0	3.0	3.0	1.0	2.1	0.066	0.141
61WOR05	5.0	3.0	3.0	3.0	3.0	3.3	0.066	0.219
61WOR06	3.0	1.0	3.0	5.0	3.0	2.7	0.113	0.302
61WOR07	5.0	3.0	3.0	5.0	1.0	3.0	0.113	0.334
61WOR08	4.1	3.9	3.0	5.0	1.5	3.2	0.164	0.532
62WPP01	1.0	1.0	2.0	5.0	2.0	1.8	0.080	0.145
62WPP02	3.0	1.2	2.0	4.0	2.0	2.3	0.027	0.061
62WPP03	3.0	2.0	2.0	5.0	2.3	2.7	0.027	0.071
62WPP04	4.0	1.3	2.0	5.0	3.0	2.7	0.027	0.072
62WPP05	3.9	1.3	2.0	5.0	2.0	2.5	0.019	0.048
62WPP06	4.0	1.3	2.0	4.0	3.0	2.6	0.021	0.054
62WPP07	4.0	2.2	2.0	3.0	3.0	2.8	0.021	0.057
62WPP08	4.0	2.6	2.0	3.0	1.1	2.3	0.023	0.053
62WPP09	5.0	3.0	2.0	4.0	2.0	3.0	0.025	0.076
62WPP10		1.0	1.7	3.0	2.1	1.8	0.022	0.040
62WPP11	5.0	2.0	2.0	3.0	2.0	2.6	0.026	0.067
62WPP12	5.0	2.0	2.0	3.0	1.1	2.3	0.027	0.061
62WPP13	5.0	2.0	2.0	3.0	2.0	2.6	0.028	0.074
62WPP14	5.0	2.2	2.0	3.0	2.0	2.7	0.028	0.076
62WPP15	5.0	1.3	1.3	2.0	1.1	1.8	0.021	0.037
62WPP16	4.0	2.0	2.0	3.0	2.3	2.6	0.028	0.073
62WPP17	4.0	2.2	2.0	3.0	2.0	2.5	0.028	0.072
62WPP18	4.0	2.0	2.0	3.0	2.0	2.5	0.028	0.071
62WPP19	3.0	1.0	2.0	3.0	1.0	1.8	0.066	0.118
62WPP20	5.0	2.4		4.0	1.3	2.8	0.037	0.102
62WPP21	5.0	2.8		5.0	1.3	3.1	0.024	0.075
62WPP22	3.0	1.1		4.0	1.1	2.0	0.021	0.041
62WPP23	2.0	2.0	2.0	3.0	1.0	1.9	0.043	0.082
63WPM01	3.0	4.0	3.0	5.0	3.0	3.5	0.029	0.104
63WPM02	5.0	4.0	3.0	5.0	3.0	3.9	0.038	0.147
63WPM03	4.0	4.0	4.0	4.0	4.0	4.0	0.083	0.333
63WPM04	3.0	3.0	3.0	3.0	3.0	3.0	0.089	0.267
63WPM05	5.0	5.0	5.0	5.0	5.0	5.0	0.075	0.376

Table J.1: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
63WPM06	3.0	3.0	3.0	3.0	3.0	3.0	0.089	0.267
63WPM07	3.6	3.3	3.0	5.0	1.7	3.1	0.065	0.202
63WPM08	4.0	3.0	3.0	4.0	2.3	3.2	0.080	0.258
63WPM09	5.0	4.9	3.0	5.0	1.7	3.6	0.089	0.324
63WPM10	5.0	4.1	3.0	3.0	2.3	3.3	0.068	0.227
63WPM11	5.0	3.8	3.0	3.0	2.3	3.3	0.075	0.249
63WPM12	5.0	3.7	3.0	3.0	2.0	3.2	0.052	0.165
70QAC01	5.0	3.0	3.0	5.0	1.0	3.0	0.080	0.237
70QAC02	5.0	3.0	1.0	5.0	1.0	2.4	0.072	0.172
70QAC03	5.0	3.0	3.0	5.0	1.0	3.0	0.080	0.237
70QAC06	5.0	4.0	5.0	5.0	5.0	4.8	0.163	0.781
70QAC07	1.0	3.0	3.0	5.0	1.0	2.1	0.100	0.214
70QAC08	1.0	3.0	3.0	3.0	1.0	1.9	0.100	0.193
70QAC09	3.0	3.0	3.0	3.0	1.0	2.4	0.072	0.174
70QAC10	5.0	3.0	3.0	3.0	3.0	3.3	0.072	0.241
70QAC11	5.0	3.0	3.0	3.0	3.0	3.3	0.095	0.316
81CMC02	3.0	3.0	3.0	3.0	1.0	2.4	0.290	0.697
81CMC03	5.0	3.0	1.0	5.0	1.0	2.4	0.290	0.687
81CMC04	4.0	4.0	3.0	5.0	1.0	3.0	0.196	0.587

Table J.2: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	r_4	M_{ir} (Geomean)	w_i	WMi
21IFL16	4.0	3.0	3.0	1.0	2.4	1.000	2.449
23ITE02	3.0	2.0	3.0		2.6	0.338	0.885
23ITE03	1.2	3.2	1.5		1.8	0.087	0.154
23ITE04	3.0	3.0	1.0	1.0	1.7	0.208	0.360
23ITE05	3.0	3.0	1.0	1.0	1.7	0.158	0.273
24IFA01	1.0	3.0	1.0	3.0	1.7	0.264	0.458
24IFA02	1.0	4.0	1.0	1.9	1.7	0.264	0.440
24IFA03	3.0	1.0	1.0	1.0	1.3	0.102	0.134
24IFA04	1.9	4.1	2.3	3.3	2.8	0.134	0.375
24IFA05	5.0	5.0	5.0	5.0	5.0	0.063	0.314
30DES01	2.8	3.6	3.4	2.2	2.9	0.069	0.202
30DES02	2.0	5.0	4.0	1.0	2.5	0.032	0.081
30DES03	3.0	3.0	3.0	3.0	3.0	0.035	0.105
30DES04	2.0	2.0	2.0	1.0	1.7	0.028	0.048
30DES05	2.0	2.0	2.5	1.5	2.0	0.027	0.052
30DES06	3.0	3.0	3.0	1.0	2.3	0.020	0.045
30DES07	3.0	3.0	3.0	1.0	2.3	0.026	0.059
30DES08	3.0	2.1	2.2	2.2	2.3	0.034	0.080
30DES09	2.0	2.0	2.0	1.0	1.7	0.037	0.063
30DES10	1.0	1.1	1.0	1.5	1.1	0.028	0.032
30DES11	1.0	1.0	1.0	1.0	1.0	0.063	0.063
30DES12	1.0	1.0	3.0	1.0	1.3	0.073	0.096
30DES13	1.8	3.1	2.9	1.4	2.1	0.040	0.087
30DES14	3.0	3.0	1.0	1.0	1.7	0.028	0.049
30DES15	2.0	1.0	2.0	2.0	1.7	0.026	0.044
30DES16	3.8	3.2	1.0	1.3	2.0	0.023	0.046
30DES17	3.0	3.0	2.0	1.0	2.1	0.014	0.030
30DES18	3.0	1.0	1.0	1.0	1.3	0.035	0.046
30DES19	4.0	1.0	2.0	1.0	1.7	0.042	0.071
30DES20	2.0	1.3	1.7	1.7	1.6	0.046	0.075
30DES21	1.8	3.0	2.5	1.8	2.2	0.028	0.062
30DES22	3.0	3.4	1.4	3.0	2.6	0.037	0.096
40MPP01	2.8	3.0	1.4	3.0	2.4	0.163	0.397
40MPP02	2.0	2.0	1.0	1.0	1.4	0.083	0.117
40MPP03	1.0	5.0	5.0	3.0	2.9	0.100	0.294

Table J.2: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	M_{ir} (Geomean)	w_i	WMi
40MPP04	3.0	3.0	1.0	1.0	1.7	0.173	0.300
40MPP06	3.5	3.0	3.0	2.1	2.9	0.083	0.237
40MPP09	3.0	1.6	2.6	1.3	2.0	0.116	0.231
40MPP11	2.1	2.7	3.0	2.0	2.4	0.051	0.124
40MPP12	3.0	1.0	1.0	1.0	1.3	0.039	0.051
51APL01	2.0	2.0	1.0	1.0	1.4	0.081	0.114
51APL02	1.0	3.0	1.0	3.0	1.7	0.033	0.057
51APL03	2.0	3.0	3.0	3.0	2.7	0.033	0.090
51APL04	5.0	5.0	5.0	5.0	5.0	0.019	0.096
51APL06	2.0	2.0	2.0	2.0	2.0	0.040	0.080
51APL08	5.0	3.0	3.0	3.0	3.4	0.057	0.196
51APL09	3.0	3.0	3.0	3.0	3.0	0.053	0.158
51APL11	5.0	5.0	5.0	5.0	5.0	0.054	0.269
51APL12	0.7	1.1	2.4	0.5	1.0	0.038	0.038
51APL13	2.0	2.0	2.0	2.0	2.0	0.038	0.075
51APL14	1.4	2.8	3.0	2.3	2.3	0.065	0.149
51APL15	2.0	1.0	1.0	1.0	1.2	0.044	0.052
51APL16	2.0	2.3	1.5	1.7	1.8	0.040	0.074
51APL19	3.0	3.0	3.0	3.0	3.0	0.025	0.075
51APL20	1.0	3.0	3.0	3.0	2.3	0.050	0.113
51APL21	1.0	4.0	3.0	4.0	2.6	0.038	0.099
51APL22	3.0	3.0	1.0	3.0	2.3	0.050	0.113
51APL24	3.0	3.0	1.0	1.0	1.7	0.056	0.097
52ARM03	4.0	3.0	1.0	1.8	2.2	0.276	0.597
52ARM05	1.0	3.0	1.0	1.0	1.3	0.188	0.247
52ARM06	5.0	3.0	1.0	3.0	2.6	0.333	0.864
61WOR01	3.0	3.0	1.0	1.0	1.7	0.050	0.087
61WOR02	1.0	3.0	1.0	1.0	1.3	0.083	0.109
61WOR03	1.0	3.0	3.0	5.0	2.6	0.201	0.520
61WOR04	1.0	3.0	3.0	3.0	2.3	0.083	0.188
61WOR05	1.0	3.0	1.0	3.0	1.7	0.118	0.205
61WOR07	3.0	5.0	3.0	3.0	3.4	0.134	0.458
61WOR08	1.0	2.8	2.0	1.0	1.5	0.019	0.029
62WPP23	2.0	2.0	3.0	1.0	1.9	1.000	1.861
63WPM01	2.0	2.0	4.0	1.0	2.0	0.065	0.130
63WPM02	3.0	3.0	3.0	3.0	3.0	0.097	0.291
63WPM03	1.3	2.8	1.9	1.9	1.9	0.060	0.114
63WPM04	1.0	1.0	1.0	1.0	1.0	0.060	0.060
63WPM05	3.0	3.0	5.0	3.0	3.4	0.065	0.221

Table J.2: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	M_{ir} (Geomean)	w_i	WMi
63WPM06	2.3	2.0	3.6	3.3	2.7	0.060	0.162
63WPM08	3.0	3.8	4.0	3.0	3.4	0.045	0.155
63WPM09	1.0	1.3	1.0	3.0	1.4	0.030	0.043
63WPM10	2.5	3.0	3.0	3.0	2.9	0.034	0.099
63WPM11	1.0	2.8	3.7	1.0	1.8	0.158	0.282
63WPM12	1.7	2.1	1.4	1.1	1.5	0.052	0.081
70QAC01	1.0	3.0	1.0	3.0	1.7	0.233	0.404
70QAC02	1.0	1.0	1.0	1.0	1.0	0.109	0.109
70QAC03	5.0	3.0	1.0	1.0	2.0	0.109	0.215
70QAC04	3.0	3.0	2.0	1.5	2.3	0.189	0.431
70QAC09	1.0	3.0	1.0	3.0	1.7	0.166	0.288
81CMC02	1.0	1.0	1.0	1.0	1.0	0.289	0.289
81CMC04	4.0	3.0	1.0	3.0	2.4	0.645	1.581

Table J.3: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
13PPT02	3.3	5.0	3.1	3.7	0.726	2.689
13PPT06	4.8	3.5	5.0	4.4	0.198	0.866
14POS01	5.0	5.0	5.0	5.0	0.300	1.498
14POS02	4.0	4.0	4.0	4.0	0.039	0.157
14POS03	4.0	3.0	5.0	3.9	0.075	0.295
14POS04	5.0	5.0	5.0	5.0	0.069	0.346
14POS05	2.0	4.0	2.0	2.5	0.043	0.108
14POS06	3.0	3.0	3.0	3.0	0.054	0.161
14POS07	2.9	4.1	1.2	2.4	0.144	0.346
14POS08	3.0	3.0	2.0	2.6	0.157	0.410
14POS09	3.0	3.0	1.4	2.3	0.036	0.083
21IFL01	3.0	3.4	3.4	3.2	0.090	0.291
21IFL02	3.3	3.8	1.7	2.8	0.062	0.173
21IFL06	1.0	3.0	1.0	1.4	0.062	0.090
21IFL07	1.7	3.1	1.7	2.1	0.068	0.140
21IFL08	3.0	2.2	1.2	2.0	0.068	0.136
21IFL09	3.0		1.0	1.7	0.068	0.117
21IFL10	3.0		1.0	1.7	0.076	0.131
21IFL11	2.0		1.0	1.4	0.076	0.107
21IFL12	3.0		1.0	1.7	0.076	0.131
21IFL13	2.5		1.2	1.7	0.068	0.117
21IFL14	5.0		5.0	5.0	0.076	0.378
21IFL15	2.0		1.1	1.5	0.068	0.099
21IFL16	3.0		3.0	3.0	0.068	0.203
22IEN01	4.7		4.5	4.6	0.547	2.529
22IEN02	3.0	3.0	3.0	3.0	0.286	0.859
23ITE06	3.0	3.0	3.0	3.0	1.000	3.000
24IFA01	3.0	3.0	1.0	2.1	0.122	0.254
24IFA02	3.0	3.0	3.7	3.2	0.158	0.507
24IFA03	3.0	1.0	1.0	1.4	0.234	0.337
24IFA04	4.0	4.5	4.0	4.2	0.085	0.353
24IFA05	5.0	5.0	5.0	5.0	0.234	1.170
30DES07	3.0	3.0	3.0	3.0	0.218	0.654
30DES08		3.0	2.0	2.4	0.073	0.178
30DES09	3.0	2.0	1.0	1.8	0.073	0.132

Table J.3: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
30DES10	2.9	3.0	1.0	2.1	0.105	0.216
30DES13	1.5	2.6	0.9	1.5	0.105	0.161
30DES14	3.0	3.0	1.0	2.1	0.105	0.218
30DES16	3.8	3.8	2.6	3.3	0.114	0.379
30DES18	3.0	3.0	3.0	3.0	0.105	0.314
40MPP06	3.0	3.0	1.0	2.1	0.446	0.927
40MPP11	3.0	3.0	1.9	2.6	0.214	0.553
40MPP14	3.0	3.0	1.0	2.1	0.233	0.485
51APL02	2.0	2.0	1.0	1.6	0.085	0.135
51APL06	3.0	3.0	1.0	2.1	0.041	0.085
51APL08	3.0	3.0	3.0	3.0	0.059	0.176
51APL09	3.0	3.0	3.0	3.0	0.092	0.276
51APL10	3.0	3.0	1.0	2.1	0.130	0.269
51APL11	3.0	3.0	3.0	3.0	0.044	0.133
51APL12	3.0	3.0	1.0	2.1	0.162	0.337
51APL13	2.0	2.0	2.0	2.0	0.009	0.019
51APL14	3.0	3.0	1.0	2.1	0.119	0.248
51APL15	3.0	3.0	1.5	2.4	0.041	0.097
51APL16	2.2	2.2	1.1	1.7	0.041	0.071
61WOR01	2.0	2.0	2.0	2.0	0.208	0.416
61WOR02	5.0	5.0	3.0	4.2	0.144	0.608
61WOR03	5.0	5.0	3.3	4.3	0.100	0.433
61WOR05	3.0	3.0	3.0	3.0	0.109	0.326
61WOR06	1.0	1.0	1.0	1.0	0.109	0.109
61WOR07	3.0	3.0	1.0	2.1	0.100	0.208
61WOR08	2.0	2.0	3.0	2.3	0.109	0.249
62WPP01	1.0	1.0	5.0	1.7	0.107	0.183
62WPP03	2.0	2.0	2.0	2.0	0.052	0.104
62WPP04	3.0	2.0	2.0	2.3	0.052	0.118
62WPP07	3.0		2.0	2.4	0.052	0.126
62WPP08	3.0	2.1	2.0	2.3	0.052	0.120
62WPP10	3.0	1.8	2.0	2.2	0.052	0.114
62WPP11	3.0	3.1		3.0	0.052	0.156
62WPP12	3.0	2.4	2.0	2.4	0.052	0.125
62WPP13	3.0	2.3	2.0	2.4	0.052	0.124
62WPP14	3.0	2.4	2.0	2.4	0.052	0.126
62WPP16	3.0	2.4	2.0	2.4	0.052	0.125
62WPP17	3.0	2.1	2.0	2.3	0.052	0.120
62WPP18	3.0	3.6	2.0	2.8	0.052	0.144

Table J.3: Shipyard 200 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
62WPP20	3.0	3.6		3.3	0.052	0.169
62WPP21	3.0	3.0	3.0	3.0	0.056	0.168
62WPP22	3.0	2.2	2.0	2.4	0.052	0.122
62WPP23	2.0	2.0	1.0	1.6	0.052	0.082
63WPM01	3.0	3.0	3.0	3.0	0.091	0.273
63WPM02	3.0	3.0	3.0	3.0	0.063	0.189
63WPM03	2.5	2.5	2.6	2.5	0.084	0.212
63WPM04	3.0	3.0	1.0	2.1	0.084	0.174
63WPM05	3.0	3.0	3.0	3.0	0.084	0.251
63WPM06	1.2	1.3	1.7	1.4	0.084	0.115
63WPM07	2.3	2.4	1.1	1.8	0.084	0.149
63WPM08	2.0	2.0	4.0	2.5	0.075	0.188
63WPM09	3.2	3.2	0.9	2.1	0.063	0.133
63WPM10	4.8	4.8	1.1	2.9	0.044	0.129
63WPM11	3.7	4.3	1.0	2.5	0.044	0.110
63WPM12	4.7	4.7	1.2	3.0	0.044	0.133
70QAC01	3.0	3.0	1.0	2.1	0.361	0.750
70QAC03	3.0	3.0	3.0	3.0	0.173	0.520
70QAC05	2.7	2.7	1.0	1.9	0.173	0.333
70QAC06	3.0	3.0	1.0	2.1	0.173	0.361

Table J.4: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
14POS03	3.0	2.0	4.0	3.0	3.0	2.9	1.000	2.930
21IFL01	3.0	3.0	3.8	4.5	4.6	3.7	0.031	0.117
21IFL02	1.0	2.8	1.7	2.0	3.0	2.0	0.062	0.121
21IFL03	1.0	1.0	4.0	3.0	2.0	1.9	0.051	0.096
21IFL04	4.0	2.0	3.0		1.0	2.2	0.051	0.113
21IFL05	2.0	2.0	1.0	4.0	2.0	2.0	0.021	0.042
21IFL06	1.0	1.0	1.0	3.0	1.0	1.2	0.030	0.037
21IFL07	1.0	1.1	1.8	1.7	1.0	1.3	0.051	0.065
21IFL08	1.0	2.3	2.4	2.6	1.1	1.7	0.054	0.094
21IFL09	1.0	1.0	1.0	3.0	1.0	1.2	0.034	0.043
21IFL10	3.0	3.0	3.0	3.0	3.0	3.0	0.034	0.102
21IFL11	1.0	1.0	4.0	2.0	3.0	1.9	0.031	0.059
21IFL12	3.0	1.0	3.0	3.0	1.0	1.9	0.034	0.066
21IFL13	1.0	1.0	1.3	2.3	2.2	1.5	0.034	0.050
21IFL14	5.0	5.0	5.0	2.0	2.0	3.5	0.063	0.219
21IFL15	1.1	1.6	2.0	1.0	2.2	1.5	0.066	0.100
21IFL16	1.0	3.0	3.0	2.0	3.0	2.2	0.036	0.081
22IEN01	2.3	4.4	4.8	3.8	2.9	3.5	0.661	2.322
22IEN02	1.0	1.0	3.0	3.0	3.0	1.9	0.250	0.483
23ITE01	2.0	4.0	5.0	2.0	5.0	3.3	0.251	0.831
23ITE02	4.0	2.0	3.0	3.0	2.0	2.7	0.095	0.256
23ITE03	1.0	3.7	3.3	3.3	2.9	2.6	0.063	0.164
23ITE04	1.0	3.0	3.0	3.0	1.0	1.9	0.142	0.274
23ITE05	1.0	3.0	3.0	3.0	3.0	2.4	0.125	0.300
23ITE06	1.0	3.0	3.0	3.0	3.0	2.4	0.154	0.371
24IFA01	1.0	2.0	2.0	3.0	1.0	1.6	0.304	0.500
24IFA02	1.0	1.6	2.0	2.0	1.0	1.4	0.091	0.131
24IFA03	1.0	1.0	1.0	5.0	5.0	1.9	0.124	0.236
24IFA04	4.3	0.7	1.3	4.5	2.8	2.2	0.124	0.267
24IFA05		5.0	5.0	5.0	5.0	5.0	0.124	0.620
30DES17	1.0	1.0	2.0	2.5	2.0	1.6	0.413	0.655
30DES19	1.0	1.0	1.0	2.0	1.0	1.1	0.104	0.120
30DES20	2.0	2.8	1.5	3.0	1.0	1.9	0.104	0.198
30DES21	1.0	1.0	1.5	3.1	1.2	1.4	0.129	0.181
30DES22	1.1	1.1	2.7	2.0	1.0	1.5	0.147	0.214
40MPP01	2.6	1.0	3.7	3.0	1.0	1.9	0.098	0.192

