

ERGOLEAN: AN INTEGRATION OF ERGONOMICS AND LEAN BY
STRUCTURAL EQUATION MODELING

by

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ABSTRACT

ERGOLEAN: AN INTEGRATION OF ERGONOMICS AND LEAN BY STRUCTURAL EQUATION MODELING

Ergonomics and Lean approaches independently have significant positive effects on enterprises in terms of improved productivity, employee well-being, and overall organizational performance. Since the two approaches share similar goals and are closely interrelated in their applications, it is logical to establish an integrated management system. This study aims to link both approaches by identifying and combining the critical success factors common to both approaches that are necessary for organizational success to develop a strategic plan that focuses on ergonomics and lean principles to achieve holistic development within the organization; and based on this developing a framework to illustrate the relationship between “Lean and Ergonomics categories” and “Business Success”, and employing a hypothesis model to assess the direct, indirect, and total effects of these categories on business success. The study examines the impact of six categories namely, “Employee”, “Organization”, “Methods, Tools and Technology”, “Tasks”, “Environment and Safety”, and “Customer and Supplier” on business success. To achieve this, a hypothesis model was developed to illustrate the relationships between these categories and business success. Data were collected through a developed questionnaire survey targeted at managers in both the production and service sectors. Structural Equation Modeling (SEM) was used to analyze the direct, indirect, and total effects of these categories. Results indicated that the “Customer and Supplier” category had the strongest impact on business success. It was also found that the significant impacts of the “Task” and “Environment” categories are primarily due to organizational characteristics. The developed integration model is hoped to assist decision-makers in implementing strategies to reach business goals and help them remain competitive.

ÖZET

ERGOLEAN: ERGONOMİ VE YALININ YAPISAL EŞİTLİK MODELLEMESİ İLE ENTEGRASYONU

Ergonomi ve Yalın yaklaşımların, bağımsız olarak işletmeler üzerinde artan üretkenlik, çalışan refahı ve genel kurumsal performans açısından önemli olumlu etkileri vardır. Bu yaklaşımların benzer hedefleri paylaşması ve uygulamalarının birbirleriyle yakından ilişkili olması, entegre bir yönetim sistemi kurmanın mantıklı olduğunu göstermektedir. Bu çalışma, işletmelerin organizasyon içinde bütüncül gelişme sağlamak amacıyla ergonomi ve yalın prensiplere odaklanan stratejik bir plan geliştirmesine yönelik ortak kritik faktörleri tanımlamayı ve her iki yaklaşımı birbirine bağlamayı amaçlamaktadır. Bu çerçevede, “Yalın ve Ergonomi kategorileri” ile “İş Başarısı” arasındaki ilişkiyi gösteren bir hipotez modeli geliştirilmiş ve bu kategorilerin iş başarısı üzerindeki doğrudan, dolaylı ve toplam etkileri değerlendirilmiştir. Araştırma altı kategorinin (Çalışan, Organizasyon, Yöntem-Araç-Teknoloji, Görevler, Çevre ve Güvenlik, Müşteri ve Tedarikçi) iş başarısı üzerindeki etkilerini incelemektedir. Bu amaçla, bu kategoriler ile iş başarısı arasındaki ilişkileri gösteren bir hipotez modeli kullanılmıştır. Veriler, hem üretim hem de hizmet sektöründeki yöneticilere yönelik bir anket aracılığıyla toplanmıştır. Yapısal Eşitlik Modellemesi (SEM) kullanılarak bu kategorilerin doğrudan, dolaylı ve toplam etkileri analiz edilmiştir. Sonuçlar, “Müşteri ve Tedarikçi” kategorisinin iş başarısı üzerinde en güçlü etkiye sahip olduğunu göstermektedir. Ayrıca, “Görev” ve “Çevre” kategorilerinin önemli etkilerinin öncelikle organizasyonel özelliklerden kaynaklandığı tespit edilmiştir. Benzer şekilde, “Müşteri” ve “Çalışan” kategorilerinin de önemli etkilerinin organizasyonel özelliklerden kaynaklandığı belirlenmiştir. Geliştirilen entegrasyon modelinin, karar vericilere iş hedeflerine ulaşmak için stratejiler uygulama ve sektörde rekabetçi kalma konusunda yardımcı olması umulmaktadır.

