

APPLICATIONS OF SPECIALIZED PROJECT MANAGEMENT TECHNIQUES FOR NEW PRODUCT DEVELOPMENT IN IT & MANUFACTURING

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ABSTRACT

This paper researches applications of project management models and techniques in new product development (NPD) practices in IT and manufacturing industries. After analyzing implementation of various models and techniques in IT and manufacturing new product development projects, detailed research was conducted for manufacturing NPD implementations. Advantages and disadvantages of specific techniques were investigated through a questionnaire and real world case studies. Findings revealed limitations of traditional techniques (PERT/CPM) and Critical Chain Project Management's (CCPM) potential of overcoming these limitations. Nevertheless, CCPM has some drawbacks need to be improved and recommendations based on these limitations were stated.

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I would like to thank to my friends at Mentor Proje Yonetimi Consultancy who provided valuable information and comment.

Finally, I am thankful to my parents Nihal Alma and Harun Alma for their supports.

DECLARATION OF ORIGINALITY

I confirm that the attached dissertation is my own work and that all the work I shall submit with this thesis will be my own, save where (and to the extent that) the work and/or ideas of others are expressly acknowledged and attributed.

Busra Alma

30.09.2010



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NOTATIONS

CCPM: Critical Chain Project Management

CPM: Critical Path Method

DEA: Data Envelopment Analysis

DMM: Domain Mapping Matrix

DSM: Design Structure Matrix

EV: Earned Value

FBMM: Feed-Back Modification Mechanism

FDSM: Fuzzy Design Structure Matrix

FFMM: Feed-Forward Modification Mechanism

GERT: Graphical Evaluation and Review Technique

ISDM: Information Systems Development Methodologies

IT: Information Technology

NPD: New Product Development

OBS: Organisational Breakdown Structure

PERT: Program Evaluation and Review Technique

PM: Project Management

PMBOK: Project Management Body of Knowledge

PMI: Project Management Institute

WBS: Work Breakdown Structure

XP: Extreme Programming

CHAPTER 1. INTRODUCTION

1.1 Project Background

Design, development and implementation of new and complicated systems never attempted before are among the most challenging engineering activities that have been conducted over the past few decades. Construction of oil drilling platforms in the North Sea off the coast of Great Britain, development of the manned space program in both the United States and the former Soviet Union and the worldwide installation of fibre optic lines for broadband telecommunications are among these activities. Essence of project management emerged from the need for new methods of planning, organizing and controlling events that aid completing the development of these systems within reasonable schedules and budgets (Shutub, Bard and Globerson, 2005).

This dissertation conducts a research to investigate project management models and techniques widely used in organizations and Chapter 3 represents the detailed investigation into these models and techniques. However, major framework of the dissertation is to present how development of new products never attempted before are managed in various IT and manufacturing organizations. Chapter 4 provides this purpose by narrowing the detailed examination and in Chapter 4 focus is shifted to investigation of IT and manufacturing new product development (NPD) project management models and techniques. Another critical research framework is elaborated analysis of NPD project management techniques for manufacturing. Together with case study examinations, data gathered from a questionnaire is combined for this purpose, and in Chapter 5 efficiency improvement ideas are suggested based on the analyses of this data.

1.2 Objectives

Broadly, objective of this thesis is to conduct a research to evaluate different types of project management models in general and to specifically focus on existing project management models and techniques which are applied in new product development

practices. Moreover, it is aimed to do recommendations for enhancing the efficiency of these methods in NPD after identifying major limitations of certain techniques. In the way of accomplishment the research processes have been driven by the following objectives:

1. General investigation into project management models and techniques in the literature
2. Focus on current applications of project management models and techniques in NPD
3. Analyses of software product development and manufacturing product development practices through real world applications
4. Reach an informed decision by weighing the manufacturing new product development practises thoughtfully
5. Discovering techniques in manufacturing product development which there is a need for improvement and finding out possibilities for efficiency enhancement
6. Presenting recommendations for increasing the capability and efficiency of certain techniques.

1.3 Methodology

Data and information about existing project management models and techniques in the literature were obtained thorough books, e-resources, and internet. Detailed information about NPD projects and supportive case studies including real world applications of some models and techniques were provided by the same way.

Observation and data collection contributed to understand applications of project management practices in organizations dealing with NPD projects. Depending on the fact that main focus of thesis is on manufacturing new product development projects, manufacturing companies' project management applications were deeply analyzed at first to discover some specific common problems in project management practices.

This contributed to define initial questionnaire questions which were performed to acquire some information about current project management practices of companies, their drawbacks and potential improvement areas.

Results demonstrated an obvious trend which was about the limitations of the most commonly used traditional techniques. This provided to form a reasonable pattern for choosing the case studies to be analyzed in the thesis.

One case study using traditional PM techniques and suffering from drawbacks was selected and four case studies applying relatively new ways of project management for performance improvement were chosen. The common goal for implementing NPD techniques in the organizations that were studied through case studies was to overcome certain problems in traditional techniques and three organizations applying Critical Chain Project Management (CCPM) demonstrated successful results. However, the method has its own disadvantages.

Limitations discovered through case studies provided insight for defining potential improvement areas. In order to build strong foundation for proposing efficiency improvement strategies and to underpin proposed ideas more case studies were analyzed. However, the suggestions provided had to be combined with some real world experiences by means of contact with a project management consultancy. Thus, contact through email with Mentor Proje Yonetimi Consultancy firm was established.

1.3.1. Questionnaire Design

The questionnaire was designed to gather real world experiences of companies designing and manufacturing new products. Questionnaire was prepared so as to get qualitative data. Four questions were designed in tick-box format (See Appendix A).

First question was to find out project management techniques that the company is currently using, the second one questioned approximate number of projects failed in satisfying their deadlines over a five year period of time, and the other question asked respondents to rate a set of drawback factors that they experience in their processes. Last question was designed to enquire respondents to score a set of activities that may improve efficiency of project management performance.

The purpose of asking project performers to score between a set of factors was to obtain response tendency for each improvement factor by measuring the average of response values.

Questionnaire was sent to 30 overseas companies and 18 responses were obtained, reflecting a 60% response rate. Companies were manufacturing organizations that conduct NPD projects.



CHAPTER 2. NATURE OF PROJECT MANAGEMENT

2.1. Background

Project is a group of organized activities intends achieving a common goal. Projects require to be considered and managed as separate attempts, depending on the fact that they are large and complex enough. Teams have appeared for this purpose, and to help providing necessary talents. However, as they make information flow more complex management also has to deal with coordination and communication of teams. Moreover budget and schedule constraints have made management issues more complex, and have given an incentive for development of methodologies that are different from the ones used for management of organizations. The Project Management Institute (PMI) is in the leading position in developing project management methodologies and offering workshops, training and professional literature. Project Management Body of Knowledge (PMBOK) is one of its main publications. Besides, PMI has a certification program named Project Management Professional which is provides certificate to experienced project managers who pass a written exam on PMBOK (Shutub, Bard and Globerson, 2005).

2.2. Project Characteristics

Project management deals with activities that aim to achieve a set of goals. Therefore progress and results are evaluated according to some critical factors which include specifications, performance, quality, due dates, milestones, cost, profits and market acceptance. If goals are defined clearly, suitable performance measures can be developed, organizational structure, necessary resources and team members can be chosen for the accomplishment of these goals (Shutub, Bard and Globerson, 2005). Figure 2.1 demonstrates major processes in project management.

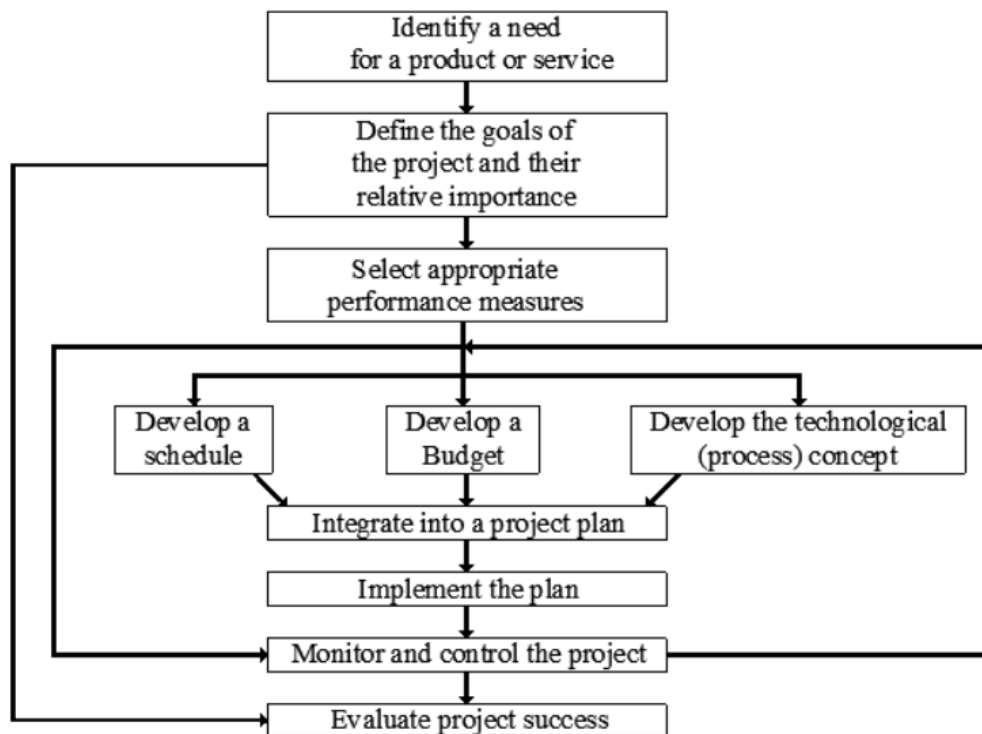


Figure 2.1 “Major Processes in Project Management” (by Shutub, Bard and Globerson, 2005, p.5)

2.2.1. Project Risks and Uncertainty

High degrees of uncertainty in project management environment constitute the basis of risk. Most projects especially R&D ones have lots of risks which should be taken into account. Some common sources of uncertainty cover variations in component and subsystem performance, incorrect and insufficient data, forecast errors due to lack of experience. Scheduling cost and technological factors are other specific causes of uncertainty.

Uncertainty in scheduling: As some changes in the project environment may not be possible to be predicted, they have a significant effect on the duration of particular activities. Methods and techniques are required to handle uncertain and changeable time estimates.

Uncertainty in cost: Information insufficiency about activity durations leads to inappropriate resource estimates which results in uncertainty in cost. Besides,

changing material costs and expected hourly rate of resources have role on cost uncertainty.

Technological uncertainty: R&D projects have technological uncertainty characteristically, as new technologies, methods, techniques and products are developed or used. This type of uncertainty may impact on schedule, cost and performance of the project. Projects require technology integration, software-hardware development and embedded software increases the uncertainty degree.

Organizational structure and political environment may impact and lead to uncertainty with introducing new regulations, policies and personnel turnover (Shutub, Bard and Globerson, 2005).

2.2.2. Project Phases

Even though the names of the project phases which project pass throughout its lifecycle depend on the nature of project and organization's management policy, generally they cover those illustrated in Figure 2.3.

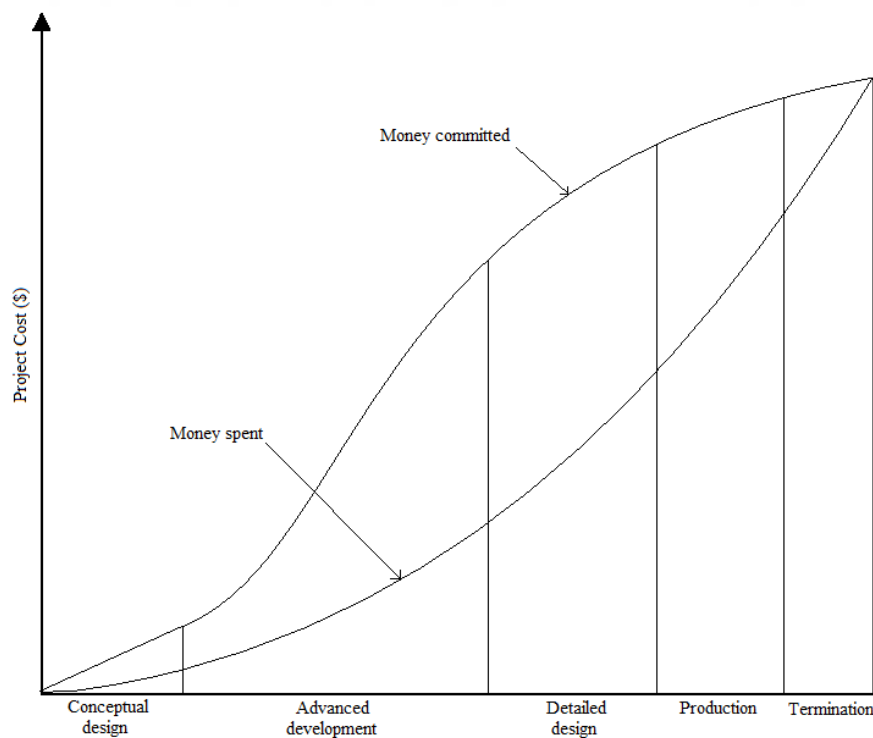


Figure 2.2 “Relationship between project lifecycle and cost” (by Shutub, Bard and Globerson, 2005, p.9).

The Figure 2.3 above represents the five phases of a project as a function of time. The conceptual design phase starts with the need for a project. Next step is advanced development phase in which plan including budget and scheduling is created by project manager and maybe relevant staff. When approval is confirmed project passes through the detailed design, production and termination phases. Management has a critical role in conceptual design, advanced development and detailed design phases as goals are defined, performance measures are chosen and work is planned in these steps. If these phases are overlooked and adequate planning is not provided, project in the execution phase carries high risks of cost and schedule overruns.

In most projects a Work Breakdown Structure (WBS) is created during the conceptual design phase. WBS divides the project into main elements and then smaller tasks so that the project can be easily conducted and a framework for planning, monitoring, budgeting and control is provided (Shutub, Bard and Globerson, 2005).

2.2.3. Organizing for a Project

Organizing for a project is significantly important as relationship between participants, responsibilities, duties and authority are defined.

As most projects are dynamic, a few organizational structures can be used together over the project lifecycle. These organizational structures define the relationship between project personnel and consider project team, project interfaces, matrix organizational structure and responsibility matrix according to required principles. Project team establishes the relationship and communication between the project manager and the other team members (Burke, 2003). A project team centered on the project manager is illustrated in Figure 2.4.

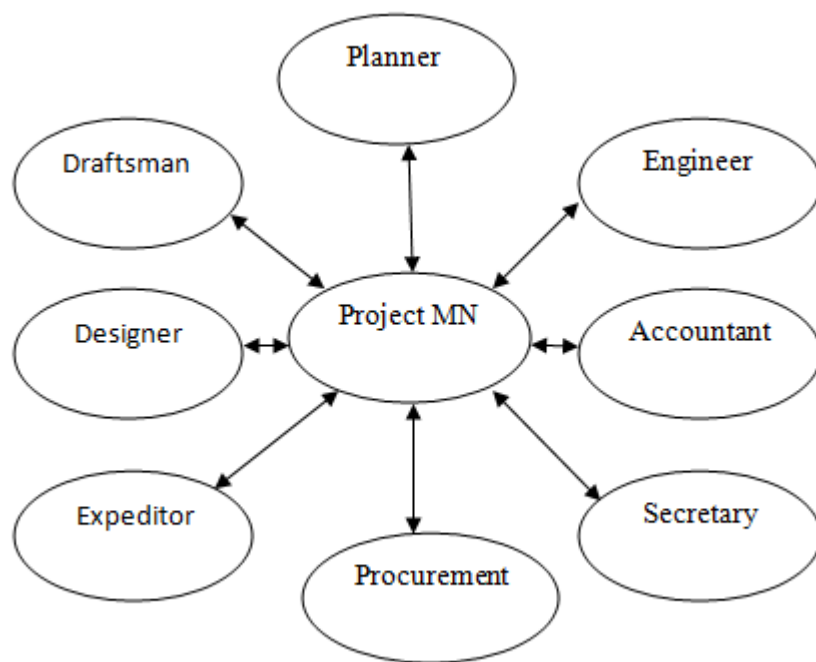


Figure 2.3 “Project Team” (by Burke, 2003, p. 285)

Organizational structure depends on the type of business that the company is doing, goals and time for the underlying tasks, skills of the relevant employees, responsibilities and so on. For simplicity main types of project organization structures will be briefly discussed.

2.2.3.i. Functional Organization Structure

In a functional organization which is also called traditional organization structure disciplines are divided into separate departments with a vertical hierarchy. Figure 2.5 demonstrates how particular functional departments are under the authority of general manager and reporting to him/her.

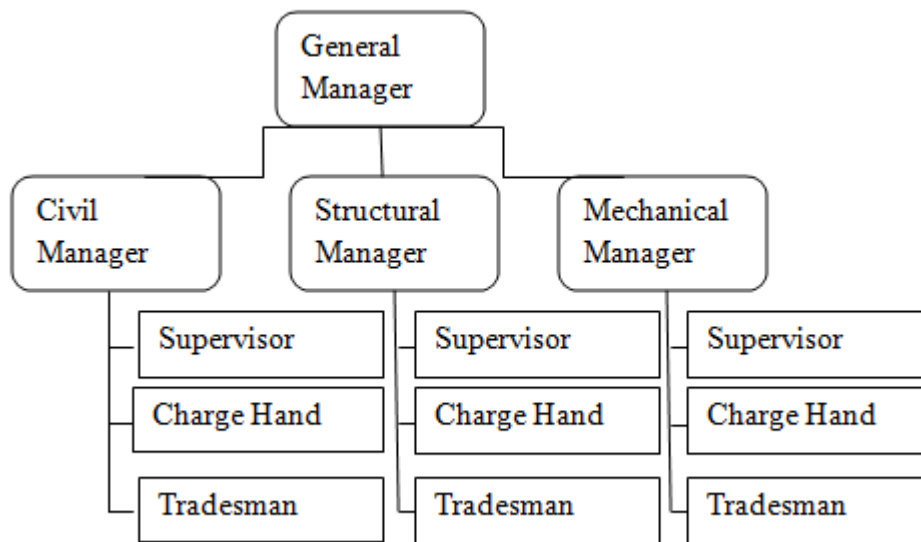


Figure 2.4 “Functional Organization Structure” (by Burke, 2003, p. 288)

Functional departments offer the advantages of technical expertise, good support, easy communication, quick reaction time, simpler and easy management and flexibility inside the department as responsible people can switch from one work to another easily. However, it is not effective for multi-project environment and complex projects. First of all as there is no project management role general manager should deal with co-ordinating, linking and all other enterprise issues. Second, lack of communication lines between departments prevents easy problem-solving and decision-making. In addition to these, responsibilities are not well defined, and lack of interaction between departments is not suitable for multi-disciplined scope of work. Matrix organization structure addresses the integration problems (Burke, 2003).

2.2.3.ii. Matrix Organization Structure

In this type of structure project manager is the single point of responsibility and responsible from the project completion within a budget. The project manager communicates with the functional managers for task accomplishment and provides the coordination between functional units and functional managers are responsible

from employees and task assignments in their departments. Thus, it integrated the WBS with the Organizational Breakdown Structure (OBS).