Table J.4: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
40MPP02	1.0	1.0	2.0	2.0	2.0	1.5	0.037	0.056
40MPP03	5.0	1.0	5.0	3.0	5.0	3.3	0.053	0.174
40MPP04	1.0	3.0	1.0	1.0	1.0	1.2	0.066	0.082
40MPP05	1.0	1.8	3.5	1.0	2.0	1.7	0.127	0.210
40MPP06	2.5	1.9	2.0	3.5	2.5	2.4	0.050	0.121
40MPP07	3.0	3.0	3.0	3.0	3.0	3.0	0.040	0.121
40MPP08	2.0	2.0	2.0	3.0	3.0	2.4	0.053	0.125
40MPP09	1.0	2.8	1.0	2.8	2.7	1.8	0.029	0.053
40MPP10	2.0	2.0	2.0	2.0	3.0	2.2	0.049	0.106
40MPP11	2.9	1.0	2.0	2.8	2.0	2.0	0.027	0.053
40MPP12	1.0	1.0	3.0	1.0	1.0	1.2	0.037	0.046
40MPP13	1.0	3.0	3.0	1.0	1.0	1.6	0.023	0.036
40MPP14	1.0	1.0	1.0	1.0	5.0	1.4	0.021	0.028
51APL01	1.0	1.0	2.0	1.0	2.0	1.3	0.045	0.060
51APL02	1.0	2.0	3.0	1.0	2.0	1.6	0.016	0.026
51APL03	1.0	1.0	3.0	3.0	1.0	1.6	0.021	0.033
51APL04	1.0	2.0		2.0	2.0	1.7	0.014	0.024
51APL05	1.0	5.0	5.0	5.0	3.0	3.3	0.026	0.086
51APL06	1.0	2.0	2.0	3.0	2.0	1.9	0.028	0.053
51APL07	1.0	1.0	3.0	3.0	3.0	1.9	0.028	0.054
51APL08	3.0	3.0	3.0	3.0	3.0	3.0	0.026	0.079
51APL09	3.0	3.0	3.0	3.0	3.0	3.0	0.026	0.079
51APL10	2.0	1.2	2.7	1.3	2.7	1.9	0.020	0.038
51APL11	1.0	3.0	3.0	3.0	3.0	2.4	0.015	0.037
51APL12	4.0	1.4	1.3	3.0	3.0	2.3	0.020	0.047
51APL13	2.0	2.0	2.0	2.0	2.0	2.0	0.040	0.080
51APL14	1.0	1.0	1.3	3.0	3.0	1.6	0.017	0.028
51APL15	1.0	1.0	1.0	3.0	1.3	1.3	0.014	0.019
51APL16	1.1	2.0	3.7	2.5	1.0	1.8	0.020	0.037
51APL17	3.0	3.0	3.0	3.0	3.0	3.0	0.060	0.179
51APL18	5.0	1.0	5.0	1.0	1.0	1.9	0.012	0.023
51APL19	1.0	1.0	1.0	3.0	1.0	1.2	0.013	0.017
51APL20	1.0	1.0	1.0	1.0	1.0	1.0	0.025	0.025
51APL21	1.0	4.0	5.0	4.0	4.0	3.2	0.042	0.132
51APL22	3.0	3.0	3.0	3.0	3.0	3.0	0.037	0.110
51APL23	3.0	1.0	3.0	3.0	3.0	2.4	0.040	0.096
51APL24	3.0	1.0	3.0	3.0	1.0	1.9	0.034	0.067
52ARM01	5.0	5.0	3.0	5.0	3.0	4.1	0.283	1.154
52ARM02	3.0	1.0	3.0	3.0	4.0	2.6	0.088	0.226

Table J.4: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
52ARM03	2.8	1.0	2.3	2.5	3.2	2.2	0.127	0.278
52ARM04	2.0	1.0	2.0	2.0	1.0	1.5	0.127	0.192
52ARM05	1.0	1.0	1.0	3.0	1.0	1.2	0.096	0.120
52ARM06	1.0	1.0	5.0	3.0	1.0	1.7	0.167	0.287
61WOR01		1.0	3.0	2.0	2.0	1.9	0.168	0.312
61WOR02	1.0	1.0	3.0	3.0	1.0	1.6	0.072	0.112
61WOR03	1.0	1.2	5.0	4.5	1.2	2.0	0.089	0.179
61WOR04	5.0	1.0	1.0	3.0	1.0	1.7	0.074	0.127
61WOR05	3.0	1.0	3.0	3.0	3.0	2.4	0.068	0.163
61WOR06	3.0	1.0	1.0	3.0	1.0	1.6	0.065	0.101
61WOR07	3.0	1.0	3.0	3.0	1.0	1.9	0.158	0.305
61WOR08	1.5	2.0	2.5	3.0	2.0	2.1	0.081	0.173
62WPP01	3.0	2.0	3.0	2.0	5.0	2.8	0.178	0.502
62WPP02	1.0	1.1		2.0	2.0	1.4	0.034	0.049
62WPP03	1.0	1.0		2.0	2.0	1.4	0.034	0.048
62WPP04	2.3	1.0		2.0	2.0	1.7	0.034	0.059
62WPP05		1.0		2.0	2.0	1.6	0.034	0.053
62WPP06		1.0		2.0	2.0	1.6	0.034	0.053
62WPP07		1.0		2.0	2.0	1.6	0.034	0.053
62WPP08		1.0		2.0	2.0	1.6	0.034	0.053
62WPP09	2.0	1.0		2.0	2.0	1.7	0.031	0.052
62WPP10		1.0		2.0	2.0	1.6	0.031	0.049
62WPP11		1.0		2.0	2.0	1.6	0.031	0.049
62WPP12		1.0		2.0	2.0	1.6	0.038	0.060
62WPP13		1.0		2.0	2.0	1.6	0.038	0.060
62WPP14		1.0		2.0	2.0	1.6	0.038	0.060
62WPP15		1.0		2.0	2.0	1.6	0.038	0.060
62WPP16		1.0		2.0	2.0	1.6	0.038	0.060
62WPP17		1.0		2.0	2.0	1.6	0.038	0.060
62WPP18		1.0		2.0	2.0	1.6	0.038	0.060
62WPP19		1.0		2.0	2.0	1.6	0.031	0.049
62WPP20		1.0		2.0	2.0	1.6	0.045	0.071
62WPP21		1.8		2.0	2.0	1.9	0.045	0.086
62WPP22		1.0		2.0	2.0	1.6	0.045	0.071
62WPP23		1.0	2.0	2.0	2.0	1.7	0.045	0.075
63WPM01	1.0	2.0	1.0	2.0	2.0	1.5	0.124	0.187
63WPM02	2.0	2.0	3.0	2.0	2.0	2.2	0.047	0.101
63WPM03	2.0	2.1	2.3	2.6	3.0	2.4	0.094	0.222
63WPM04	1.0	3.0	3.0	3.0	3.0	2.4	0.066	0.158
63WPM05	1.0	3.0	3.0	3.0	3.0	2.4	0.022	0.054

Table J.4: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	M_{ir} (Geomean)	w_i	WMi
63WPM06	1.0	1.5	1.1	3.0	2.5	1.7	0.044	0.073
63WPM07	1.0	1.0	3.4	1.1	1.4	1.4	0.100	0.140
63WPM08	1.0	2.0	3.3	3.0	4.0	2.4	0.100	0.240
63WPM09	1.0	1.7	2.1	4.6	1.6	1.9	0.067	0.128
63WPM10	1.2	4.8	3.0	3.0	3.0	2.7	0.026	0.070
63WPM11	2.4	1.0	1.0	3.0	1.0	1.5	0.044	0.066
63WPM12	1.0	1.0	2.1	1.6	1.8	1.4	0.071	0.102
(70QAC01)	1.0	1.0	1.0	3.0	1.0	1.2	0.194	0.242
70QAC02	1.0	1.0	1.0	1.0	1.0	1.0	0.069	0.069
70QAC03	1.0	5.0	3.0	1.0	1.0	1.7	0.075	0.129
70QAC06	1.0	3.0	3.0	3.0	1.0	1.9	0.130	0.251
70QAC07	1.0	1.0	1.0	3.0	1.0	1.2	0.080	0.099
70QAC08	1.0	1.0	1.0	3.0	1.0	1.2	0.061	0.076
70QAC09	1.0	1.0	1.0	3.0	1.0	1.2	0.061	0.076
70QAC10	1.0	1.0	3.0	3.0	1.0	1.6	0.072	0.111
70QAC11	3.0	1.0	3.0	3.0	1.0	1.9	0.057	0.110
81CMC02	1.0	1.0	3.0	3.0	1.0	1.6	0.296	0.460
81CMC03	1.0	1.0	4.0	1.0	1.0	1.3	0.207	0.273
81CMC04	1.0	1.0	5.0	3.0	5.0	2.4	0.240	0.568

Table J.5: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	r_6	M_{ir} (Geomean)	w_i	WMi
21IFL16	2.0		4.0	2.0	5.0	1.0	2.4	1.000	2.402
23ITE02	2.0	1.0	2.0	3.0	3.0	1.0	1.8	0.384	0.698
23ITE03	3.2	4.3	3.5	1.5	1.5	1.0	2.2	0.130	0.283
23ITE04	3.0	3.0		3.0	3.0	1.0	2.4	0.128	0.308
23ITE05	3.0	3.0	3.0	3.0	3.0	1.0	2.5	0.147	0.368
24IFA01	2.0	2.0		1.0	5.0	1.0	1.8	0.248	0.452
24IFA02	1.6	1.0		2.1	2.4	1.0	1.5	0.210	0.319
24IFA03		3.0		1.0	5.0	1.0	2.0	0.128	0.253
24IFA04	3.6	2.0		2.7	4.2	1.6	2.7	0.061	0.162
24IFA05	5.0			5.0	5.0	1.0	3.3	0.054	0.182
30DES01	5.0	1.6	1.0	2.2	3.2	3.8	2.4	0.078	0.191
30DES02	4.0	1.0	1.0	4.0	2.0	1.0	1.8	0.016	0.028
30DES03	3.0	3.0	3.0	1.0	5.0	3.0	2.7	0.033	0.089
30DES04	5.0	3.0	1.0	2.0	1.0	1.0	1.8	0.039	0.069
30DES05	2.5	2.0	2.0	1.2	2.0	1.3	1.8	0.026	0.046
30DES06	3.0	1.0		1.0	1.0	1.0	1.2	0.031	0.039
30DES07	3.0	3.0		3.0	3.0	1.0	2.4	0.036	0.087
30DES08	2.4	3.0	2.4	3.0	3.8	2.5	2.8	0.034	0.095
30DES09	2.0	1.0	2.0	2.0	1.0	2.0	1.6	0.027	0.043
30DES10	1.0	1.0	2.9	1.1	1.5	1.0	1.3	0.035	0.046
30DES11	2.0	1.0	2.0	2.0	4.0	1.0	1.8	0.033	0.059
30DES12	3.0	1.0	3.0	1.0	1.0	1.0	1.4	0.027	0.039
30DES13	1.7	2.1	1.6	2.0	4.8	1.3	2.0	0.035	0.070
30DES14	3.0	3.0	3.0	1.0	1.0	1.0	1.7	0.022	0.039
30DES15	2.0	2.0	1.0	4.0	4.0	1.0	2.0	0.036	0.072
30DES16	3.2	2.3	2.2	3.8	3.8	1.0	2.5	0.021	0.052
30DES17	1.2	2.1	4.6	4.0	3.3	1.3	2.4	0.052	0.124
30DES18	3.0	3.0	3.0	3.0	3.0	1.0	2.5	0.038	0.095
30DES19	2.0	4.0	4.0	4.0	4.0	1.0	2.8	0.023	0.065
30DES20	1.0	1.0	1.0	2.8	2.8	1.0	1.4	0.060	0.084
30DES21	3.2	3.4	3.0	2.4	2.3	1.0	2.4	0.052	0.123
30DES22	3.0	3.0	3.2	2.5	2.9	1.0	2.4	0.035	0.084
40MPP01	1.3	3.0	1.3	2.1	2.1	1.0	1.7	0.191	0.323
40MPP02	2.0	3.0	2.0	3.0	3.0	1.0	2.2	0.073	0.160
40MPP03	3.0	5.0	3.0	5.0	1.0	1.0	2.5	0.058	0.142
40MPP04	3.0	3.0	3.0	1.0		3.0	2.4	0.044	0.106

Table J.5: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	r_6	M_{ir} (Geomean)	w_i	WMi
40MPP06	4.2	3.8	3.0	3.9		2.0	3.3	0.096	0.312
40MPP09	2.3	4.9	3.0	1.9	1.9	1.0	2.2	0.092	0.203
40MPP11	3.0	3.0	3.0	2.0	2.0	1.0	2.2	0.077	0.167
40MPP12	3.0	3.0	1.0	1.0	1.0	1.0	1.4	0.088	0.127
51APL01	2.0	2.0	1.0	2.0	2.0	1.0	1.6	0.111	0.176
51APL02	3.0	1.0	1.0	3.0	3.0	1.0	1.7	0.050	0.087
51APL03	3.0	4.0	3.0	5.0	5.0	1.0	3.1	0.030	0.094
51APL04	2.0	2.0	5.0	5.0		1.0	2.5	0.036	0.090
51APL06	2.0	2.0	2.0	2.0	5.0	1.0	2.1	0.038	0.078
51APL08	3.0	3.0	3.0	3.0	5.0	3.0	3.3	0.038	0.126
51APL09	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.035	0.104
51APL11	3.0	3.0	3.0	5.0	5.0	1.0	3.0	0.044	0.131
51APL12	2.3	0.7	0.7	2.0	2.8	0.6	1.2	0.039	0.047
51APL13	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.040	0.081
51APL14	2.6	3.0	3.0	2.1	2.1	1.0	2.2	0.044	0.096
51APL15	1.0	1.3	1.4	3.0	3.0	1.0	1.6	0.054	0.086
51APL16	2.5	1.2	2.0	1.7	1.6	2.0	1.8	0.033	0.059
51APL19	3.0	3.0	3.0	1.0	1.0	3.0	2.1	0.042	0.087
51APL20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.049	0.049
51APL21	4.0	3.0	1.0	3.0	1.0	2.0	2.0	0.037	0.075
51APL22	3.0	3.0	3.0	3.0	3.0	1.0	2.5	0.037	0.092
51APL24	3.0	1.0	3.0	3.0	3.0	1.0	2.1	0.026	0.053
52ARM03	5.0	2.0	5.0	3.8	3.8	1.0	3.0	0.526	1.574
52ARM05	1.0	3.0	3.0	1.0	5.0	1.0	1.9	0.177	0.335
52ARM06	1.0	5.0	3.0	5.0	5.0	1.0	2.7	0.150	0.402
61WOR01	3.0	3.0	5.0	2.0	2.0	1.0	2.4	0.220	0.522
61WOR02	1.0	3.0	3.0	1.0	1.0	1.0	1.4	0.106	0.152
61WOR03	3.0	3.0	3.0	1.0	1.0	1.0	1.7	0.106	0.184
61WOR04		1.0	3.0	3.0	3.0	1.0	1.9	0.101	0.196
61WOR05	3.0	5.0	3.0	5.0	5.0	1.0	3.2	0.081	0.261
61WOR07	3.0	5.0	3.0	3.0	3.0	1.0	2.7	0.132	0.360
61WOR08	2.8	2.3	2.0	2.5	2.5	2.0	2.3	0.101	0.236
62WPP23	1.0	3.0	3.0	2.0	2.0	1.0	1.8	1.000	1.817
63WPM01	3.0	2.0	3.0	2.0	2.0	1.0	2.0	0.077	0.158
63WPM02	3.0	2.0	3.0	2.0	2.0	1.0	2.0	0.050	0.102
63WPM03	2.7	1.5	3.0	1.1	1.1	1.0	1.6	0.068	0.106
63WPM04	3.0	1.0	1.0	3.0	3.0	1.0	1.7	0.069	0.119
63WPM05	5.0	3.0	3.0	3.0	3.0	1.0	2.7	0.119	0.324
63WPM06	1.2	1.3	1.5	1.5	1.5	1.0	1.3	0.062	0.082
63WPM08	1.0	2.8	3.0	1.6	1.6	1.0	1.7	0.085	0.141

Table J.5: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	r_4	r_5	r_6	M_{ir} (Geomean)	w_i	WMi
63WPM09	3.0	3.0	3.0	3.3	3.3	1.0	2.6	0.066	0.169
63WPM10	3.0	2.9	2.9	2.2		1.0	2.2	0.043	0.096
63WPM11	1.6	3.2	2.8	2.0	2.4	1.0	2.0	0.107	0.216
63WPM12	1.7	1.3	2.5	1.1	1.1	1.2	1.4	0.079	0.112
70QAC01		3.0	1.0	1.0	1.0	1.0	1.2	0.331	0.412
70QAC02		1.0	1.0	1.0	1.0	1.0	1.0	0.183	0.183
70QAC03		1.0	1.0	3.0	3.0	1.0	1.6	0.125	0.194
70QAC04	2.0	3.0	1.0	1.3	1.3	1.0	1.5	0.106	0.157
70QAC09	1.0	3.0	1.0	3.0	3.0	1.0	1.7	0.115	0.199
81CMC02	1.0	3.0	1.0	1.0	1.0	1.0	1.2	0.354	0.425
81CMC04	4.0	4.0	4.0	4.0	4.0	1.0	3.2	0.529	1.678

Table J.6: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses.

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
13PPT02	2.7		2.5	2.6	0.315	0.813
13PPT06	2.0		4.0	2.8	0.603	1.704
14POS01	1.0		3.0	1.7	0.287	0.496
14POS02	2.0		2.0	2.0	0.061	0.121
14POS03	3.0		4.0	3.5	0.057	0.198
14POS04	1.0		3.0	1.7	0.053	0.091
14POS05	1.5		2.3	1.8	0.168	0.308
14POS06	3.0		3.0	3.0	0.088	0.263
14POS07	2.5		2.9	2.7	0.116	0.310
14POS08	1.7		2.0	1.8	0.072	0.132
14POS09	2.7		1.7	2.1	0.050	0.106
21IFL01	3.4		2.5	2.9	0.096	0.283
21IFL02	3.0		2.4	2.7	0.041	0.111
21IFL06	1.0		1.0	1.0	0.045	0.045
21IFL07	1.9		2.1	2.0	0.050	0.101
21IFL08	2.5		3.0	2.7	0.042	0.115
21IFL09	3.0	1.0	1.0	1.4	0.067	0.096
21IFL10	3.0	3.0	3.0	3.0	0.096	0.289
21IFL11	1.0	4.0	1.0	1.6	0.096	0.153
21IFL12	3.0	3.0	3.0	3.0	0.096	0.289
21IFL13	2.5	2.0	2.3	2.2	0.086	0.193
21IFL14	3.0	5.0	2.0	3.1	0.067	0.208
21IFL15	3.1	2.1	1.3	2.0	0.041	0.084
21IFL16	3.0	4.0	2.0	2.9	0.038	0.110
22IEN01	3.5	4.0	2.7	3.4	0.721	2.431
22IEN02	2.0	4.0	2.0	2.5	0.203	0.511
23ITE06	1.0	3.0	1.0	1.4	1.000	1.442
24IFA01	3.0	3.0	1.0	2.1	0.190	0.395
24IFA02	1.1	1.0	3.2	1.5	0.063	0.096
24IFA03	1.0	1.0	5.0	1.7	0.084	0.143
24IFA04	4.4	2.0	4.6	3.4	0.065	0.223
24IFA05	5.0	5.0	4.0	4.6	0.325	1.508
30DES07	1.0	3.0	3.0	2.1	0.314	0.653
30DES08	3.0	4.0	2.0	2.9	0.046	0.133
30DES09	2.0	3.0	2.0	2.3	0.105	0.240

Table J.6: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
30DES10	1.0	3.1	1.0	1.5	0.042	0.062
30DES13	2.1		1.8	1.9	0.067	0.129
30DES14	3.0	3.0	1.0	2.1	0.052	0.107
30DES16	4.3	2.4	0.9	2.1	0.124	0.259
30DES18	3.0	3.0	1.0	2.1	0.046	0.096
40MPP06	4.0	2.0	2.0	2.5	0.570	1.436
40MPP11	2.0	2.0	3.0	2.3	0.174	0.399
40MPP14	1.0	3.0	3.0	2.1	0.174	0.362
51APL02	2.0	3.0	1.0	1.8	0.139	0.253
51APL06	2.0	2.0	1.0	1.6	0.055	0.087
51APL08	3.0	3.0	3.0	3.0	0.055	0.165
51APL09	3.0	3.0	1.0	2.1	0.055	0.115
51APL10	1.3	3.0	3.0	2.3	0.115	0.262
51APL11	3.0	3.0	1.0	2.1	0.022	0.046
51APL12	4.4	3.0	2.0	3.0	0.073	0.218
51APL13	2.0	2.0	2.0	2.0	0.027	0.054
51APL14	1.7	1.2	1.0	1.3	0.086	0.110
51APL15	1.0	1.0	1.0	1.0	0.065	0.065
51APL16	1.1	2.0	2.0	1.6	0.046	0.075
61WOR01	3.0	2.0	4.0	2.9	0.135	0.389
61WOR02	1.0	3.0	1.0	1.4	0.111	0.160
61WOR03	1.7	1.0	4.0	1.9	0.077	0.145
61WOR05	5.0	3.0	3.0	3.6	0.174	0.618
61WOR06	1.0	1.0	1.0	1.0	0.029	0.029
61WOR07	1.0	3.0	3.0	2.1	0.024	0.049
61WOR08	1.8	2.2	3.5	2.4	0.206	0.496
62WPP01	3.0	5.0	5.0	4.2	0.433	1.828
62WPP03		2.0	2.0	2.0	0.032	0.065
62WPP04		2.0	2.0	2.0	0.032	0.065
62WPP07		2.0	2.0	2.0	0.032	0.065
62WPP08		2.0	2.0	2.0	0.032	0.065
62WPP10		2.0	2.0	2.0	0.032	0.065
62WPP11		2.0	2.0	2.0	0.032	0.065
62WPP12		2.0	2.0	2.0	0.032	0.065
62WPP13		2.0	2.0	2.0	0.032	0.065
62WPP14		2.0	2.0	2.0	0.032	0.065
62WPP16		2.0	2.0	2.0	0.032	0.065
62WPP17		2.0	2.0	2.0	0.032	0.065
62WPP18		2.0	2.0	2.0	0.032	0.065

Table J.6: Shipyard 300 (hypothetical) - Effect magnitudes (M_{ir}) and Weighted Magnitudes (WMi) of Outfitting before Ship Launching (OUT) process, calculated from second phase survey responses (continued).