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LIST OF ACRONYMS/ABBREVIATIONS

6S	Sort, Set in Order, Shine, Standardize, Sustain, Safety
AGFI	Adjusted Goodness of Fit
AHP	Analytic Hierarchy Process
AMOS	Analysis of Moment Structures
AVE	Average Variance Extracted
CA	Cronbach's Alpha
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CMIN	Chi-Square
CR	Composite Reliability
CSFs	Critical Success Factors
CSR	Corporate Social Responsibility
DMAIC	Define, Measure, Analyze, Improve, Control
DPMO	Defects Per Million Opportunities
EFA	Explanatory Factor Analysis
EMP	Employee
ENV	Environment and Safety
FMCG	Fast-Moving Consumer Goods
FMEA	Failure Mode and Effect Analysis
GFI	The Goodness of Fit Index
HCI	Human-Computer Interaction
HFACS	Human Factors Analysis and Classification System
JIT	Just-in-Time
KANBAN	Kanban
KMO	Kaiser-Meyer-Olkin
LSS	Lean Six Sigma
MaxR (H)	Maximum Redundancy of an Indicator
MI	Modification Indices

ML	Maximum Likelihood
MLE	Maximum Likelihood Estimation
MSDs	Musculoskeletal Disorders
MSV	Maximum Shared Variance
NBM	Nordic Body Map
NFI	Normed Fit Index
OHS	Occupational Health and Safety
ORG	Organization
PCA	Principal Component Analysis
RCA	Root Cause Analysis
REBA	Rapid Entire Body Assessment
RMSEA	Root Mean Square of Error Approximation
RSI	Repetitive Strain Injuries
RULA	Rapid Upper Limb Assessment
SB	Business Success
SEIPS	Systems Engineering Initiative for Patient Safety
SEM	Structural Equation Modelling
SIPOC	Supplier Input Process Output Customer diagram
SMC	Squared Multiple Correlation
SMED	Single Minute Exchange of Die
SMEs	Small and Medium-sized Enterprises
SPSS	Statistical Package for the Social Sciences
TASK	Task
TLI	Tucker-Lewis Index
TPM	Total Productive Maintenance
TPS	Toyota Production System
VSM	Value Stream Mapping
WRMSDs	Work-Related Musculoskeletal Disorders

1. INTRODUCTION

In response to escalating customer demands, both the manufacturing and service sectors are optimizing their processes to maintain competitiveness in the market. This is being achieved through the implementation of various methodologies aimed at improving product and service quality, reducing costs and ensuring high levels of employee performance, morale and customer satisfaction. Ergonomic interventions and lean six sigma methodology are the two main approaches for this practical and efficient process management.

Ergonomics is an applied science that design the interaction between humans and other system elements by using method, principle and theory and aims to optimize this interaction and increase the overall performance of the system [1]. Ergonomics, which is divided into microergonomics and macroergonomics, has three main domains: physical, cognitive and organizational. While microergonomics deals with human-machine interaction, macroergonomics deals with human-work system interaction. For this reason, macroergonomics approaches have become more critical for companies to increase the overall performance of the system. The macroergonomics approach has five primary factors: person, organization, task, environment, tools and technology. Companies need to determine critical success elements related to these factors and apply them to procedures to increase the system and process performance. Lean approach aims to identify and reduce all non-value added activities in the process, namely wastes [2]. There are various tools in lean to improve processes and increase performance. These tools include Value Stream Mapping, Continuous Flow, KANBAN, Pull system, Single Minute Exchange of Die (SMED), 5S, Line Balancing and Poke Yoke. Ultimately, it is an approach that aims to increase efficiency.

Studies on the critical success factors related to ergonomics at the micro and macro levels have been carried out in the literature [3, 4, 5, 6, 7]. Similarly, there are many studies on critical success factors related to lean [8, 9, 10, 11]. However, a

study on critical success factors that integrates these two methodologies, which have similar goals at the organizational level does not exist. Therefore, this thesis focuses on identifying and classifying the most important success factors of ergonomics and the lean methodologies and determining the direct, indirect and total effects of these integrated categories on business success.

The thesis consists of the following sections, respectively. Following the Introduction, the second chapter is about Literature review. The third chapter is about Rationale and objectives of the study. The fourth chapter is about Methodology. The fifth chapter consists of the Results of the study. The sixth chapter is about the Discussion of Results and the last chapter consists of Conclusion and Recommendations. Figure 1.1 shows the main steps involved in the study.