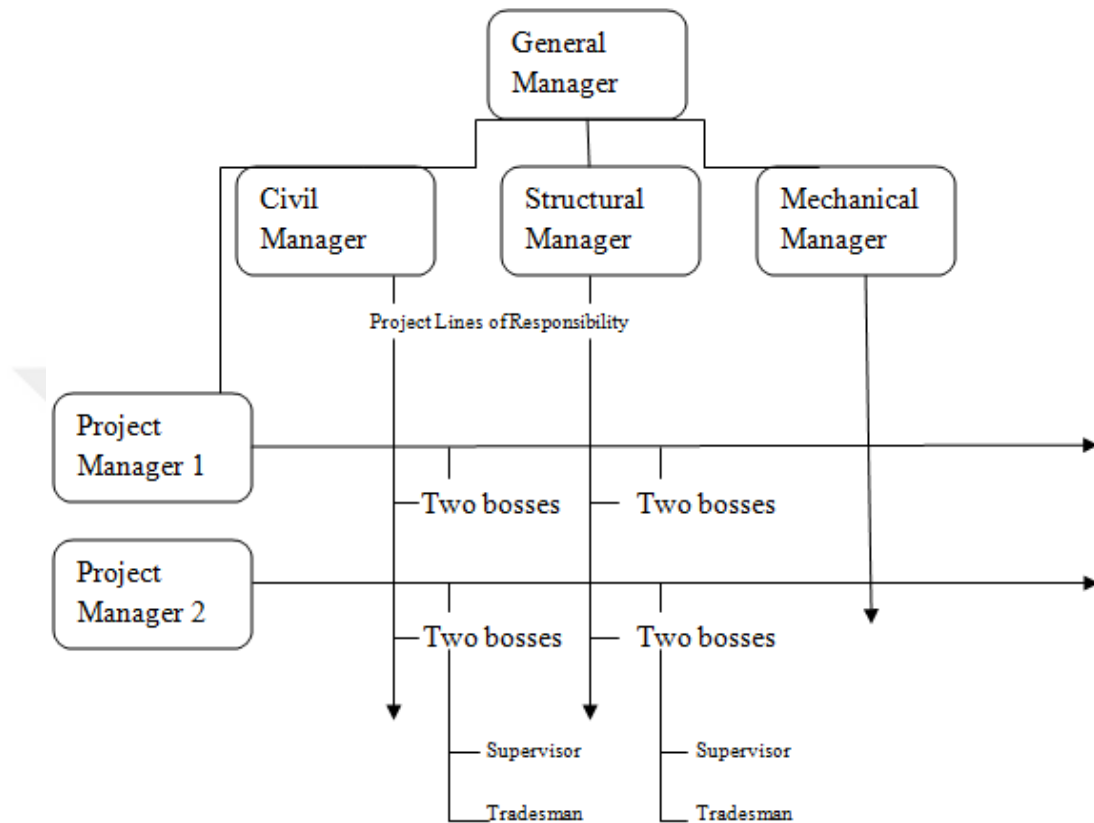


Figure 2.5 “Matrix Organization Structure” (by Burke, 2003, p. 290)

2.2.3.iii. Project Team

A critical project which requires long time duration and full-time efforts of special skilled members can be directed by a project team. Particular employees are given the responsibility for the project and project tasks are allocated to project members. Project team is separated from the company with its own management structure and budget (Shutub, Bard and Globerson, 2005).

2.2.3.iv. Co-ordinating Matrix

Project manager which is called project co-ordinator, progress chaser or expeditor coordinates the resources and activities within the functional departments. The co-ordinator communicates with functional managers and drives the project. However, as co-ordinator is usually in junior position, limitation of his/her formal authority delimitates managing the project, controlling resources and decision-making. In order to overcome this, a coordinating service can be established and project management processes can be performed with integrating particular communication and personal skills (Burke, 2003).

Based on the project characteristics discussed above such as uncertainty, risk, complexity, and organizational structure requirements, managing them becomes a more challenging and difficult issue. Integration of science, experience and skills should be provided so as to complete the project successfully. Project manager is responsible for these various efforts and disciplines to accomplish the project goals. Since people from different departments and various backgrounds may come together for the project, communication and organization of many interrelated tasks conducted by people require special attention and effort.

Because of the reasons expressed above for describing and communicating the planned activities, and providing relationship between multiple activities tools, techniques and methodologies should exist to guide the project leader (Shutub, Bard and Globerson, 2005).

A computer-based scheduling and monitoring system is usually essential. Network techniques such as critical path method (CPM) and program evaluation and review technique (PERT) are likely to figure prominently in such systems. CPM was developed in 1957 by J.E. Kelly of Remington-Rand and M.R. Walker of Dupont to aid in scheduling maintenance shutdowns of chemical plants. PERT was developed in 1958 under the sponsorship of the U.S. Navy Special Projects Office, as a management tool for scheduling and controlling the Polaris missile program.

(Shutub, Bard and Globerson, 2005, p.15)

Early attempts were about developing and providing specific techniques that address difficulties in only particular project activities. They concentrated on different problems in project management. Several techniques for allocating of resources, project budgeting, controlling and scheduling were introduced. For example, Gantt

chart and the Critical Path Method (CPM) are among the techniques that were developed to deal with scheduling issues. Some of these techniques are explained in detail in the sections that follow.

Hence, despite the fact that each technique is capable of overcoming certain problems, they are only useful in handling specific processes in project management. For instance, scheduling techniques are not capable of addressing problems in configuration management.

It is critical to combine these techniques so as to assist decision-making processes throughout the project life cycle in order to interpret dynamics of the project environment. That being the case, a methodology is vital to support the management of projects (Shutub, Bard and Globerson, 2005).

Charvat (2005) states that a methodology consists of a set of steps and procedures to accomplish the completion of a project. In project management context methodology is considered another word of project life cycle and the set of principles that the methodology includes can be adapted to particular situations.

According to Charvat (2005), some of the project management methodologies or models focus more on details on system design and development whereas others focus more on a generic approach. When the projects require technology development such as new product development and software development projects approach how to manage this kind of projects should be chosen carefully. Methodology offers a guide for choosing the level of project management attention suitable to a specific project which sometimes called the degree of ceremony. According to project risks, goals and characteristics it is vital to adapt project management techniques and the degree of the ceremony for each project. Heavy methodologies require high degree of ceremony, where light ones include a few or no ceremony. Complexity of the project determines the approach that is used. Thus, project manager's role is significantly important in determining which methodology to apply for project management. Eighteen of these project management approaches and their comparison can be summarized as illustrated in Figure 2.7. These methodologies and some techniques that they use are discussed thoroughly in the following section.

Description	Suited to control of:				Phases	Project Size	Comments
	S	Q	T	\$			
Project Management Frameworks Methodologies							
Rational Unified Process	Y	Y	Y	Y	Y	M, L	1, 2, 3, 4
PRINCE2	Y	Y	Y	Y	Y	M, L	4
System Development Life Cycle (SDLC)	Y	Y	N	?	Y	S, M, L	3, 4, 6
Solutions-based Project Methodology	Y	Y	N	N	Y	S, M	3, 5
TenStep	Y	Y	Y	N	N	S, M	5
Technology Development Management Methodologies							
The "Agile" Group:							
Extreme Programming (XP)	N	Y	N	N	N	S, M	5
Scrum	N	Y	N	N	N	S, M	5
Crystal	N	Y	N	N	N	S, M	5, 7
Dynamic Sys. Development (DSDM)	Y	Y	Y	?	Y	S, M	5
Rapid Applications Development (RAD)	Y	Y	Y	?	Y	M, L	5
Unicycle	Y	Y	Y	Y	Y	S, M, L	4
Code-and-fix Approach	N	N	N	N	N	S	7
V-methodology	Y	Y	Y	Y	Y	M, L	4
Waterfall	Y	Y	Y	Y	Y	M, L	4, 6
Open Source	N	N	N	N	N	S, M	5
Spiral	Y	Y	N	N	Y	M, L	4
Synchronize and Stabilize	Y	Y	N	N	Y	M, L	
Reverse Engineering Development	Y	Y	N	N	Y	M, L	4
General Publication Methodology	Y	Y	N	?	Y	M	4, 8
Structured System Analysis & Design	Y	Y	N	N	Y	M, L	4
Pramis	Y	Y	Y	Y	Y	M, L	4
Offshore Development	Y	Y	Y	Y	Y	L	4
General Drug Development	N	Y	N	N	Y	L	4
Classic Building Construction	Y	?	Y	Y	Y	M, L	4

Comments:

1. Y, N, ?: Yes, No, Undetermined
2. S, M, L: Small, Medium or Large projects
3. Arguably an IT/software development methodology, i.e. belongs under Technology Management
4. High management ceremony
5. Low management ceremony
6. Classic "waterfall" sequence
7. Not suited to virtual teams
8. For book and periodical publishing

Figure 2.6 “Comparison of various methodologies from a project management perspective” (by Charvat, 2003, p.5)

Over the past decade there have been changes and movements in risk management, scheduling, structure, project team coordination, control, impact of new technologies and process-based management areas of project management. More advanced up-front methodologies for risk assessment have been developed and for scheduling

new approaches such as critical chain project management seem to introduce new improvements. Critical Chain Project Management (CCPM) is different from traditional approaches such as PERT and CPM and seems to offer improvements to solve limitations of traditional approaches. In the structure of project management organizations, there has been an increase both in the use of heavyweight project organization and project management offices. Focus on cross-functional cooperation and the model of punctuated equilibrium which is suitable for intra-team dynamics are the two major improvements in project team coordination. There has been a great enhancement in using distributed and virtual project teams due to internet and advances in internet and web technologies. Virtual project teams facilitate close collaboration for groups that may not have physical interaction. PMBOK (PMI Standards Committee 2000) is process-based project management methodology which combines integration management, scope management, time management, cost management, quality management, human resources management, communication management, risk management and procurement management. All of these knowledge areas cover a series of processes and accomplishment of these processes is vital for that field (Shutub, Bard and Globerson, 2005).

Next section explains PMBOK and some other approaches in the literature by discussing their pros and cons and application areas. Important techniques that assist project management approaches and models are covered and explained as well in the section that follows.

CHAPTER 3. PROJECT MANAGEMENT METHODOLOGIES AND TECHNIQUES

3.1. Project Management Body of Knowledge (PMBOK)

PMBOK is a collection of industry-standard techniques and it is a project management framework. PMI carries on improving PMBOK so as to offer best practices, tools and techniques explaining the accepted sum of knowledge. In addition to splitting the project processes into five phases: initiating, planning, executing, controlling and closing, PMBOK also defines nine knowledge areas which are previously mentioned.

PMBOK Guide includes techniques and methodologies that are applied more commonly and are believed to be practical for many projects. Hence, it offers a very generic approach to project management, and knowledge and processes that it documents need to be tailored by the project management team for any particular project. Some popular techniques that PMBOK covers are Earned Value (EV) management, Program Evaluation and Review technique (PERT) and CPM (SE Project, 2004).

PMBOK offers users the advantages of a unified project management methodology and provides necessary knowledge to carry out the project. Key areas of project management that are not included in some models such as people side of projects, procurement, contract administration and cost control are documented in PMBOK, and it shows how to interpret quality plans and use them in project management (Bell, 2010).

However, although it is capable of teaching the subject content of knowledge areas, it is difficult to manage a certain project by using the guide as it is too generic and several project management methods and techniques are not described in detail. Thus, consultation to specialized texts is necessary so as to acquire all the exact details (SE Project, 2004).

3.2. Critical Chain Project Management

Critical Chain Project Management (CCPM) was introduced by Goldratt (1997) as an application of theory of constraints to project management and project scheduling. Its major focus is on scheduling and it is different from traditional project management approaches using PERT and CPM. Traditional methods estimate time of individual activities with including provision for contingencies. All these individual activity buffers become a project buffer in critical chain. Due to accumulation of the total contingency reserve and taking the contingency reserves away from individual activities, time required to finish the project can be decreased. It gives chance for making realistic estimates to project team members, and people sharing expectations on activity durations try to achieve the realistic estimates (Steyn, 2002)

CCPM specifies the critical chain rather than the critical path as the project constraint. This path includes resource dependencies, and does not change during project execution. It uses 50% probable activity times, and aggregates allowances for uncertainty of estimates and activity performance into buffers at the end of activity chains. CCPM uses buffers as an immediate and direct measurement tool to control project schedule and it defines the constraint for multiple projects as the constraining company resource. It also seek to change project team behaviour; encouraging reporting early completion of activities and elimination of multitasking.

(Leach, 1999, p.39)

Depending on the fact that team members deal with activity padding less and task accomplishment more, even summing 50% of the saved time importantly eliminates the total project schedule. Even though the delivery date cannot be met (as it is the case most of the time) 50% of the time, total impact on project duration is eliminated on account of the downstream aggregated buffer. This method can be instrumental in dealing with tasks that are not on the critical chain as well. Feeding buffers are placed for the activities that are on noncritical chain so as to handle all feeder path activities (Shutub, Bard and Globerson, 2005).

It has been a topic of a debate as to whether critical chain is an effective discipline or not. There is no doubt that it is successful especially in overcoming limitations of traditional techniques and case studies in the literature prove its success. However, according to critics due to nonexistence of milestones in critical chain project

management approach, coordinated scheduling especially with suppliers is affected negatively (Shutub, Bard and Globerson, 2005).

Despite of the limitations above, CCPM is still capable of being effective in different types of projects and it is suitable for both large and small companies. It can be all used in construction, software development and high technology R&D projects (Leach, 1999).

3.3. Project Lifecycle Models

3.3.1. Waterfall Project Lifecycle Model

Winston W. Royce presented the Waterfall model in 1970 as an IT system development type model which brought procedural approaches and controls for IT project management tasks. Waterfall model has its roots on manufacturing and construction industries in which requirements are defined early in the project and phases are not revisited. Waterfall model is considered as a classical and traditional project lifecycle model which system design is divided into a set of sequential stages. Each phase has particular goals and one phase cannot start unless the previous one finishes. Due to this kind of structure there is no overlap between phases and each phase in the project lifecycle is considered to be impossible to reverse which offers a set of discrete phases (Hass, 2007). Waterfall model is illustrated in Figure 3.1.

Waterfall Model

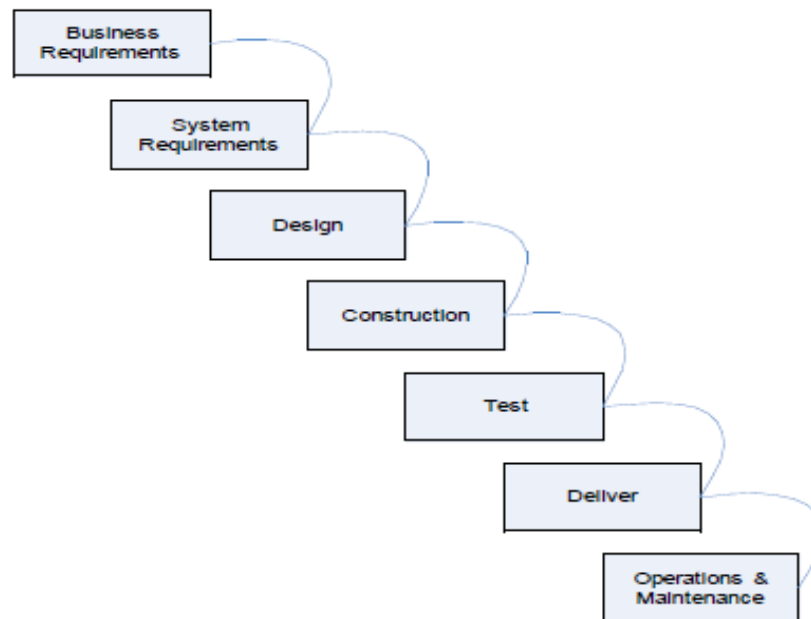


Figure 3.1 “The Waterfall Project Lifecycle Model” (by Hass, 2007, p.1)

The model is advantageous as it is easy and simple. Activities can be followed phase by phase and complexity is eliminated. Besides, it facilitates quality management by means of justification and confirmation steps. Justification and confirmation steps which each phase includes provides inspection so as to check whether the task carried out in that phase matches with goals and done properly.

Nevertheless, model is not capable of providing a prescribed technique for the control issues in project management. Planning, controlling and risk management are not included in the model and it is complex to approximate cost and time for each stage. If requirements change, it may take long time to complete the project lifecycle.

Even though the limitations above, this traditional model can be suitable for projects which reworking is least or not required. For example construction and some manufacturing projects can be carried out by using waterfall model. Due to its simplicity it provides cost and time saving in the case of right application when project is unvarying in nature and is not changeable.

If the system requirements cannot be defined at the beginning of the project and it is predicted that project will undergo a significant number of changes, spiral model which is another project lifecycle model can be useful (Bista, 2010).

3.3.2. Spiral Project Lifecycle Model

In dealing with IT projects it is quite difficult to be incapable of being affected from changing requirements as they are different from classical projects. For instance, in a construction project the specifications of a building that will be constructed can be defined before the implementation and after a certain point of design it is very costly to change some features and specifications. In contrast, in software development projects if some vital changes and specifications are combined after a major part of the project is tested and installed then much better results are obtained.

Spiral model demonstrates an iterative approach for management of software development projects. Definition of requirements continues during the project lifecycle and this provides to contribute more knowledge and experience to another step of requirements definition. Number of iteration cycles should be planned according to time required to finish the product. Thus, it is essential to keep communication between stakeholders and team members (Project Management Knowhow, 2010).

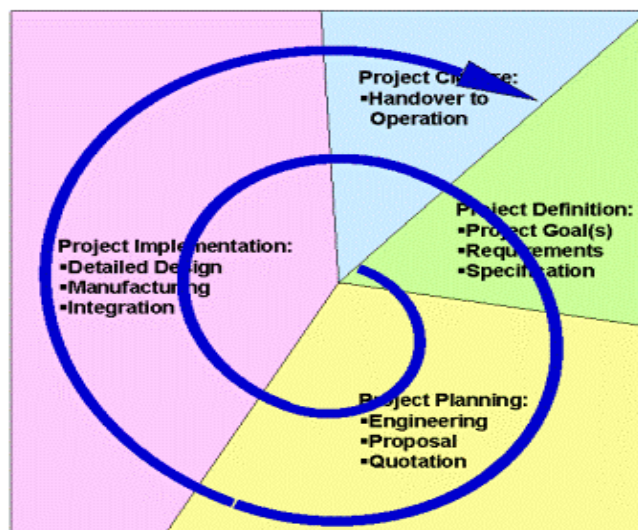


Figure 3.2 “Spiral Project Lifecycle Model” (by Project Management Knowhow, 2010)

Depending on that spiral model is appropriate for risky projects and changing requirements, it has become common for the management of aerospace, defense and engineering projects. Due to conservativeness of business projects and their nature of dealing with definite issues, this model has not totally penetrated into this field (Sorensen, no date).

Incremental release model and prototype model are other project lifecycle models. Project management methodology is formed when project lifecycle model is combined with the ideas of project processes. Project lifecycle's phase include certain processes and the collection of processes form the project management methodology (Shutub, Bard and Globerson, 2005).

3.4. Agile Project Management Approaches

There has been a growing interest in describing a theory of project management that is capable of dealing with more complex and uncertain project management environment due to new economy and changing conditions. Fernandez and Fernandez (2009) support the views of Koskela and Howell (2002) on underlying theory of project management is out of date. Basic theories of PMI's PMBOK depend on the transformation view of production and three theories of management: management-as-planning, the dispatching model for execution and thermostat model of control. In managing uncertainty and complexity, new components such as focus on flow and value generation in addition to transformation, participation of management-as-organizing for planning, the language/action perspective for execution and scientific experimentation model can be included.

For instance, Scrum is such an agile project management approach and representing an extensive project management model with including the disciplines mentioned above.

Fernandez and Fernandez (2009) present the William's (2005) research to state that traditional approaches of project management (including PMBOK) can be unsuitable for projects that are complicated, uncertain in nature and should be accomplished in a limited time. On the contrary, agile project management approaches have lots of benefits to offer for this type of projects.

There are different agile models in the literature, and Scrum, extreme programming, DSDM and Crystal Clear are among the most popular ones. Although agile project management offers different methodologies with different strategies, agile proposes the following generic processes and disciplines.

Initiation: Project initiation starts with the definition of project scope and vision. Then it is important to pick up the right methodology and catch high level requirements rapidly.

Redefinition of roles: This activity requires defining the role of customer and general purpose developer

Planning: Planning includes lifecycle, project plan, timebox plan and estimation processes. Lifecycle in agile means timeboxes groups into releases and project plan is then formed by allocating requirements in timeboxes. Team creates the timebox plan and estimation is done by developers (Thomas, 2010).

Control: Control is provided by means of product quality releases and by co-location of team members. Daily team meetings and visible charts contribute to control the project processes. Change management is facilitated by requirement tradeoffs.

Quality: Applying quality in a continuous manner is critically important and peer reviews such as pair programming is instrumental in quality issues.

Besides, risk elimination by process utilization, simple design creation and thinking deeply on processes are other disciplines that agile project management approaches incorporate (Thomas, 2010).

3.4.1. Scrum Project Management Model

Scrum which is an agile project management model has been used since 1990. It is known as a hyper-productivity tool which has been proposed to enhance efficiency and productivity in teams formerly suffered from heavier methodologies.