EFFECT Nr.	r_1	r_2	r_3	M_{ir} (Geomean)	w_i	WMi
62WPP20		3.0		3.0	0.032	0.097
62WPP21		3.0	2.0	2.4	0.032	0.079
62WPP22		2.0	2.0	2.0	0.032	0.065
62WPP23	2.0	2.0	2.0	2.0	0.032	0.065
63WPM01	2.0	1.0	1.0	1.3	0.090	0.114
63WPM02	3.0	2.0	2.0	2.3	0.039	0.089
63WPM03	3.8	3.3	1.0	2.3	0.081	0.187
63WPM04	3.0	3.0	1.0	2.1	0.154	0.321
63WPM05	1.0	3.0	3.0	2.1	0.040	0.083
63WPM06	1.8	1.6	3.0	2.0	0.025	0.052
63WPM07	1.4	1.8	2.6	1.9	0.036	0.067
63WPM08	4.0	3.0	3.0	3.3	0.039	0.128
63WPM09	4.4	3.5	3.9	3.9	0.040	0.156
63WPM10	3.8	3.0	1.1	2.3	0.014	0.034
63WPM11	2.2	2.6	1.0	1.8	0.025	0.046
63WPM12	1.1	1.0	2.1	1.3	0.039	0.051
70QAC01	1.0	3.0	1.0	1.4	0.356	0.513
70QAC03	5.0	3.0	3.0	3.6	0.052	0.186
70QAC05	1.0	1.0	1.0	1.0	0.171	0.171
70QAC06	3.0	3.0	1.0	2.1	0.153	0.318

APPENDIX K. TIME SCHEDULES

Table K.1: Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
14POS03		2	2	1	3	2
21IFL02	3	4	5	6	2	*2*
21IFL05		5	5	5	5	5
21IFL06	2	5	2	5	3	2
21IFL07	2	2	5	5	5	5
21IFL08	5	6	2	6	4	6
21IFL13	5	5	5	3	3	5
21IFL14	3	2		3	3	3
21IFL16	5	5	2	3	2	5
22IEN01		2	2	3	2	2
22IEN02	3	5	2	5	2	5
23ITE01		2		2	3	2
23ITE02		3		1	2	*2*
23ITE03		5	2	2	2	2
23ITE04		2	2	1	2	2
23ITE05		3	2	2	3	3
23ITE06		2	2	1	3	2
30DES17	5	3	2	2	2	2
30DES19	5	3	4	2	2	2
30DES20	5	2	2		3	2
30DES21	3	2	5		3	3
30DES22	5	2	2	2	3	2
40MPP01	5	2	4	2	4	2
40MPP04		2	2	2	3	2
40MPP07		2	2		3	2
40MPP08		4	2	2	2	2
40MPP09	5	4	4	2	3	4
40MPP11	3	5	2		3	3
40MPP12	3	3	3		3	3
40MPP13	3	3	2		2	3
40MPP14	5	2	4		2	2
51APL01		5	4		6	*5*
51APL02	3	5	2		2	2
51APL03		5	4		2	*4*
51APL05		2			4	*2*
51APL06	3	6	4		2	*2*

Table K.1: Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
51APL07	3	6	4		2	*2*
51APL10		5	2	2	2	2
51APL11		2	2	2	2	2
51APL13		3	4	2	2	2
51APL15	3	5	2	6	2	2
51APL16		4	2	2	3	2
51APL17		4		2		*2*
51APL19		5	3	2	5	5
51APL20		6	2	2	2	2
51APL21	3	3	2	2	2	2
51APL22	3	2	2	1	2	2
51APL23		2	2	2	3	2
52ARM01		1	2	2	2	2
52ARM02		2	2	1	2	2
52ARM03		2	2	1	2	2
52ARM05	2	3	2	1	4	2
61WOR01		1	3	2	4	*2*
61WOR05		5	4	2	2	2
61WOR06		2	2	5	3	2
61WOR07		6	2	2	3	2
62WPP02	5	5	4	6	3	5
62WPP03	5	5	4	2	3	5
62WPP04	5	5	4	2	3	5
62WPP05	5	5	4	2	3	5
62WPP06	5	5	2	2	2	2
62WPP07	5	5	2	2	3	5
62WPP08	5	5	5	5	3	5
62WPP09	5	5	5	5	3	5
62WPP10		5	3	5	3	5
62WPP11		5	3	5	3	5
62WPP12		5	3	3	3	3
62WPP13		5	5	5	3	5
62WPP14	5	5	5	5	3	5
62WPP15		5	5	3	3	5
62WPP16		5	5	5	3	5
62WPP17		5	5	5	3	5
62WPP18		5	5	5	3	5
62WPP19		1	1	6	1	1
62WPP20		3		3	1	3

Table K.1: Shipyard 200 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
62WPP21		3		2	2	2
62WPP22		5		2	2	2
62WPP23	3	3	3	5	3	3
63WPM02		4	2	5	2	2
70QAC07		3	3	3	3	3
70QAC08		3	5	3	3	3
70QAC09		3	5	3	3	3
70QAC10		3	5	5	3	3
70QAC11		3	5	5	3	3
81CMC02		2	2	2	2	2
81CMC03		2	2	6	2	2
81CMC04		5	2	3	2	2

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

Table K.2: Shipyard 200 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_i (mode) (*)
21IFL16	2	2	2	2	2
23ITE02	3	2	2		2
23ITE03	3		2		*2*
23ITE04	2	2	2	1	2
23ITE05	2	2	2	1	2
30DES01	5	5	4	5	5
30DES02	5	4	4	6	4
30DES04	4	5	3	1	*1*
30DES05	5	2	4	4	4
30DES07	5	5	3	5	5
30DES10	5	2	3	2	2
30DES11	5	2	4	4	4
30DES12	5	2	4		*2*
30DES13	5	2	4	5	5
30DES14	5	4	3	5	5
30DES15	3	2	5	2	2
30DES16	5	5	3	4	5
30DES17	2	1	6	2	2
30DES18	3	1	3	5	3
30DES19	3	2	3	5	3
30DES20	5	3	6	2	*2*
30DES21	2	2	2	6	2
30DES22	5	5	5	5	5
40MPP01	4	4	4	4	4
40MPP04	2	2	2	1	2
40MPP09	5	2	4	4	4
40MPP11	5	5	6	6	5
40MPP12	3	1	3	6	3
51APL01	2	2	2	6	2
51APL02	5	2	4	4	4
51APL03	2	2	2	4	2
51APL06	2	2	2	2	2
51APL11	2	2	1	2	2
51APL13	5	4	6	2	*2*
51APL15	3	2	3	2	3

Table K.2: Shipyard 200 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_i (mode) (*)
51APL16	4	2	4	5	4
51APL19	5	1	6	4	*1*
51APL20	2	2	3	2	2
51APL21	2	2	3	2	2
51APL22	2	2	3	2	2
52ARM03	5	4	2	4	4
52ARM05	3	4	5	2	*2*
61WOR01	5		5	3	5
61WOR05	2	2	5	4	2
61WOR07	2	1	4	2	2
62WPP23	3	2	5	4	*2*
63WPM02	3	2	4	3	3
70QAC04	5	2	4	4	4
70QAC09	3	1	5	3	3
81CMC02	4	1	4	4	4
81CMC04	4	5	3	4	4

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

Table K.3: Shipyard 200 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir4}	T_i (mode) (*)
13PPT02	5	6	5	5
13PPT06	5	5	4	5
14POS01	5	2	5	5
14POS02	3	4	4	4
14POS03	3	4	1	*1*
14POS04	5	3	3	3
14POS05	3	3	5	3
14POS06	3	2	5	*2*
14POS07	3	4	4	4
14POS08	5	6	5	5
14POS09	3	3	2	3
21IFL02	4	3	5	*5*
21IFL06	3	3	5	3
21IFL07	5	2	2	2
21IFL08	5	2	2	2
21IFL13	5		2	*2*
21IFL14	3		1	*1*
21IFL16			2	2
22IEN01	2	2	2	2
22IEN02	2	3	5	*2*
23ITE06	4	4	1	4
30DES07	2	2	5	2
30DES10	2	2	5	2
30DES13	5	2	5	5
30DES14	3	3	2	3
30DES16	3	3	2	3
30DES18	3	3	2	3
40MPP11	3	3	5	3
40MPP14	3	3	2	3
51APL02	3	3	6	3
51APL06	3	3	2	3
51APL10	3	3	5	3
51APL11	3	3	1	3
51APL13	5	5	2	5
51APL15	2	2	2	2
51APL16	2	2	2	2

Table K.3: Shipyard 200 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir4}	T_i (mode) (*)
61WOR01	3	3	1	3
61WOR05	3	3	1	3
61WOR06	3	3	2	3
61WOR07	3	3	1	3
62WPP03	4	4	2	4
62WPP04	3	3	2	3
62WPP07	5	3	2	*2*
62WPP08	5	3	2	*2*
62WPP10	5	4	2	*2*
62WPP11	3	3		3
62WPP12	3	3	2	3
62WPP13	5	3	2	*2*
62WPP14	3	3	2	3
62WPP16	5	3	2	*2*
62WPP17	3	6	2	*2*
62WPP18	3	3	2	3
62WPP20	5	3		*3*
62WPP21	3	2	2	2
62WPP22	5	2	2	2
62WPP23	3	3	1	3
63WPM02	6	6	1	6
70QAC05	4	4	5	4

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

Table K.4: Shipyard 300 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
14POS03	3	5	1	5	3	3
21IFL02	5		4	4	4	4
21IFL05	3	2	2	5	4	2
21IFL06		5	5	5	3	5
21IFL07	5	5	5	5	3	5
21IFL08	5	4	2	5	2	5
21IFL13	5	5	3	5	3	5
21IFL14				2	3	*2*
21IFL16	2	2	2	2	2	2
22IEN01	2	2	3	2	3	2
22IEN02		5	2	2	2	2
23ITE01	2	2	3	2	3	2
23ITE02	2	2	3	4	3	2
23ITE03	2	2	3	4	3	2
23ITE04	2	2	3	4	3	2
23ITE05	2	2	2	4	2	2
23ITE06	2	2	5	4	2	2
30DES17	2	5	2	5	4	2
30DES19	3	5	3	6	4	3
30DES20	5	5	4	6	3	5
30DES21	1	5	3	4	3	3
30DES22	2	5	2	5	3	2
40MPP01	2	5	5	4	3	5
40MPP04	3	5	2	2	3	3
40MPP07	3	5	2			*2*
40MPP08	2	5	4	3	4	4
40MPP09	4	5	2	5	3	5
40MPP11	3	5	4	5	3	3
40MPP12	3	5	3	3	5	3
40MPP13	2	5	2	5	2	2
40MPP14	5	5	2	3	3	5
51APL01	2	5	4	4	4	4
51APL02	3	5	5	5	3	5
51APL03	2	2	2	5	2	2
51APL05	2		1	4	3	*2*
51APL06	2	2	2	5	3	2

Table K.4: Shipyard 300 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
51APL07	2	2	2	5	4	2
51APL10	5	5	2	4	3	5
51APL11		2	3	5	2	2
51APL13	5	5	4	3	4	5
51APL15	2	2	2	5	3	2
51APL16	5	2	4	5	4	5
51APL17	4	1	5	5	1	1
51APL19	4	1	2	5	4	4
51APL20	2	2	2	2	3	2
51APL21	2	2	5	5	3	2
51APL22	5	2	2	5	2	2
51APL23	5	1	2	5	3	5
52ARM01			4	1	4	4
52ARM02	5	2	2	2	2	2
52ARM03	2	2	5	2	3	2
52ARM05	4	2	5	5	3	5
61WOR01	5	2	2	4	3	2
61WOR05	6	5	2	4	4	4
61WOR06	3	2	3	3	2	3
61WOR07	3	2	2	3	2	2
62WPP02	4			5	4	4
62WPP03	5	5		3	4	5
62WPP04	4	5		3	3	3
62WPP05	4	5		3	5	5
62WPP06	4	5		4	4	4
62WPP07		5		3	3	3
62WPP08		5		3	5	5
62WPP09		5		3	4	*5*
62WPP10		1		3	4	*1*
62WPP11		5		3	2	*2*
62WPP12		5		3	2	*2*
62WPP13		5		3	2	*2*
62WPP14		5		3	3	3
62WPP15		1		3	3	3
62WPP16		5		3	3	3
62WPP17		5		3	3	3
62WPP18		5		3	3	3
62WPP19		1		1	1	1
62WPP20		1		5	5	5

Table K.4: Shipyard 300 (hypothetical) – Time Distribution Types of Shipbuilding Management (MNG) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_i (mode) (*)
62WPP21		3		3	2	3
62WPP22		4		4	2	4
62WPP23		4	5	2	2	2
63WPM02		2	3		2	2
70QAC07	3	5	3	3	3	3
70QAC08	5	5	3	3	2	5
70QAC09	2	5	1	3	5	5
70QAC10	2	3	3	3	5	3
70QAC11	4	3	2	3	3	3
81CMC02	4	4	2	3	2	4
81CMC03	4	4	5	3	2	4
81CMC04	3	4	5	3	2	3

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

Table K.5: Shipyard 300 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_{ir6}	T_i (mode) (*)
21IFL16	2	2	3	2	1	2	2
23ITE02	2	2	5	2	2	2	2
23ITE03	2	2	5	2	2	2	2
23ITE04	5	2		3	3	2	2
23ITE05	4	2	5	1	1	2	2
30DES01	5	5	5	5	4	5	5
30DES02	5	4	5	5	4	5	5
30DES04	2	2	4	2	5	3	2
30DES05	5	2		4	5	4	5
30DES07	5	5	5	5	5	3	5
30DES10	5	2	5	2	2	3	2
30DES11	5	2	4	1	1	1	1
30DES12	5	2	4	2	2	5	2
30DES13	5	2	5	5	5	3	5
30DES14	5	2	5	2	2	3	2
30DES15	5	5	5	2	2	3	5
30DES16	4	2		1	1	3	1
30DES17	5	5	5	2	2	2	5
30DES18	5	5	5	3	3	3	5
30DES19	4	5	3	5	4	3	4
30DES20	5	5	3	4	4	3	5
30DES21	5	2	5	2	2	3	2
30DES22	5	5	5	2	2	2	5
40MPP01	5	2	3	4	4	3	3
40MPP04	4	2	5	4	3	2	4
40MPP09	5	3	3	5	5	5	5
40MPP11	3	5	3	5		3	3
40MPP12	3	3	3	3	3	3	3
51APL01	4	2	4	4	4	2	4
51APL02	4	4	4	4	4	3	4
51APL03	2	2	5	1	2	2	2
51APL06	2	2	5	2	2	2	2
51APL11	2	2	5	2	2	2	2
51APL13	5	5	5	2	3	3	5
51APL15	2	5	3	2	2	2	2
51APL16	4	4	5	1	1	2	4

Table K.5: Shipyard 300 (hypothetical) – Time Distribution Types of Ship Design (DES) process, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir3}	T_{ir4}	T_{ir5}	T_{ir6}	T_i (mode) (*)
51APL19	5	5	5	3	2	1	5
51APL20	2	5	5	2	2	2	2
51APL21	3	2	5	2	2	2	2
51APL22	2	2	5	5	5	2	2
52ARM03	5	1	5	4	4	4	4
52ARM05	5	4	5	5	4	2	5
61WOR01	4	2	5	1	2	2	2
61WOR05	2	2	5	1	1	2	2
61WOR07	4	2	5	4	4	2	4
62WPP23	3	3	5	6	6	3	3
63WPM02	5	2	5	3	3	2	5
70QAC04	5	2	5	2	2	4	2
70QAC09	3	3	3	1	1	5	3
81CMC02	4	1	3	2	2	2	2
81CMC04	4	1	5	4	4	2	4

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

Table K.6: Shipyard 300 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses.

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir4}	T_i (mode) (*)
13PPT02	5	5	5	5
13PPT06	5	5	2	5
14POS01	3	4	5	*5*
14POS02	5	4	5	5
14POS03	5	5	2	5
14POS04	5	4	5	5
14POS05	5	2	5	5
14POS06	3	2	5	*2*
14POS07	3	5	5	5
14POS08	5	2	2	2
14POS09	3	2	3	3
21IFL02	3	2	2	2
21IFL06	5	2	5	5
21IFL07	5	2	5	5
21IFL08	3	2	2	2
21IFL13	3	5	5	5
21IFL14	3	5	3	3
21IFL16		2	2	2
22IEN01	2	2	3	2
22IEN02	2	2	3	2
23ITE06	2	1	3	*2*
30DES07	5	2	5	5
30DES10	5	2	5	5
30DES13	5	2	5	5
30DES14	5	5	5	5
30DES16	3	2	3	3
30DES18	3	2	3	3
40MPP11	5	2	5	5
40MPP14	3	2	5	*2*
51APL02	5	2	5	5
51APL06	5	2	2	2
51APL10	5	5	5	5
51APL11	5	2	3	*2*
51APL13	5	5	5	5
51APL15	2	2	2	2
51APL16	2	2	4	2

Table K.6: Shipyard 300 (hypothetical) – Time Distribution Types of Outfitting before Ship Launching (OUT) subprocess, calculated from second phase survey responses (continued).

EFFECT Nr.	T_{ir1}	T_{ir2}	T_{ir4}	T_i (mode) (*)
61WOR01	2	5	2	2
61WOR05	2	2	5	2
61WOR06	2	2	3	2
61WOR07	2	2	2	2
62WPP03		5	5	5
62WPP04		5	5	5
62WPP07		5	5	5
62WPP08		5	5	5
62WPP10		5	2	*2*
62WPP11		3	5	*3*
62WPP12		5	5	5
62WPP13		5	2	*2*
62WPP14		5	5	5
62WPP16		5	5	5
62WPP17		5	2	*2*
62WPP18		5	2	*2*
62WPP20		5		*5*
62WPP21		5	2	*2*
62WPP22		5	2	*2*
62WPP23	5	5	5	5
63WPM02	5	2	3	*2*
70QAC05	5	2	5	5

(*) Where Mode is not applicable, most appropriate time distribution type to the choices was applied by the student.

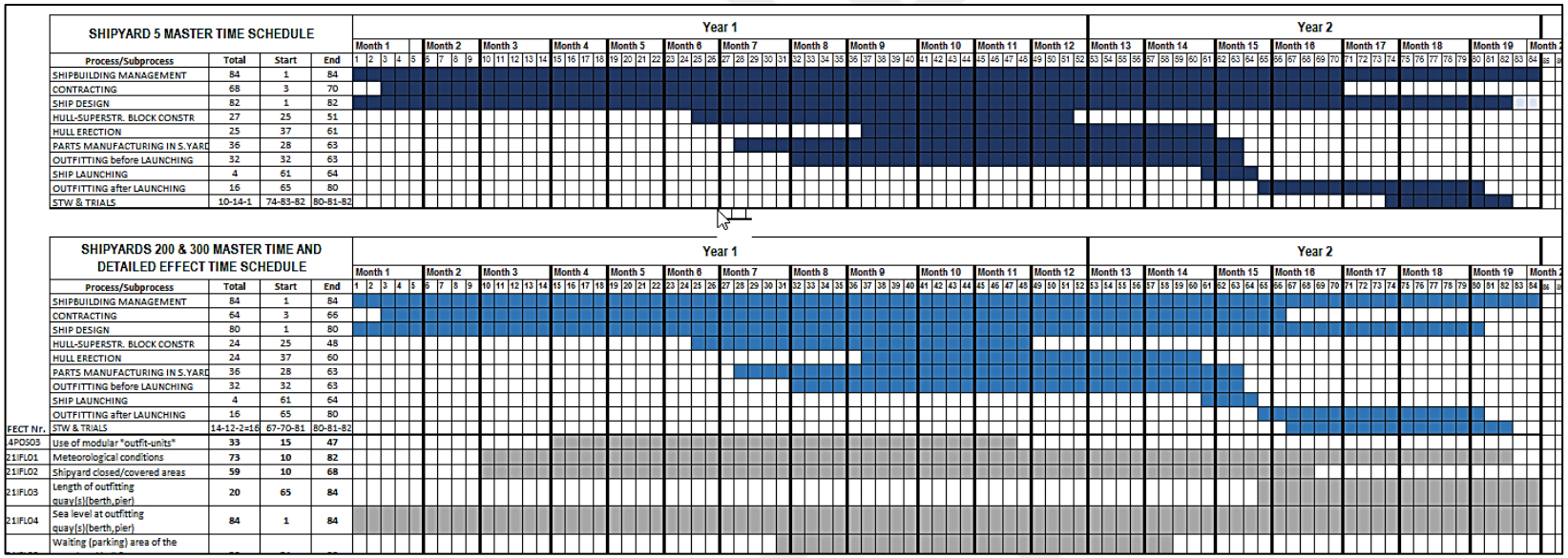


Figure K.1: Shipyard 5 and Shipyards 200 & 300 Master Time Schedules.

Table K.7: Shipyards 200 and 300 (hypothetical) – Master Time Schedule.

Process/Subprocess	**Start week**	**Finish week**	**Total (weeks)**
Entire process	1	84	84
Shipbuilding Management	1	84	84
Ship Design	1	80	80
Ship Production	3	82	80
Contracting	3	66	64
Hull & Superstructure Blocks Construction	25	48	24
Hull Erection	37	60	24
Parts Manufacturing in Shipyard	28	63	36
Outfitting before Ship Launching	32	63	32
Ship Launching	61	64	4
Outfitting after Ship Launching	65	80	16
Set.-to-Work, Harbor and Sea Trials	67-70-81	80-81-82	14-12-2

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule.