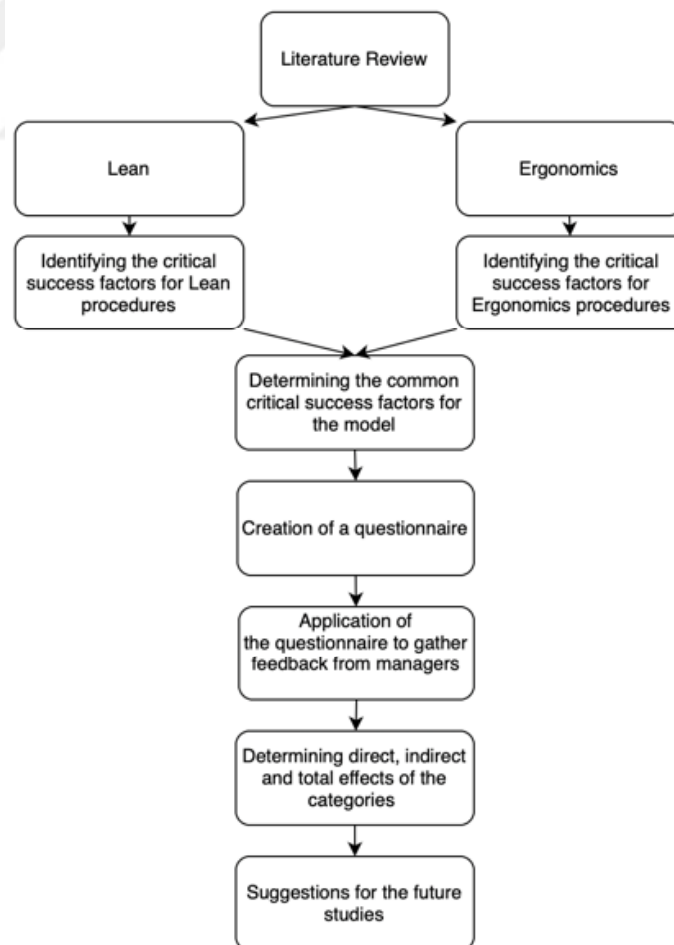


Figure 1.1. Flowchart of the study.

2. LITERATURE REVIEW

2.1. Overview of Ergonomics

Ergonomics, also known as human factors engineering, is a multidisciplinary field aimed at enhancing productivity, quality, efficiency, safety and comfort in human interactions with various systems and products through design and arrangement. This discipline integrates knowledge from human anatomy, physiology, psychology, bio mechanics and well being to optimize the interaction between human and systems.

In the workplace, ergonomics operates on two fundamental principles. Firstly, it involves designing the work and workplace to fit the employees, encompassing physical aspects of workplace design. Secondly, it entails adapting the job to the employee through appropriate education and training. These principles establish a symbiotic relationship between the employee and the work system [12].

Ergonomics is divided into two sub-disciplines: microergonomics and macroergonomics [13]. Microergonomics focuses on the interaction between humans and machines. This includes aspects such as maintaining correct body posture, designing tasks suitable for the job and selecting appropriate equipment and tools, all aimed at enhancing employee performance [13].

On micro level, ergonomics is the science of designing tasks, tools and environments to accommodate the capabilities, abilities and limitations of the human body on a micro level [15, 16, 17]. Its goal is to enhance workplace productivity, efficiency, safety and comfort by minimizing the risk of injury and physical strain [15, 18]. Implementation of ergonomic principles can significantly improve worker well being and performance, leading to increased productivity and higher quality of work [19, 16]. Here is a concise overview of ergonomics at the micro level:

- (i) Human Factors; It encompasses a wide range of factors including body size, strength, sensory abilities and cognitive functions [21], ensuring that the design of products, environments and systems is well suited to human body.
- (ii) Workplace Design; Workplace design is an essential aspect that ensures the comfort and well being of employees. Ergonomics plays a critical role in designing workspaces by strategically arranging furniture, equipment and tools to reduce strain and fatigue while maximizing productivity and quality. This is achieved by tailoring the workplace environment to meet the needs and comfort of the workers. Ergonomic design enhances efficiency, productivity and also contributes to employee well being and job satisfaction.
- (iii) Product Design; Ergonomics is dedicated to developing products that prioritize comfort and usability [24]. This encompasses the design of product shape, size and controls to align with the needs and abilities of the user [25]. By integrating ergonomic principles into product design, manufacturers aim to enhance user satisfaction, usability and overall product performance, resulting in a more positive user experience.
- (iv) Health and Safety; Health and safety in the workplace are of utmost importance. Ergonomics is a field of study dedicated to reducing the risk of workplace injuries and health problems. It involves identifying and addressing ergonomic hazards that can lead to musculoskeletal disorders and other health issues. By implementing ergonomic principles, employers can create safer and healthier work environments for their employees, resulting in increased well being and productivity. Bernard (1997) conducted a study that showed the effectiveness of ergonomic practices in reducing work-related injuries and health problems [26].
- (v) User Experience (UX); User Experience (UX) refers to the intersection of ergonomics and user experience design, particularly in the digital domain [27]. This involves developing software applications and interfaces that prioritize intuitive design and easy navigation [28]. By incorporating ergonomic principles into digital design, developers aim to improve user satisfaction, efficiency and overall usability, resulting in a more seamless and enjoyable user experience.

- (vi) Research and Analysis; Ergonomics encompasses the study of human interaction with their environment [17]. This involves conducting ergonomic assessments and analyzing data related to workplace injuries and other relevant factors [29]. By systematically studying these interactions, ergonomists gain valuable insights that inform the design of safer and more efficient work environments, ultimately contributing to enhanced well being and productivity.