Scrum includes principles such as sprint, backlog, sprint backlog, product backlog and scrum. Sprint means time spent on a set of activities to accomplish a deliverable which is usually 30 days time period or less. Backlog comprises all work with well

defined requirements that will be carried out in the future that can be foreseen. Sprint backlog and product backlog incorporate activities that should be done during the current sprint and activities that should be done for the entire product, respectively. Scrum is the name of the daily meetings that the progress of the work and the handicaps are discussed (SE Project, 2004). Figure 3.3 illustrates the workflow of the Scrum.

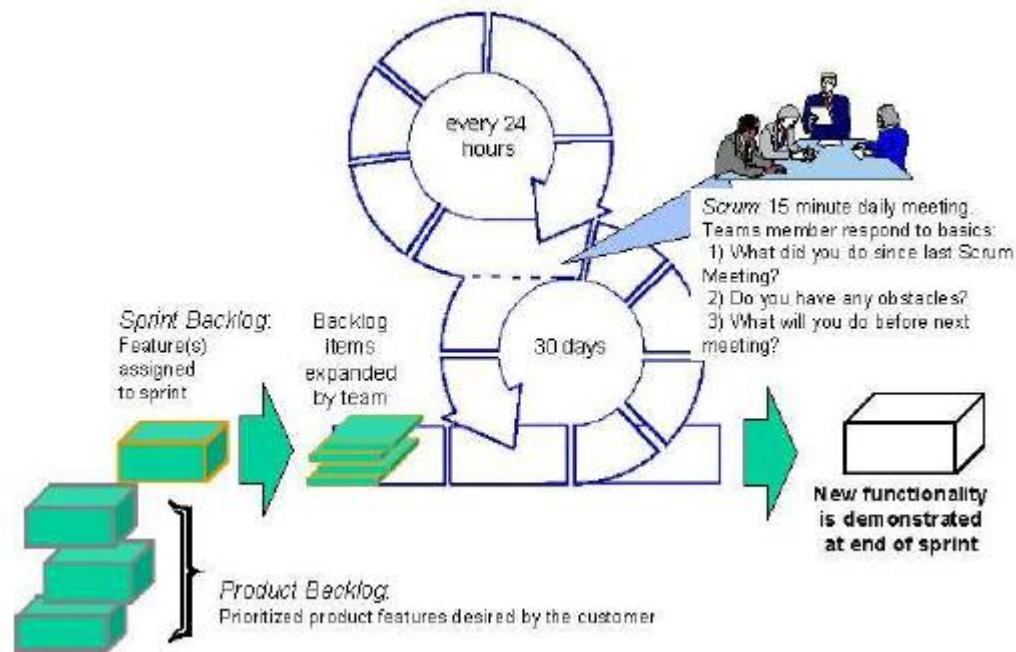


Figure 3.3 “The Scrum Workflow” (by SE Project, 2004, p.18)

Scrum is an iterative, incremental process for developing a product. It works by first defining a backlog of things that need to be done: this list is usually maintained by one person. Other interested parties can request things to be put on a backlog. For each sprint a subset of the backlog is chosen to be done. During the sprint the team will only work on the things that are in the sprint's backlog to keep people focused and creative. Each day of a sprint there is a Scrum in which the team members respond the following questions: What did you do since the last Scrum meeting? Do you have any obstacles? What will you do before the next meeting?

(SE Project, 2004, p. 18)

The leader of the sprint is Scrum Master who is responsible from overcoming limitations that the team experienced. This provides the team to focus on the task only.

Although, management and customer may participate to Scrum meetings they are not allowed to participate conversations between team members and Scrum Master. After each sprint the work has been done so far is evaluated and a new sprint backlog

is created which integrates the results of the last sprint and modifications to requirements. Team empowerment and adaptability are major disciplines in Scrum model. Team has the great part of responsibility and they interact with management only to inform about the progress of the work and to report things that should be taken care.

Scrum is used for software development projects and for efficiency team size should be small. Scrum offers flexibility by evaluating the processes between two sprints and making changes. As there are no outside factors affecting the Scrum sprint team can keep concentration which improves creativity and productivity. However, lack of management participation may be disadvantageous sometimes. Management have to trust team members heavily which necessitates very skilled and qualified members. Another shortcoming of this approach is that it does not guide for the engineering part of the product and this engineering methodology should be defined by the team. Hence, it makes Scrum work better when combined with any other models (SE Project, 2004)

3.4.2. Extreme Programming (XP)

Extreme programming is a software development methodology which includes the management of software development projects and its major goal is to eliminate risks in this kind of projects. Specifically, its focus is to eliminate the cost of postponing design decisions as implementing changes to a software project can be costly at the later stages of the development.

XP is considers that the project is formed from releases. The first release is to create the first working version of the product. The following releases improve the functionality of the project, alter behaviour and fix bugs. Time interval between releases change from one to three months and each release is split up to iterations which last in one or three weeks.

All requirements are not defined at the beginning of the project. Project starts with a release plan. In order to define the requirements user stories which are written by the customer are used. User stories comprise features and specifications of the project and can both be written at the beginning or during the execution of the project. Based

on the user stories a release plan is developed and team identifies the cost of each story which generally should be one, two or three programming weeks. Stories should be combined or divided according to estimated costs to ensure that they have appropriate cost. After that, releases are formed by dividing the stories. Stories are used to estimate release dates or according to arranged release dates stories can be split up. Accuracy of estimates improves during the course of work (SE Project, 2004).

At the beginning of each iteration, customer chooses stories from relevant release based on their importance to identify the ones that will be implemented in that iteration period. Stories are divided into tasks so that they can be assigned to particular members for estimation and implementation. This model encourages learning by providing experience acquisition from iteration and release estimates and thus contributes to do more accurate estimations in planning phase (SE Project, 2004).

XP is considered as a lightweight approach and it is suitable for small-to-medium-sized teams (approximately 10 people) which work on software development projects in a highly changing environment. The model fits to projects that do not have clear or changeable requirements because of the fact that, it divides the project into lots of small cycles. Small cycles principle gives opportunity for easy and fast modifications to planning as it facilitates separate planning for each cycle.

This model is capable of being easily shaped and some piece of product can be released quickly and used by the customer. It can also be improved and developed depending on the feedback from users. One obvious limitation of this approach is that its success depends on the proper involvement of the customer which can be quite difficult when customer does not accept to allocate an employee to work in the project team (SE Project, 2004).

3.5. Project Management Techniques

3.5.1. Work Breakdown Structure (WBS)

Work Breakdown Structure aims to divide the scope of the work so that each task can easily be managed and assigned to relevant department or person. For efficiency similar activities are grouped together and complexity is reduced. Subdivision of the work provides expressing quantity of the overall work as a list of tasks and it a fundamental technique in terms of expressing the scope of the work. Structure, methods of subdivision, numbering or coding system, level of detail, number of WBS levels, roll-up and integrating WBS/OBS to assign responsibility are the main components of WBS. Structure, design methods or level number vary according to project characteristics and the one that works well for the project is chosen (Burke, 2008).

Graphically in boxes and text indents are two ways of demonstrating WBS. However, the best way of presenting is graphical subdivision of the project scope into boxes as it is easy to understand. Following figure represents a WBS divided in boxes.

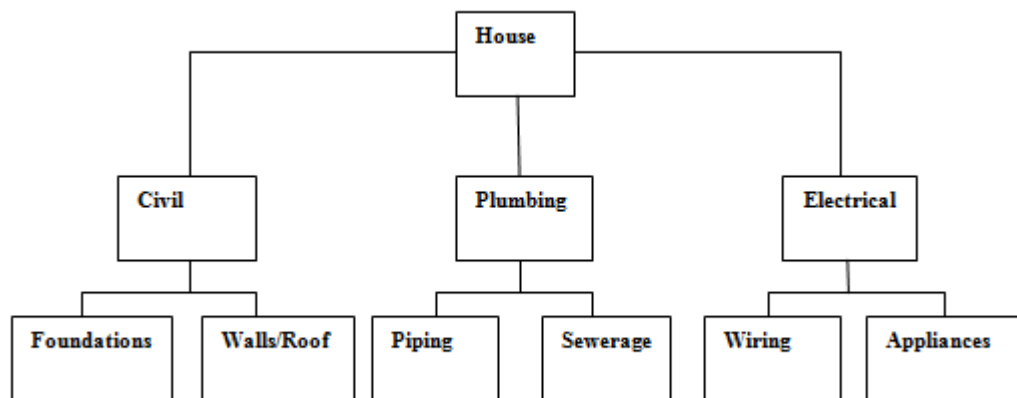


Figure 3.4 “House Project WBS Subdivided into Boxes” (by Burke, 2008, p. 116)

According to project characteristics, method of division into tasks can also alter. Product breakdown structure (PBS), organization breakdown structure (OBS), cost breakdown structure (CBS), contact breakdown structure (CBS), location breakdown structure (LBS), system breakdown structure, and project life cycle

structure are among sub-division methods and more than one can be used during project execution.

In the case of defining number of WBS levels which represent subdivided scope into more tasks with more detail, required level of detail, risks of the project and required degree of control should be taken into account. For instance, if there is high degree of risk and uncertainty, WBS can be subdivided into more detailed tasks to supply information (Burke, 2008).

The numbering system WBS facilitates is very useful as all components identified in a unique manner by numerically and logically combination of work packages to project schedule, resources or any other accounts can be done easily.

Moreover, with combining WBS and OBS, responsibility matrix can be obtained showing who is responsible from a particular task. However, as the detail increases presentation of the matrix can be quite difficult (Burke, 2008).

3.5.2 Program Evaluation and Review Technique PERT

At the end of 1950s, a development team was formed by the US Navy incorporation with Lockheed Aircraft Company and consultant Booz Allen & Hamilton in order to develop a planning and control system to manage a large scale project about Polaris Submarine development system (Burke, 2008).

PERT technique implements statistical handling over a possible range of activity duration with offering a three time probabilistic analysis model. Pessimistic (p), optimistic (o) and most likely (m) time durations are used by model and normal distribution of durations calculates the expected time of the activity. Figure 3.5 represents the probabilistic analysis of PERT.

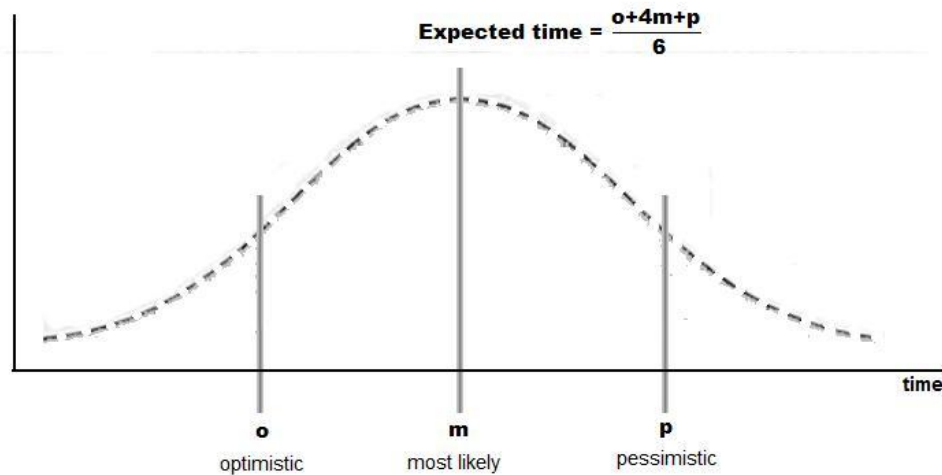


Figure 3.5 “PERT Three Time Probabilistic Analysis” (by Burke, 2008, p. 19)

In practice one would estimate around the most likely time. The optimistic time would be slightly shorter, if everything went better than planned. While the pessimistic time would be extended if everything went worse than planned (late delivery or a machine breakdown)

(Burke, 2008, p. 19)

As a result of achievement in the Polaris Submarine project, PERT started to be used as a planning technique in many large organizations since Polaris Submarine project’s success at that time was thought to be associated with PERT.

None the less, PERT has limitations that have been experienced during the utilization of the technique for various projects. These factors are found to limit the effectiveness of the PERT. One of them is time estimation done according to project manager’s own views, and the other one is the need for overmuch effort in the case of estimating each task duration separately. Besides, the time estimations are frequently undervalued resulting in failures in meeting the deadline or budget overruns due to increasing resources so as to meet the deadline.

However, especially in milestone planning it offers benefits to users by facilitating simple planning and providing sub-contractors to be in charge of accomplishing their key dates. Moreover, as PERT uses a probabilistic approach for the estimation of time durations, it is better at handling projects which have altering time durations than the deterministic critical path method (Burke, 2008)

3.5.3 GANTT Chart

Gantt chart was developed by Henry L. Gantt as a project scheduling and controlling tool and it is the most commonly used management tool. Activities carried out are demonstrated by numbers on the vertical axis of Gantt chart, whereas their associated durations are represented on the horizontal axis. Activities can also be scheduled according to early-start or late-start logic. With regard to early-start approach, each activity is started as early as possible without breaking the precedence relations, and according to late-start logic each activity is postponed as much as possible during the time that the earliest finish time of the project is not exposed to danger (Shtub, Bard and Globerson, 2005).

After implementing combinations of early-start and late-start a range of schedules is created on the Gantt chart, and earliest finish time of the project is obtained by carrying out the early-start schedule. Earliest finish time then represents the necessary finish time for the late-start schedule.

In order to create the late-start schedule based upon the earliest finish time, each activity is changed position to the right up as much as possible. Slack or float of an activity is the difference between the start or finish time of an activity represented on early-start and late-start schedules (Shtub, Bard and Globerson, 2005).

Activities without slack are named critical activities, and critical activities linking the start and end points of a project is named critical path which shows the longest path of the network. Critical activity delays cause project delay, and total duration of critical activities is known as the shortest time that the project can be completed. An example of a Gantt chart for a new product development project is represented in Figure 3.6.

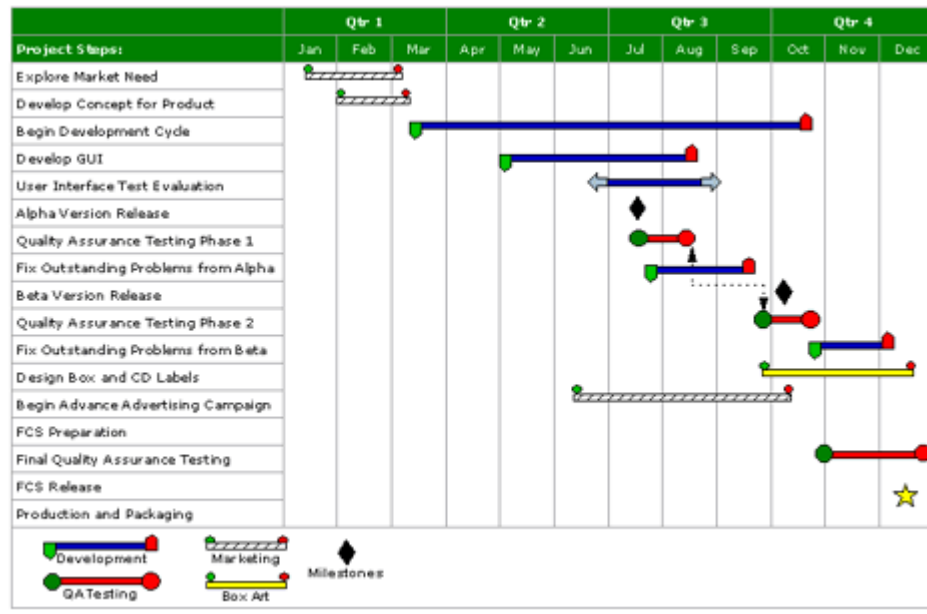


Figure 3.6 Gantt chart for a product development project (by Smartdraw, 2010)

As shown in the figure Gantt charts are easy to interpret and can easily be constructed. Gantt chart usually includes the tasks defined in the WBS, and milestones which can represent project commence or critical design evaluations are scheduled together with tasks. Gantt chart can be altered according to project status and budget status of tasks can also be included by using the appropriate feature.

In addition to budget status, many different features of Gantt chart showing the project status in a more detailed manner can be used. One widely used property is changing bar charts with lines and putting triangles so as to mark revising times and point out project status. However, modifying the chart with adding features can be ambiguous and difficult to interpret. One significant drawback of Gantt chart is its ignorance of task dependencies and time-resource exchanges which necessitates Gantt chart to be used in conjunction with network techniques to complement these drawbacks (Shtub, Bard and Globerson, 2005).

3.5.4. Critical Path Method CPM

Tasks required to be accomplished in a project are sequentially organized on a directed acyclic graph and critical path method functions on this graph which is known as project network. An example of a project network is illustrated in Figure 3.7

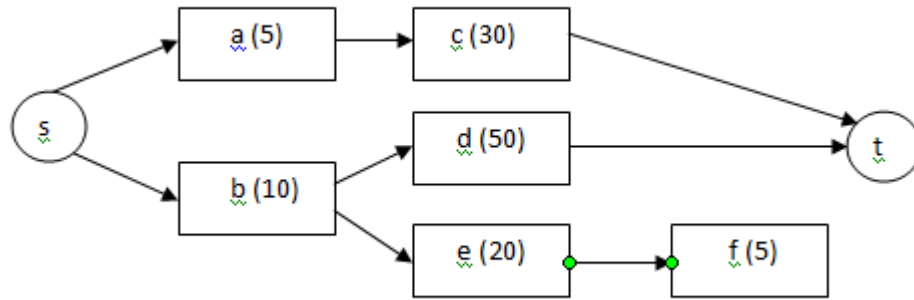


Figure 3.7 “An example of a project network” (by SE Project, 2004, p. 32)

Tasks linked through a project network are components of a work breakdown structure, and project network graph indicates the order of various tasks required to be accomplished by demonstrating task dependencies. Each task is allocated a cost exhibiting its completion time and critical path is the longest path from the beginning of the project to its finish. Projects’ duration is its total cost in time which is the shortest time interval that project can be accomplished. According to graph on Figure 3.7, projects’ critical path is (s, b, d, t) representing a cost of 60 days. Delay of the activities on critical path results with project delay and these critical activities do not have slack which means there is no way to delay these activities. Activities having slack can be postponed with the time slack describes (SE Project, 2004).

CPM is appropriate for task scheduling of any project. Nevertheless, it is more capable of handling routine activities. Depending on the fact that, certainty and accurate estimation is significantly important for the task durations when uncertainties exist task durations cannot be indicated properly. Thus, reality of the model is lost when the level of uncertainty between task dependencies increase. In

order to achieve a trustable analysis, existing task dependencies should be apparent (SE Project, 2004).

Notwithstanding, CPM is suitable for projects that are not ambiguous and it is simple to use. It facilitates the critical activity identification and slack estimations for non critical activities.

CPM is a commonly used technique and various project management tools offer critical path analysis. Microsoft Project, PlanBee and Open Plan are among commercial project management packages that support CPM (SE Project, 2004).



CHAPTER 4. PROJECT MANAGEMENT FOR NEW PRODUCT DEVELOPMENT

4.1. Background New Product Development Project Management

Buyukozan and Feyzioglu (2004) stated that NPD and innovation are known as key success factors in order to be competitive in various markets. Nowadays, markets are demanding products with great level of quality and performance, and it is required to develop products rapidly with lower cost. Moreover, predictability in the product development phase is highly demanded to achieve best performance.

Buyukozkan and Feyzioglu (2004) showed Goldenberg, Lehmann and Mazursky's (2001) work to state that number of failures in NPD projects and their associated costs are significantly high, and this makes NPD a more complex process needed to be handled carefully.

For NPD projects there is a huge gap between the information that the organization already has and the information necessary to carry out a specific task. Uncertainty in NPD stems from this gap and constitutes the basis of risk. It is a commonly accepted idea that uncertainty management contributing towards eliminating risks in NPD projects is critically important to achieve project goals. Because of this reason, in managing NPD projects, utilizing approaches that are capable of eliminating risks originated from uncertainty is significantly important (Buyukozan and Feyzioglu, 2004).

In order to achieve efficiency in NPD processes, techniques and approaches taking uncertainties into account and bringing a systematic approach to handle them so as to reduce risks have much more benefits to offer these projects.

Case studies are analyzed in the next sections indicate organizations' common tendency in selecting project management approaches and techniques that are promising to achieve this aim. Both in the software and manufacturing new product development projects analyzed, approaches that are more capable of dealing with various uncertainty sources were used.

In the case of software development projects examined through case studies applications that are good at creating flexible processes, handling unknown product

specifications, providing easy modification for plan and design, supporting decision making and providing visibility through project status in order to overcome risks from uncertainties were used, and analyses of these approaches are done in the next section.