Process/Subprocess	EFFECT Nr.	Start week	Finish week
MNG	14POS03	15	47
MNG	21IFL01	10	82
MNG	21IFL02	10	68
MNG	21IFL03	65	84
MNG	21IFL04	1	84
MNG	21IFL05	31	58
MNG	21IFL06	10	83
MNG	21IFL07	10	82
MNG	21IFL08	22	80
MNG	21IFL09	25	80
MNG	21IFL10	10	82
MNG	21IFL11	1	84
MNG	21IFL12	10	82
MNG	21IFL13	10	82
MNG	21IFL14	49	80
MNG	21IFL15	25	82
MNG	21IFL16	1	84
MNG	22IEN01	8	84
MNG	22IEN02	10	84
MNG	23ITE01	1	84
MNG	23ITE02	1	84
MNG	23ITE03	1	84
MNG	23ITE04	1	48
MNG	23ITE05	12	48
MNG	23ITE06	12	72
MNG	24IFA01	1	84
MNG	24IFA02	1	84
MNG	24IFA03	1	84
MNG	24IFA04	1	84
MNG	24IFA05	1	84
MNG	30DES17	6	70
MNG	30DES19	2	9
MNG	30DES20	1	84
MNG	30DES21	1	84
MNG	30DES22	29	84
MNG	40MPP01	2	21
MNG	40MPP03	1	84

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
MNG	40MPP04	2	21
MNG	40MPP05	1	84
MNG	40MPP06	10	69
MNG	40MPP07	10	69
MNG	40MPP08	25	70
MNG	40MPP09	15	63
MNG	40MPP10	10	84
MNG	40MPP11	6	84
MNG	40MPP12	5	84
MNG	40MPP13	14	67
MNG	40MPP14	16	79
MNG	51APL01	2	83
MNG	51APL02	6	81
MNG	51APL03	2	83
MNG	51APL04	2	18
MNG	51APL05	2	20
MNG	51APL06	2	83
MNG	51APL07	10	80
MNG	51APL08	2	82
MNG	51APL09	6	81
MNG	51APL10	10	84
MNG	51APL11	2	84
MNG	51APL12	1	84
MNG	51APL13	25	79
MNG	51APL14	25	82
MNG	51APL15	3	84
MNG	51APL16	3	84
MNG	51APL17	28	63
MNG	51APL18	32	84
MNG	51APL19	11	78
MNG	51APL20	2	84
MNG	51APL21	3	84
MNG	51APL22	4	84
MNG	51APL23	2	55
MNG	51APL24	3	82
MNG	52ARM01	1	10
MNG	52ARM02	2	84
MNG	52ARM03	3	84
MNG	52ARM04	1	84
MNG	52ARM05	10	84

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
MNG	52ARM06	4	84
MNG	61WOR01	1	84
MNG	61WOR02	1	82
MNG	61WOR03	1	84
MNG	61WOR04	5	31
MNG	61WOR05	11	82
MNG	61WOR06	37	82
MNG	61WOR07	5	84
MNG	61WOR08	6	81
MNG	62WPP01	25	82
MNG	62WPP02	25	44
MNG	62WPP03	32	59
MNG	62WPP04	31	82
MNG	62WPP05	32	48
MNG	62WPP06	29	63
MNG	62WPP07	32	82
MNG	62WPP08	32	80
MNG	62WPP09	78	80
MNG	62WPP10	39	82
MNG	62WPP11	34	82
MNG	62WPP12	53	82
MNG	62WPP13	41	68
MNG	62WPP14	49	69
MNG	62WPP15	67	82
MNG	62WPP16	28	62
MNG	62WPP17	41	67
MNG	62WPP18	47	82
MNG	62WPP19	61	64
MNG	62WPP20	37	82
MNG	62WPP21	32	82
MNG	62WPP22	32	80
MNG	62WPP23	15	84
MNG	63WPM01	2	80
MNG	63WPM02	32	82
MNG	63WPM03	1	84
MNG	63WPM04	1	84
MNG	63WPM05	1	84
MNG	63WPM06	1	84
MNG	63WPM07	1	84
MNG	63WPM08	1	84
MNG	63WPM09	1	84

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
MNG	63WPM10	1	84
MNG	63WPM11	1	84
MNG	63WPM12	1	84
MNG	70QAC01	1	84
MNG	70QAC02	1	84
MNG	70QAC03	1	84
MNG	70QAC06	25	82
MNG	70QAC07	53	84
MNG	70QAC08	62	81
MNG	70QAC09	53	80
MNG	70QAC10	71	81
MNG	70QAC11	68	82
MNG	81CMC03	2	9
MNG	81CMC04	5	9
CON	30DES19	3	9
CON	40MPP01	7	31
CON	40MPP04	7	31
CON	51APL01	3	66
CON	52ARM01	3	10
CON	52ARM02	3	66
CON	52ARM03	4	66
CON	52ARM05	10	66
CON	81CMC01	3	4
CON	81CMC02	2	5
CON	81CMC02	3	5
CON	81CMC03	3	9
CON	81CMC04	5	9
CON	81CMC05	3	11
CON	82CSC01	5	24
CON	82CSC02	5	31
BLK	11PSB02	25	30
BLK	11PSB03	26	30
BLK	11PSB04	26	34
BLK	11PSB05	27	35
BLK	11PSB06	27	42
BLK	11PSB07	27	42
BLK	11PSB08	25	45
BLK	11PSB09	34	48
BLK	11PSB10	33	48
BLK	13PPT01	27	45
BLK	13PPT06	25	47

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
BLK	14POS01	31	46
BLK	14POS02	29	48
BLK	14POS05	29	48
BLK	21IFL01	25	48
BLK	21IFL02	25	48
BLK	21IFL05	31	48
BLK	21IFL06	25	47
BLK	21IFL07	25	48
BLK	21IFL08	25	48
BLK	21IFL09	25	48
BLK	21IFL10	25	48
BLK	21IFL11	25	48
BLK	21IFL12	25	48
BLK	21IFL13	25	48
BLK	21IFL15	25	48
BLK	21IFL16	25	48
BLK	22IEN01	25	48
BLK	22IEN02	25	48
BLK	23ITE06	25	30
BLK	24IFA01	25	48
BLK	24IFA02	25	48
BLK	24IFA03	25	48
BLK	24IFA04	25	48
BLK	24IFA05	25	48
BLK	30DES07	25	42
BLK	30DES08	25	48
BLK	30DES09	25	48
BLK	30DES10	25	42
BLK	30DES11	25	48
BLK	30DES12	25	48
BLK	30DES13	25	48
BLK	30DES16	25	48
BLK	40MPP06	25	48
BLK	40MPP14	25	48
BLK	51APL02	25	47
BLK	51APL06	25	48
BLK	51APL08	25	48
BLK	51APL09	25	48
BLK	51APL10	25	48
BLK	51APL11	25	48
BLK	51APL12	25	48

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
BLK	51APL13	25	48
BLK	51APL14	25	48
BLK	51APL15	25	48
BLK	51APL16	28	48
BLK	51APL17	28	48
BLK	51APL19	31	46
BLK	61WOR01	25	48
BLK	61WOR02	25	48
BLK	61WOR03	25	48
BLK	61WOR05	27	48
BLK	61WOR06	37	48
BLK	61WOR07	25	48
BLK	61WOR08	25	48
BLK	62WPP02	25	44
BLK	62WPP04	31	48
BLK	62WPP05	32	48
BLK	62WPP07	32	48
BLK	62WPP08	32	43
BLK	63WPM01	25	48
BLK	63WPM02	29	48
BLK	63WPM03	25	48
BLK	63WPM04	25	48
BLK	63WPM05	25	48
BLK	63WPM06	25	48
BLK	63WPM07	25	48
BLK	63WPM08	25	48
BLK	63WPM09	25	48
BLK	63WPM10	25	48
BLK	63WPM11	25	48
BLK	63WPM12	25	48
BLK	70QAC01	25	48
BLK	70QAC03	25	48
BLK	70QAC04	26	48
BLK	70QAC05	28	48
BLK	70QAC06	25	48
ASLY	12PSE01	37	59
ASLY	13PPT01	37	59
ASLY	13PPT06	38	60
ASLY	14POS06	37	60
ASLY	14POS09	37	60
ASLY	21IFL02	37	60

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
ASLY	21IFL05	37	58
ASLY	21IFL06	37	59
ASLY	21IFL07	37	60
ASLY	21IFL08	37	60
ASLY	21IFL13	37	60
ASLY	21IFL14	49	60
ASLY	21IFL16	37	60
ASLY	22IEN01	37	60
ASLY	22IEN02	37	60
ASLY	23ITE06	37	42
ASLY	30DES07	37	54
ASLY	30DES10	37	54
ASLY	30DES13	37	60
ASLY	30DES16	37	60
ASLY	40MPP14	37	60
ASLY	51APL02	37	59
ASLY	51APL06	37	60
ASLY	51APL10	37	60
ASLY	51APL11	37	60
ASLY	51APL13	37	60
ASLY	51APL15	37	60
ASLY	51APL16	40	60
ASLY	61WOR01	37	60
ASLY	61WOR05	39	60
ASLY	61WOR06	55	63
ASLY	61WOR07	37	60
ASLY	62WPP03	37	59
ASLY	62WPP10	39	54
ASLY	62WPP22	37	60
ASLY	63WPM02	41	60
ASLY	70QAC04	37	58
ASLY	70QAC05	38	60
PPT	13PPT01	32	60
PPT	13PPT02	28	60
PPT	13PPT03	30	55
PPT	13PPT04	28	63
PPT	13PPT05	30	63
PPT	13PPT06	28	63
PPT	14POS01	30	63
PPT	21IFL02	28	63
PPT	21IFL06	28	62

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
PPT	21IFL07	28	63
PPT	21IFL08	28	63
PPT	21IFL13	28	63
PPT	21IFL16	28	63
PPT	22IEN01	28	63
PPT	22IEN02	28	63
PPT	23ITE06	28	35
PPT	30DES07	28	59
PPT	30DES10	28	59
PPT	30DES11	28	63
PPT	30DES12	28	63
PPT	30DES13	28	63
PPT	40MPP14	28	63
PPT	51APL02	28	62
PPT	51APL06	28	63
PPT	51APL10	28	63
PPT	51APL11	28	63
PPT	51APL13	28	63
PPT	51APL15	28	63
PPT	51APL16	31	63
PPT	51APL17	31	63
PPT	61WOR01	28	63
PPT	61WOR05	30	63
PPT	61WOR07	28	63
PPT	62WPP06	29	63
PPT	62WPP16	28	62
PPT	63WPM02	32	63
PPT	70QAC05	29	63
OUT	13PPT02	32	60
OUT	13PPT06	34	63
OUT	14POS01	32	63
OUT	14POS02	32	47
OUT	14POS03	32	47
OUT	14POS04	41	62
OUT	14POS05	32	63
OUT	14POS06	33	63
OUT	14POS07	32	63
OUT	14POS08	32	63
OUT	14POS09	32	63
OUT	21IFL01	32	63
OUT	21IFL02	32	63

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
OUT	21IFL06	32	62
OUT	21IFL07	32	63
OUT	21IFL08	32	63
OUT	21IFL09	32	63
OUT	21IFL10	32	63
OUT	21IFL11	32	63
OUT	21IFL12	32	63
OUT	21IFL13	32	63
OUT	21IFL14	49	62
OUT	21IFL15	32	63
OUT	21IFL16	32	63
OUT	22IEN01	32	63
OUT	22IEN02	32	63
OUT	23ITE06	32	39
OUT	24IFA01	32	63
OUT	24IFA02	32	63
OUT	24IFA03	32	63
OUT	24IFA04	32	63
OUT	24IFA05	32	63
OUT	30DES07	32	60
OUT	30DES08	32	63
OUT	30DES09	32	63
OUT	30DES10	32	60
OUT	30DES13	32	63
OUT	30DES14	32	63
OUT	30DES16	32	63
OUT	30DES18	34	63
OUT	40MPP06	32	63
OUT	40MPP11	34	63
OUT	40MPP14	32	60
OUT	51APL02	32	62
OUT	51APL06	32	63
OUT	51APL08	32	63
OUT	51APL09	32	63
OUT	51APL10	32	63
OUT	51APL11	32	63
OUT	51APL12	32	63
OUT	51APL13	32	63
OUT	51APL14	32	63
OUT	51APL15	32	63
OUT	51APL16	35	63

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
OUT	61WOR01	32	63
OUT	61WOR02	32	63
OUT	61WOR03	32	63
OUT	61WOR05	34	63
OUT	61WOR06	60	63
OUT	61WOR07	32	63
OUT	61WOR08	32	63
OUT	62WPP01	32	63
OUT	62WPP03	32	59
OUT	62WPP04	34	63
OUT	62WPP07	39	63
OUT	62WPP08	43	63
OUT	62WPP10	45	63
OUT	62WPP11	34	63
OUT	62WPP12	53	63
OUT	62WPP13	41	63
OUT	62WPP14	49	63
OUT	62WPP16	32	63
OUT	62WPP17	41	63
OUT	62WPP18	47	63
OUT	62WPP20	37	63
OUT	62WPP21	32	63
OUT	62WPP22	32	63
OUT	62WPP23	32	63
OUT	63WPM01	32	63
OUT	63WPM02	36	63
OUT	63WPM03	32	63
OUT	63WPM04	32	63
OUT	63WPM05	32	63
OUT	63WPM06	32	63
OUT	63WPM07	32	63
OUT	63WPM08	32	63
OUT	63WPM09	32	63
OUT	63WPM10	32	63
OUT	63WPM11	32	63
OUT	63WPM12	32	63
OUT	70QAC01	32	63
OUT	70QAC03	32	63
OUT	70QAC05	34	63
OUT	70QAC06	32	63
LCH	14POS08	61	64

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
LCH	21IFL02	61	64
LCH	21IFL06	61	63
LCH	21IFL07	61	64
LCH	21IFL08	61	64
LCH	21IFL13	61	64
LCH	21IFL14	61	62
LCH	21IFL16	61	64
LCH	22IEN02	67	64
LCH	23ITE06	61	63
LCH	30DES07	61	62
LCH	40MPP14	61	64
LCH	51APL02	61	63
LCH	51APL06	61	64
LCH	51APL10	61	64
LCH	51APL11	61	64
LCH	51APL15	61	64
LCH	51APL16	62	64
LCH	61WOR01	61	64
LCH	61WOR05	62	64
LCH	62WPP19	61	64
LCH	62WPP21	61	64
LCH	62WPP22	61	64
LCH	63WPM02	62	64
QAY	14POS05	65	80
QAY	14POS08	65	80
QAY	14POS09	65	80
QAY	16POQ01	65	66
QAY	16POQ02	65	80
QAY	21IFL02	65	68
QAY	21IFL03	65	80
QAY	21IFL04	65	80
QAY	21IFL06	65	79
QAY	21IFL07	65	80
QAY	21IFL08	65	80
QAY	21IFL13	65	80
QAY	21IFL14	69	80
QAY	21IFL16	65	80
QAY	22IEN02	65	80
QAY	23ITE06	65	72
QAY	30DES07	65	76
QAY	30DES10	65	76

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
QAY	30DES14	65	80
QAY	30DES16	65	80
QAY	30DES18	65	80
QAY	40MPP11	65	80
QAY	40MPP14	65	80
QAY	51APL02	65	79
QAY	51APL06	65	80
QAY	51APL10	65	80
QAY	51APL11	65	80
QAY	51APL13	65	79
QAY	51APL15	65	80
QAY	51APL16	68	80
QAY	61WOR01	65	80
QAY	61WOR05	67	80
QAY	61WOR06	79	80
QAY	61WOR07	65	80
QAY	62WPP04	66	80
QAY	62WPP07	65	80
QAY	62WPP08	65	80
QAY	62WPP09	78	80
QAY	62WPP10	65	80
QAY	62WPP11	65	80
QAY	62WPP12	69	80
QAY	62WPP13	65	68
QAY	62WPP14	65	69
QAY	62WPP15	67	80
QAY	62WPP17	65	67
QAY	62WPP18	66	80
QAY	62WPP20	65	70
QAY	62WPP21	65	80
QAY	62WPP22	65	80
QAY	62WPP23	65	80
QAY	63WPM02	69	80
TEST	14POS09	67	82
TEST	21IFL08	67	82
TEST	21IFL13	67	82
TEST	21IFL16	67	82
TEST	30DES18	67	82
TEST	30DES19	67	80
TEST	51APL02	67	81
TEST	51APL06	67	82

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
TEST	51APL10	67	82
TEST	51APL11	67	82
TEST	51APL15	67	82
TEST	51APL16	68	82
TEST	61WOR01	67	82
TEST	61WOR05	68	82
TEST	61WOR06	80	82
TEST	61WOR07	67	82
TEST	62WPP04	67	82
TEST	62WPP07	67	82
TEST	62WPP10	67	82
TEST	62WPP11	67	82
TEST	62WPP12	67	82
TEST	62WPP15	67	82
TEST	62WPP18	67	82
TEST	62WPP20	71	82
TEST	62WPP21	67	82
TEST	62WPP23	67	82
TEST	63WPM02	71	82
TEST	70QAC07	67	82
TEST	70QAC08	67	82
TEST	70QAC09	67	79
TEST	70QAC10	71	81
TEST	70QAC11	70	82
DES	21IFL16	1	80
DES	23ITE02	1	80
DES	23ITE03	1	80
DES	23ITE04	1	48
DES	23ITE05	1	52
DES	24IFA01	1	80
DES	24IFA02	1	80
DES	24IFA03	1	80
DES	24IFA04	1	80
DES	24IFA05	1	80
DES	30DES01	1	80
DES	30DES02	1	52
DES	30DES04	1	14
DES	30DES05	6	39
DES	30DES03	1	60
DES	30DES06	6	44
DES	30DES07	12	79

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
DES	30DES08	6	80
DES	30DES09	12	80
DES	30DES10	16	79
DES	30DES11	10	62
DES	30DES12	10	70
DES	30DES13	19	70
DES	30DES14	23	80
DES	30DES15	10	55
DES	30DES16	18	80
DES	30DES17	6	70
DES	30DES18	6	80
DES	30DES19	2	20
DES	30DES20	1	80
DES	30DES21	1	80
DES	30DES22	1	80
DES	40MPP01	2	31
DES	40MPP02	6	69
DES	40MPP02	6	22
DES	40MPP03	1	80
DES	40MPP04	2	31
DES	40MPP06	10	69
DES	40MPP09	15	63
DES	40MPP11	6	80
DES	40MPP12	5	80
DES	51APL01	2	79
DES	51APL02	2	79
DES	51APL03	2	79
DES	51APL04	2	18
DES	51APL06	2	80
DES	51APL08	2	80
DES	51APL09	2	79
DES	51APL11	2	80
DES	51APL12	1	80
DES	51APL13	15	79
DES	51APL14	25	80
DES	51APL15	3	80
DES	51APL16	3	80
DES	51APL19	10	64
DES	51APL20	2	80
DES	51APL21	3	80
DES	51APL22	4	80

Table K.8: Shipyards 200 and 300 (hypothetical) – Effects' detailed time schedule (continued).

Process/Subprocess	EFFECT Nr.	Start week	Finish week
DES	51APL24	3	79
DES	52ARM03	3	80
DES	52ARM05	10	80
DES	52ARM06	4	80
DES	61WOR01	2	80
DES	61WOR02	1	80
DES	61WOR03	1	80
DES	61WOR04	6	22
DES	61WOR05	11	64
DES	61WOR07	5	64
DES	61WOR08	2	79
DES	62WPP23	2	80
DES	63WPM01	1	80
DES	63WPM02	15	78
DES	63WPM03	1	80
DES	63WPM04	1	80
DES	63WPM05	1	80
DES	63WPM06	1	80
DES	63WPM08	1	80
DES	63WPM09	1	80
DES	63WPM10	1	80
DES	63WPM11	1	80
DES	63WPM12	1	80
DES	70QAC01	1	80
DES	70QAC02	1	80
DES	70QAC03	1	80
DES	70QAC04	10	60
DES	70QAC09	53	80
DES	81CMC02	2	5
DES	81CMC04	5	9

APPENDIX L. SECTOR WEIGHTS

Use below data with caution since sample size is very low.

"0.001" values of the Confidence Interval are minus values in reality, but weight can not be negative, so revised as 0.001 here.

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data.

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
11PSB00	**PRODUCTION : HULL BLOCKS (PSB)**	4	0.141	**0.121**	0.001 - 0.366
11PSB01	Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard	3	0.141	**0.190**	0.001 - 0.489
11PSB02	Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard	4	0.086	**0.115**	0.001 - 0.301
11PSB03	The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing	4	0.053	**0.071**	0.001 - 0.195
11PSB04	The use of CNC profile processing machine in the hull & superstructure blocks manufacturing	4	0.053	**0.071**	0.001 - 0.195
11PSB05	The use of roll/press/bender for sheet metal and profile bending processes	4	0.118	**0.159**	0.001 - 0.486
11PSB06	The use of welding robots in the hull & superstructure semi-block assembly stages	4	0.060	**0.081**	0.001 - 0.166
11PSB07	Categorization of block panel/assembly lines according to their difficulties	4	0.046	**0.062**	0.001 - 0.156
11PSB08	Use of jigs in the hull & superstructure blocks production	4	0.043	**0.057**	0.001 - 0.154
11PSB09	Block Blasting-Painting	4	0.065	**0.088**	0.001 - 0.175
11PSB10	Completion of outfitted or non-outfitted hull & superstructure blocks	4	0.079	**0.106**	0.001 - 0.302
12PSE00	**PRODUCTION : HULL ERECTION (PSE)**	7	0.111	**0.095**	0.001 - 0.218
12PSE01	Hull & Superstructure blocks erection	4	1.000 (*)	**1.000 (*)**	---
13PPT00	**PRODUCTION : PARTS MANUFACTURING (PPT)**	21	0.098	**0.078**	0.001 - 0.158
13PPT01	Metal joining techniques	12	0.542	**0.405**	0.283 - 0.526
13PPT02	Manufacturing and installation of piping systems in the ship	11	0.343	**0.198**	0.001 - 0.399
13PPT03	Cast parts and their machining	3	0.074	**0.054**	0.032 - 0.074
13PPT04	Use of high-tech materials	3	0.103	**0.084**	0.001 - 0.274
13PPT05	Production of parts and molds from 3D Printers	4	0.101	**0.076**	0.042 - 0.109
13PPT06	Manufacturing and installation automation, use of robots	22	0.245	**0.183**	0.078 - 0.288
14POS00	**PRODUCTION : OUTFITTING before Launching (POS)**	31	0.077	**0.040**	0.032 - 0.046
14POS01	Manufacturing and assembly of the outfit infrastructure elements	16	0.494	**0.455**	0.308 - 0.602
14POS02	Equipment to be taken into the block before the hull erection	14	0.065	**0.065**	0.046 - 0.083
14POS03	Use of modular "outfit-units"	8	0.328	**0.069**	0.061 - 0.075
14POS04	Outfitting after hull assembly	9	0.054	**0.055**	0.039 - 0.069
14POS05	Paint manufacturer	15	0.117	**0.087**	0.052 - 0.120
14POS06	External hull works, outfitting and painting	10	0.142	**0.068**	0.054 - 0.081

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data (continued).