Ergonomics is initially dominated by microergonomics, focused on designing individual work units and their interaction with employees. Over time, however, there has been a noticeable shift towards macroergonomics approaches, which encompass the entire organizational structure. This transition has been driven by the positive outcomes achieved through macroergonomic approaches, leading to desired improvements and developments in products, services and overall quality, thereby increasing the significance of macroergonomics within the field over time [30].

Macro and micro-level ergonomic approaches have demonstrated improvements in overall company performance [31], [32], [33]. Unlike microergonomics, which focuses on specific areas, macroergonomics aims to improve and develop the company's situation at the organizational level [31], [34]. This sub discipline emerged in 1986 when Hendrick observed the absence of an organizational level sub discipline in ergonomics, prompting him to write a book on Macroergonomics [31], [35]. By analyzing essential factors and designing systems, macroergonomics seeks to enhance overall system processes and organizational structure, bringing them closer to optimal performance levels. Factors addressed by macroergonomics include human factors, organizational conditions, tools and technology, environment and tasks [31], [3].

Macroergonomics takes a broader perspective, addressing the interaction between humans and work systems. It involves analyzing, designing and evaluating systems and their association with people. The fundamental principles of macroergonomics are as follows [13], [38]:

- Recognize the dynamic and complex nature of working systems, acknowledging that changes made in one part of the system can have a ripple effect throughout the entire organization [39]. Therefore, collaboration and careful planning are essential considerations in both system design and organizational management.
- Prioritize the human factor in the design and implementation of technologies, software and tools [40]. This involves ensuring that interface designs and software systems are user-friendly, easy to understand and accessible, thereby reducing intuitive errors and enhancing overall system performance.
- Encompasses the planning, design and performance management of organizational structures, in addition to technological considerations. By aligning with the goals and values of the institution, while also taking into account employee welfare, satisfaction and participation, macroergonomics aims to optimize all stages from the design process to system management.
- Furthermore, macroergonomics considers both the physical and psycho social properties of the system, including aspects such as lighting, temperature, noise and accidents, thus fostering a more productive working environment.

In summary, macroergonomics aims to facilitate effective and sustainable interactions between people, organizations, tools and technology, tasks and the environment. By doing so, it enhances employee welfare, health and safety, while optimizing all stages of the system design and management process. As mentioned earlier, the macroergonomics perspective encompasses five different factors: person, organization, tools and technology, tasks and environment, each consisting of various elements as illustrated in Figure 2.1 [13].

2.2. Ergonomics Domains

Ergonomics, as a multidisciplinary field, encompasses three main domains: Physical Ergonomics, Cognitive Ergonomics and Macroergonomics.

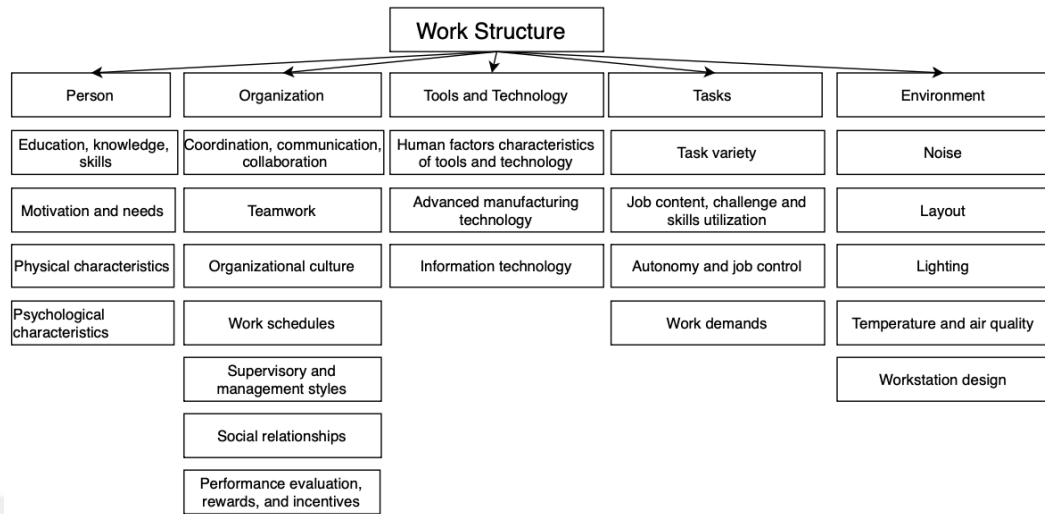


Figure 2.1. Macroergonomics factors and elements source adapted from [13]

2.2.1. Physical Ergonomics

Physical Ergonomics focuses on improving people's interactions with their work environment to prevent injuries and diseases, such as musculoskeletal disorders (MSDs). These issues often arise due to physical factors such as incorrect posture and movements during the interaction between individuals and their work environment [41, 42]. Important considerations for physical ergonomics include:

- **Workstation Design;** This involves designing workstations, including tables, desks, chairs and computer setups, to determine the most optimal posture for employees and reduce bodily tension.
- **Manual Handling;** Physical Ergonomics aims to develop tools and techniques that reduce the risk of accidents and injuries when lifting, pushing, pulling and carrying heavy objects in the work environment.
- **Repetitive Tasks;** Analysis of tasks involving repetitive movements is crucial to reduce the risk of repetitive strain injuries (RSIs), such as carpal tunnel syndrome, which can occur as a result of prolonged exposure to repetitive tasks.