4.2. Project Management for Software New Product Development

4.2.1 Case Study 1

This case study examines an innovative software product development project which facilitates e-commerce comprising online customer services and product offers for sale. This kind of software development project was quite challenging for the company as the client company was small and lack of resources to conduct its own marketing and support for the end product by means of e-commerce channels. Besides, client aimed to gain competitive advantage with implementing strategy thorough a high quality and innovative e-commerce environment. Content formation was not only limited to identifying client specifications as market driven conditions should also be examined. Development team had to broaden client expectations with taking competitors' products, market trends and socio-cultural issues into account which required a market driven approach for management of an e-commerce development project (Deakins and Dillon, 2004).

After making critical evaluations of Information Systems Development Methodologies (ISDM), linear models were not found appropriate for the e-commerce development project because of eliminating team's capability of embodying requirement changes, and resulting ambiguity problems. Depending on their past experience with spiral model and its relatively better complexity handling nature, team decided to use spiral model.

Notwithstanding the model was capable of handling some modifications in scope and specifications at first, rapid and big scale changes such as firmly combination of external databases, web properties and further developments in online customer services and transactions could not be handled with the spiral model well. Although the aim of the spiral development is to provide contribution of each design task to final product, barely progressing of some design tasks pushed each task to spiral

towards its own completion instead of taking into account mutually dependent components to achieve an end product completion. Non-technical development tasks such as marketing plan activities did not match with cyclical type of development (Deakins and Dillon, 2004).

Thus, company evolved its spiral model of approach to a new one which they called helical model to overcome the limitations above. Figure 4.1 illustrates the new model.

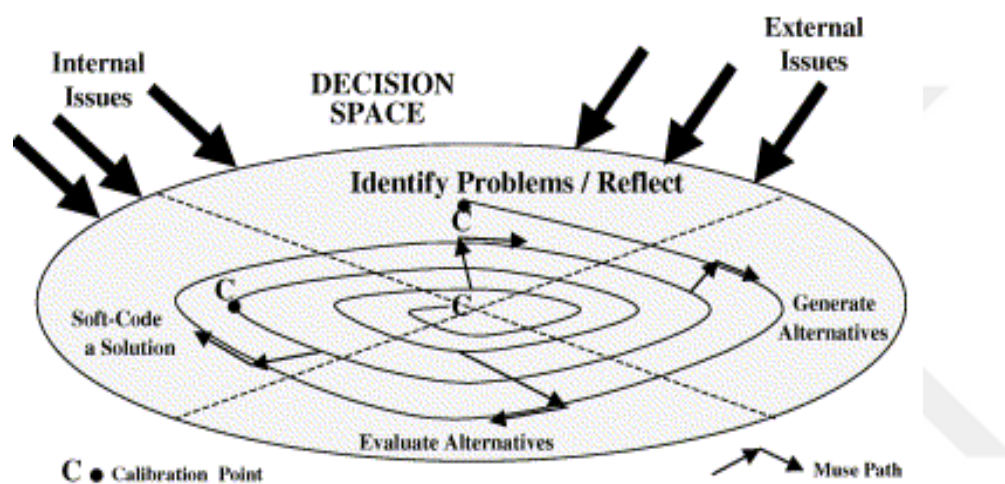


Figure 4.1 “Helical model-component decision space” (by Deakins and Dillon, 2004, p.70)

According to model, a design task and design spiral is surrounded by its unique decision space which is the area for decision-making for project members. With regard to scale of changing conditions this area enlarges or shrinks. It facilitates communication for developer team and environment for overcoming problems and evaluating opportunities in design activities such as design specifications or market appraisal.

After identifying baseline requirements, project activities passed through four steps of: describe limitations/reflect, produce alternatives, assessment of alternatives and a soft-code solution. Assessment of alternatives was done based on the associated decision space criteria, comprising risk analysis. Market risks and technical risks were identified to assist team in decision for the best design alternative and this

procedure gave insight for prioritizing risks, taking preventative actions and developing contingency plans.

Each previous phase provided information to other phase and rapid prototyping was instrumental in examining a business case for suggested design alternatives over the project life cycle which contributed to time savings. In all steps evaluation of emerging design tasks and their suitability with other components was performed (Deakins and Dillon, 2004).

Muse paths which can be seen in Figure 4.1 represent the discontinuities in the progress of work and they are related to unforeseen actions that took place in neighbouring decision space. By keeping record of these activities and design decisions software developers could perform backtracking to previous phases of product development. Calibration points were defined as specific time points for appraisal of progress including several components. This mechanism provided project manager to make necessary resource allocations by using traditional project management software tool (Deakins and Dillon, 2004).

Figure 4.2 demonstrates how helical model progresses and design components' act of travelling.

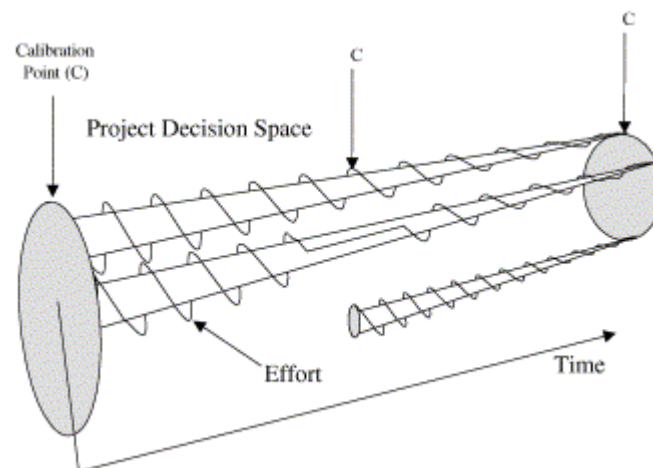


Figure 4.2 “Helical Model-action trajectories” (by Deakins and Dillon, 2004, p.71)

This figure represents only three activities of the process and unlike spiral model, this model considers that there is a distinct design spiral for each main design component with its unique design space.

Using helical model for the development of such an innovative software development project company obtained the benefits of rapid development, capability of making late design changes and creativity which was increased by experimentation as all modifications were reversible. Decision-making based on collaboration and cooperation enhanced project outcome. Besides, prototyping and testing contributed to integrate customer feedback and assessment of new market opportunities. Moreover, it provided project manager a tool for anticipating an innovative project. Concentration on the end product and chance for improving business case rather than struggling with design activities decreased the need for very tight project control. Besides, model was capable of handling detailed design activities and facilitated continuous improvement and learning for team members.

Nevertheless, there were some limitations encountered during implementation. First of all, it did not provided sufficient control tools and it was quite difficult to plan and provide control over a wide range of design spirals for project manager in the rapidly changing environment. However, integration with traditional project management techniques provided to overcome this situation. Other drawback was that because of as developers were depending on the backtrack mechanism they had tendency to delay some challenging decisions and undervalue some important design issues. These drawbacks did not affect the success of the outcome and model can be considered more appropriate for software new product development projects that are highly innovative (Deakins and Dillon, 2004).

4.2.2 Case Study 2

This case study explores an agile project management approach particularly Scrum in a multi- project environment. Scrum provides an iterative and incremental procedure for product development and it is a project management approach which is basically used for software development projects. It is an agile project management methodology which is a relatively new concept in managing complex and ambiguous projects and there is an ongoing trend in utilization of agile methods. Companies like Yahoo, Microsoft and Intel have already implemented Scrum. Specifically, Scrum is on the way of being considered as a de-facto standard in the industry (Marchenko and Abrahamsson, no date).

Nokia's department which is developing software for speech recognition, synthesis and associated fields adopted Scrum model of project management for software product development in a multi-project environment. Development of phone product programs were involved in the case study and Scrum implementation for this type of software product development project was discussed.

Three Scrum teams formed comprising around 20 people and structure of the department can be seen in Figure 4.3

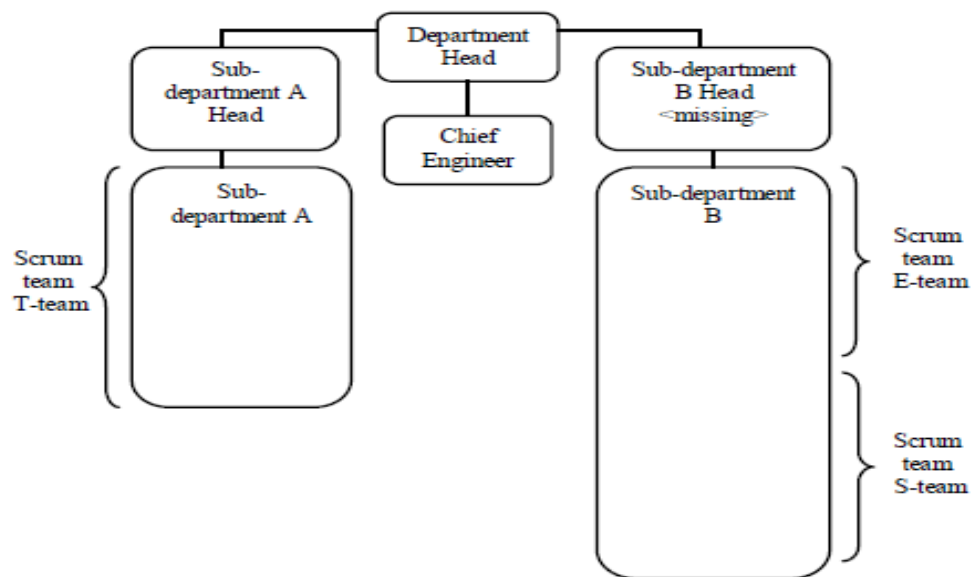


Figure 4.3 “Department structure” (by Marchenko and Abrahamsson, no date, p.4)

Scrum implementation started in April 2007 by the scrum practices of E-team and other departments participated in August 2007. Seven Scrum discipline including Scrum master, Product backlog, Scrum meetings, Sprint and Sprint review were introduced. A Scrum master who is responsible from problem solving and imposing process procedures was attained. After that, Product backlog including well defined requirements and activities that should be carried out during the entire process was created which took a significant amount of time. Each product backlog item comprised a set user stories. Team started to meet daily for only around 15 minutes for the appraisal of work done since the previous meeting and problems they experienced. Sprint planning meetings were carried out to organize and identify the functionality to be developed in the next sprint which is an interval of time for accomplishing sprint commitments. During Sprint periods as prescribed by the agile

principles, only team members were allowed to manage and perform actions, and product owner or Scrum master were not allowed to join or affect the process. Representation of work done to the product owner or to customer in some cases was performed in sprint review meetings (Marchenko and Abrahamsson, no date).

Marchenko and Abrahamsson (no date) stated that Scrum teams experienced some obstacles during the project. When the scrum implementation started in entire department in August, one of the teams discovered that priorities were not assigned to tasks and at the sprint planning meeting product owner wanted some tasks that he just picked randomly to be done. When the entire department backlog was prepared, it was obvious that the department was trying to deal with many development projects concurrently and backlog divided into smaller units. It was discovered that product owner sometimes gave priority to projects that bring more benefit to him/her rather than the entire department.

Another difficulty was observed in the case of social changes necessitated by Scrum. As there were specialized software developers in teams, it was quite hard to provide collaboration of them with team members. Specialized members did not want to participate to estimation and planning periods and they found it meaningless to represent their own work since many people were not able to anticipate improvements.

These limitations did not affect the further implementation of Scrum, since advantages that company gained overweighed the problems mentioned above. Speed of project cycle increased and developers were able to contact with managers more frequently. Company is still using the Scrum project management model which is the main approach to its software product development.

4.2.3. Case Study 3

USSTRATCOM is an interconnected command including members from four departments of U.S. military and its central office is in Offutt Air Force Base in Nebraska. Information functions and processes, strategic warning and defence operations are among department's responsibilities. Department uses a Strategic Knowledge Integration website (SKIWeb) to facilitate information follow and

knowledge share concerning military issues. SKIWeb system aids communication in military environment by offering a command and control system. Department decided to develop a new software product for the enhancement and support of the system (Fruhling, McDonald and Dunbar, 2008).

Fruhling, McDonald and Dunbar (2008) claimed that traditional plan driven project management methods for software development have been the main support for most of the military services since they are more appropriate to military culture because of its hierarchical organization and are perceived less risky.

Nevertheless, USSTRATCOM discovered that, traditional project management methods for software development due to their linearity and heavy documentation requirements could not cope with the quickly changing operational requirements of military information systems. As spiral methodology attempts in the department addressed the problems particularly, agile methodology was introduced to more simplify the process to increase its efficiency.

Extreme Programming (XP) which is one type of agile project management methodology for software projects was applied with its twelve principles. These principles and their brief description can be seen in Appendix B.

At the beginning of the project, project team was formed comprising a development team, developers, a human factors engineer (HFE) who was in charge of user interface creation and a customer representative who was the government functional manager. Apart of government functional manager all project members were from an outside contractor (Fruhling, McDonald and Dunbar, 2008).

Meetings were performed on daily basis between developers and user collaborator, and weekly basis between project team to evaluate the progress of the work and report it to customer representatives.

After the identification of the user stories which included the features of the software that would be developed, release plan was created. Release is a piece of software comprising a set of stories. The first release was determined to be the advanced search capability, and it divided into four iterations. Although, each iteration was planned to have two weeks delivery time, iterations were able to be completed in three weeks cycle time still representing a short delivery cycle. Other functions built

on this first release providing continually enhancement by means of user feedback. XP implementation was successful in the aspect of customer satisfaction and produced a high quality product with a small number of defects (Fruhling, McDonald and Dunbar, 2008).

Not defining entire requirements at the beginning of the project and small size planning impacted to deliver the project in a shorter time without extra rework and problems. Having the releases in every three weeks, customers were able to test the software and give feedback to development team for further improvement. Due to splitting the product into small cycles and planning individually, changes were easily reflected to plan and continuous improvement provided. Increasing the reactivity to change, made the project more resistant to changing internal and external conditions, especially in the case of environments tending to change.

Fruhling, McDonald and Dunbar (2008) stated that a few limitations discovered during the project execution, one of which was the extra time spent on unrelated tasks as developers had to work on some other projects they were assigned. Besides, new specifications had to be added to user interface and human factors engineer (HFE) was not available at that time to assist development team for scope changes.

Nevertheless, as the project process, status and orientation is transparent by means of extreme practices and meetings management is capable of foreseeing. Thus, for certain situations like distraction of developers with unrelated tasks, management can participate more to practices to keep the team operating. Furthermore, providing appropriate ways of gathering all project members including experts at the proper time may get the collaboration better of.

When collaboration and communication is improved, it is more likely to get full benefit from XP and undoubtedly, in addition to eliminating the burden of conventional planning and documentation, it decreases risks in software product development projects.

4.2.3. Case Study 4

This case study represents a successful implementation of agile Scrum methodology for managing a new software product development project for a remote customer. Project was implementation of a series of new features to increase the functionality of an existing web portal comprising social network components.

Project was difficult as it necessitated thoroughly analysis of business requirements and understanding of software requirements. Furthermore, knowledge transfer with regarding to existing product's functional capability and work needed to be conducted joined with the remote customer team caused a more challenging process.

In order to provide rapid communication between teams, to ease combination of project deliverables with customer's and to offer a visible project management practice Scrum project management model was chosen (RobinLab, 2007).

In addition to product development Scrum team, a quality assurance team was assigned to start exerting effort on project by establishing close contact with customer and business analysts for making the requirements clear and for developing test documentation. Knowledge gathered through appraisal of business requirements and project documentation was passed on development scrum team for project implementation.

Project team divided the project scope into releases so as to occur every month and releases were further divided to short weekly phases. New features were built on release iterations demonstrating an iterative and incremental planning procedure. In Scrum meetings conducted after each iteration, performance of the processes was discussed and potential improvements were identified for the next sprint.

Product was driven to market two weeks before the scheduled time which was fourteen months after the project initiation and it was consistent with the existing software. Increased number of service users which was reported by client's marketing department indicates the high quality of the developed software product. Planning the work well in Scrum perspective and tight cooperation impacted to achieve the results above (RobinLab, 2007).

4.2.4. Sectional Summary and Analysis

Four of the case studies examined above indicate organizations' demand for high quality solutions for their software product development practices in volatile and unstable environments. Companies attempted to implement more creative models for their project management practices under time constraints to handle uncertainties better and decrease risks.

In the cases of e-commerce software development and strategic knowledge integration website development projects, attempts for linear models and spiral project management model indicated the necessity of advanced and more lightweight methodologies for software development. One common problem in software projects is difficulty in content creation which requires tight collaboration between team members and between customers in most cases. Besides, case studies demonstrated that all projects underwent considerable scope changes needed to be reflected to plan. Helical model used in e-commerce software development project handles this by its decision space mechanism, which includes the period of description of limitations, creation and assessment of alternatives for each design task. Allowing a time period for assessment of alternatives and facilitating experimentation and prototyping indicates capability for incorporating customer feedback and late scope changes. Assessment of alternatives performed through a risk analysis for each task impacts to value generation by facilitating the determination for the best alternative. Moreover, communication between team members is enhanced by means of assessment periods and decision space mechanism.

Scrum and Extreme programming agile project management approaches also demonstrated high capability of coping with scope changes and enhancing collaboration. In Scrum, user feedback and assessment of work done in sprint meetings contributed to modify the building of the project and facilitate integration of scope changes between iterations. Extreme strategy is similar to Scrum with its iterative cycles, and it alters the scope according to feedback from iterations. Short planning cycles are another discipline that contributes towards easy scope and requirement adjustments.

In the case of collaboration enhancement, both Scrum and XP demonstrate high performance due to their prescribed regular and systematic meetings, activities, and social and organizational changes that they offer.

Accommodation of continuous improvement and enhancement of learning of project members are another common characteristic of models used in these case studies. Short planning cycles and altering the work or specifications with regard to feedback and frequent status meetings provide learning for project members in Scrum and XP. Helical model also facilitates continuous improvement and learning with its prototyping and examination of alternatives tools. Providing learning is critically important as it gives the power of acute observation for uncertainties and chance for better handling them in the future.

The level of insight into the time ahead requirements increases because of processes' transparency which alleviates the burden of project manager and provides opportunity for improvement of operations. Despite the fact that, models all specify collaborative activities as a necessary procedure, if the activities and meetings are not conducted properly with full participation of all members on time benefits coming from collaborative work cannot be obtained.

Specifically focus on people, flexible processes, easy modification, scope alteration mechanisms and capability with unknown product specifications are significantly important in IT product development projects. Despite the planning, management, activities, documentation and procedures may be altered in various approaches, they should be all capable of offering the critical factors mentioned above. Software NPD models in the way of achieving efficiency should be mentally quick and able to be modified easily to provide flexibility and adapt changing environments.

4.3. Project Management for Manufacturing New Product Development

4.3.1. Questionnaire Results

Question_1. Project Management techniques that are currently in use in the company:

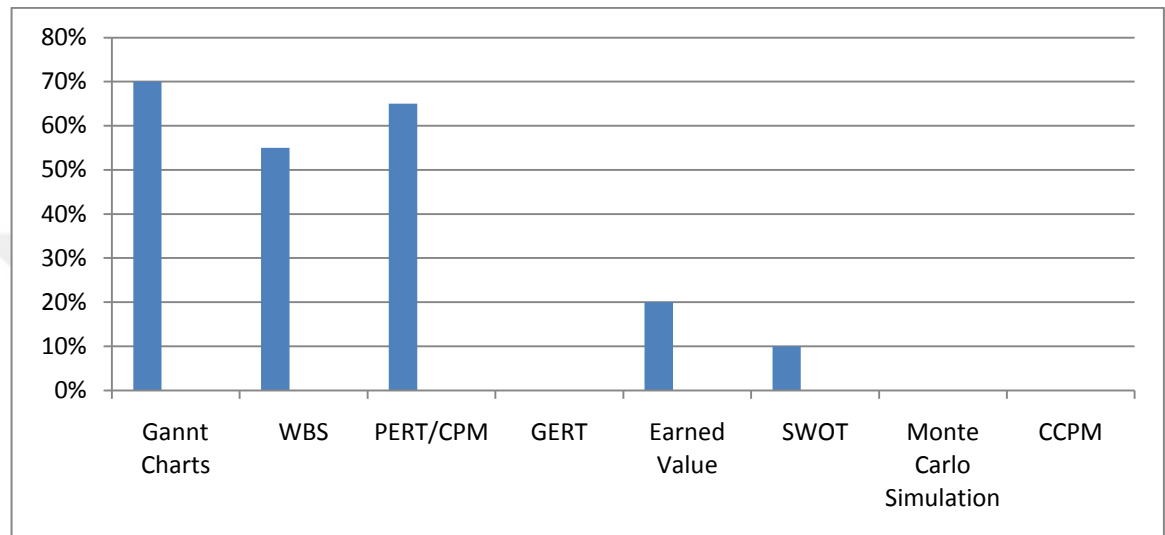


Figure 4.4 Project management techniques in use

As Figure 1 shows, the most widely used project management techniques are Gantt charts among respondents. Approximately 65% of respondents reported that they use PERT/CPM for their projects and around 55% of project performers utilize WBS. None of the respondents claimed that they use Graphical Evaluation and Review (GERT), Monte Carlo Simulation and CCPM in their practices.