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
14POS07	Embarkation of the equipment on board	14	0.086	**0.087**	0.048 - 0.125
14POS08	Protection of the ship and equipment on board	8	0.195	**0.061**	0.051 - 0.070
14POS09	Provision of adequate capacity of compressed air, electricity, water, steam	14	0.119	**0.053**	0.037 - 0.069
15PLA00	**PRODUCTION : LAUNCHING (PLA)**	4	0.030	**0.026**	0.001 - 0.149
15PLA01	Ship launching	4	1.000 (*)	**1.000 (*)**	--
16POQ00	**PRODUCTION : OUTFITTING after Launching (POQ)**	4	0.037	**0.029**	0.007 - 0.055
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching	3	0.449	**0.476**	0.001 - 1.446
16POQ02	Minimum outfitting effort requirement after launching	3	0.278	**0.524**	0.001 - 1.494
21IFL00	**INFRASTRUCTURE : LAYOUT (IFL)**	57	0.042	**0.033**	0.026 - 0.040
21IFL01	Meteorological conditions	28	0.098	**0.053**	0.041 - 0.065
21IFL02	Shipyard closed/covered areas	34	0.062	**0.065**	0.052 - 0.077
21IFL03	Length of outfitting quay(s)(berth, pier)	16	0.058	**0.074**	0.050 - 0.097
21IFL04	Sea level at outfitting quay(s)(berth, pier)	16	0.059	**0.076**	0.056 - 0.095
21IFL05	Waiting (parking) area of the completed hull & superstructure blocks	19	0.042	**0.049**	0.031 - 0.066
21IFL06	Appropriate layout for material flow and workflow	38	0.054	**0.060**	0.049 - 0.069
21IFL07	Storage, warehousing	40	0.053	**0.064**	0.054 - 0.074
21IFL08	Work equipment, machine park proficiency	41	0.067	**0.074**	0.065 - 0.083
21IFL09	Minimum mobility requirement in the workstation area	35	0.060	**0.069**	0.057 - 0.079
21IFL10	Minimum worker movement distances	34	0.043	**0.055**	0.043 - 0.066
21IFL11	Sidewalks, walking zones	46	0.039	**0.050**	0.040 - 0.059
21IFL12	Minimum material movement distances	33	0.052	**0.064**	0.052 - 0.076
21IFL13	Transport of loads heavier than 23 kgs	43	0.044	**0.051**	0.042 - 0.058
21IFL14	Use of the hull-side elevator	27	0.066	**0.069**	0.052 - 0.084
21IFL15	Ventilation, air conditioning, illumination in working areas	37	0.053	**0.065**	0.055 - 0.074
21IFL16	Cleaning of work areas	44	0.102	**0.061**	0.051 - 0.071
22IEN00	**INFRASTRUCTURE : ENVIRONMENT (IEN)**	42	0.039	**0.033**	0.025 - 0.041
22IEN01	Energy saving and protection of natural resources; use of clean (green) energy	34	0.550	**0.608**	0.518 - 0.697
22IEN02	Hazardous waste management	42	0.354	**0.392**	0.287 - 0.495
23ITE00	**INFRASTRUCTURE: TECHNOLOGY (ITE)**	49	0.043	**0.035**	0.026 - 0.043
23ITE01	Utilizing up-to-date information technologies in shipbuilding	10	0.120	**0.104**	0.045 - 0.161
23ITE02	Information integration for shipyard automation systems	26	0.243	**0.286**	0.182 - 0.388
23ITE03	External integration of Shipyard Information System network	24	0.104	**0.109**	0.083 - 0.135
23ITE04	Research & Development (R&D) investments	22	0.157	**0.166**	0.121 - 0.209
23ITE05	Computer systems investments	24	0.137	**0.147**	0.121 - 0.172
23ITE06	Technical investments	12	0.504	**0.189**	0.129 - 0.248
24IFA00	**INFRASTRUCTURE : AMENITIES (IFA)**	56	0.037	**0.029**	0.021 - 0.037
24IFA01	Dressing-Lockers, Showers-Toilets	48	0.197	**0.336**	0.282 - 0.389
24IFA02	Dining-Resting areas	41	0.112	**0.099**	0.080 - 0.117

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data (continued).

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
24IFA03	Proximity to public transport	50	0.087	**0.108**	0.093 - 0.122
24IFA04	Parking lots	54	0.114	**0.158**	0.138 - 0.177
24IFA05	Nursery (preschool, kinder-garten)	54	0.177	**0.299**	0.232 - 0.366
30DES00	**DESIGN & PRODUCTION ENGINEERING (DES)**	56	0.075	**0.055**	0.045 - 0.064
30DES01	Design methods	14	0.103	**0.077**	0.029 - 0.123
30DES02	Design method for design from scratch	12	0.021	**0.017**	0.009 - 0.024
30DES03	Level of difference between the design of the proposed ship and design of the contracted ship	13	0.038	**0.030**	0.013 - 0.047
30DES04	Conformance of the design to shipyard	11	0.032	**0.022**	0.008 - 0.035
30DES05	Design for Hull Block Outfitting	12	0.037	**0.026**	0.011 - 0.041
30DES06	"Design for Production"	13	0.031	**0.028**	0.016 - 0.039
30DES07	Compliance of design document deliveries with the ship production schedule	44	0.118	**0.119**	0.044 - 0.193
30DES08	Quality of design documents	33	0.082	**0.047**	0.037 - 0.055
30DES09	Easy-to-understand production design documentation	34	0.073	**0.049**	0.037 - 0.060
30DES10	Material/Parts Lists of work packages/workmanship drawings	32	0.054	**0.043**	0.036 - 0.050
30DES11	Plate & profile Part numbering system	21	0.046	**0.043**	0.026 - 0.060
30DES12	Sheet metalwork/Workpiece documents, numerical (digital) data	19	0.047	**0.038**	0.025 - 0.050
30DES13	Hot-works management	30	0.060	**0.049**	0.038 - 0.059
30DES14	Outfitting workmanship documents, installation instructions	25	0.046	**0.040**	0.026 - 0.052
30DES15	Clash detection in design	12	0.035	**0.026**	0.014 - 0.038
30DES16	Easy access of shipbuilding field workers to the ship's 3-dimensional design model	34	0.052	**0.047**	0.032 - 0.062
30DES17	Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers	17	0.074	**0.033**	0.013 - 0.052
30DES18	Equipment/system installation and operating instructions	31	0.058	**0.055**	0.039 - 0.071
30DES19	Consideration of Ship Acceptance Test requirements at early stages of design	28	0.075	**0.056**	0.034 - 0.078
30DES20	Technical Coordination with the Classification Society and the Buyer	20	0.077	**0.055**	0.035 - 0.073
30DES21	Project Configuration Management	21	0.059	**0.043**	0.026 - 0.059
30DES22	Ship weight management	20	0.082	**0.057**	0.040 - 0.072
40MPP00	**MATERIALS & PROCUREMENT (MPP)**	46	0.062	**0.045**	0.037 - 0.051
40MPP01	Selection of subcontractors/ manufacturers for the project	22	0.092	**0.063**	0.041 - 0.084
40MPP02	Contract/Purchase Form standardization in procurements	26	0.071	**0.060**	0.038 - 0.081
40MPP03	Long-term cooperation with subcontractors, manufacturers, suppliers	25	0.060	**0.049**	0.032 - 0.065
40MPP04	Local content	24	0.073	**0.055**	0.028 - 0.080
40MPP05	Geolocation	15	0.054	**0.040**	0.021 - 0.058
40MPP06	Correct material supply	57	0.245	**0.240**	0.150 - 0.329
40MPP07	Just-in-Time (JIT) arrival of the supplies	12	0.066	**0.069**	0.029 - 0.108
40MPP08	Delays in manufacturers' deliveries	12	0.050	**0.053**	0.006 - 0.098
40MPP09	Product Acceptance Inspections, Factory Acceptance Tests (FAT)	23	0.055	**0.047**	0.031 - 0.063
40MPP10	Supply of flawless products	15	0.075	**0.072**	0.043 - 0.099
40MPP11	Buyer furnished material-equipment-systems	35	0.090	**0.073**	0.059 - 0.085
40MPP12	Ship spares and First-outfit material procurement management	25	0.062	**0.059**	0.044 - 0.073
40MPP13	Preventive maintenance in the storage and on board	11	0.036	**0.034**	0.019 - 0.048
40MPP14	Storage/transport of heavy equipment/systems	36	0.101	**0.087**	0.065 - 0.108

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data (continued).

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
51APL00	**MANAGEMENT : PLANNING & BUDGETING (APL)**	56	0.067	**0.050**	0.041 - 0.059
51APL01	Shipbuilding Project Schedule groups	19	0.071	**0.039**	0.028 - 0.049
51APL02	Scope of the Shipbuilding Projects Labor Planning	35	0.078	**0.032**	0.026 - 0.038
51APL03	Integration of schedules	23	0.038	**0.036**	0.027 - 0.044
51APL04	Scheduling techniques	25	0.025	**0.026**	0.019 - 0.032
51APL05	Project scheduling simulations	10	0.024	**0.018**	0.004 - 0.031
51APL06	Dynamic schedule management : Continuous monitoring and feedback	52	0.057	**0.057**	0.050 - 0.062
51APL07	Dynamic schedule management : Progress and Budget evaluation	11	0.054	**0.054**	0.036 - 0.072
51APL08	Accurate time-schedules	56	0.054	**0.050**	0.042 - 0.056
51APL09	Accurate labor planning	54	0.052	**0.051**	0.043 - 0.058
51APL10	Job-order system	41	0.058	**0.058**	0.049 - 0.066
51APL11	Performance measurements, Efficiency calculations	59	0.050	**0.055**	0.047 - 0.062
51APL12	Job standardization; Visible indication of job performance metrics and values at the workstation	54	0.046	**0.049**	0.040 - 0.056
51APL13	Density of the Change Requests, Rework	50	0.045	**0.048**	0.038 - 0.057
51APL14	Production management - Field Engineering	57	0.054	**0.057**	0.049 - 0.063
51APL15	Project Progress Meetings, Reports	59	0.047	**0.053**	0.045 - 0.060
51APL16	Waiting times	56	0.046	**0.047**	0.039 - 0.054
51APL17	Unnecessary overproduction of parts	18	0.049	**0.044**	0.031 - 0.057
51APL18	Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period	12	0.017	**0.019**	0.012 - 0.025
51APL19	Work sharing	30	0.027	**0.031**	0.023 - 0.037
51APL20	Budget tracking methodology	25	0.036	**0.041**	0.030 - 0.052
51APL21	Cost control per unit time	23	0.034	**0.032**	0.020 - 0.042
51APL22	Tracking and management of operating costs, indirect costs	22	0.045	**0.042**	0.029 - 0.053
51APL23	Buy-Rent, Buy-Repair decisions, Service subcontracting decisions	11	0.031	**0.030**	0.02 - 0.038
51APL24	Speed of decision making to revise schedules to meet customer demands	23	0.034	**0.033**	0.026 - 0.039
52ARM00	**MANAGEMENT : RISK MANAGEMENT (ARM)**	27	0.058	**0.047**	0.036 - 0.058
52ARM01	Preparation for the risks identified in PESTEL-SWOT analyzes	12	0.141	**0.135**	0.085 - 0.185
52ARM02	Risk management team	15	0.122	**0.163**	0.131 - 0.194
52ARM03	Project Risk management	20	0.254	**0.215**	0.179 - 0.249
52ARM04	Project Risk management breakdown	15	0.139	**0.186**	0.159 - 0.211
52ARM05	Change management	22	0.150	**0.152**	0.131 - 0.173
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions	19	0.174	**0.149**	0.127 - 0.170
61WOR00	**WORK FORCE : ORGANIZATION (WOR)**	56	0.057	**0.046**	0.038 - 0.053
61WOR01	Staff status of employees (shipyard's own etc.)	58	0.192	**0.266**	0.206 - 0.326
61WOR02	Number of experienced, permanent employees	51	0.092	**0.100**	0.088 - 0.112
61WOR03	Trained and experienced employees	53	0.093	**0.107**	0.092 - 0.120
61WOR04	Trained and experienced employee of the subcontractors	26	0.088	**0.114**	0.085 - 0.143
61WOR05	Quick Workgroups for repetitive tasks	49	0.091	**0.102**	0.090 - 0.112
61WOR06	Leveraging the learning curve	37	0.088	**0.111**	0.096 - 0.125
61WOR07	Backup of critical personnel	39	0.096	**0.083**	0.074 - 0.091
61WOR08	Work planning suitable for the personnel with special conditions	54	0.097	**0.116**	0.101 - 0.131
62WPP00	**WORK FORCE : PERFORMANCE & PRACTICES (WPP)**	56	0.061	**0.049**	0.041 - 0.057

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data (continued).

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
62WPP01	Use of Subcontractors (If subcontractor(s) is/are used)	17	0.154	**0.158**	0.076 - 0.240
62WPP02	Hull & Superstructure Blocks construction subcontractor (if any)	10	0.067	**0.032**	0.021 - 0.042
62WPP03	Hull Steel Outfitting Subcontractors (if any)	20	0.060	**0.038**	0.030 - 0.046
62WPP04	Hull Outfitting Subcontractors (Equipment, if any)	21	0.070	**0.043**	0.032 - 0.054
62WPP05	Blasting-Painting Subcontractors (if any)	14	0.036	**0.033**	0.015 - 0.051
62WPP06	Pipe Manufacturing Subcontractor (if any)	11	0.069	**0.028**	0.016 - 0.039
62WPP07	Pipe Installation Subcontractor (if any)	31	0.046	**0.045**	0.036 - 0.053
62WPP08	Insulation Subcontractor (if any)	27	0.040	**0.039**	0.028 - 0.049
62WPP09	Deck Covering Subcontractor (if any)	14	0.043	**0.037**	0.022 - 0.051
62WPP10	Main Propulsion System Installation Subcontractor (if any)	29	0.053	**0.046**	0.035 - 0.056
62WPP11	Ship Service Systems Subcontractors (if any)	24	0.047	**0.041**	0.032 - 0.048
62WPP12	Ship Electrical System Installation Subcontractor (if any)	25	0.045	**0.041**	0.033 - 0.048
62WPP13	Cable Trays Installation Subcontractor (if any)	24	0.038	**0.039**	0.031 - 0.047
62WPP14	Cable Pulling Subcontractor (if any)	24	0.041	**0.042**	0.034 - 0.049
62WPP15	Ship Electronics/Navigation Systems Installation Subcontractor (if any)	17	0.043	**0.042**	0.028 - 0.054
62WPP16	HVAC Ducts Manufacturing Subcontractor (if any)	20	0.044	**0.037**	0.030- 0.043
62WPP17	HVAC Ducting Installation Subcontractor (if applicable)	23	0.032	**0.033**	0.027 - 0.038
62WPP18	HVAC System Installation Subcontractor (if any)	26	0.036	**0.035**	0.029 - 0.041
62WPP19	Ship Launching Subcontractor	9	0.079	**0.030**	0.023 - 0.036
62WPP20	Tank Cleaning/Preparation Subcontractor (if any)	24	0.045	**0.040**	0.031 - 0.048
62WPP21	General Service Subcontractor (ship cleaning etc., if any)	24	0.049	**0.035**	0.026 - 0.042
62WPP22	Staging/Scaffolding Construction/Dismantling Subcontractor (if any)	25	0.047	**0.037**	0.027 - 0.047
62WPP23	Manufacturers' technical support	26	0.134	**0.047**	0.039 - 0.055
63WPM00	**WORKFORCE : MOTIVATION (WPM)**	57	0.061	**0.047**	0.039 - 0.055
63WPM01	Believing in being a good shipyard, motivation	34	0.109	**0.070**	0.059 - 0.080
63WPM02	Efficient, productive work	52	0.045	**0.065**	0.056 - 0.072
63WPM03	Wages, salaries	48	0.055	**0.074**	0.066 - 0.081
63WPM04	Promotions	53	0.053	**0.088**	0.079 - 0.097
63WPM05	Employee circulation	49	0.053	**0.054**	0.046 - 0.061
63WPM06	Job descriptions, work sharing	61	0.060	**0.094**	0.084 - 0.103
63WPM07	Occupational safety	46	0.072	**0.118**	0.101 - 0.134
63WPM08	Protective clothing, safety equipment	51	0.070	**0.096**	0.086 - 0.106
63WPM09	Work ergonomics	58	0.062	**0.098**	0.089 - 0.107
63WPM10	Improvement suggestions	56	0.048	**0.070**	0.061 - 0.078
63WPM11	Negative work psychology	45	0.064	**0.077**	0.069 - 0.083
63WPM12	Compliance with working hours	60	0.059	**0.096**	0.085 - 0.106
70QAC00	**QUALITY (QAC)**	58	0.065	**0.055**	0.046 - 0.063
70QAC01	Effectiveness of the Quality Assurance System	60	0.295	**0.265**	0.198 - 0.331
70QAC02	Quality Assurance certification status	22	0.097	**0.070**	0.048 - 0.090
70QAC03	Quality control	51	0.095	**0.076**	0.066 - 0.085
70QAC04	Dimensional accuracy control in hull construction	19	0.110	**0.082**	0.054 - 0.110
70QAC05	Welding quality	18	0.105	**0.079**	0.065 - 0.093
70QAC06	Stopping the production in case of faulty production detection	23	0.169	**0.080**	0.074 - 0.085
70QAC07	Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management	14	0.093	**0.075**	0.060 - 0.089
70QAC08	Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)	14	0.089	**0.070**	0.054 - 0.085
70QAC09	Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment	24	0.097	**0.068**	0.057 - 0.077

Table L.1: List of Effects' sector weights based on groups and subgroups, with cleaned data (continued).

Nr.	EFFECT	Sample Size	Sector Weight	Normalized Sector Weight	95% Confidence Interval
70QAC10	Yard Trial - Preliminary check of Sea Trials (SAT) preparations	14	0.091	**0.070**	0.055 - 0.085
70QAC11	Availability of a Quick Defects Repair Team	14	0.085	**0.064**	0.045 - 0.082
81CMC00	**CONTRACTING : MAIN CONTRACT (CMC)**	18	0.090	**0.047**	0.034 - 0.058
81CMC01	Pre-review of an incoming query	3	0.112	**0.100**	0.058 - 0.142
81CMC02	Bid/Proposal preparation standardization	27	0.295	**0.264**	0.157 - 0.371
81CMC03	Shipbuilding Contract preparations	15	0.249	**0.223**	0.105 - 0.339
81CMC04	Participation in Shipbuilding Contract negotiations	26	0.281	**0.241**	0.133 - 0.349
81CMC05	The governing law for the contracts	3	0.191	**0.171**	0.001 - 0.727
82CSC00	**CONTRACTING : SUBCONTRACTS (CSC)**	3	0.043	**0.037**	0.027 - 0.046
82CSC01	Subcontractor Contracts preparations	3	0.794	**0.797**	0.692 - 0.900
82CSC02	Participation in Subcontractor Contract negotiations	3	0.203	**0.203**	0.099 - 0.307

(*) Based on statistically "bad (trash)" data. See subsection 3.2.3.

Table L.2: List of Effects' group/subgroups sector weights in the order of priority.

Group/Subgroup Nr.	Effects' Group/Subgroup	Normalized Sector Weight
11PSB00	PRODUCTION : HULL & SUPERSTRUCTURE BLOCKS CONSTRUCTION (PSB)	0.121
12PSE00	PRODUCTION : HULL ERECTION (PSE)	0.095
13PPT00	PRODUCTION : PARTS MANUFACTURING IN THE SHIPYARD (PPT)	0.078
30DES00	DESIGN & PRODUCTION ENGINEERING (DES)	0.055
70QAC00	QUALITY (QAC)	0.055
51APL00	MANAGEMENT : PLANNING & BUDGETING (APL)	0.050
62WPP00	WORK FORCE : PERFORMANCE & PRACTICES (WPP)	0.049
63WPM00	WORKFORCE : MOTIVATION (WPM)	0.047
52ARM00	MANAGEMENT : RISK MANAGEMENT (ARM)	0.047
81CMC00	CONTRACTING : MAIN CONTRACT (CMC)	0.047
61WOR00	WORK FORCE : ORGANIZATION (WOR)	0.046
40MPP00	MATERIALS & PROCUREMENT (MPP)	0.045
14POS00	PRODUCTION : OUTFITTING before LAUNCHING (POS)	0.040
82CSC00	CONTRACTING : SUBCONTRACTS (CSC)	0.037
23ITE00	INFRASTRUCTURE: TECHNOLOGY (ITE)	0.035
21IFL00	INFRASTRUCTURE : LAYOUT (IFL)	0.033
22IEN00	INFRASTRUCTURE : ENVIRONMENT (IEN)	0.033
16POQ00	PRODUCTION : OUTFITTING after LAUNCHING (POQ)	0.031
24IFA00	INFRASTRUCTURE : AMENITIES (IFA)	0.029
15PLA00	PRODUCTION : LAUNCHING (PLA)	0.026

Table L.3: List of Effect sector weights in the order of priority.