- **Environmental Factors;** Optimizing physical environmental factors such as noise, temperature and lighting can positively impact employee performance, comfort and productivity.

2.2.2. Cognitive Ergonomics

It focuses on the study of mental processes, work load and human computer interaction to improve cognitive processes [43, 44]. Key aspects of cognitive ergonomics include:

- **User Interface Design;** Designing user friendly interfaces for websites and software to enhance user efficiency and effectiveness in human system interaction.
- **Information Design;** Providing information in a clear and simple manner to minimize errors and reduce cognitive load.
- **Task Analysis;** Identifying and redesigning the cognitive demands, steps, sources of cognitive strain and difficulties of a cognitive process.
- **Attention and Perception;** Understanding people's information comprehension and processing processes and designing systems that support comprehension, processing and attention management of information.

2.2.3. Macroergonomics

It deals with the relationship between various organizational components, such as people, equipment and technology, to enhance the welfare, quality and productivity of a system. Influenced by organizational structure and corporate culture, it focuses on optimizing sociotechnical systems [45, 46]. Key aspects of Macroergonomics include:

- **Organizational Design;** Designing the company's structure, workflows and employee roles to increase efficiency, employee welfare and collaboration.
- **Safety Culture;** Creating a culture that encourages and empowers employees to identify and resolve safety risks.

- Workplace Health Promotion; Developing ergonomics training, occupational health and safety training and healthy lifestyle programs to positively affect employee welfare and health.
- Human-System Integration; Integrating people into complex systems to enable effective, safe and efficient human-system and human-technology interaction.
- Teamwork and Communication; Designing systems that facilitate communication and collaboration in complex organizational structures.

Ergonomics plays a crucial role in optimizing human-system interaction by designing systems and environments that promote employee well being, safety and performance.

2.3. Ergonomics Principles

The principles include the following:

- (i) User-Centered Design; It involves including users in the design process and considering their preferences, abilities and skills [15, 16, 47]. By prioritizing users' needs and incorporating their feedback throughout the design life cycle, the resulting design becomes more user-friendly and effective.
- (ii) Anthropometry; It involves designing products, working environments and systems that account for differences in proportions and sizes of the human body [48, 49, 50]. This results in ergonomic designs that are compatible with a wide range of people and provide comfort.
- (iii) Occupational Biomechanics; It aims to design systems that minimize physical strain and fatigue by supporting the musculoskeletal system anatomy of employees [51]. This is achieved by optimizing movements, postures and the force required for work, with the goal of preventing work-related musculoskeletal disorders.
- (iv) Work Physiology; It involves designing systems that consider the body's energy expenditure, fatigue and muscle power production mechanisms.

- (v) Workplace Design; It aims to create ergonomic workplaces that increase employee comfort and well being by regulating environmental factors such as lighting, temperature and noise [52]. This helps create productive and efficient workflows and processes by organizing workstations, equipment and tools.
- (vi) Task Design; It involves designing processes and tasks that consider the limitations and abilities of employees [53]. The aim is to reduce repetitive tasks that may cause errors or fatigue and to diversify and simplify tasks in accordance with employees' physiology.
- (vii) Human Computer Interaction (HCI); HCI aims to enhance user experience by designing user friendly interfaces and systems [54]. This includes studying issues such as error prevention, screen layout and navigation experience.
- (viii) Safety; It involves creating safe system and process designs to minimize injuries, errors and accidents resulting from risks [55]. This includes implementing warning systems, safety precautions, protective measures and protective clothing.
- (ix) Training and Education; Training and Education are important for raising awareness about ergonomic practices and organizing training based on ergonomic principles for the ergonomic and safe use of tools and equipment [23]. This helps users identify problems and develop solutions proactively.
- (x) Continuous Improvement; Continuous Improvement involves receiving continuous feedback from users, regular inspection and evaluation of systems and processes and evaluation of performance criteria [56]. This is an essential component of ergonomics.
- (xi) Legislation and Standards; Legislation and Standards are developed by organizations and governments to ensure employee health and safety [57]. Compliance with ergonomic criteria in working environments and work systems results in high-quality processes and products.
- (xii) System Perspective; Macroergonomics takes a comprehensive approach to understanding a system, including its components, their interactions and the interfaces of the technological components [58]. This perspective emphasizes the importance of considering the system as a whole.