Question_2. Approximate percentage of projects with delays in deadline over a five year period:

The categorization was done as follows:

- A: %75- less than %100
- B: %50- less than %75
- C: %25- less than %50
- D: 0- less than %25

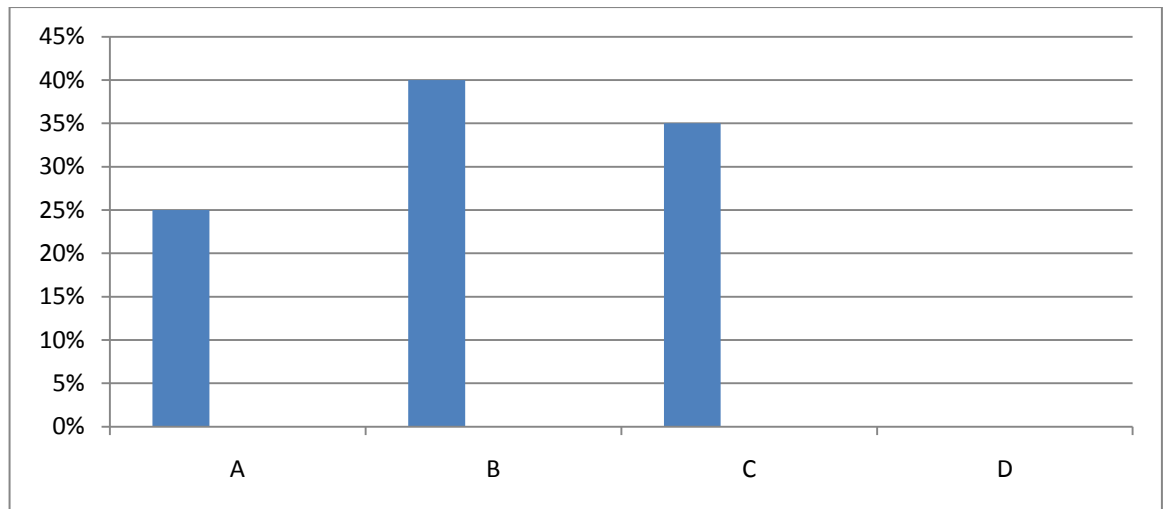


Figure 4.5 Approximate percentages of projects with delays in deadline over a five year period

All companies claimed that more than 25% of their projects per each five year period could not meet the deadline. Among companies 25% of them reported that more than 75% of their projects were not capable of satisfying the deadline, which is a significantly high number. The Figure demonstrates that 40% of users reported that between 50% and 75% of their projects they experienced delays regarding to project deadline. As a result, all companies seem to suffer from time overruns.

Question_3. Drawbacks of the project management techniques in use:

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	2	3	4	5

Respondents assigned values from 1 to 5 for each following factor:

- A: Insufficiency for complex projects
- B: Inaccurate time estimates
- C: Inadequate planning
- D: Incapability in controlling and monitoring project over duration
- E: Insufficiency in predicting problems
- F: Resource scarcity due to inefficiencies in resource allocation
- G: Difficult to conduct multi projects

H: Insufficient communication mechanisms

I: Incapability of handling scope changes

J: Employee tendency of spending safety times embedded in tasks

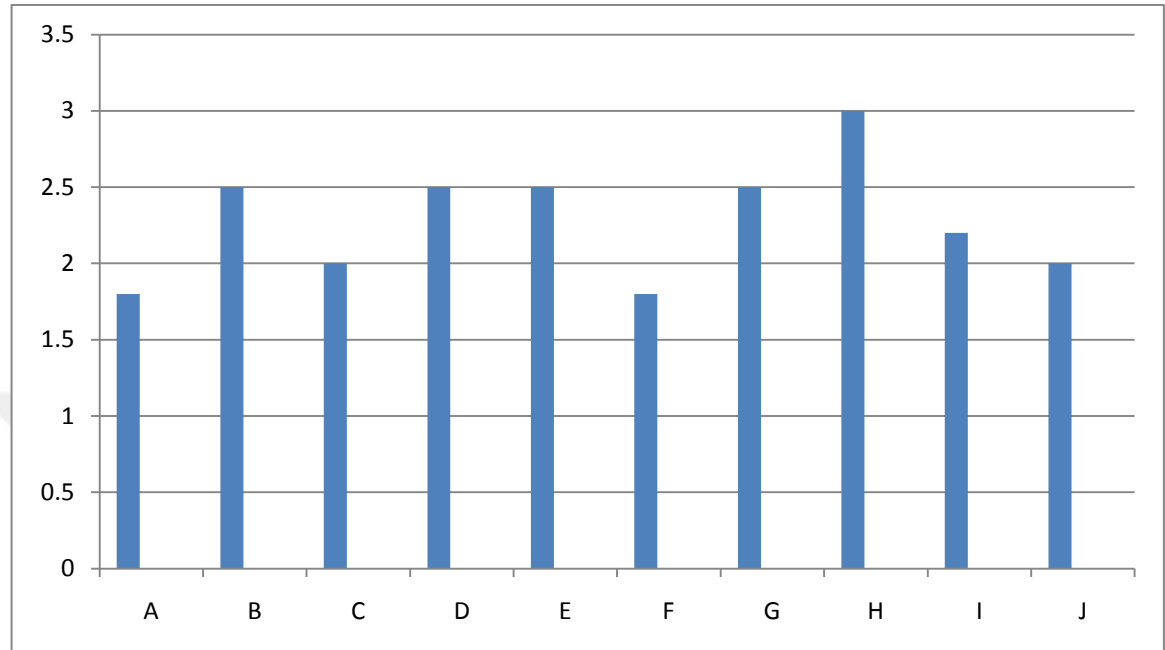


Figure 4.6 Drawbacks of project management techniques in use

Depending on the fact that average value of each factor represents respondents overall tendency in considering a factor as a drawback in their project management experiences, changing values between around 1.8 and 3, indicate that all users agreed that they encounter limitation factors defined above. Insufficiency for complex projects and resource allocation problems were the factors that respondents showed slightly more tendency towards strongly agreeing.

Question_4. Factors that may enhance and improve performance of project management practices:

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	2	3	4	5

A: Improving communication between project members through regular meetings and increasing involvement in planning

B: Effective resource allocation mechanisms

C: Realistic and reliable project schedule

D: Improving concurrency through multi project pipelining

E: Effective monitoring and feedback mechanisms that give insight to management

F: Better defining of roles and responsibilities of project members

G: Integrating mechanisms for capturing complexities and interdependencies of projects

H: More effort can be spent on preliminary analysis for workflow planning for decreasing and anticipating complexities due to dependent activities

I: Spending more effort on risk management activities

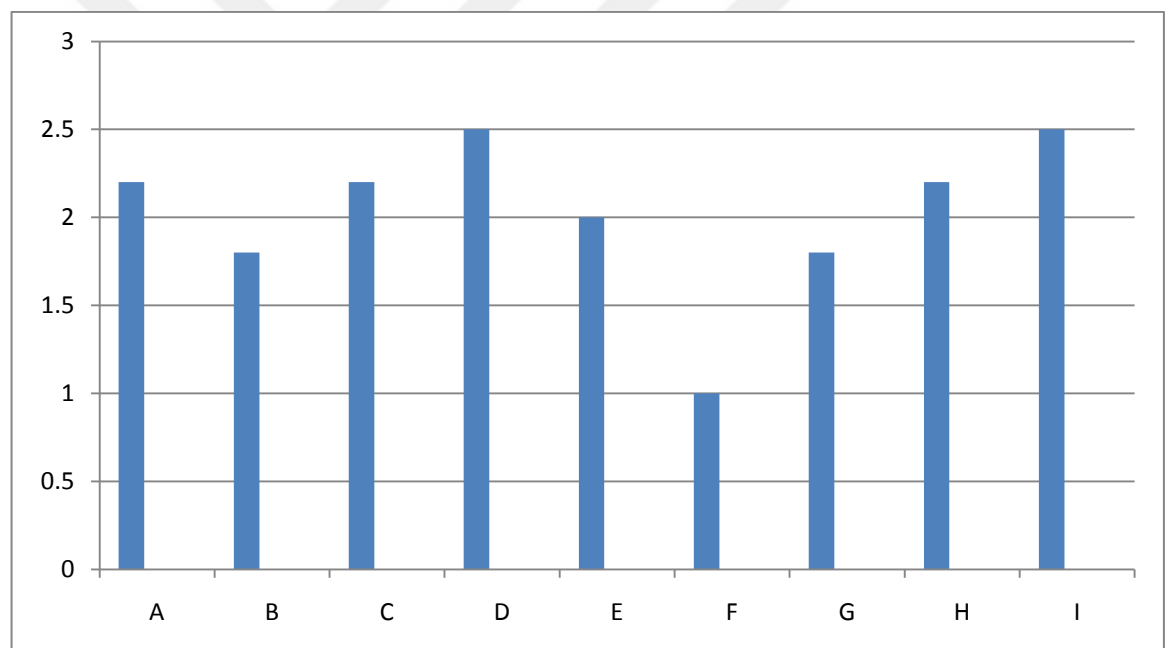


Figure 4.7 Factors to enhance performance of project management techniques

As Figure 4.7 illustrates, respondents strongly agreed that defining roles and responsibilities of project members may have noticeable effect on the efficiency of project performance. Figures varying between 1.5 and 2.5 exhibit the agreement of respondents to all other factors that may have increase efficiency.

For instance, integrating mechanisms and tools for anticipating dependencies, better workflow planning tools and risk management activities have significant potential to improve practices.

4.3.2. Case Study 5

The organization that is investigated in this study designs and manufactures consumer products which include fairly large engineering production activities. Main product of the company is dishwasher and this case study represents what kind of project management approach they used for the development of a new product.

PMBOK approach together with MS Project software tool was chosen as it is one of the most conventional and common approach. Besides, it is easy to have feedback and support in the case of implementation due to easy access to its practitioners (Pons, 2008).

Because of uncertainties due to characteristics of NPD projects a high-level WBS was developed. Since high-level work breakdown suggestion of PMBOK comprises five stages including initiating, planning, executing, monitoring & control and closing, forming such a detailed WBS for this type of project was quite difficult by using generic PMBOK.

Activity modelling was conducted by means of MS Project which produced the necessary critical path and Gantt chart. Gantt chart, which is demonstrated in Figure 4.8 provided a guide for defining and distributing responsibilities, developing the organization chart and identifying workloads (Pons, 2008).

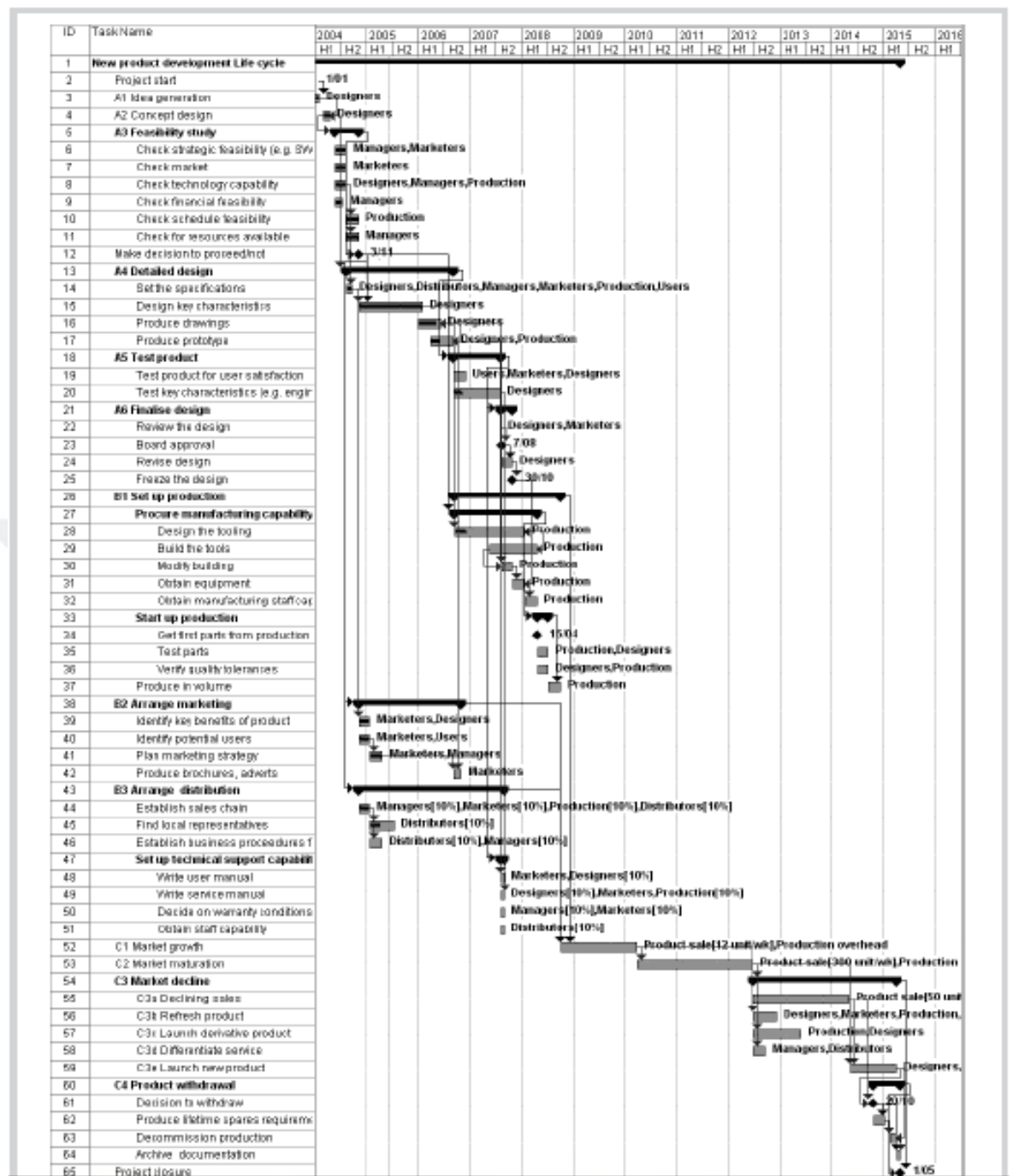


Figure 4.8 “Gantt Chart for project, showing the phases of the lifecycle, the resources, and the schedule” (by Pons, 2008, p.92)

Pons (2008) claimed that during the implementation some limitations were encountered. First, too much effort was put in the development of WBS because of uncertainties in scope definition. In addition to this, complex interconnected activities that occurred during the design phase caused rework activities and scope changes which impacted the reality of the plan created by MS Project. Plan and

schedule were not capable of adapting changes well and accurate duration estimates could not be performed. In addition to this, as product development was carried out as multiple projects, there were difficulties in managing resources between projects due to resource paucity and project management software was not able to support this function. In the matter of controlling, as accuracy was lost because of changes, part of the work completed according to schedule could not be measured properly.

PMBOK's scope management did not provide a good guide for the company because of complexities such as uncertain scope and its generic approach to product development. Depending on that PMBOK is lack of disciplines such as organizational culture, team dynamics and leadership, social and behavioural aspects and collaboration could not be met well by this approach (Pons, 2008).

For this project PMBOK provides an incomplete guide that needed to be supported with particular tools and techniques. MS Project and traditional PERT/CPM techniques does not take resource availability account and complex interrelated activities and task dependencies cannot be handled properly.

4.3.3. Case Study 6

The company which the case study examines its project management approach is in Shanghai, China and designs and manufactures mobile phones. In order to enhance product development performance, to decrease product development lead time company focused on the internal structure of the product development process. Traditional project management techniques PERT/CPM were not capable of handling iterative product development process due to not taking iterations into account and company applied a dynamic development process model for managing overlapped iterative product development (Lin et al., 2008).

Overlapping means downstream activities start before the completion of upstream activities and upstream development errors in the product development are revised with regard to feedback from downstream activities. Company needed to compare time decreased by overlapping with cost and time increased because of rework activities. Model considering the dynamics of rework probability and activity

duration simulates the continuous upstream evolution and its impact on downstream rework by means of system dynamics approach (Lin et al., 2008).

When overlapping policies were identified, impacts of these policies were tested for the three different types of development projects. As can be seen in Figure 4.9, project performance changes according to different levels of overlapping.

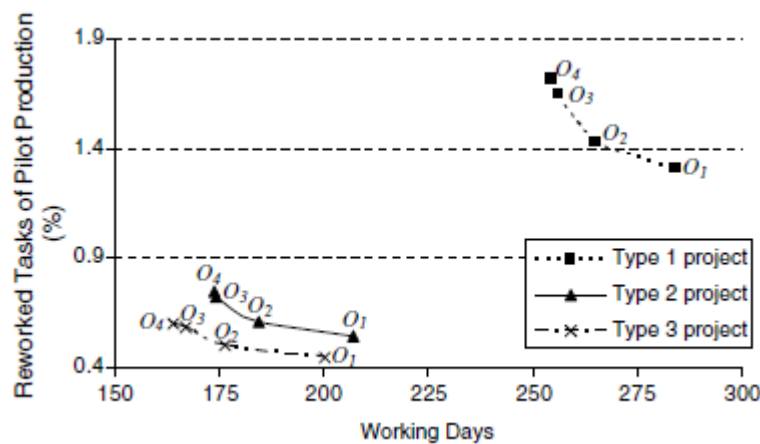


Figure 4.9 “Project Performance with different levels of overlapping between design and pilot production” (by Lin et al., 2008, p.388)

Based on results suitable policy that would be applied to that particular project was chosen. For instance O2 can be applied to project 1, whereas O3 can be more suitable for second and third type of development projects. This model started to be implemented in company in June 2004 and after the application of the model average product lead time decreased by %30.

Major strength of the model is that, in the case of complex and iterative product development, it is instrumental in giving insight to management for measuring the impact of different policies on project performance as overlapping strategies are prone to project uncertainty. However, resource allocation issues were not considered in the model, and delay that may be caused due to using resources for rework for a particular project could not be included by using the model which affects the accuracy of analysis (Lin et al., 2008).

To sum up, case study demonstrates the importance of modelling NPD projects by considering iterations and overlapping affects is significant to deal with uncertainties

for this sort of projects. Model decreases the side effects of uncertainties and contributes speed of new product introduction processes. Notwithstanding the model is capable of handling dynamics of activity completion time and rework issues in contrast with PERT/CPM that disregards iterative processes, ignoring resource allocation analysis which affects the duration of activities is the shortcoming of the model.

Besides, delay in some other projects was observed. Lack of proper resource allocation mechanisms limits conducting the development projects as multiple projects manner, which is the most common way of conducting new product development projects.

4.3.4. Case Study 7

Abbott Diagnostic Division (ADD), which is operating in UK designs and manufactures health care equipments such as diagnostic instruments and monitoring machines for indicators of health that are used worldwide. At the end of 90s, company questioned efficiency and productivity of its project management approach for new product development projects and by comparing actual business results, company came up with a conclusion that it is not capable of achieving project management efficiency. Major problem was the significantly long project delivery time. Depending on that their strategic decision-making was based on project schedule was making their business decisions incapable (Brandt, 2003).

Based on the many world-class organizations are supporting the CCPM approach and increasing acceptance of the approach as a best-in-class model encouraged company to attempt implementation. Company after consulting to various organizations advocating the adoption of CCPM approach, it embraced CCPM for implementation and ProChain Software which is supporting the CCPM techniques was chosen. In contrast to the company's previous methodology that included provision contingencies at the individual task level for time estimates, a project buffer aggregating the whole provisions was used and inserted at the end of last activity in critical chain approach (Brandt, 2003).