EFFECT Nr.	EFFECTS	Normalized Sector Weight
12PSE01	Hull & Superstructure blocks erection (Hull Construction)	1.000 (*)
15PLA01	Ship launching	1.000 (*)
82CSC01	Subcontractor Contracts preparations	0.797
22IEN01	Energy saving and protection of natural resources; use of clean (green) energy	0.608
16POQ02	Minimum outfitting effort requirement after launching	0.524
16POQ01	Works, installations on the shell, external hull and exterior paint during the outfitting after launching	0.476
14POS01	Manufacturing and assembly of the outfit infrastructure elements	0.455
13PPT01	Metal joining techniques	0.405
22IEN02	Hazardous waste management	0.392
24IFA01	Dressing-Lockers, Showers-Toilets	0.336
24IFA05	Nursery (preschool, kinder-garten)	0.299
23ITE02	Information integration for shipyard automation systems	0.286
61WOR01	Staff status of employees (shipyard's own etc.)	0.266
70QAC01	Effectiveness of the Quality Assurance System	0.265
81CMC02	Bid/Proposal preparation standardization	0.264
81CMC04	Participation in Shipbuilding Contract negotiations	0.241
40MPP06	Correct material supply	0.240
81CMC03	Shipbuilding Contract preparations	0.223
52ARM03	Project Risk management	0.215
82CSC02	Participation in Subcontractor Contract negotiations	0.203
13PPT02	Manufacturing and installation of piping systems in the ship	0.198
11PSB01	Stowage, protection, transportation of shipbuilding plates (steel or else) arrived in the shipyard	0.190
23ITE06	Technical investments	0.189
52ARM04	Project Risk management breakdown	0.186
13PPT06	Manufacturing and installation automation, use of robots	0.183
81CMC05	The governing law for the contracts	0.171
23ITE04	Research & Development (R&D) investments	0.166
52ARM02	Risk management team	0.163
11PSB05	The use of roll/press/bender for sheet metal and profile bending processes	0.159
62WPP01	Use of Subcontractors (If subcontractor(s) is/are used)	0.158
24IFA04	Parking lots	0.158
52ARM05	Change management	0.152
52ARM06	Identification of the risks which may result in delay the delivery of the ship or prevent the delivery; taking precautions	0.149
23ITE05	Computer systems investments	0.147
52ARM01	Preparation for the risks identified in PESTEL-SWOT analyzes	0.135
30DES07	Compliance of design document deliveries with the ship production schedule	0.119
63WPM07	Occupational safety	0.118
61WOR08	Work planning suitable for the personnel with special conditions	0.116
11PSB02	Stowage, protection, transportation of shipbuilding profiles (steel or else) arrived in the shipyard	0.115
61WOR04	Trained and experienced employee of the subcontractors	0.114
61WOR06	Leveraging the learning curve	0.111
23ITE03	External integration of Shipyard Information System network	0.109

Table L.3: List of Effect sector weights in the order of priority (continued).

EFFECT Nr.	EFFECTS	Normalized Sector Weight
24IFA03	Proximity to public transport	0.108
61WOR03	Trained and experienced employees	0.107
11PSB10	Completion of outfitted or non-outfitted hull & superstructure blocks	0.106
23ITE01	Utilizing up-to-date information technologies in shipbuilding	0.104
61WOR05	Quick Workgroups for repetitive tasks	0.102
61WOR02	Number of experienced, permanent employees	0.100
81CMC01	Pre-review of an incoming query	0.100
24IFA02	Dining-Resting areas	0.099
63WPM09	Work ergonomics	0.098
63WPM08	Protective clothing, safety equipment	0.096
63WPM12	Compliance with working hours	0.096
63WPM06	Job descriptions, work sharing	0.094
63WPM04	Promotions	0.088
11PSB09	Block Blasting-Painting	0.088
14POS07	Embarkation of the equipment on board	0.087
40MPP14	Storage/transport of heavy equipment/systems	0.087
14POS05	Paint manufacturer	0.087
13PPT04	Use of high-tech materials	0.084
61WOR07	Backup of critical personnel	0.083
70QAC04	Dimensional accuracy control in hull construction	0.082
11PSB06	The use of welding robots in the hull & superstructure semi-block assembly stages	0.081
70QAC06	Stopping the production in case of faulty production detection	0.080
70QAC05	Welding quality	0.079
63WPM11	Negative work psychology	0.077
30DES01	Design methods	0.077
70QAC03	Quality control	0.076
21IFL04	Sea level at outfitting quay(s)(berth, pier)	0.076
13PPT05	Production of parts and molds from 3D Printers	0.076
70QAC07	Setting-to-Work (STW), Harbor (HAT) and Sea Trials (SAT) Management	0.075
21IFL08	Work equipment, machine park proficiency	0.074
63WPM03	Wages, salaries	0.074
21IFL03	Length of outfitting quay(s)(berth, pier)	0.074
40MPP11	Buyer furnished material-equipment-systems	0.073
40MPP10	Supply of flawless products	0.072
11PSB03	The use of CNC plasma cutting machine in the hull & superstructure blocks manufacturing	0.071
11PSB04	The use of CNC profile processing machine in the hull & superstructure blocks manufacturing	0.071
70QAC08	Coordination with manufacturers, Classification Society and Buyer prior to Setting-to-Work (STW), Harbor (HAT)and Sea Trials (SAT)	0.070
70QAC10	Yard Trial - Preliminary check of Sea Trials (SAT)preparations	0.070
63WPM10	Improvement suggestions	0.070
63WPM01	Believing in being a good shipyard, motivation	0.070
70QAC02	Quality Assurance certification status	0.070
40MPP07	Just-in-Time (JIT) arrival of the supplies	0.069
21IFL09	Minimum mobility requirement in the workstation area	0.069
21IFL14	Use of the hull-side elevator	0.069
14POS03	Use of modular "outfit-units"	0.069
14POS06	External hull works, outfitting and painting	0.068
70QAC09	Pre-controls of Harbor (HAT)and Sea Trials (SAT) Test Aids, Equipment	0.068
21IFL02	Shipyard closed/covered areas	0.065
21IFL15	Ventilation, air conditioning, illumination in working areas	0.065
14POS02	Equipment to be taken into the block before the hull erection	0.065
63WPM02	Efficient, productive work	0.065

Table L.3: List of Effect sector weights in the order of priority (continued).

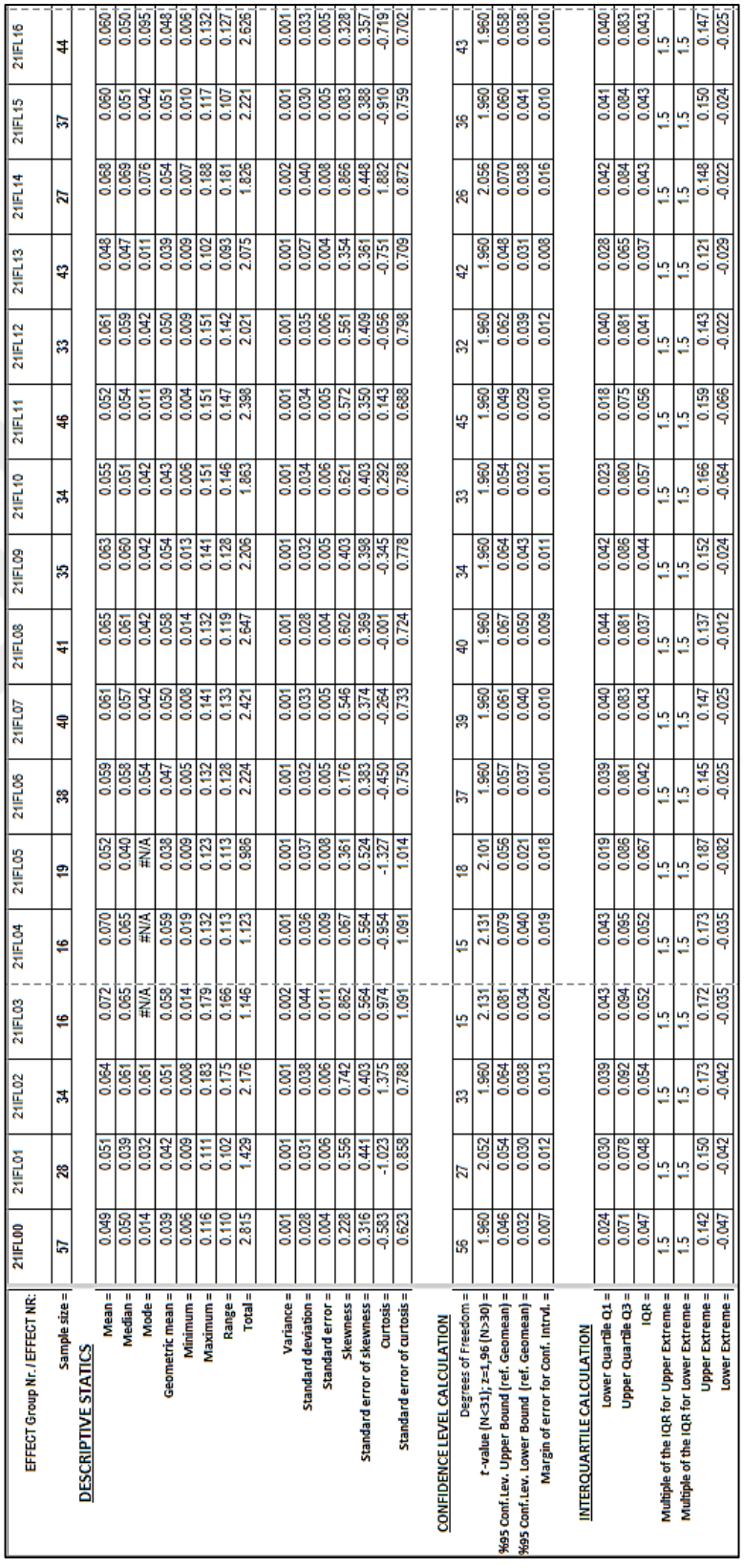
EFFECT Nr.	EFFECTS	Normalized Sector Weight
21IFL12	Minimum material movement distances	0.064
21IFL07	Storage, warehousing	0.064
70QAC11	Availability of a Quick Defects Repair Team	0.064
40MPP01	Selection of subcontractors/ manufacturers for the project	0.063
11PSB07	Categorization of block panel/assembly lines according to their difficulties	0.062
21IFL16	Cleaning of work areas	0.061
14POS08	Protection of the ship and equipment on board	0.061
40MPP02	Contract/Purchase Form standardization in procurements	0.060
21IFL06	Appropriate layout for material flow and workflow	0.060
40MPP12	Ship spares and First-outfit material procurement management	0.059
51APL10	Job-order system	0.058
11PSB08	Use of jigs in the hull & superstructure blocks production	0.057
51APL14	Production management - Field Engineering	0.057
51APL06	Dynamic schedule management : Continuous monitoring and feedback	0.057
30DES22	Ship weight management	0.057
30DES19	Consideration of Ship Acceptance Test requirements at early stages of design	0.056
30DES18	Equipment/system installation and operating instructions	0.055
51APL11	Performance measurements, Efficiency calculations	0.055
21IFL10	Minimum worker movement distances	0.055
30DES20	Technical Coordination with the Classification Society and the Buyer	0.055
40MPP04	Local content	0.055
14POS04	Outfitting after hull assembly	0.055
51APL07	Dynamic schedule management : Progress and Budget evaluation	0.054
63WPM05	Employee circulation	0.054
13PPT03	Cast parts and their machining	0.054
14POS09	Provision of adequate capacity of compressed air, electricity, water, steam	0.053
21IFL01	Meteorological conditions	0.053
51APL15	Project Progress Meetings, Reports	0.053
40MPP08	Delays in manufacturers' deliveries	0.053
51APL09	Accurate labor planning	0.051
21IFL13	Transport of loads heavier than 23 kgs	0.051
21IFL11	Sidewalks, walking zones	0.050
51APL08	Accurate time-schedules	0.050
30DES09	Easy-to-understand production design documentation	0.049
40MPP03	Long-term cooperation with subcontractors, manufacturers, suppliers	0.049
30DES13	Hot-works management	0.049
21IFL05	Waiting (parking) area of the completed hull & superstructure blocks	0.049
51APL12	Job standardization; Visible indication of job performance metrics and values at the workstation	0.049
51APL13	Density of the Change Requests, Rework	0.048
62WPP23	Manufacturers' technical support	0.047
40MPP09	Product Acceptance Inspections, Factory Acceptance Tests (FAT)	0.047
30DES16	Easy access of shipbuilding field workers to the ship’s 3-dimensional design model	0.047
51APL16	Waiting times	0.047
30DES08	Quality of design documents	0.047
62WPP10	Main Propulsion System Installation Subcontractor (if any)	0.046
62WPP07	Pipe Installation Subcontractor (if any)	0.045
51APL17	Unnecessary overproduction of parts	0.044
30DES10	Material/Parts Lists of work packages/workmanship drawings	0.043

Table L.3: List of Effect sector weights in the order of priority (continued).

EFFECT Nr.	EFFECTS	Normalized Sector Weight
30DES11	Plate & profile Part numbering system	0.043
62WPP04	Hull Outfitting Subcontractors (Equipment, if any)	0.043
30DES21	Project Configuration Management	0.043
62WPP14	Cable Pulling Subcontractor (if any)	0.042
51APL22	Tracking and management of operating costs, indirect costs	0.042
62WPP15	Ship Electronics/Navigation Systems Installation Subcontractor (if any)	0.042
62WPP12	Ship Electrical System Installation Subcontractor (if any)	0.041
51APL20	Budget tracking methodology	0.041
62WPP11	Ship Service Systems Subcontractors (if any)	0.041
40MPP05	Geolocation	0.040
62WPP20	Tank Cleaning/Preparation Subcontractor (if any)	0.040
30DES14	Outfitting workmanship documents, installation instructions	0.040
62WPP13	Cable Trays Installation Subcontractor (if any)	0.039
51APL01	Shipbuilding Project Schedule groups	0.039
62WPP08	Insulation Subcontractor (if any)	0.039
62WPP03	Hull Steel Outfitting Subcontractors (if any)	0.038
30DES12	Sheet metalwork/Workpiece documents, numerical (digital) data	0.038
62WPP22	Staging/Scaffolding Construction/Dismantling Subcontractor (if any)	0.037
62WPP09	Deck Covering Subcontractor (if any)	0.037
62WPP16	HVAC Ducts Manufacturing Subcontractor (if any)	0.037
51APL03	Integration of schedules	0.036
62WPP18	HVAC System Installation Subcontractor (if any)	0.035
62WPP21	General Service Subcontractor (ship cleaning etc., if any)	0.035
40MPP13	Preventive maintenance in the storage and on board	0.034
62WPP05	Blasting-Painting Subcontractors (if any)	0.033
62WPP17	HVAC Ducting Installation Subcontractor (if applicable)	0.033
30DES17	Compatibility of the Design and material/equipment supplied by Subcontractors/Manufacturers	0.033
51APL24	Speed of decision making to revise schedules to meet customer demands	0.033
62WPP02	Hull & Superstructure Blocks construction subcontractor (if any)	0.032
51APL02	Scope of the Shipbuilding Projects Labor Planning	0.032
51APL21	Cost control per unit time	0.032
51APL19	Work sharing	0.031
30DES03	Level of difference between the design of the proposed ship and design of the contracted ship	0.030
62WPP19	Ship Launching Subcontractor	0.030
51APL23	Buy-Rent, Buy-Repair decisions, Service subcontracting decisions	0.030
62WPP06	Pipe Manufacturing Subcontractor (if any)	0.028
30DES06	"Design for Production"	0.028
51APL04	Scheduling techniques	0.026
30DES15	Clash detection in design	0.026
30DES05	Design for Hull Block Outfitting	0.026
30DES04	Conformance of the design to shipyard	0.022
51APL18	Expiration of Warranties for Equipment, Systems before ship delivery or during the Ship Warranty Period	0.019
51APL05	Project scheduling simulations	0.018
30DES02	Design method for design from scratch	0.017

(*) Based on statistically “bad (trash)” data. See subsection 3.2.3.

APPENDIX M. SAMPLE DESCRIPTIVE STATICS OF EFFECT SECTOR WEIGHTS



EFFECT Group Nr. / EFFECT NR:	21FL00	21FL01	21FL02	21FL03	21FL04	21FL05	21FL06	21FL07	21FL08	21FL09	21FL10	21FL11	21FL12	21FL13	21FL14	21FL15	21FL16
Sample size =	57	28	34	16	16	19	38	40	41	35	34	46	33	43	27	37	44
DESCRIPTIVE STATICS																	
Mean =	0.049	0.051	0.064	0.072	0.070	0.052	0.059	0.061	0.065	0.063	0.055	0.052	0.061	0.048	0.068	0.060	0.060
Median =	0.050	0.039	0.061	0.065	0.065	0.040	0.058	0.057	0.061	0.060	0.051	0.054	0.059	0.047	0.069	0.051	0.050
Mode =	0.014	0.032	0.061	#N/A	#N/A	#N/A	0.054	0.042	0.042	0.042	0.042	0.011	0.042	0.011	0.076	0.042	0.095
Geometric mean =	0.039	0.042	0.051	0.058	0.059	0.038	0.047	0.050	0.058	0.054	0.043	0.039	0.050	0.039	0.054	0.051	0.048
Minimum =	0.006	0.009	0.008	0.014	0.019	0.009	0.005	0.008	0.014	0.013	0.006	0.004	0.009	0.009	0.007	0.010	0.006
Maximum =	0.116	0.111	0.183	0.179	0.132	0.123	0.132	0.141	0.132	0.141	0.151	0.151	0.151	0.102	0.188	0.117	0.132
Range =	0.110	0.102	0.175	0.166	0.113	0.113	0.128	0.133	0.119	0.128	0.146	0.147	0.142	0.093	0.181	0.107	0.127
Total =	2.815	1.429	2.176	1.146	1.123	0.986	2.224	2.421	2.647	2.206	1.863	2.398	2.021	2.075	1.826	2.221	2.626
Variance =	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
Standard deviation =	0.028	0.031	0.038	0.044	0.036	0.037	0.032	0.033	0.028	0.032	0.034	0.034	0.035	0.027	0.040	0.030	0.033
Standard error =	0.004	0.006	0.006	0.011	0.009	0.008	0.005	0.005	0.004	0.005	0.006	0.005	0.006	0.004	0.008	0.005	0.005
Skewness =	0.228	0.556	0.742	0.862	0.067	0.361	0.176	0.546	0.602	0.403	0.621	0.572	0.561	0.354	0.866	0.083	0.328
Standard error of skewness =	0.316	0.441	0.403	0.564	0.564	0.524	0.383	0.374	0.369	0.398	0.403	0.350	0.409	0.361	0.448	0.388	0.357
Curtosis =	-0.583	-1.023	1.375	0.974	-0.954	-1.327	-0.450	-0.264	-0.001	-0.345	0.292	0.143	-0.056	-0.751	1.882	-0.910	-0.719
Standard error of curtosis =	0.623	0.858	0.788	1.091	1.091	1.014	0.750	0.733	0.724	0.778	0.788	0.688	0.798	0.709	0.872	0.759	0.702
CONFIDENCE LEVEL CALCULATION																	
Degrees of Freedom =	56	27	33	15	15	18	37	39	40	34	33	45	32	42	26	36	43
t-value (N<31); z=1,96 (N>30) =	1.960	2.052	1.960	2.131	2.131	2.101	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	2.056	1.960	1.960
%95 Conf.Lev. Upper Bound (ref. Geomean) =	0.046	0.054	0.064	0.081	0.079	0.056	0.057	0.061	0.067	0.064	0.054	0.049	0.062	0.048	0.070	0.060	0.058
%95 Conf.Lev. Lower Bound (ref. Geomean) =	0.032	0.030	0.038	0.034	0.040	0.021	0.037	0.040	0.050	0.043	0.032	0.029	0.039	0.031	0.038	0.041	0.038
Margin of error for Conf. Intrvl. =	0.007	0.012	0.013	0.024	0.019	0.018	0.010	0.010	0.009	0.011	0.011	0.010	0.012	0.008	0.016	0.010	0.010
INTERQUARTILE CALCULATION																	
Lower Quartile Q1 =	0.024	0.030	0.039	0.043	0.043	0.019	0.039	0.040	0.044	0.042	0.023	0.018	0.040	0.028	0.042	0.041	0.040
Upper Quartile Q3 =	0.071	0.078	0.092	0.094	0.085	0.086	0.081	0.083	0.081	0.086	0.080	0.075	0.081	0.065	0.084	0.084	0.083
IQR =	0.047	0.048	0.054	0.052	0.052	0.067	0.042	0.043	0.037	0.044	0.057	0.056	0.041	0.037	0.043	0.043	0.043
Multiple of the IQR for Upper Extreme =	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Multiple of the IQR for Lower Extreme =	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Upper Extreme =	0.142	0.150	0.173	0.172	0.173	0.187	0.145	0.147	0.137	0.152	0.166	0.159	0.143	0.121	0.148	0.150	0.147
Lower Extreme =	-0.047	-0.042	-0.042	-0.035	-0.035	-0.082	-0.025	-0.025	-0.012	-0.024	-0.064	-0.066	-0.022	-0.029	-0.022	-0.024	-0.025

Figure M.1: Sample descriptive statistics, confidence interval and interquartile calculation results table of EFFECT groups' and EFFECTs' Sector Weights.

APPENDIX N. MANAGEMENT:BASIS INFORMATION PAIRWISE QUESTIONS AND CALCULATED WEIGHTS

The list of pairwise questions in Management:Basis section of the survey questionnaire is given below. The rows in bold letters are the anchor questions to be compared with the items in rows (in normal fonts) with regard to importance.

Table N.1: List of pairwise questions in Management:Basis section of the survey questionnaire.