- (xiii) Holistic Approach; Macroergonomics focuses on the impact of individual tasks on the entire system from a holistic perspective, considering processes, culture and organizational structures [59].
- (xiv) Work System Design; Work System Design focuses on creating an integrated system in which tools, technologies, tasks and organizational structures work in harmony with human skills and limitations [60].
- (xv) Participatory Design; Macroergonomics involves all stakeholders in the system design process, allowing for feedback and collaboration throughout [61]. This approach values the input of not only employees but also other stakeholders.
- (xvi) Work-Life Integration; Macroergonomics encourages the design of workloads, job design and work schedules that support work-life balance, leading to increased employee well being [62].
- (xvii) Ethical Considerations; Macroergonomics prioritizes ethical issues such as equality and justice in system design [60]. Ergonomists work to design systems that uphold ethical standards and respect the rights of individuals.

These principles of ergonomics are integrated into the design processes of systems, processes and products with the aim of improving user well being, performance and safety.

2.4. Ergonomics Tools

Ergonomics provides human and system integration while utilizing various methods and tools for ergonomic analysis. Some of these tools are:

- (i) Anthropometric Data: Anthropometric data contains information about the proportions and dimensions of the human body [63]. Anthropometric data is used to create designs that can appeal to a wider users in work environments and product designs.
- (ii) Posture Analysis Tools: Posture analysis tools are used to analyze body postures in various movements and activities. Some of these tools include posture analysis

grids and posture assessment software [64]. By using these tools, ergonomists determine the optimum postures that support the musculoskeletal system. This helps prevent musculoskeletal disorders that occur as a result of injuries and long-term exposure.

- (iii) Task Analysis Methods: Task analysis aims to divide complex tasks into more manageable parts [65]. Ergonomists use various task analysis methods such as cognitive task analysis and hierarchical task analysis to detect and minimize risk factors.
- (iv) Evaluation Tools: Evaluation tools such as the Rapid Entire Body Assessment (REBA) are observational evaluation tools that aim to detect ergonomic risks by considering factors such as force, posture and repetition [66].
- (v) NIOSH Lifting Equation: The NIOSH Lifting Equation is a tool based on manual lifting as an activity, affected by factors such as lifting frequency, technique and weight of the load [67]. It is used to reduce the risks that may arise as a result of lifting and determining the optimum weights to be lifted.
- (vi) Ergonomic Checklists: Ergonomic checklists have been created so that evaluations can be made according to ergonomic guidelines, standards and principles. These lists control the tools, workstations, equipment and processes with which users interact [52]. They enable risks and hazards to be detected in advance and ergonomic solutions to be offered.
- (vii) Software Tools: Software tools such as 3D human modeling and ergonomic simulation software enable ergonomic visualization and analysis through the virtual environment [68]. Ergonomists use these tools in the analysis and design stages for processes and workstations.
- (viii) Surveys and Questionnaires: Surveys and questionnaires are used to collect qualitative and quantitative data from users [69]. Ergonomists analyze this data to produce solutions that improve user experience.
- (ix) Environmental Measurement Tools: Environmental measurement tools such as noise meters, thermal comfort monitors and light meters are used to measure environmental factors that affect human performance [70]. Ergonomists use these

tools to increase employee welfare and performance by keeping these environmental factors at the optimal level.

- (x) Human Factors Analysis and Classification System (HFACS): The Human Factors Analysis and Classification System (HFACS) is used to analyze various risk factors and predict problems caused by human error [71]. It tries to get to the root cause of errors and designs to prevent these errors from recurring. It is used in more complex business systems.
- (xi) Work System Analysis: Work System Analysis involves analyzing the interaction between human, tasks, environment and technology factors within a work system [58]. The purpose is to identify areas for development and strengths within the system.
- (xii) Systems Thinking: Systems Thinking aims to understand the interconnected components within a system and how changes in one part can impact the entire system [72]. Feedback loops are an important part of Systems Thinking.
- (xiii) Participatory Ergonomics: Participatory Ergonomics encourages active participation from employees and stakeholders during system design and improvement phases [59]. Knowledge and experience transfer is crucial for success in Participatory Ergonomics.
- (xiv) Workload Assessment Tools: Workload Assessment Tools measure the physical and mental demands of employees during task performance [73]. The goal is to identify excessive or inadequate workloads and design balanced systems that align with employee capabilities.
- (xv) Simulation and Modeling: Simulation and Modeling techniques are especially useful in complex systems, where different scenarios can be simulated and evaluated [74]. These tools primarily focus on testing changes through simulation, evaluating alternative solutions and ultimately optimizing system performance.
- (xvi) Work Design Workshops: Work Design Workshops involve stakeholders from various disciplines in the design of work systems [61]. These workshops encourage creativity, consensus, brainstorming and communication to achieve results that meet the demands of all stakeholders.

- (xvii) **Organizational Culture Assessments:** Organizational Culture Assessments evaluate the norms and values of an organization. If there are obstacles preventing change, efforts can be made to adopt a culture that embraces ergonomic principles and overcome these obstacles [75].