According to this mechanism when duration of a particular task was less than the 50% estimate, savings are added to the project buffer, and when duration is more than this value time is drawn back from buffer.

In order to get full potential from buffers some behavioural changes were adapted. For instance, starting the task as soon as possible after the previous task finishes instead of waiting for the scheduled time was provided. Controlling of the project status according to completed level of work was performed by means of measuring the project buffer status each week. To sum up, overall focus of the implemented project management approach is the following:

It creates an environment in which global requirements are linked with physical reality and behaviour changes result in consistent critical chain project timelines that are combined into a multi-product pipeline model. In this way, the reality of activities “in the trenches” is captured in realistic individual project timelines, which feed the multi-project pipeline, and eventually this reality is reflected in the strategic plan. Stated another way, this system ensures that the strategic plan is meaningfully translated into the work defined by each project timeline’s individual tasks.

(Brandt, 2003, p.20)

Brandt (2003) stated that in the implementation phase company experienced some difficulties. One major obstacle was the organizational resistance to new approach which was triggered by the difficulties in planning. Sizing buffers due to interrelated activities associated with complex structure of the developed products made planning more challenging. In addition to this, behavioural changes required to adapt the technique. Heavy training and education were given to staff to provide rapid handoffs of tasks and to facilitate quick communication between members to evaluate possible task delays and create contingencies so as to improve project timelines. Despite of these obstacles, company got benefit from increased on time and delivery, enhanced sales and profits, improved visibility, control and quality. For instance, according to data, among 33 new product development projects that were scheduled by this approach, 15 ended one to three months early, 12 ended two weeks early and just 6 ended one month early.

4.3.5. Case Study 8

Segway Inc. is a company in US which was established to develop and manufacture Segway Human Transporter which is a self balancing human transportation device. Company adapted a hybrid project management approach so as to deal with the development of this innovative product.

In addition to complex structure of the product including embedded software, high safety requirements, quality, cost and performance maximization aimed by the company enforced company for a challenging project management approach. Company blended agile and CCPM techniques which is not a very common approach. Content management of iterations was carried out by agile development and iterations implementation was modelled by critical chain scheduling (Gelbwaks, 2003).

Gelbwaks (2003) expressed that company experienced difficulties in using critical chain merely as no specific endpoint was described. Instead of developing a schedule with a specific release date company decided not to market before whole completion. This was important in critical chain approach as project network starts with the endpoint of the product and other activities are defined accordingly. It was quite difficult to create the project network because of ambiguities and product process structure identification required to spend too much effort. However, after the creation of network, critical chain and resource dependencies could be established easily. Instead of tasks, stories reflecting the product specifications were created in the agile perspective. Implementation of stories was performed in parallel manner and buffers were replaced to handle uncertainties. Schedules were developed by group agreement. Team members conversed about stories, and after sizing and identifying the task breakdowns schedule was formed for the story. In the case of buffer management, two meetings were carried out per week to evaluate actual progress against scheduled work.

Segway saved significant amount of time and only after 18 months from initiation product completed. Besides, safety was provided in every hardware system and zero defect was encountered in the embedded software.

4.3.6. Case Study 9

This case study investigates the CCPM implementation in Bosch CCTV Eindhoven in Netherlands. This is the development division of the company and designs digital video security systems such as cameras and video recording products. Over years this market has become more competitive with increasing technology causing more functionality and complexity requirements for new product development projects of this field. In this competitive environment, company aimed to prevent project delays, enhance visibility and predictability, provide realistic schedule and increase number of projects done by same resources.

After consulting and getting feedback from users such as Atos Origin which is a supplier of the company, CCPM implementation decision was taken. After introducing critical chain methodology without software package in 2003 and orientations, in 2004 implementation with Concerto software package was carried out. In 2005, company initiated the other step for the approach and implemented CCPM multi-project pipelining (Dilmaghani, 2008).

Research by Dilmaghani (2008) indicates that in contrast to general buffer sizing approach which specifies cutting the estimates for task duration by 50% and replacing a buffer at the end of the chain which is around 50% of the length of the chain, company used a different approach by first increasing the task estimates by 25% and then sizing the buffer about 34% of the total task durations. Although the schedule was longer than the 50% original method, it was approximately the same with the original schedule plan without buffers.

This reflects the strategy of the company that wanted to preserve the existing product development lead time instead of decreasing it as it was the first practical experience.

Depending on the fact that project developed was large and complex it was divided into subprojects using a common resource pool and the most constraining resource that was shared by many projects was identified. According to principles of critical chain, scheduling of these projects was done so as to optimize resources' capability of being used. Resources were allocated between critical tasks of the project with regard to rate of project buffer consumption (Dilmaghani, 2008).

Buffer consumption rate aids to identify the task which is in risk to meet its due date and to allocate the particular resource to the task of the project although the resource is required by various tasks of different projects at the same instant. Thus, task priorities and resource distributions depend on project priorities and a project task's level of importance. Based on this mechanism, allocation of critical resources between concurrent tasks of multi projects is done based on project priorities which is calculated by the ratio of critical chain percent complete to percentage of project buffer consumption.

However, Dilmaghani (2008) stated that this multi project approach was cancelled in the company and left to continue its experimental stage due to complexities in the implementation. There were a lot of dependencies between subprojects which project members could not cope with and delayed to use this approach. Then, each subproject was scheduled and implemented in a separate manner. Because of the fact that, chosen software tool Concerto was suitable for multi project approach, not applying it restricted the capability of the CCPM software.

When compared with the company's initial objectives CCPM deployment in Bosch CCTV was successful. Project delays could not be prevented but they were shorter, company gained more insight about the status of the project in terms of time and performance by means of buffer analysis, predictability in promised project due date was enhanced. Early warning system that buffer management facilitates according to buffer consumption status enhanced visibility for discovering problems and taking preventative actions such as assigning resources to critical tasks.

However, the objective of carrying out more projects with the same resources pool could not be achieved as multi project strategy was postponed.

In the implementation phase company experienced some limitations of CCPM. First of all, due to scope changes and occurrence of unpredictable new tasks, replaced buffers were totally consumed as they were not capable of handling these changes. Complex interconnected activities resulted in new tasks and rework. Depending upon it was difficult to predict the size of the buffers because of uncertainties and complexities, re-scheduling and re-sizing of buffers were required to be done in a frequent manner to maintain reliability of the schedule.

Interchanging of resources between tasks when buffer consumption was significantly high was difficult to apply. Besides, despite of working against aggressive duration estimates and putting too much effort to finish a task, early consumed buffers and warning signals in the implementation phase caused decreasing employee morale and motivation (Dilmaghani, 2008).

4.3.7. Sectional Summary and Analysis

In case study 5 use of MS Project with traditional techniques impacted reality of the project plan due to their incapability of handling complex interrelated activities and dependencies. Dishwasher project underwent changes in the scope which could not be reflected in plan and estimates for task durations lost its preciseness resulting delays in project completion. Soft ware (MS Project) was not able to support resource issues in multi project environment and resource allocation was done separately without considering the availability of resources. PERT/CPM's prescription of adding provision for contingencies for each individual task encouraged project members to work for duration of that specific task and consume safety in the task instead of finishing earlier.

Case study 6 examined an application of a dynamic model that considers iterations and affects of rework activities in a mobile phone development company in China. Company's goal was to decrease product development time by acquisition of gain from overlapping activities, and to handle dynamics of activity completion time and rework caused by uncertainties. Approach was instrumental in assisting decision-making for project managers as it gives insight about rework probabilities. Implementation results in the company demonstrated that development lead time reduced. However, as model ignores resource allocation and does not support multi project approach, rework issues that ignore resource constraints prevented model from fulfilling its potential. Delay of other projects in the company is an indication of inappropriate resource allocation mechanisms between projects.

In Case study 7, long delivery time of projects and limitations in scheduling such as decision making dependence on the traditional scheduling provided company to switch its management approach to CCPM. Buffers were sized by 50% cut and paste method and resource allocation at multi-project level was provided. Monitoring and control of buffers were carried out each week. Cultural and behavioural changes in

the company which CCPM necessitates were practiced through training and workshops. Depending on that CCPM requires employees to work against project due date rather than focus on task due date, it was difficult for employees switching to such a mechanism that necessitates too much effort spending. Due to complexity of project structure, planning with buffers was challenging and project network creation was difficult. Nevertheless, company achieved reduced delivery date which is a significant impact of proper resource allocation and proper buffer management policies.

Case study 8 analyzed, used a hybrid project management approach which used agile and critical chain principles together. The product company developed was an innovative product that had never been tried before which increased uncertainties. Project's scope was highly indefinite because of specifications could not be identified completely by users. Even an end point for product development was not defined which led obstacles in critical chain. However, integrated agile principles complemented critical chain in this aspect by facilitating creation of stories instead of tasks and providing an end story for network scheduling initiation. Identification of story details only when they were required for a particular iteration, contributed towards time and resource savings by preventing impacts of specification changes. Significantly short development time of 18 months reflects company's successful implementation which is the result of effective buffer management, high level of collaboration in story and schedule creations with agile integration.

In case study 9, implementation of CCPM for a new camera development project was investigated. Benefits gained through implementation comprise more insight and visibility, shorter delays and enhanced predictability. More insight and visibility means project team is more capable of taking preventative actions when there are signals that project due date cannot be met. Buffer analysis of CCPM provided this by facilitating the use of buffer trend charts and weekly meetings for status evaluation. Depletion of buffers and early consumption signals indicates that buffer sizing issues were difficult. Although buffers were inserted so as to absorb uncertainties such as scope changes and risks, early consumption shows larger size of buffers were required to deal with complexities of the product development. Scope changes and unforeseen tasks that affect the details of the plan impacted on delays of schedule.

However, as delays were shorter than the previous projects' management approaches of the company, time savings was achieved. Based on the fact that multi project pipelining application failed in the company full benefit from critical chain project management could not be obtained and increase in number of projects completed by the same resources could not be provided. It also limited allocation of resources properly. Critical Chain approach's interchanging resources mechanism was difficult to apply which can be explained by the following argument:

In the product development project where mostly high skilled people and the so-called knowledge workers are engaged, the CCPM prescription for interchanging resources is difficult to apply. In practice, as the project progresses, the resource inter changeability decreases. It is then difficult to swap resources when a chain of tasks is started and affinity to the tasks has been developed. The further the chain process, the harder the resource swapping becomes. This is because the original resource has developed a knowledge pool that would need to be transferred to the new resource which takes more time than what is remaining or estimated in the original task.

(Dilmaghani, 2008, p.46)

4.4. Analysis and Evaluation of Results

4.4.1. Comparison between Advantages and Disadvantages of Manufacturing New Product Development Approaches

Case studies and questionnaire results demonstrate that project management planning and scheduling for new product development is challenging because of complex activities which necessitate dealing with great amount of design data, issues about how to sequence interdependent activities so as to prevent design failures. Rework, unforeseen tasks and scope changes are inevitable in product development projects. Thus, in this environment for effective planning and control companies are focusing on improvements to their project management approaches.

Case study 5 investigates a company's traditional project management approach using PMBOK as a guide and scheduling techniques PERT/CPM. Although these traditional techniques are capable of planning and controlling big and complicated projects, they are more suitable for projects with a particular level of uncertainty. These techniques are deterministic and cannot handle changes in time. Results of questionnaire findings and Case study 5 demonstrate limitations and other Case studies represent organizations' tendency to do improvements to their processes by

using different approaches or integrating new techniques to their project management practices.

Traditional scheduling requires adding provisions for contingencies for each individual task and duration of each task is a milestone. Employees focus on finishing their task and they have tendency to spend the safety time of the task as they concentrate to duration of their task. This leads to long delay in project duration. As indicated in Case study 5, critical path does not consider resource constraints, and it is done as a separate activity. All resources are considered as they are unlimited and constraints are disregarded.

MS Project with PERT/CPM is not able to support resource allocation in multi project environment which is a significant obstacle in new product development projects as projects are usually conducted in this way. Due to neglecting complicated interactions, resource allocations control over project duration cannot be provided properly by PERT/CPM. Project management approach implemented in Case study 5 shows that most of the limitations that questionnaire revealed match with the ones analyzed through the Case study.

Models considering overlapped iterative product development with applying system dynamics approach can be applied by companies that want to improve their efficiency and decrease product development lead time. This type of models measure how much the degree of overlapping can be for a particular project by capturing rework probabilities. Rework activities cause more resource and time spending, thus a particular overlapping strategy should offer gain against rework costs. Practical application of the model examined in Case study 6, resulted in decreased project durations in product development projects. Nevertheless, in measuring rework effects they do not take resource allocation into account and they cannot support conducting projects in multi-project structures.

Critical chain and its integrated approaches overcome most of the limitations stated above and offer efficiency for project management practices. Benefits that CCPM bring into project management for NPD mostly match with efficiency improvement factors that companies agreed through the questionnaire.

First of all, specifying a critical chain comprising critical resources rather than critical path with only tasks shows resource constraints are considered in critical chain approach. Besides, because of the fact that critical chain scheduling approach gives opportunity for scheduling interdependent projects that use common resources, it can be predicted how the duration of other projects will be affected by a particular project delay. This is multi-project approach of CCPM. It gives capability for a better resource allocation mechanism, by allocating resources according to criticality of tasks. This approach can also be helpful in making decision about when it is appropriate to introduce a new project to the system by evaluating the status of most constraint resource in the system and other projects' criticality.

However, implementation of multi project mechanism could not be done properly in the Bosch Case study as it required high degree of collaboration and communication together with understanding interdependencies between projects. For instance, there was not only a single constraining resource due to projects' complicated nature. Case study results demonstrate that its applicability changes with regard to different types of NPD projects. It is beneficial and has potential to improve the number of projects carried out at the same time with same resources.

Furthermore, in contrast to making decisions and controlling according to completion time of each task in PERT/CPM, it eases the burden of project management and control by facilitating buffer analysis. Increasing predictability through buffer management and analysis contribute to better manage uncertainties and risks. Thus, CCPM is an effective tool which assists risk management through giving opportunity for eliminating uncertainties with contingency buffer mechanisms. Three different CCPM approaches implemented in organizations studied through case studies provided improved visibility with regard to project status, accuracy for project estimates, decision-making and predictability.

Aggressive task duration estimates, working against project duration and handing out a task as soon as it finishes contribute savings in product development lead time.

However, case study results reveal how different approaches to buffer sizing and management impact on output. They should be sized according to the complexity and uncertainties that a particular project has. Case study 9 exhibits a buffer sizing strategy which was not successful at capturing dependencies, unforeseen tasks and any other uncertainties that cause delay in the estimated project duration. As a result of not properly allocating time to buffers, early depletion of buffers observed which caused decreasing employee morale.

How much benefit obtained through CCPM is also closely related with an organization's way of applying critical chain principles. The degree of achievements in organizational and behavioural changes is significantly important.

Case study 8 represents that critical chain project management can also be combined with agile principles when no end point is defined for product. By means of creating stories instead of detailed tasks provided to spend less effort on project network creation. Extremely short project duration for an innovative project demonstrates the potential of critical chain even when it is combined with agile project management.

One limitation of CCPM discovered through Case studies is that it is not easy to transfer resources from non critical activities to the critical ones when buffer status indicates need for resources. It takes a certain period of time for a team member that is performing a task to pass his/her acquired information to a new person. This time may outweigh the time saved by resource allocation mechanism.

In some cases of CCPM applications, employees resisted to adapt the new principles which affected the efficiency of the processes.

Furthermore, even in CCPM applications product structure complexities could not be addressed properly. Workflow planning was quite difficult and project network creation took significant amount of time. Thus, buffer sizing was difficult because of dependencies in the product structure. The degree of benefit that is obtained from CCPM highly depends on creating an appropriate workflow planning.

CHAPTER 5: RESULTS & RECOMMENDATIONS

5.1. Proposals to Limitations of Project Management Approaches for New Product Development

Complexities and uncertainties limit capability of the project management techniques analyzed. According to analysis through case studies, literature and findings reveal that CCPM is a more robust project management methodology compared to traditional techniques such as PERT/CPM in the case of new product development.

However, it still suffers from risks originated from uncertainties which prevent to achieve its potential. Buffer sizing and management is challenging. When there are dependent activities, rework and new task occurrences due to complex structure of developed product CCPM is affected. Thus, these project management techniques should be integrated with particular tools that are instrumental in anticipating complexity of the product structure and eliminating the uncertainties in the planning process. Decision making, risk analysis and preliminary analysis techniques can be instrumental in capturing uncertainties that affect CCPM to perform efficiently.

According to questionnaire conducted, most project performers agreed that spending more effort on risk management can be instrumental in increasing efficiency. Moreover, they agreed that preliminary analysis for workflow planning for decreasing and anticipating complexities due to dependent activities can be beneficial.

They further agreed that effective resource allocation mechanisms, realistic and reliable schedule, effective monitoring and feedback mechanisms that give insight to management, better defining roles and responsibilities and increasing concurrency through multi-project systems are among efficiency improvement strategies in NPD projects.

Although, CCPM offers most of them, it has still limitations that have to be overcome.

- **Multi-project systems' incapability due to interdependent complex projects**

Specifically, matrix based techniques such as Design Structure Matrix (DSM) can be used to conduct a preliminary analysis and to eliminate uncertainties originated from iterations and dependencies. Since these tools aim to develop a simplified design data with minimized dependencies, they can be useful in minimizing risks in scheduling by decreasing the probability for rework and not expected tasks.

Domain Mapping Matrix (DMM) together with DSM can be helpful to handle complexity and unclearness. They give an insight to product development manager about how to eliminate complexity in product design structure, project flow sequence and design of organization (Danilovic and Browning, 2007).

Depending on that one problem in CCPM is the application of its multi- project pipelining mechanism in complicated environments and it fails when collaboration and communication cannot be provided, DSM and DMM can be useful in this case for overcoming obstacles in CCPM. Use of these techniques aids organizing according to dependencies between project domains in the organization. Application of the techniques at two manufacturing organizations represented in Case study 10 in next section, demonstrates its practicality. DSM and DMM techniques together provided a more robust multi-project structure and more carefully planned communication and coordination among multi projects and organization.

- **Difficulties in workflow planning and problematic buffer sizing processes**

If workflow planning can be done better and complex design workflow can be enhanced, performance of project management planning and scheduling can be increased. Systematic workflow methodologies for making new product development optimal in the aspect of informational structure can be effective tools

for increasing capabilities of CCPM. It is a time consuming to plan the workflow when the product structure is complicated, however with a systematic approach that provides visibility for interdependent activities efficiency can be increased. Iterations can be reduced by reordering method and dynamic information flow among design activities can be identified. After managers can take notice to interdependent activities, their dependency degrees and their potential risks, CCPM can be applied.

By way of eliminating risks stem from rework and unexpected tasks a more accurate scheduling can be obtained. It can be instrumental in overcoming buffer sizing unclearness due to unforeseen interdependent activities by offering visibility to project manager and more accurate time duration estimates can be provided.

Implementation of such a strategic methodology which optimizes workflow by using fuzzy design structure matrix (FDSM) is investigated in Case study 11 (in Section 5.2) and this method proposes an optimal activity planning for workflow. Company which applied the proposed method is OBM international electronic company operating in China. By means of implemented method company obtained an efficient process which is open to change for the development of a new power line adaptor communication. Methodology provided fuzzy evaluation and it was instrumental in determining the dependency degree of activities and bringing order to design tasks.

- **CPM/PERT schedule delay and resource allocation problem**

One significant problem with PERT/CPM according to findings from questionnaire, literature review and case study analyses is the resource allocation problem which does not consider resource constraints and thus causing schedule delays. Besides, when using these techniques frequently resource allocation is done as a separate step and it is based on the subjective perception of project managers. Objective methodologies that give opportunity for optimization of resource allocation to prevent unexpected schedule delays can assist project managers by providing effective decision support tools.

For instance, benchmarking modification mechanisms for improving new product development activities and for avoiding unforeseen delays in project schedule can be utilized. These decision-making supporting techniques can be helpful to overcome problematic issues about long project durations and resource constraints. By means of these techniques project manager is able to acquire precise understanding about resource allocations and time of activities, and can alter the plan correspondingly.

Specifically, data envelopment analysis (DEA) based benchmarking methodologies can be used to optimize product development processes and to overcome resource and schedule overruns in PERT/CPM applications. By using a systematic benchmarking approach, subjective behaviour in time estimates and resource distributions can be prevented.