Nr.	QUESTION
MBS101	**If "Costs" are considered, the "Shipbuilding Contract and Subcontractor Contracts" process,**
MBS102	Hull & Superstructure Blocks Construction
MBS103	Hull Erection
MBS104	Parts Manufacturing in the Shipyard
MBS105	Outfitting Before Launching
MBS106	Ship Launching
MBS107	Outfitting After Launching
MBS108	Setting-to-Work, Harbor and Sea Trials
MBS201	**If "Use of labor (man x hour etc.)" is considered, the "Shipbuilding Contract and Subcontractor Contracts" process,**
MBS202	Hull & Superstructure Blocks Construction
MBS203	Hull Erection
MBS204	Parts Manufacturing in the Shipyard
MBS205	Outfitting Before Launching
MBS206	Ship Launching
MBS207	Outfitting After Launching
MBS208	Setting-to-Work, Harbor and Sea Trials
MBS301	**If "Time duration (weeks etc.)" is considered, the "Shipbuilding Contract and Subcontractor Contracts" process,**
MBS302	Hull & Superstructure Blocks Construction
MBS303	Hull Erection
MBS304	Parts Manufacturing in the Shipyard
MBS305	Outfitting Before Launching
MBS306	Ship Launching
MBS307	Outfitting After Launching
MBS308	Setting-to-Work, Harbor and Sea Trials
MBS101	**If "Costs" are considered, the "Shipbuilding Contract and Subcontractor Contracts" process,**
MBS102	Hull & Superstructure Blocks Construction
MBS103	Hull Erection
MBS104	Parts Manufacturing in the Shipyard
MBS105	Outfitting Before Launching
MBS106	Ship Launching
MBS107	Outfitting After Launching
MBS108	Setting-to-Work, Harbor and Sea Trials

Table N.1: List of pairwise questions in Management:Basis section of the survey questionnaire (continued).

Nr.	QUESTION
MBS401	**In general, the "Shipbuilding Contract and Subcontractor Contracts" process for this type/class ship,**
MBS402	Hull & Superstructure Blocks Construction
MBS403	Hull Erection
MBS404	Parts Manufacturing in the Shipyard
MBS405	Outfitting Before Launching
MBS406	Ship Launching
MBS407	Outfitting After Launching
MBS408	Setting-to-Work, Harbor and Sea Trials
MBS501	**If "Costs" are considered, the "Ship Production stages" from contracting to ship delivery,**
MBS502	Management
MBS503	Ship Design
MBS601	**If "Use of labor (man x hour etc.)" is considered, the "Ship Production stages" from contracting to ship delivery,**
MBS602	Management
MBS603	Ship Design
MBS701	**If "Time duration (weeks etc.)" is considered, the "Ship Production stages" from contracting to ship delivery,**
MBS702	Management
MBS703	Ship Design
MBS801	**In general, the "Ship Production stages" from contracting to ship delivery for this type/class ship,**
MBS802	Management
MBS803	Ship Design
MBS901	**In general, the "Ship Production stages" from contracting to ship delivery for this type/class ship,**
MBS902	Infrastructure
MBS903	Ship Design
MBS904	Materials & Procurement
MBS905	Management
MBS906	Quality Assurance
MBS991	**Productivity of the Shipyard,**
MBS992	Competitiveness

Table N.2: List of weights based on Management:Basis Information, with cleaned data.

Nr.	Subject	Shipyard Weight		Sector Weight	
		SY 200	SY 300	Sample Size	Sector Weight
MBS101	**If "Costs" are considered, the "Shipbuilding Contract and Subcontractor Contracts" process**	0.158	0.217	12	0.204
MBS102	Hull & Superstructure Blocks Construction	0.078	0.089	12	0.078
MBS103	Hull Erection	0.078	0.089	12	0.078
MBS104	Parts Manufacturing in the Shipyard	0.118	0.060	11	0.072
MBS105	Outfitting Before Launching	0.096	0.089	11	0.096
MBS106	Ship Launching	0.078	0.117	12	0.090
MBS107	Outfitting After Launching	0.118	0.089	12	0.102
MBS108	Setting-to-Work, Harbor and Sea Trials	0.103	0.117	11	0.105
MBS201	**If "Use of labor (man x hour etc.)" is considered, the "Shipbuilding Contract and Subcontractor Contracts" process**	0.199	0.185	12	0.171
MBS202	Hull & Superstructure Blocks Construction	0.078	0.100	12	0.095
MBS203	Hull Erection	0.078	0.100	12	0.095
MBS204	Parts Manufacturing in the Shipyard	0.135	0.100	11	0.111
MBS205	Outfitting Before Launching	0.108	0.100	12	0.108
MBS206	Ship Launching	0.087	0.100	12	0.099
MBS207	Outfitting After Launching	0.135	0.100	11	0.111
MBS208	Setting-to-Work, Harbor and Sea Trials	0.087	0.100	12	0.099
MBS301	**If "Time duration (weeks etc.)" is considered, the "Shipbuilding Contract and Subcontractor Contracts" process**	0.178	0.154	12	0.167
MBS302	Hull & Superstructure Blocks Construction	0.078	0.125	11	0.078
MBS303	Hull Erection	0.078	0.125	11	0.084
MBS304	Parts Manufacturing in the Shipyard	0.121	0.072	11	0.084
MBS305	Outfitting Before Launching	0.093	0.072	12	0.086
MBS306	Ship Launching	0.097	0.125	10	0.100
MBS307	Outfitting After Launching	0.121	0.072	10	0.090
MBS308	Setting-to-Work, Harbor and Sea Trials	0.097	0.095	12	0.086
MBS401	**In general, the "Shipbuilding Contract and Subcontractor Contracts" process for this type/class ship**	0.207	0.109	12	0.195
MBS402	Hull & Superstructure Blocks Construction	0.081	0.132	11	0.088
MBS403	Hull Erection	0.081	0.132	12	0.101
MBS404	Parts Manufacturing in the Shipyard	0.174	0.068	12	0.115
MBS405	Outfitting Before Launching	0.101	0.068	11	0.078
MBS406	Ship Launching	0.074	0.132	12	0.097
MBS407	Outfitting After Launching	0.092	0.090	11	0.082
MBS408	Setting-to-Work, Harbor and Sea Trials	0.074	0.132	11	0.084
MBS501	**If "Costs" are considered, the "Ship Production stages" from contracting to ship delivery**	0.410	0.630	12	0.444
MBS502	Management	0.202	0.132	12	0.191
MBS503	Ship Design	0.238	0.181	12	0.234
MBS601	**If "Use of labor (man x hour etc.)" is considered, the "Ship Production stages" from contracting to ship delivery**	0.417	0.533	12	0.387
MBS602	Management	0.181	0.159	12	0.192
MBS603	Ship Design	0.243	0.219	12	0.276

Table N.2: List of weights based on Management:Basis Information, with cleaned data (continued).

Nr.	Subject	Shipyard Weight		Sector Weight	
		SY 200	SY 300	Sample Size	Sector Weight
MBS701	**If "Time duration (weeks etc.)" is considered, the "Ship Production stages" from contracting to ship delivery**	0.410	0.608	12	0.457
MBS702	Management	0.202	0.157	11	0.165
MBS703	Ship Design	0.238	0.190	12	0.247
MBS801	**In general, the "Ship Production stages" from contracting to ship delivery for this type/class ship**	0.417	0.513	12	0.448
MBS802	Management	0.181	0.174	12	0.198
MBS803	Ship Design	0.243	0.240	12	0.253
MBS901	**In general, the "Ship Production stages" from contracting to ship delivery for this type/class ship**	0.120	0.256	12	0.209
MBS902	Infrastructure	0.174	0.080	12	0.105
MBS903	Ship Design	0.085	0.157	12	0.123
MBS904	Materials & Procurement	0.085	0.157	12	0.118
MBS905	Management	0.112	0.105	12	0.112
MBS906	Quality Assurance	0.206	0.091	11	0.133
MBS991	**Productivity of the Shipyard**	0.338	0.733	12	0.528
MBS992	Competitiveness	0.319	0.184	12	0.313

	WEIGHTS FROM THE SHIPYARD							
	"IN GENERAL" BASIS	"IN GENERAL" BASIS (Normalized)	"COST" BASIS	"COST" BASIS (Normalized)	"LABOR" BASIS	"LABOR" BASIS (Normalized)	"TIME" BASIS	"TIME" BASIS (Normalized)
CONTRACTING	0.207	0.234	0.158	0.191	0.199	0.219	0.178	0.207
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.081	0.092	0.078	0.094	0.078	0.086	0.078	0.090
HULL ERECTION	0.081	0.092	0.078	0.094	0.078	0.086	0.078	0.090
PARTS MANUFACTURING IN THE SHIPYARD	0.174	0.197	0.118	0.143	0.135	0.149	0.121	0.140
OUTFITTING BEFORE SHIP LAUNCHING	0.101	0.115	0.096	0.116	0.108	0.119	0.093	0.108
SHIP LAUNCHING	0.074	0.083	0.078	0.094	0.087	0.096	0.097	0.112
OUTFITTING AFTER SHIP LAUNCHING	0.092	0.104	0.118	0.143	0.135	0.149	0.121	0.140
SETTING-to-WORK, HARBOR AND SEA TRIALS	0.074	0.083	0.103	0.124	0.087	0.096	0.097	0.112
SHIPBUILDING MANAGEMENT	0.181	0.215	0.202	0.238	0.181	0.215	0.202	0.238
SHIP PRODUCTION	0.417	0.496	0.410	0.482	0.417	0.496	0.410	0.482
SHIP DESIGN	0.243	0.289	0.238	0.280	0.243	0.289	0.238	0.280

	SECTOR WEIGHTS							
	"IN GENERAL" BASIS	"IN GENERAL" BASIS (Normalized)	"COST" BASIS	"COST" BASIS (Normalized)	"LABOR" BASIS	"LABOR" BASIS (Normalized)	"TIME" BASIS	"TIME" BASIS (Normalized)
CONTRACTING	0.195	0.232	0.204	0.248	0.171	0.193	0.167	0.216
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.088	0.104	0.078	0.095	0.095	0.107	0.078	0.100
HULL ERECTION	0.101	0.120	0.078	0.095	0.095	0.107	0.084	0.108
PARTS MANUFACTURING IN THE SHIPYARD	0.115	0.138	0.072	0.087	0.111	0.125	0.084	0.108
OUTFITTING BEFORE SHIP LAUNCHING	0.078	0.093	0.096	0.116	0.108	0.122	0.086	0.111
SHIP LAUNCHING	0.097	0.115	0.090	0.109	0.099	0.111	0.100	0.130
OUTFITTING AFTER SHIP LAUNCHING	0.082	0.098	0.102	0.124	0.111	0.125	0.090	0.116
SETTING-to-WORK, HARBOR AND SEA TRIALS	0.084	0.100	0.105	0.127	0.099	0.111	0.086	0.111
SHIPBUILDING MANAGEMENT	0.198	0.220	0.191	0.219	0.192	0.225	0.165	0.190
SHIP PRODUCTION	0.448	0.498	0.444	0.511	0.387	0.453	0.457	0.525
SHIP DESIGN	0.253	0.282	0.234	0.269	0.276	0.322	0.247	0.285

Figure N.1: List of weights based on Management:Basis Information, with cleaned data and normalized as tabulated before for Shipyard 200 Dashboard data entry (screen-view).

	WEIGHTS FROM THE SHIPYARD							
	"IN GENERAL" BASIS	"IN GENERAL" BASIS (Normalized)	"COST" BASIS	"COST" BASIS (Normalized)	"LABOR" BASIS	"LABOR" BASIS (Normalized)	"TIME" BASIS	"TIME" BASIS (Normalized)
CONTRACTING	0.109	0.126	0.217	0.250	0.185	0.209	0.154	0.184
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.132	0.153	0.089	0.103	0.100	0.113	0.125	0.149
HULL ERECTION	0.132	0.153	0.089	0.103	0.100	0.113	0.125	0.149
PARTS MANUFACTURING IN THE SHIPYARD	0.068	0.079	0.060	0.069	0.100	0.113	0.072	0.086
OUTFITTING BEFORE SHIP LAUNCHING	0.068	0.079	0.089	0.103	0.100	0.113	0.072	0.086
SHIP LAUNCHING	0.132	0.153	0.117	0.135	0.100	0.113	0.125	0.149
OUTFITTING AFTER SHIP LAUNCHING	0.090	0.104	0.089	0.103	0.100	0.113	0.072	0.086
SETTING-to-WORK, HARBOR AND SEA TRIALS	0.132	0.153	0.117	0.135	0.100	0.113	0.095	0.113
SHIPBUILDING MANAGEMENT	0.174	0.188	0.132	0.140	0.159	0.175	0.157	0.164
SHIP PRODUCTION	0.513	0.553	0.630	0.668	0.533	0.585	0.608	0.637
SHIP DESIGN	0.240	0.259	0.181	0.192	0.219	0.240	0.190	0.199

	SECTOR WEIGHTS							
	"IN GENERAL" BASIS	"IN GENERAL" BASIS (Normalized)	"COST" BASIS	"COST" BASIS (Normalized)	"LABOR" BASIS	"LABOR" BASIS (Normalized)	"TIME" BASIS	"TIME" BASIS (Normalized)
CONTRACTING	0.195	0.232	0.204	0.248	0.171	0.193	0.167	0.216
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.088	0.104	0.078	0.095	0.095	0.107	0.078	0.100
HULL ERECTION	0.101	0.120	0.078	0.095	0.095	0.107	0.084	0.108
PARTS MANUFACTURING IN THE SHIPYARD	0.115	0.138	0.072	0.087	0.111	0.125	0.084	0.108
OUTFITTING BEFORE SHIP LAUNCHING	0.078	0.093	0.096	0.116	0.108	0.122	0.086	0.111
SHIP LAUNCHING	0.097	0.115	0.090	0.109	0.099	0.111	0.100	0.130
OUTFITTING AFTER SHIP LAUNCHING	0.082	0.098	0.102	0.124	0.111	0.125	0.090	0.116
SETTING-to-WORK, HARBOR AND SEA TRIALS	0.084	0.100	0.105	0.127	0.099	0.111	0.086	0.111
SHIPBUILDING MANAGEMENT	0.198	0.220	0.191	0.219	0.192	0.225	0.165	0.190
SHIP PRODUCTION	0.448	0.498	0.444	0.511	0.387	0.453	0.457	0.525
SHIP DESIGN	0.253	0.282	0.234	0.269	0.276	0.322	0.247	0.285

Figure N.2: List of weights based on Management:Basis Information, with cleaned data and normalized as tabulated before for Shipyard 300 Dashboard data entry (screen-view).

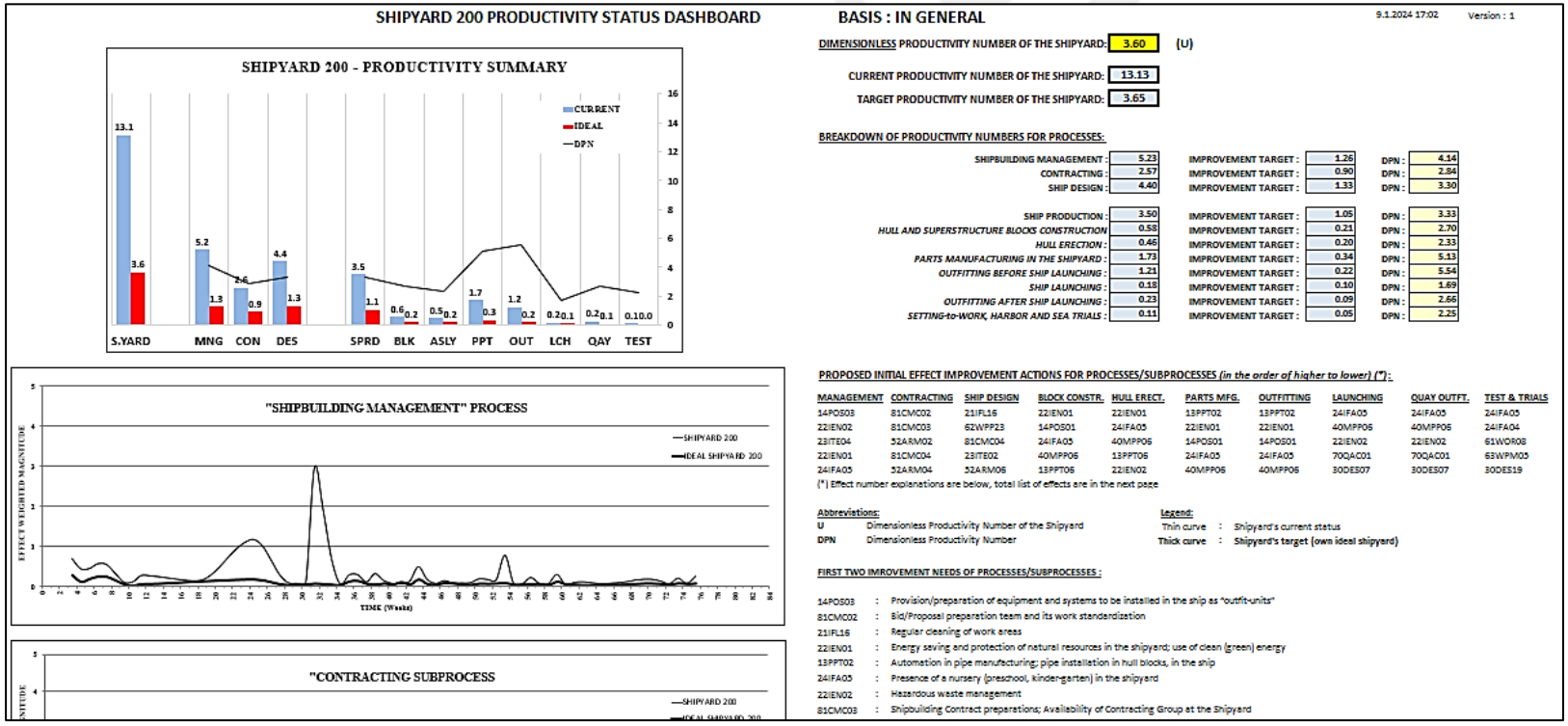


Figure O.1: Sample screen-view of Shipyard 200 Productivity Status Dashboard.

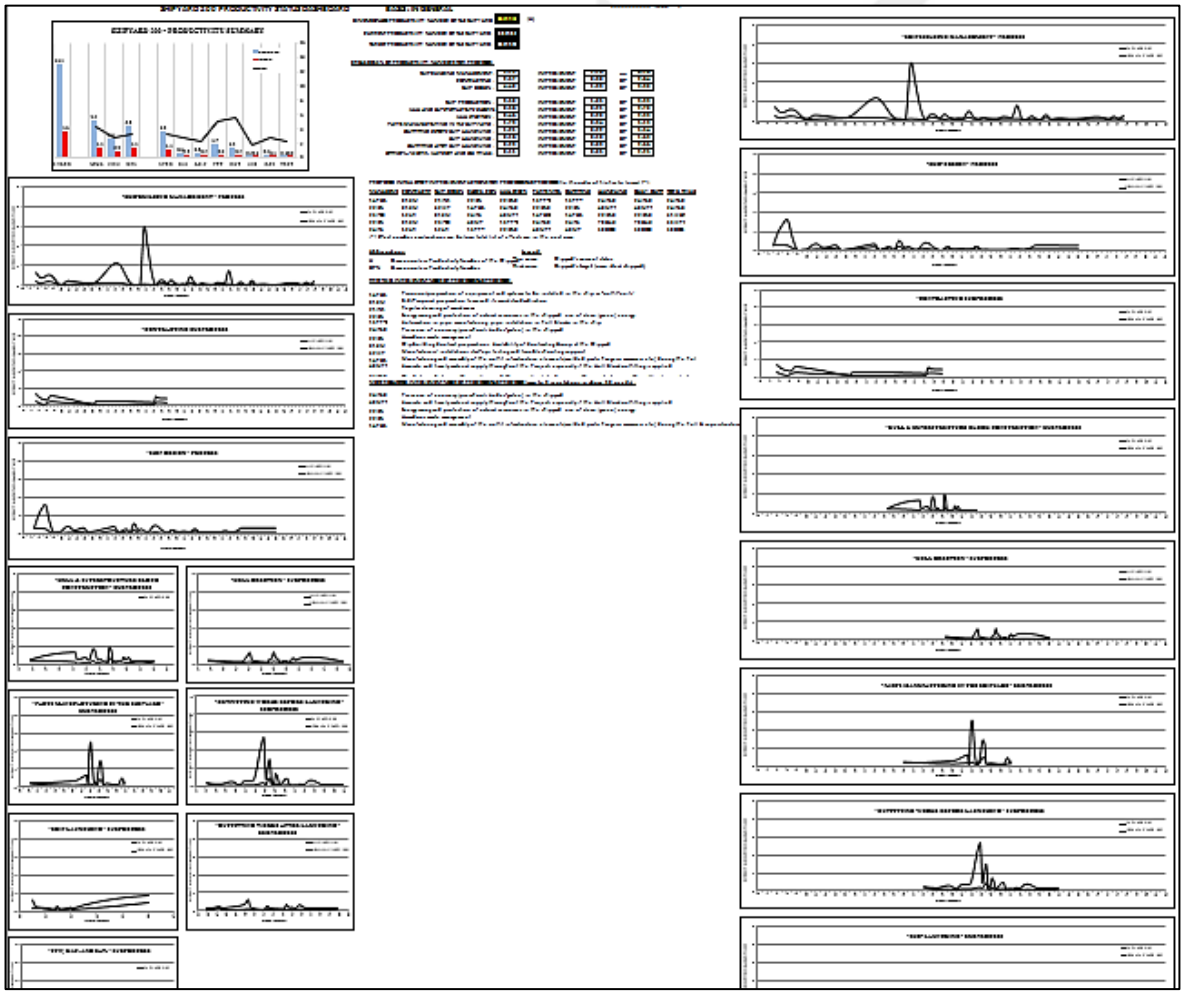
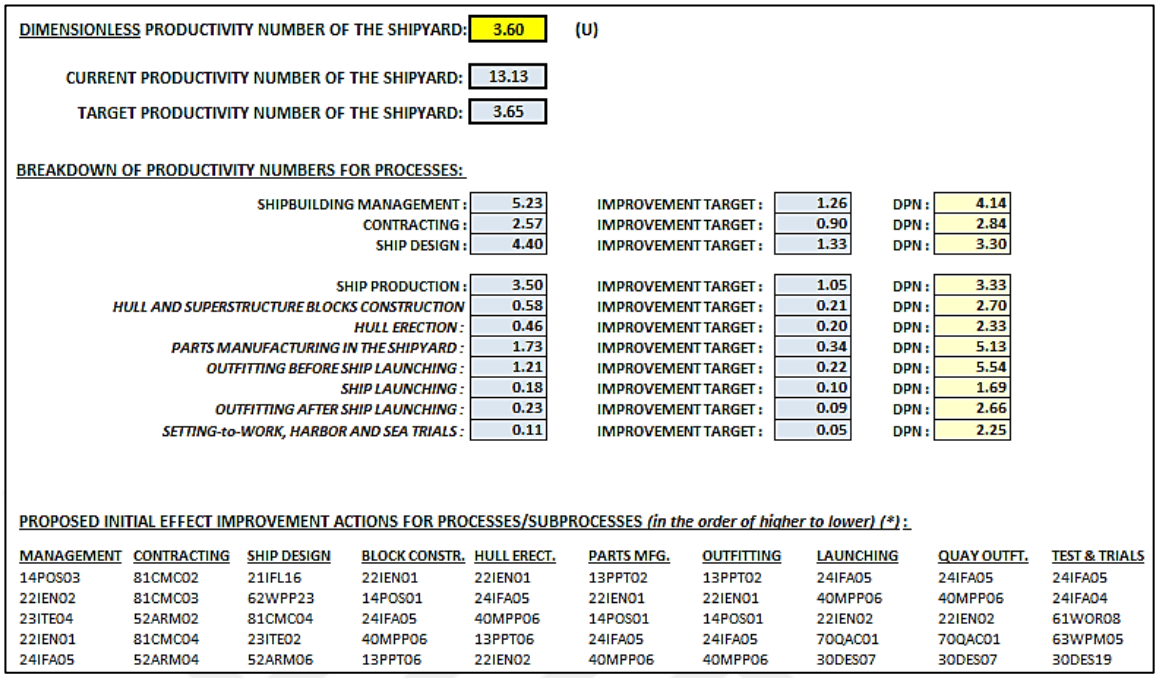


Figure O.2: Sample screen-view of Shipyard 200 Productivity Status Dashboard (expanded view).



DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD: 3.60 (U)

CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD: 13.13

TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD: 3.65

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	5.23	IMPROVEMENT TARGET :	1.26	DPN :	4.14
CONTRACTING :	2.57	IMPROVEMENT TARGET :	0.90	DPN :	2.84
SHIP DESIGN :	4.40	IMPROVEMENT TARGET :	1.33	DPN :	3.30
SHIP PRODUCTION :	3.50	IMPROVEMENT TARGET :	1.05	DPN :	3.33
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.58	IMPROVEMENT TARGET :	0.21	DPN :	2.70
HULL ERECTION :	0.46	IMPROVEMENT TARGET :	0.20	DPN :	2.33
PARTS MANUFACTURING IN THE SHIPYARD :	1.73	IMPROVEMENT TARGET :	0.34	DPN :	5.13
OUTFITTING BEFORE SHIP LAUNCHING :	1.21	IMPROVEMENT TARGET :	0.22	DPN :	5.54
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.10	DPN :	1.69
OUTFITTING AFTER SHIP LAUNCHING :	0.23	IMPROVEMENT TARGET :	0.09	DPN :	2.66
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.25

PROPOSED INITIAL EFFECT IMPROVEMENT ACTIONS FOR PROCESSES/SUBPROCESSES *(in the order of higher to lower) (*) :*

MANAGEMENT	CONTRACTING	SHIP DESIGN	BLOCK CONSTR.	HULL ERECT.	PARTS MFG.	OUTFITTING	LAUNCHING	QUAY OUTFT.	TEST & TRIALS
14POS03	81CMC02	21IFL16	22IEN01	22IEN01	13PPT02	13PPT02	24IFA05	24IFA05	24IFA05
22IEN02	81CMC03	62WPP23	14POS01	24IFA05	22IEN01	22IEN01	40MPP06	40MPP06	24IFA04
23ITE04	52ARM02	81CMC04	24IFA05	40MPP06	14POS01	14POS01	22IEN02	22IEN02	61WOR08
22IEN01	81CMC04	23ITE02	40MPP06	13PPT06	24IFA05	24IFA05	70QAC01	70QAC01	63WPM05
24IFA05	52ARM04	52ARM06	13PPT06	22IEN02	40MPP06	40MPP06	30DES07	30DES07	30DES19

Figure O.3.: Key numerical output on the dashboard of Shipyard 200.

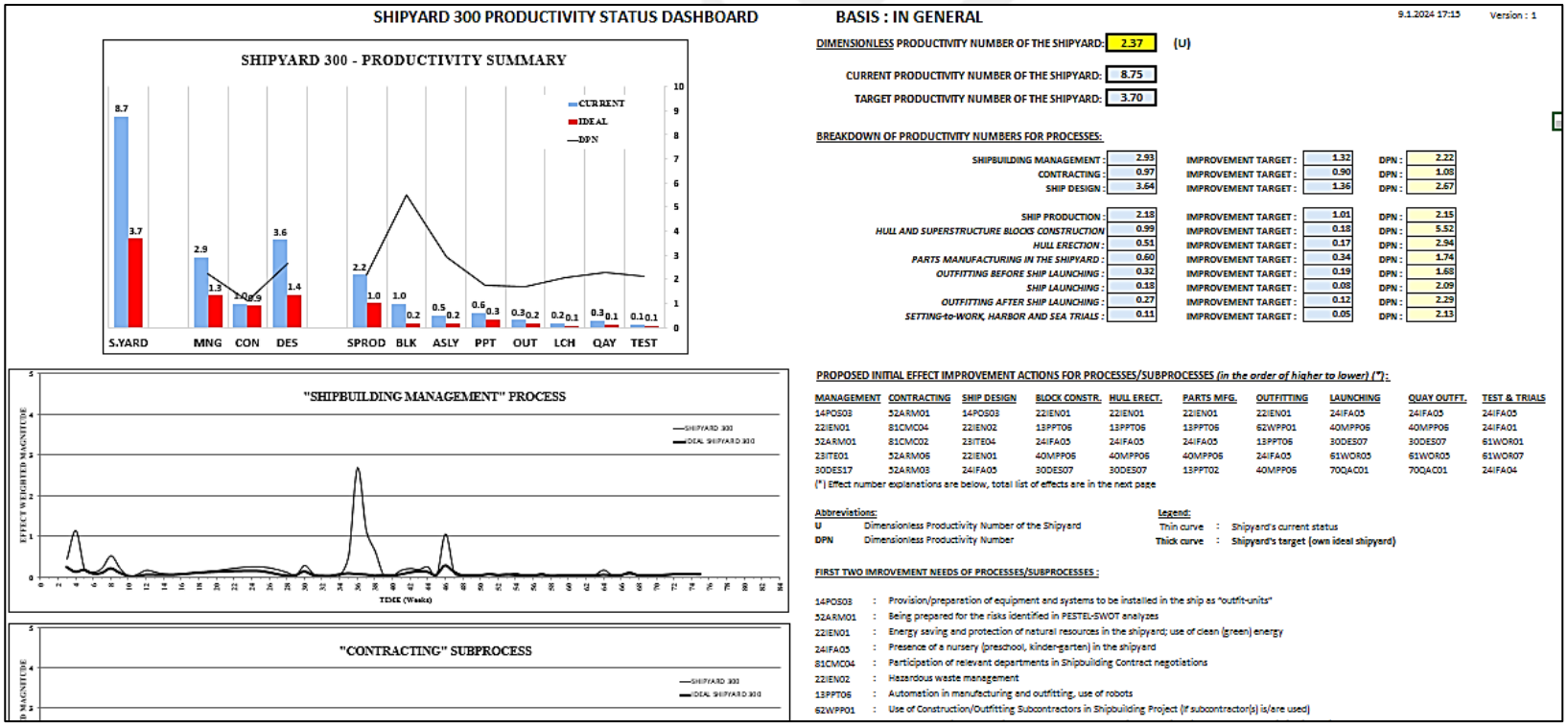


Figure O.4: Sample screen-view of Shipyard 300 Productivity Status Dashboard.

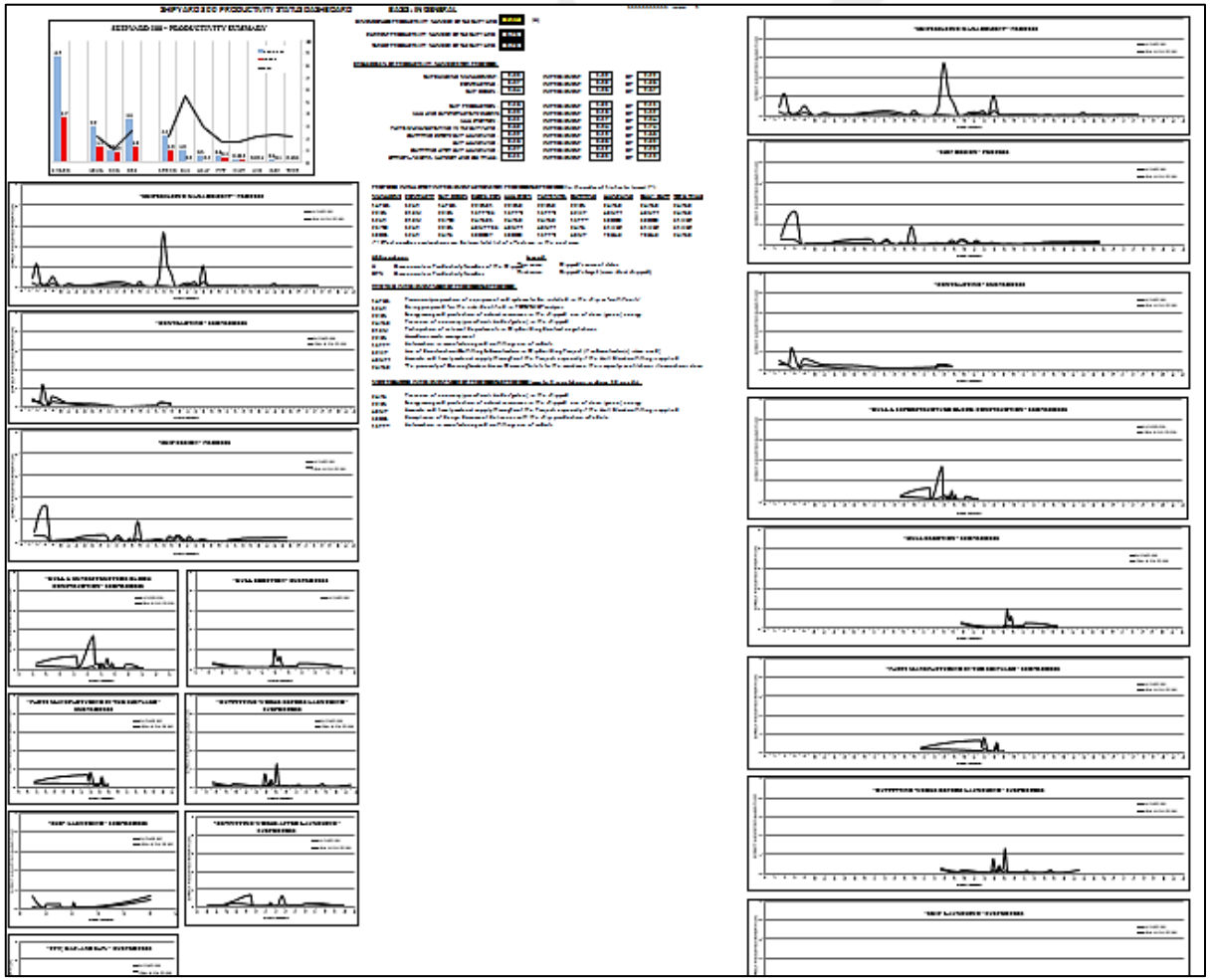
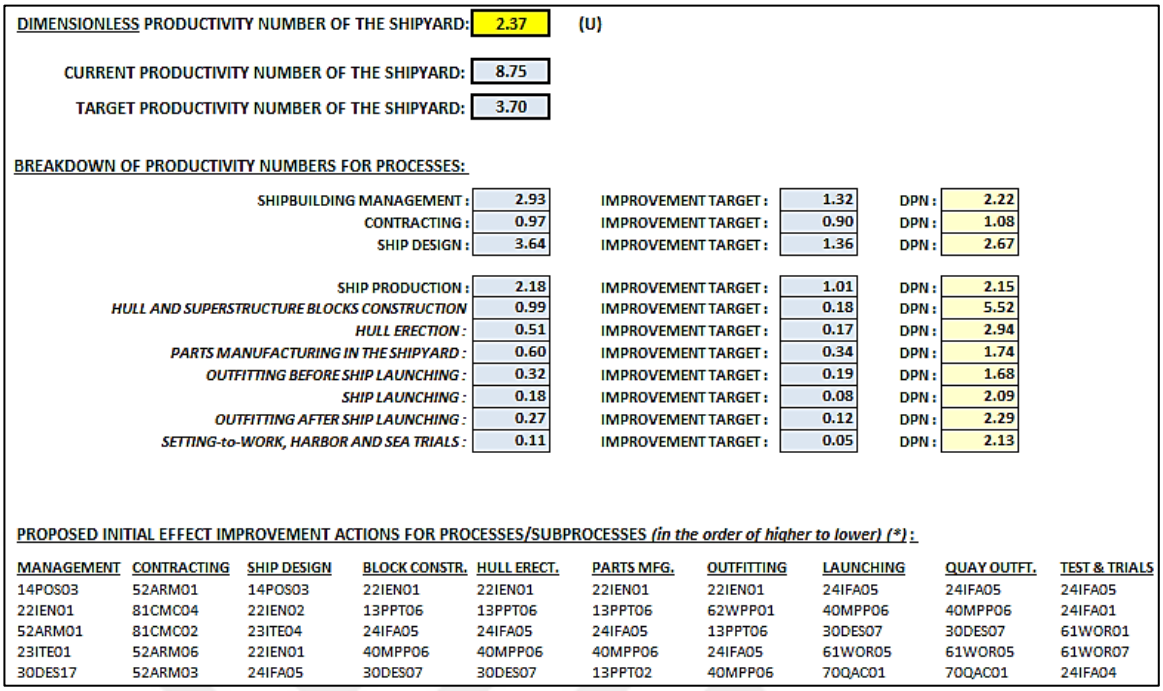


Figure O.5: Sample screen-view of Shipyard 300 Productivity Status Dashboard (expanded view).



DIMENSIONLESS PRODUCTIVITY NUMBER OF THE SHIPYARD: 2.37 (U)

CURRENT PRODUCTIVITY NUMBER OF THE SHIPYARD: 8.75

TARGET PRODUCTIVITY NUMBER OF THE SHIPYARD: 3.70

BREAKDOWN OF PRODUCTIVITY NUMBERS FOR PROCESSES:

SHIPBUILDING MANAGEMENT :	2.93	IMPROVEMENT TARGET :	1.32	DPN :	2.22
CONTRACTING :	0.97	IMPROVEMENT TARGET :	0.90	DPN :	1.08
SHIP DESIGN :	3.64	IMPROVEMENT TARGET :	1.36	DPN :	2.67
SHIP PRODUCTION :	2.18	IMPROVEMENT TARGET :	1.01	DPN :	2.15
HULL AND SUPERSTRUCTURE BLOCKS CONSTRUCTION	0.99	IMPROVEMENT TARGET :	0.18	DPN :	5.52
HULL ERECTION :	0.51	IMPROVEMENT TARGET :	0.17	DPN :	2.94
PARTS MANUFACTURING IN THE SHIPYARD :	0.60	IMPROVEMENT TARGET :	0.34	DPN :	1.74
OUTFITTING BEFORE SHIP LAUNCHING :	0.32	IMPROVEMENT TARGET :	0.19	DPN :	1.68
SHIP LAUNCHING :	0.18	IMPROVEMENT TARGET :	0.08	DPN :	2.09
OUTFITTING AFTER SHIP LAUNCHING :	0.27	IMPROVEMENT TARGET :	0.12	DPN :	2.29
SETTING-to-WORK, HARBOR AND SEA TRIALS :	0.11	IMPROVEMENT TARGET :	0.05	DPN :	2.13

PROPOSED INITIAL EFFECT IMPROVEMENT ACTIONS FOR PROCESSES/SUBPROCESSES *(in the order of higher to lower) (*) :*

MANAGEMENT	CONTRACTING	SHIP DESIGN	BLOCK CONSTR.	HULL ERECT.	PARTS MFG.	OUTFITTING	LAUNCHING	QUAY OUTFT.	TEST & TRIALS
14POS03	52ARM01	14POS03	22IEN01	22IEN01	22IEN01	22IEN01	24IFA05	24IFA05	24IFA05
22IEN01	81CMC04	22IEN02	13PPT06	13PPT06	13PPT06	62WPP01	40MPP06	40MPP06	24IFA01
52ARM01	81CMC02	23ITE04	24IFA05	24IFA05	24IFA05	13PPT06	30DES07	30DES07	61WOR01
23ITE01	52ARM06	22IEN01	40MPP06	40MPP06	40MPP06	24IFA05	61WOR05	61WOR05	61WOR07
30DES17	52ARM03	24IFA05	30DES07	30DES07	13PPT02	40MPP06	70QAC01	70QAC01	24IFA04

Figure O.6: Key numerical output on the dashboard of Shipyard 300.

CURRICULUM VITAE

NAME SURNAME : Saim Turgut KOÇAK

EDUCATION :
B.S. : 1983, Turkish Naval Academy, Naval Architecture
B.S.E. : 1989, University of Michigan, Naval Architecture and Marine Engineering
M.S.E.: 1990, University of Michigan, Naval Architecture and Marine Engineering
(Major: Ship Production)

PROFESSIONAL EXPERIENCE :
1983 – 2006 : Line Officer, Engineering Duty Officer – Turkish Navy
2006 – 2018 : Systems Engineer, Design Manager – STM A.Ş., İstanbul
2019 - 2020 : Part-time Lecturer, Vocational School, Piri Reis University, İstanbul

PUBLICATIONS ON THE THESIS :

- Koçak, S. T., Helvacıoğlu. İ. H. & Kahyaoğlu, N., (2022, September 27-29). A Novel Productivity Evaluation Method for Shipyards, *Proceedings of the SNAME Maritime Convention 2023*, San Diego, September 2023. https://doi.org/10.5957/SMC-202-007

OTHER PUBLICATIONS :

- Koçak, S. T., Dikilitaş, A., Kayıhan, Y., Tiryaki, C. & Güngör, A., (2022). Classification of contractual risks in shipbuilding projects. In İ. H. Helvacıoğlu, S. Ilgın, B. Sözer, B. Başoğlu (Eds.). *Contract Management for Shipbuilding and Repair: Technical Perspective and Settlement of Legal Disputes* (pp. 61-90). Vedat Kitapçılık.
- Koçak, S. T. & Helvacıoğlu, İ. H., (2022). Cooperation in shipbuilding projects from the perspective of main contractor candidate In İ. H. Helvacıoğlu, S. Ilgın, B. Sözer, B. Başoğlu (Eds.). *Contract Management for Shipbuilding and Repair: Technical Perspective and Settlement of Legal Disputes* (pp. 91-118). Vedat Kitapçılık:İstanbul.
- Koçak, S. T. & Yercan, F., (2021). Comparative cost-effectiveness analysis of Arctic and international shipping routes: a fuzzy analytic hierarchy process. *Transport Policy 114*, 147-164. https://doi.org/10.1016/j.tranpol.2021.08.015
- Koçak, S. T.; Özok, A. F. & Kahyaoğlu, N., (2019). Gemi inşaatı sürecinde ergonomik değerlendirmeler [Ergonomics Evaluations in Shipbuilding Process]. *Abstracts Book:25th National Ergonomics Congress*, 12. https://www.researchgate.net/profile/Saim-Kocak-3
- Koçak, S. T. & İlter, Y. K., (2013, November 28-29). *Gemi dizayn sürecinde kapsamlı yenileme ihtiyacı* [Comprehensive renovation need in ship design] [Paper presentation]. 6th Naval Systems Seminar, Ankara, Türkiye. https://www.researchgate.net/profile/Saim-Kocak-3

- Koçak, S. T., (2011, September 20-21). Reducing acquisition and operating costs of patrol vessels [Paper presentation]. 2nd Annual OPV and Maritime Unmanned Systems Summit, İstanbul, Türkiye.
  https://www.researchgate.net/profile/Saim-Kocak-3
- Koçak, S. T. & Dikilitaş, A., 2011, October 17-18). Askeri gemi inşa proje yönetiminde riskler [Risks in naval shipbuilding project management] [Paper presentation]. 4th Naval Systems Seminar, Ankara, Türkiye.
  https://www.researchgate.net/profile/Saim-Kocak-3
- Koçak, S. T., (1995, May 24-27). Tersanelerin tasarım, inşa ve onarım faaliyetleri karar safhalarında sistem güvenirliği ve risk yönetimi uygulamalarından pratik şekilde yararlanma [Practical system reliability and risk management applications during decision phases in design, ship Production and ship repair activities of shipyards**].** *Proceedings of the Turkish Navy 2nd Technical Symposium.* Turkish Navy.
  https://www.researchgate.net/profile/Saim-Kocak-3
- Koçak, S. T., (1995, May 24-27). Bilgisayarla gemi dizaynı (CAE/CAD) [Computer aided ship design]**.** *Proceedings of the Turkish Navy 2nd Technical Symposium.* Turkish Navy.
- Koçak, S. T., (1995, May 24-27). Tersanelerde Grup Teknolojisi [Group Technology in shipyards, in Turkish]. *Proceedings of the Turkish Navy 2nd Technical Symposium.* Turkish Navy.