These tools and methods help identify risk factors, plan improvements to minimize them and design safe, productive environments.

2.5. Critical Success Factors of Ergonomics for Company Strategies

This section discusses the critical success factors of ergonomics for company strategies under the categories of Organization, Person, Tool and Technology, Environment, and Tasks.

2.5.1. Organization

- **Leadership Support;** The management team emphasizes ergonomic practices and is committed to investing in the solutions offered for these practices [76].
- **Policies and Procedures;** Establishing ergonomic policies and procedures, such as workstation setup guidelines, ergonomic assessments and breaksn [77].
- **Training and Education;** Providing ergonomics training to employees, including ergonomic tool usage, proper lifting techniques and workstation setup training.

2.5.2. Person

- **Employee Engagement;** Involving employees in the entire process, receiving feedback from them, encouraging them to report negative conditions and involving them in the selection of ergonomic equipment.

- Health and Wellness Programs; Preparing programs to increase employees' health and well being, such as stress management programs, ergonomic assessments and fitness initiatives.

2.5.3. Tool and Technology

- Ergonomic Equipment; Utilizing ergonomic equipment to mitigate strain and increase comfort. This includes input devices such as keyboards and mice, ergonomic furniture such as chairs and desks, as well as accessories like footrests and adjustable monitor arms [78].
- Automation and Assistive Technology; Using Automation and Assistive Technology to reduce repetitive movements and minimize physical workload.

2.5.4. Environment

- Workstation Design; The organization prioritizes the integration of ergonomic principles into workstation design, incorporating adjustable furniture, appropriate lighting and sufficient space for movement [79].
- Temperature and Air Quality; Maintaining optimal temperature levels and ensuring good air quality within the workplace are essential for enhancing employee comfort and productivity.
- Noise Reduction; Minimizing noise levels in the workplace is crucial to decrease distractions and foster better concentration among employees [80].

2.5.5. Tasks

- Task Variation; Providing opportunities for task variation or job rotation is an effective strategy to prevent overuse injuries and alleviate monotony in work [190].
- Workload Management; Ensuring that workloads are manageable and realistic is vital to prevent employee fatigue and musculoskeletal strain [191].

- Breaks and Rest Periods; Encouraging regular breaks and providing adequate rest periods are essential for enabling employees to recover effectively and reducing the risk of ergonomic injuries [192].

2.6. Studies on Critical Success Factors of Ergonomics for Company Strategies

The literature suggests that critical success factors of ergonomics for the goal of companies can be categorized into five main groups: organization, person, tools and technology, environment and tasks [3]. Within these categories, various success factors have been frequently studied, such as;

- organizational support,
- project planning and implementation,
- worker involvement,
- work environment,
- participatory ergonomics,
- teamwork,
- organizational communication,
- work schedules,
- organizational culture,
- supervisory and management style,
- social relationships,
- organizational performance.

These factors have been analyzed and determined to be the most significant drivers of company success and performance [6]. The relevant research is summarized in Table 2.1 and Table 2.2. Table 2.1 summarizes the studies on finding the CSFs of ergonomics.

Table 2.1. Summary of the critical success factors of ergonomics.

Study	Purpose	Method	Main Findings
[6]	Hendrick discusses The common success factors of successful ergonomic-interventions by examining real cases. He also aims to conduct cost-benefit analysis of ergonomics projects.	Participatory ergonomics was used. As a result, macro ergonomic intervention outcomes were evaluated.	Organizational support, Project planning and implementation, worker involvement, work environment, participatory ergonomics, true professional leadership, expertise in ergonomics, real management commitment and ergonomics improvements to minimize work-related musculoskeletal disorders are some factors that lead to success in ergonomic interventions.
[3]	Carayon examines the human factor in socio-technical systems. Carayon has defined five components of the socio-technical system. These are the individual, tools and technologies, organizational conditions, tasks	Sociotechnical systems design has been developed. Human factor and ergonomics sub-factors were used to provide integration.	Psychological (e.g., human perception, cognitive processes, decision making), organizational (e.g., work processes, power dynamics, communication) and cultural (e.g., values, norms, beliefs) factors are essential in the design, implementation

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
	and physical environment.		and operation of socio-technical systems. Some elements of these five components are participatory ergonomics, usability, technological change, organizational change, continuous improvement, organizational and individual learning [3].
[7]	The aim of this study is to examine the relationship between macro ergonomics organizational elements and manufacturing system performance in the SEIPS model, which has macro ergonomics factors such as people, organization, technology and tools, tasks and environment, using a structural equation modeling approach.	Structural equation Modeling (SEM) is used to examine the effect of macro ergonomics organizational elements on manufacturing system performance.	In the study outcomes, it was determined that organizational components consisting of organizational communication and organizational culture directly affect customers and indirectly affect company growth and manufacturing processes.
[5]	The study aims to examine the relationship between	Analytical Hierarchy Process (AHP) was used	The factors of the conditional category are physical and