Case study 12 (Section 5.2) exhibits successful implementation of DEA based benchmarking methodologies used in the development project of a music mobile phone. According to methodology, after constructing project schedule and identifying the expected project completion time by using traditional PERT/CPM techniques, analytical processes for optimizing the NPD processes are applied. These analytical processes comprise the following modules: process modification, estimation of the project completion time, resource allocation given most likely time, time estimation given resource allocation, time estimation with added resource allocation and relative economical efficiency for the new product development processes within a product portfolio (Chiang, Trappey and Chen, 2008).

Overall benchmarking approach including the modules mentioned above is illustrated in Figure 4.10

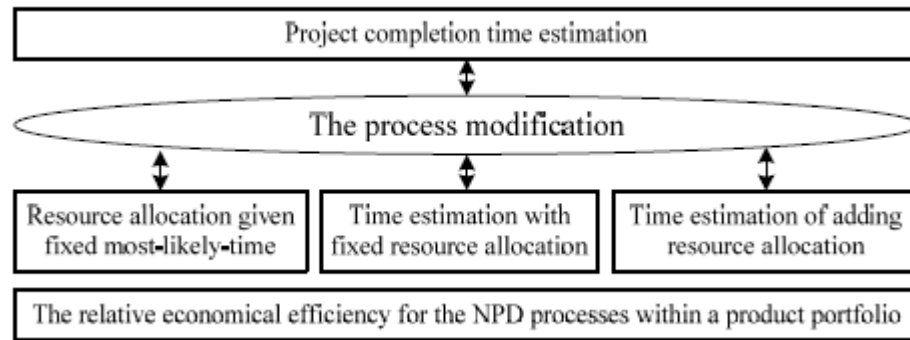


Figure 5.1 “The framework of the benchmarking-based methodology for NPD process optimization” (by Chiang, Trappey and Chen, 2008, p. 154)

In the planning phase, the feed-forward modification mechanism (FFMM), first applies the module of project completion time estimation to calculate the probability of project time set by the customer. If the estimation satisfies the customer requirements, the FFMM, then, employs the resource allocation given most likely time to benchmark and adjust all resource allocations of activities among NPD processes. On the other hand, if the time estimation cannot satisfy the customer’s requirement, the FFMM utilizes the modules of the time estimation given fixed resource allocation to reduce expected NPD process time. During the execution phase, if a certain NPD activity delays, the feed-back modification mechanism (FBMM) is activated to assess whether the subsequent NPD activities need to be modified by applying the time estimation with added resource allocation.

(Chiang, Trappey and Chen, 2008, p. 154)

With regard to questionnaire conducted introducing effective resource allocation mechanisms for project management practices was one of the improvement suggestions of project performers and most of them reported that they experience resource scarcity during their projects. These benchmarking tools have great potential to fill this gap due to optimizing resource allocation.

- **Failed cases because of behavioural changes in CCPM application**

Based on the CCPM application’s requirement for change of behaviour and mentality of working when combined with high level of complexity in some projects, employees may refuse to alter their current practices. Case studies show implementation of CCPM was exposed to employee resistance and decreasing morale because of quick buffer consumption in the early implementation.

Depending on the contact with a project management consultancy firm (Mentor Proje Yonetimi), in the case of CCPM application of some clients although they

achieved the implementation phase at first they could not maintain CCPM successfully because of employees' incapability of adapting CCPM behavioural changes. Employees working hard to meet the project due date also had to attend project meetings for analysing project status and they found these activities and procedures of CCPM time consuming and they were not willing for embracing new practices.

However, if procedures and meetings can be arranged systematically, and roles and responsibilities in CCPM culture can be assigned professionally, this problem can be overcome. It is a cultural change with new emerging roles for project environment. Planning, revision, task execution, tracking roles should be allocated properly. Especially, buffer analysis and task management roles should be assigned to ones that are skilled and capable of foreseeing risks and taking preventative measures against risks. Activities and meetings should be organized according to the nature of projects conducted. For instance, in the case of very complicated and ambiguous projects exposed to risks meetings for monitoring and analysis should be done more frequently. These suggestions are also agreed with the consultant firm and they further advised that heavy training and motivation should be provided for employees through a consultant for a particular time.

- **Problems in transferring resources from non critical activities to critical ones**

CCPM resource allocation perspective requires transfer of resources to critical activities when buffer status signals that the project is in risk to meet its duration. Transfer of resources in these cases may be problematic when resource is a human being. When tasks a specific person is executing are dependent on each other it is difficult and time consuming for another performer to anticipate the work done before. If it is the case, previous worker has to spend time for passing his information and experience about that work to another one.

This problem is also verified by the consultant. In application of CCPM to a client that is designing and manufacturing metal working machines including full automatic presses, laser machines and CNC hydraulic machines, this was

troublesome as some products designed include embedded software. Highly skilled employees were involving for the execution of a number of interdependent tasks, and interference of task performing by additional resources was meaningless as it necessitated time. Thus, full benefit from time savings that expected to be acquired through resource transferring cannot be obtained.

However, when it is the case, for instance projects that require human beings as resources and resource allocation is carried out, resource allocation strategy can be altered. Some of the resources can be assigned so as to be available and ready for a specific task performance in the matter of criticality. When task are being performed, these resources may focus on the critical ones and may develop knowledge about them by imparting and acquiring skills.

5.2. Supportive Case Studies

5.2.1 Case Study 10

This case study constitutes a good example of how DSM and DMM techniques can be used in organizations to organize complex interrelated activities, projects and alleviate project management. As it is proposed previously, these tools can increase the efficiency of project management practices when used in conjunction with CCPM. Although CCPM supports conducting projects as multi-project approach and is capable of providing resource allocation among projects, this mechanism cannot produce solution when organization between projects and activities are complex in multi-project system and there are not tools to assist CCPM planning in terms of creating a reasonable functional organization between project domains.

Two real world case studies at manufacturing organizations about how they achieved a sound communication and coordination for multi-project management are presented to support the idea and exhibit how the techniques work.

DSM is a matrix-based approach and represented by a square matrix which is used to identify dependencies and connections between elements of systems. DSM supplies self-mapping of the connections between the components of a system, through sequencing and clustering algorithms. DMM is a rectangular matrix which

has capability of coping with system dynamics between domains, and it is used to map components of two different domains to each other (Danilovic and Browning, 2007). Detailed comparison of these matrix based approaches can be seen in Appendix C.

Danilovic and Browning (2007) stated that a military aircraft manufacturing company for a new product including a great number of new functionalities, conducted DSM and DMM analysis together to determine how the project can be constructed so as to prevent delays in project duration and to gain insight about how the coordination can be done among organization and multi-projects.

After applying clustering algorithm to DSM matrix representing the original data, new matrix showing the mutual dependence of business portfolio elements was obtained as illustrated in Figure 4.11

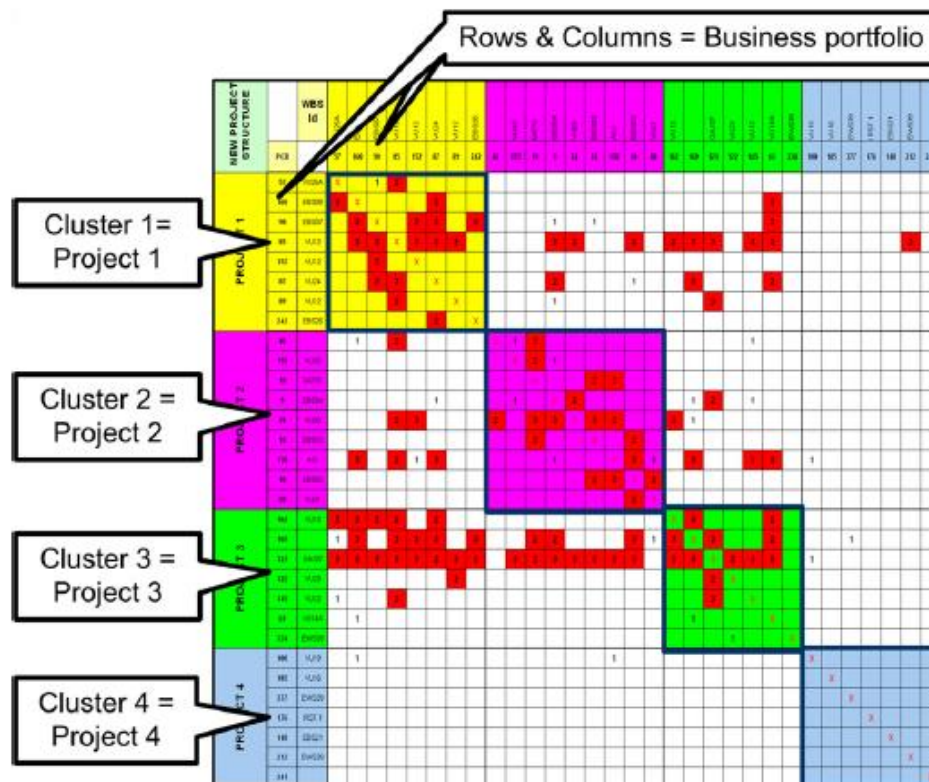


Figure 5.2 “DSM Clustering-business portfolio into multi-project portfolio” (by Danilovic and Browning, 2007, p.311)

Based on the analysis four development projects were conducted in multi-project perspective, and project teams were allocated to projects demonstrated by clusters. Second analysis (DMM) was then carried out to find out which areas among projects and functional organizations necessitate tight coordination and integration, and who should communicate for knowledge transfer. DMM analysis is shown as follows:

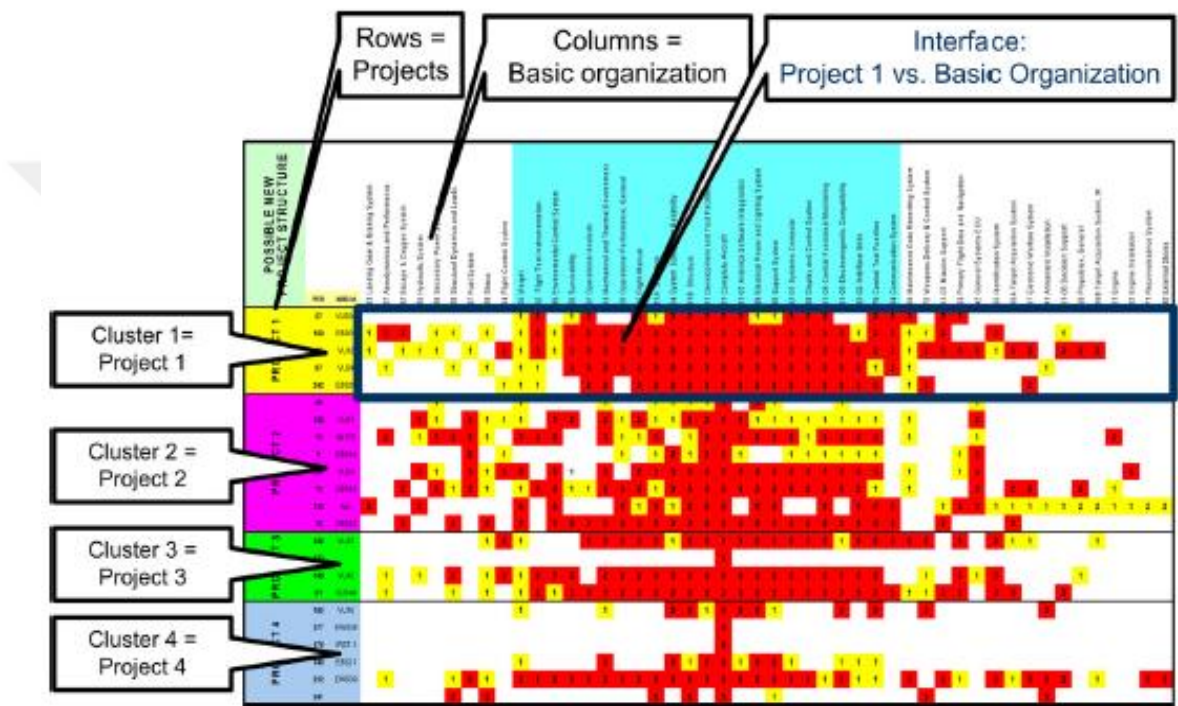


Figure 5.3 “DMM Clustering-multi project portfolio vs. organization” (by Danilovic and Browning, 2007, p.311)

A track manufacturing company’s NPD projects were problematic due to lack of coordination between other projects in the multi-project system. A dynamic analysis was conducted including two DSM and one DMM analysis for a new engine development project. Analysis contributed to anticipate interrelated departments in the organization, multi-project system and subsystems of the product. An example of the analysis can be seen in Appendix D.

5.2.2. Case Study 11

Based on the questionnaire findings and analyzed case studies, workflow planning is complex and ambiguous in NPD and it requires significant amount of time. Mutual interaction of activities causes rework and emergence of new tasks makes the planning quite difficult. Due to workflow complexity and not considering iterations at first, in CCPM implementation buffer sizing problems occurred and full benefit from buffers cannot be acquired. However, workflow optimization methods can improve the efficiency of the process by assisting project manager in forestalling complexities, reducing risks and enhancing schedule predictability.

One kind of optimization methodologies was utilized in an electronic company (OBM) in China for the development of a new power line adaptor communication and successful results were obtained (Ma, Co and Luh, 2009).

Workflow optimization method used utilizes FDSM for reducing iterations and feedback loops and their potential risks through identifying dependency degree of activities and organizing them accordingly. Approach for selecting the most effective combination of design activities is illustrated as follows:

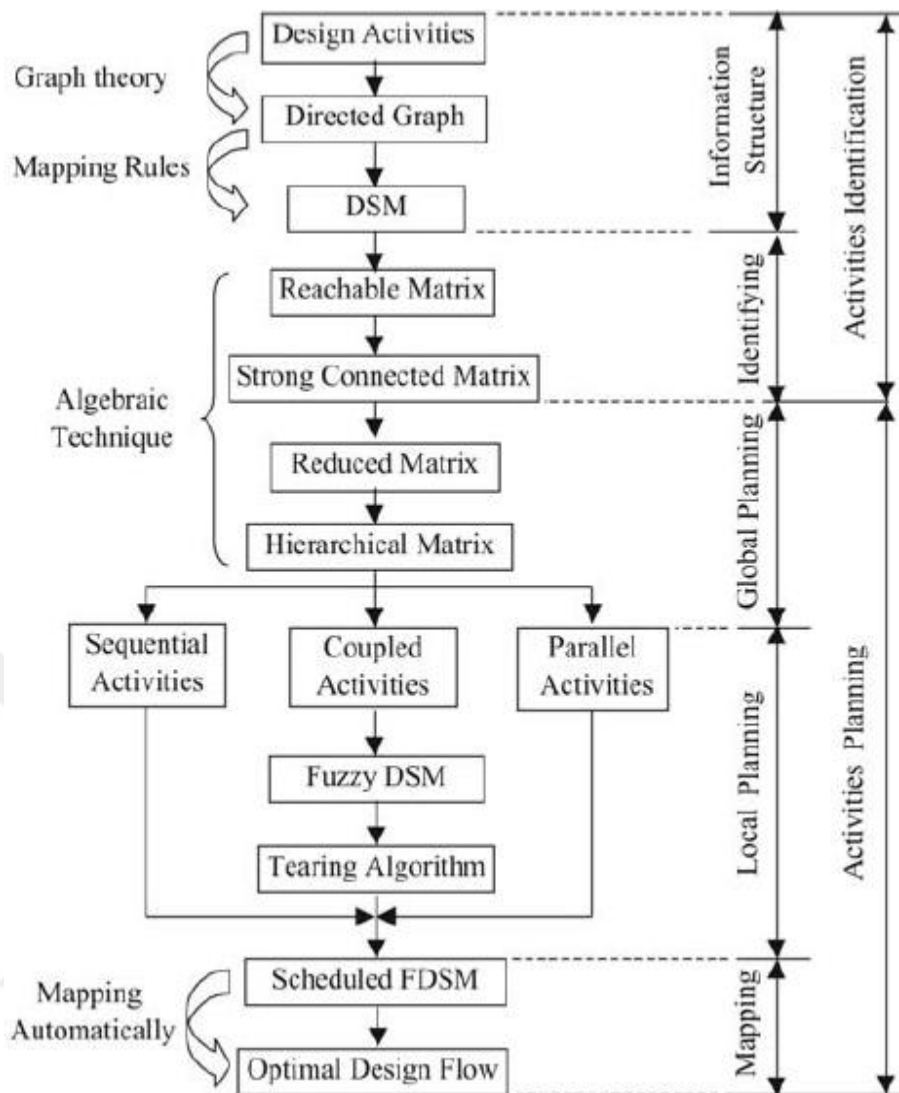


Figure 5.4 “Framework of workflow planning method” (by Ma, Ko and Luh, 2009, p. 86)

One critical step in the method is tearing procedure which is used for eliminating iterations resulted from coupled activities. Tearing algorithm automatically structures workflow, eliminates couplings and creates a new sequence in a FDSM format.

Scheduled FDSM gave the opportunity to observe new couplings with their dependency strength value and discover huge interdependencies. Design workflow was divided into seven phases based on the clusters so as to include the minimum feedback information. After automatic mapping technique, optimal design flow was obtained. Primary complex design process was changed by new information design

flow which resulted in small iterations instead of big scale ones. (Ma, Co and Luh, 2009).

In the development of the new electronic product, potential problems were detected beforehand and rework decreased to its minimum which contributed to less product development lead time. Project managers gained a careful strategy in control of NPD projects (Ma, Co and Luh, 2009).

Main contribution of such a tool to project management for new product development can be reducing the complexity and giving insight to project manager about risks stem from complicated and uncertain new product development processes. Questionnaire findings also indicated that for improving efficiency and project management practices better workflow planning is instrumental. After uncertainties are reduced, using CCPM improves effectiveness of scheduling and other relevant processes.

5.2.3. Case Study 12

This case study investigates how a benchmarking approach was applied for the acquisition of precise perception about resource allocations in new product development projects, and analyzes its implementation in a music mobile phone development project. The technique used introduces a benchmarking approach to planning so as to make NPD process optimal in terms of time and resource utilization.

First step of the methodology is to calculate expected project completion time, which is performed by PERT/CPM approach. After creating the network diagram of the product development project, its estimated duration was calculated as 197.34 days. Later on primary project planning was carried out, process modification mechanism started to work. This procedure applied a feed-forward modification mechanism (FFMM) and a feed-back modification mechanism (FBMM) during the project planning phase (Chiang, Trappey and Chen, 2008). Working principle of the FFMM is depicted in Figure 4.14

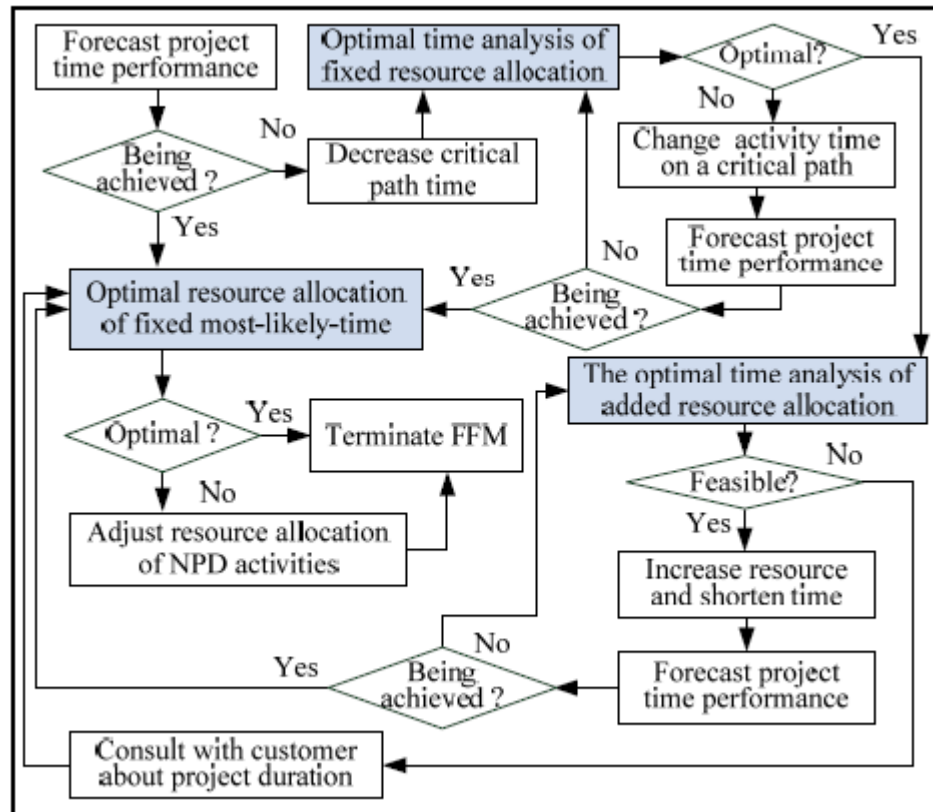


Figure 5.5 “The process architecture of the FFMM” (by Chiang, Trappey and Chen, 2008, p. 155)

In this case customer’s requirement for the project completion time was 200 days, which could not be achieved as the probability of satisfying the deadline was 0.639. Thus, FFMM examined if it was appropriate to decrease activity durations on the critical path without new resource allocation by applying the relevant algorithm. As the calculated efficiency of some activities was less than one, without additional resources the most likely durations of appropriate activities were reduced in an optimal manner. After new modifications, time performance estimation was employed again, resulting a new project completion time of 190.67 and probability of 0.972 which reflects time performance goal still could not be succeeded. Hence, in order to decrease critical path time, feasibility of adding resources was examined. Through using the related algorithm, it was analyzed that how the critical path time could be reduced in an optimal manner so as to meet customer requirements (Chiang, Trappey and Chen, 2008).

In the execution phase, FBMM mechanism was activated and its way of working is illustrated in Figure 4.15

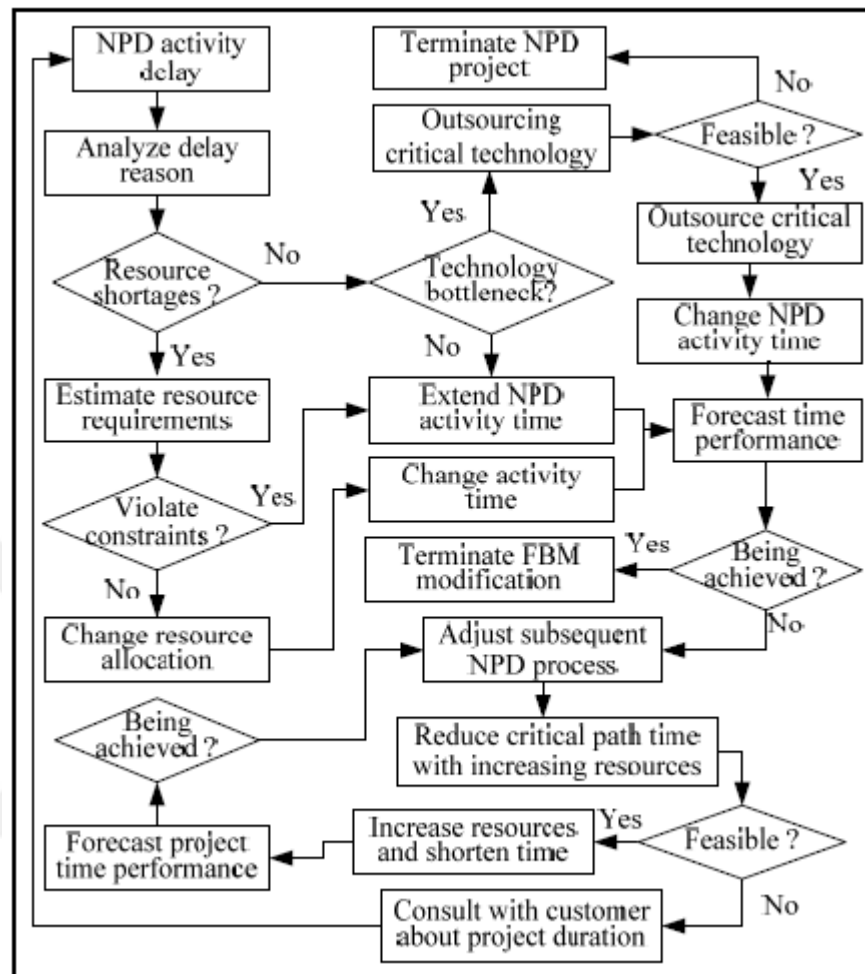


Figure 5.6 “The process architecture of the FBMM” (by Chiang, Trappey and Chen, 2008, p. 156)

According to this procedure when there is delay in NPD activities, project manager analyzes where it stems from. If it is discovered that the delay is because of lack of resources, amount of required resources are estimated again and they are checked against resource constraints. If break of resource constraints is the case, duration of the NPD activity can be extended.

In the music mobile phone development project, project manager found out that there was delay in the development and test of molds activities. Project manager decided to preserve the resource amount and modified activity times (Chiang, Trappey and Chen, 2008).

After changing time estimates of the activity, time performance of the project could not be achieved leading to adjust project resources and increase them. As a result, working time of testing engineers was increased by 208 hours. New time performance was able to satisfy customer requirements.

FFMM and FFBM mechanisms employ calculations of resource allocation under the most likely completion time, estimation of time with fixed resource allocation and estimation of time with added resource allocation by using optimization based DEA. For instance following Figure shows the methodological way of allocating resources optimally for fixed most likely time calculation (Chiang, Trappey and Chen, 2008).

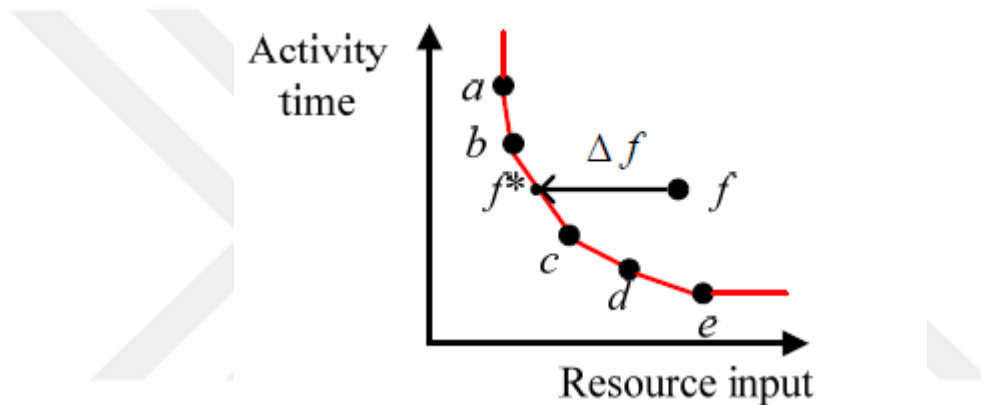


Figure 5.7 “The DEA concept for the optimal resource allocation model of fixed most likely time” (by Chiang, Trappey and Chen, 2008, p. 156)

CHAPTER 6: CONCLUSIONS AND FUTURE DIRECTIONS

The purpose of this dissertation was to conduct a research about the applications of project management models and techniques for NPD in IT and manufacturing industries, and to focus on project management techniques for NPD in manufacturing in detail. Based on the weaknesses discovered through analyses of real world case studies, questionnaire findings and literature some methods that have capability to accomplish efficiency improvement for NPD project management were recommended. Depending on limitations of traditional project management techniques (PERT/CPM) that research revealed a more advanced approach (CCPM) was examined elaborately to assess its benefits for highly uncertain and risky NPD project environments. Based on the fact that, CCPM has high capacity to improve operations and outcome of NPD projects in manufacturing environment, recommendations were done based on some CCPM weaknesses and how to fill the technique's potential.

At the beginning of Chapter 4 characteristics of NPD projects discussed and it revealed that one significant success factor for these projects is the degree of coping with uncertainty and risks. One intends to conduct a new product development project has to deal with unknown scope, specifications, internal and external conditions, market situations and many other uncertainty sources that cause risks.

Analyses of NPD projects in IT and software development addressed the research objective involving how projects in this field are managed. Common approach of these implementations is adapting methodologies that provide flexible processes and high collaboration so that unknown and changeable software specifications can easily be modified to project plan and schedule. Besides, companies utilize small scale incremental planning and do not plan all the work in advance which again contributes to deal with scope changes. Agile practices such as Scrum and XP used by these companies enable better capturing risks and provided effective processes.

The research objective of discovering techniques in manufacturing NPD practices which there is a need for improvement and finding out possibilities for efficiency enhancement was achieved through deep investigation into manufacturing NPD projects by means of a questionnaire and real world cases. According to research

findings PERT/CPM were the most widely used tools. Companies reported the number of projects that they failed to meet the deadline over a five year period which was a significantly high number. Another question revealed limitations that they experienced. Inaccurate time estimates, inadequate planning, resource scarcity due to inefficiencies in resource allocation, insufficient communication mechanisms, employee tendency of spending safety times embedded in tasks, incapability in control and management project over its duration were among some them.

CCPM implementations examined in detail via case studies showed technique's power in getting on top of drawbacks above. Allocating buffers for contingency and replacing them at the end of critical chain is the major feature of CCPM that addresses most of the limitations. Buffer mechanism replaces total contingency at the end of chain instead of separately in tasks which prevents employee tendency of spending safety inside the tasks. Buffer management discipline requires meetings for evaluating buffer status and controlling. These regular meetings increase project team's communication and collaboration. In these meetings, according to buffer consumption project condition against its commitment date is controlled and preventative actions can be taken in the case of criticality. By obtaining a tool for controlling delays stem from uncertainties such as scope changes, new task occurrence, rework or unpredictable events better control over risks can be provided. Visibility of processes and better predictability contribute to managing risks effectively.

In the aspect of resource allocation, scheduling of tasks is done by taking scarce resources into account and activities using these scarce resources are scheduled accordingly. Moreover, when buffer condition indicates that consumption is high then a particular resource can be assigned to that activity by changing place from non critical activities to critical ones.

CCPM offers capability for conducting multi-project systems. Case studies revealed that software packages such as Concerto and Prochain are also supporting this discipline. Projects carried out in the organizations usually use same resources, and schedule and plan of these projects are developed by considering these common resources. When this property is fully implemented it has potential of

enhancing the number of projects in the organization performed with the same resources. Again appropriate buffers are instrumental in changing resources between projects.

Nevertheless, it was discovered that CCPM has some limitations. First of all, when project is very complex, buffer sizing cannot be done properly due to interdependent activities. Workflow planning and network creation is considerably challenging and inappropriate workflow causes more troublesome buffer issues. Second, due to cultural changes and activities of CCPM, employees may not be inclined toward implementing CCPM practices. In addition to these, multi project application is problematic when organization among project domains is not done in the right way and dependent operations are not foreseen. Another significant problem arises when the resource is human being and it is vital to change this resource in the matter of a critical state.

In Chapter 5, research objective of presenting recommendations for increasing capability and efficiency of the certain techniques was achieved by proposing ideas that address CCPM weaknesses. Besides, it was also suggested that PERT/CPM can be used in conjunction with some techniques so as to improve their capability.

Recommended solutions for these particular problems may constitute the base for future directions in efficiency improvement of project management practices in NPD in manufacturing environment.

Against the unforeseen events and complexity of interdependent product structure that prevents CCPM from performing efficiently, decision-making, risk analysis and preliminary analysis techniques can be instrumental in gaining control over uncertainties. Questionnaire results revealed the importance of risk management in terms of efficiency enhancement.

In order to overcome difficulties in multi-project pipelining coordination, DSM and DMM matrix based techniques can be used to capture and restructure complicated project activities. These tools aid organizing activities and project members among various project domains, and contribute to find an efficient and uncomplicated way of organizing multiple projects. Thus, employing CCPM's multi-project approach

can be facilitated by using these techniques which provide better coordination of projects.

Difficulties in workflow planning and problems in buffer sizing processes can be solved by implementing robust systematic workflow structures so as to decrease iterations and rework for unpredictable tasks. Visibility of dynamic flow provides project managers to pay attention to mutually dependent tasks and their potential risks. After that, CCPM buffer sizing can be achieved without less difficulty even the project is too complex.

Against PERT/CPM's resource allocation problem utilization of benchmarking modification mechanisms can be useful. Decision-making about resource allocations is supported by these tools and project managers may find the way of distributing resources in an optimal manner even they are using PERT/CPM.

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APPENDIX A

Dear Sir / Madam

This questionnaire is a part of master thesis for the Msc Engineering Projects & Systems Management program at the Kingston University, London, UK. Questionnaire will be instrumental in providing insights into project management techniques used for new product development projects in manufacturing companies, their limitations and possible efficiency improvement strategies. Obtained information will be treated as confidential and will be used for only this thesis. I would be greatly appreciated if you could answer the questions.

Yours Faithfully

1. Which project management techniques are used in the company?

Gantt Charts	
Work Breakdown Structure (WBS)	
Program Evaluation and Review Technique (PERT)/ Critical Path Method (CPM)	
Graphical Evaluation and Review Technique (GERT)	
Earned Value	
Strengths, Weaknesses, Opportunities, and Threats (SWOT)	
Monte Carlo Simulation	
Critical Chain Project Management (CCPM)	

2. What is the approximate percentage of projects with delays in deadline over a five year period?

%75- less than %100	
%50- less than %75	
%25- less than %50	
0- less than %25	

3. Could you please tick the appropriate box for the following issue?

DRAWBACKS OF THE PROJECT MANAGEMENT TECHNIQUES IN USE

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
		1	2	3	4	5
A	Insufficiency for complex projects					
B	Inaccurate time estimates					
C	Inadequate planning					
D	Incapability in controlling and monitoring project over duration					
E	Insufficiency in predicting problems					
F	Resource scarcity due to inefficiencies in resource allocation					
G	Difficult to conduct multi projects					
H	Insufficient communication mechanisms					
I	Incapability of handling scope changes					
J	Employee tendency of spending safety times embedded in tasks					

4. Could you please tick the appropriate box for the following issue?

FACTORS THAT MAY ENHANCE AND IMPROVE PERFORMANCE OF
PROJECT MANAGEMENT TECHNIQUES

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
		1	2	3	4	5
A	Improving communication between project members through regular meetings and increasing involvement in planning					
B	Effective resource allocation mechanisms					
C	Realistic and reliable project schedule					
D	Improving concurrency for multi project pipelining					
E	Effective monitoring and feedback mechanisms that give insight to management					
F	Better defining of roles and responsibilities of project members					
G	Integrating mechanisms for capturing complexities and interdependencies of projects					
H	More effort can be spent on preliminary analysis for workflow planning for decreasing and anticipating complexities due to dependent activities					
I	Spending more effort on risk management activities					

APPENDIX B

Practice	Practice Overview
Incremental Planning	Also “Planning Game.” Work is planned in chunks, with the on-site customer playing a large part in requirements determination and work prioritization
Small Releases	Development team puts core functions into production early and then builds upon them using feedback from users and customer collaborator
Simple Design	Simple and small pieces of design allow frequent changes to be made as necessary.
Test-first Development	Writing and running unit tests as code is written to make sure the system is working properly. Frequent user acceptance tests to ensure the system is fulfilling user requirements.
Refactoring	A technique used to improve code without altering functionality. Focuses on simple, clean, non-repeating code that can be easily changed.
Pair Programming	Two programmers developing production code at the same time on one machine.
Collective Ownership	Everyone owns all of the code, allowing necessary changes to be made by anyone at any time.
Continuous Integration	Integrating changes as they are complete to detect system failures as soon as possible.
Sustainable Pace	Developers keep a normal work schedule to remain productive, and interested in the project.
On-site Customer	An on-site customer available for requirements clarification and business decisions that should not be made by the Developer
Uniform Coding Standard	Coding standards (language, formatting, syntax) agreed upon by the team at the start of a project. Facilitates communication and ease of development.
System Metaphor	An over-arching description of the system’s functionality, purpose, and conventions, providing customers and developers with common ground on which they can stand

Table B-1 Extreme Programming Practices (by Fruhing, A., McDonald, P. and Dunbar, C., 2008, p.5)

APPENDIX C

Dimensions	Design structure matrix (DSM)		Domain mapping matrix (DMM)
	Sequencing analysis	Clustering analysis	
Representation	Square matrix	Square matrix	Rectangular matrix
Analytical dimensions	Single domain	Single domain	Dual domain
Partitioning algorithm	Block diagonalization/triangularization	Clustering in blocks along the diagonal	Move items to clusters
Result, outcome of analysis	Flow of items, activities, i.e. sequencing	Clustering of items	Clustering of items
Visualization of dependencies	Parallelization of items	Clusters of items, Chunks	Clusters of items
	Sequencing of items	Interfaces between clusters	Interfaces between clusters
	Feedback and circuits, loops of items	Hierarchical structures	Hierarchical structures
Key words	Predecessors	Clustering	Clustering
	Successors	Hierarchies	Hierarchies
	Feedback and circuit loops	Interfaces	Interfaces
	Banding	Linking pins	Linking pins
Focus of analysis	Tasks	Parameters	Components/organization
	Activities	Components	◀Project/▶organizational structure
	Information flow	People	Functionality/◀product▶ architecture
	Deliverables flow	Organizations	Information flow
		Information flow	

Table C-1 “ Comparison between dependence matrix approaches” (by Danilovic and Browning, 2007, p. 308)

APPENDIX D

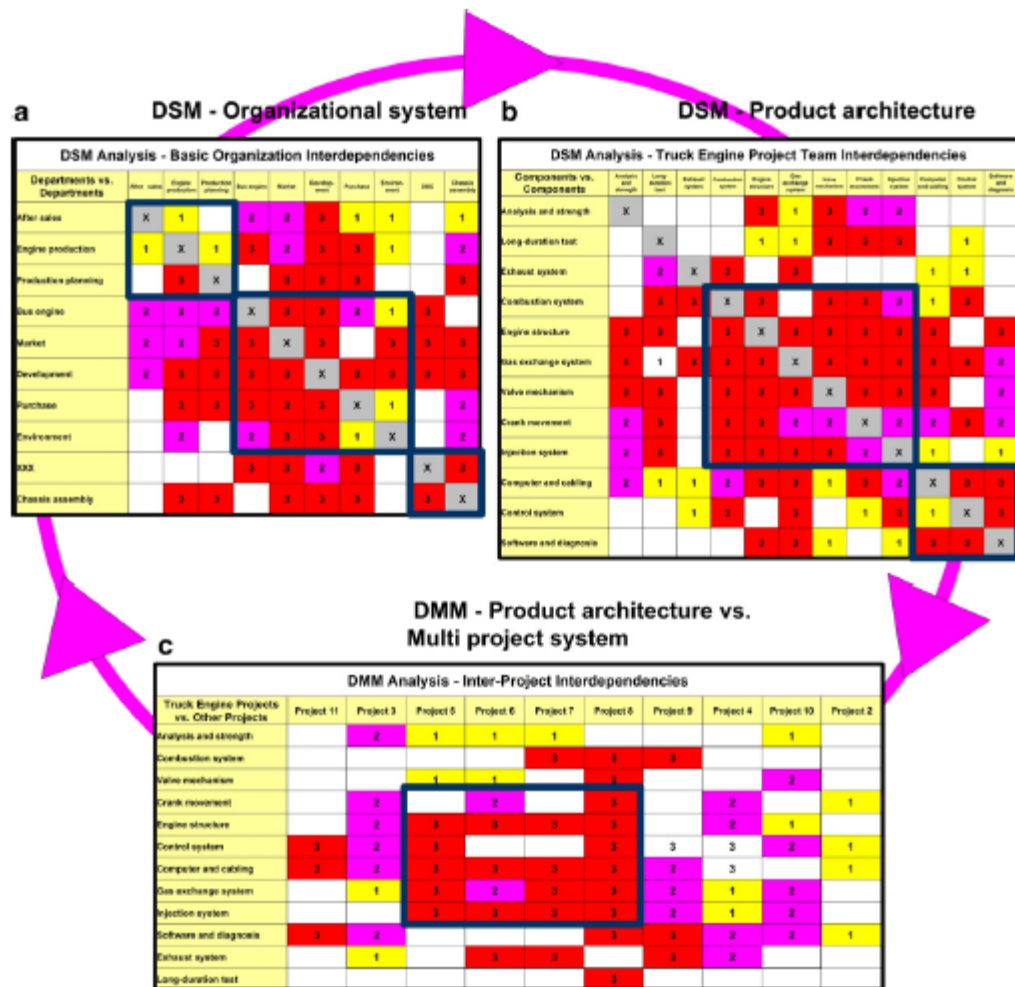


Figure D-1 “ Dynamics in product development- combination of DSM and DMM: (a) DSM-organizational system; (b) DSM-product architecture; (c) DMM-product architecture vs. multi-project system” (by Danilovic and Browning, 2007, p. 312)