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
	management style and macro ergonomics factors. There are three categories in the study: conditional, individual and managerial.	as the decision-making method.	organizational conditions, while the factors of the individual category are capability and attitude. The factors of the managerial category are leadership, participation and culture. As a result of the analysis, Management by Values was found to be the best management style.
[81]	This study aims to develop an approach that can measure the performance of human factors related to process safety.	A framework containing key topics of human factors has been developed to be used in site studies in the industry.	It has been stated that the proposed framework can make valuable contributions to industrial projects. The ten critical topics covered in this study are: Managing human errors, organizational change, design with human factors, organizational culture, maintenance, inspection and testing, shiftwork and

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
			fatigue, competence and education, critical communications for safety, staffing, procedures.
[82]	The study aims to identify, group and analyze ergonomic risk factors and to guide the industry in this regard.	In this study, a 5-point Likert scale was used for survey data collection from 5 different construction sites.	The order of importance of risk factors has been reached. Administrative, environmental, health related, miscellaneous risk factors were examined and it was concluded that the environmental risk factor was of the greatest importance. Additionally, the importance of communication between upper and lower level employees was emphasized.
[83]	The study aims to identify critical barriers to reducing common Work-Related Musculoskeletal	Fuzzy-Decision Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) method was used in the analysis of the barriers found through literature	The importance of communication between the management team and the employees and the need to invest in

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
	Disorders (WMSD), in the industry with regular inspections.	review. It is intended to categorize barriers according to cause and effect.	ergonomics were emphasized.
[84]	The aim of this study is to identify ergonomic intervention types and their benefits.	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used as the method in the study. By collecting and analyzing data through the database, health and productivity based ergonomic interventions identified.	The positive impact of workplace improvements on employee health has been reported. It has been stated that there are significant reductions in Work Related Musculoskeletal Disorders.
[85]	The study analyzed the relationship of facilitators and barriers with occupational health and safety studies in order to prevent musculoskeletal disorders.	Based on a comprehensive literature review, 11 barriers and 3 facilitators were identified.	Deficiencies in time; resources; communication; management support, commitment and participation; knowledge and training; change; work environment; scope of tasks; trust and authority; process and implementing controls represent 11 barriers. Training and knowledge;

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
			communication and participation and an effective implementation were pointed out as 3 facilitators.
[86]	The study aims to examine the importance of participatory ergonomics in reducing musculoskeletal health problems.	An extensive literature study has been conducted on the risks posed by manual work and how to reduce these risks with participatory ergonomics.	The importance of task design is emphasized. The negative impact of work postures and heavy effort on the musculoskeletal system in the long term was stated and the importance of task redesign, active participation of employees in the process, management commitment and team work was emphasized.
[87]	The study aims to analyze the effects of macro ergonomic factors on the manufacturing system.	The structural equation modeling (SEM) method was used to determine the direct, indirect and total effects of the determined factors on the performance of the manufacturing system.	Hypotheses were created to determine the effects of person, organization, tools and technologies, tasks, environment factors on the performance of the manufacturing

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
			system and a significant effect was reached as a result.
[88]	This study covers the potential hazards for the development of specialized industrial tools as well as the crucial success elements that must be taken into account.	A survey of the literature is utilized to pinpoint five success factors. Ergonomists and other specialists were invited to participate in the evaluation of these specified critical success factors on the tools.	Five CSFs were identified after conducting a review of the literature: user involvement, tool design, training, maintenance and evaluation.
[13]	The goal is to examine the common components and challenges of a participatory ergonomics and provide suggestions for further research.	A literature review was used to identify success factors and challenges on the participatory approach.	Critical success factors found: involving workers at all stages of the intervention process, ensuring that the participatory process is well-facilitated, managing resistance, tailoring the intervention to the specific context of the work place, evaluating the results of the intervention and ensuring that the intervention is sustainable.
[90]	The study aims to evaluate the importance of	Ergonomic factors were determined	The three most significant factors are improving

Table 2.1. Summary of the critical success factors of ergonomics. (cont.)

Study	Purpose	Method	Main Findings
	ergonomic goals for companies. The goals that companies want to achieve through ergonomic interventions are evaluated as ergonomic factors in this study.	using the fuzzy Delphi approach.	physical health, reducing fatigue and enhancing productivity.
[91]	This study, which is based on the manufacturing industry, identifies the elements that can result in successful ergonomics interventions and considers the actions of the ergonomics commissions.	In this study, tug-of-war scenarios and a thorough questionnaire were utilized to examine the effectiveness of ergonomics commissions in industrial firms.	Out of the five subgroups, support for the commission's exercises ranking as the most crucial one. It was also stated that the organization's support for ergonomics studies would be beneficial.

Table 2.2 lists the CSFs of ergonomics based on the relevant literature.

Table 2.2. Critical Success Factors of Ergonomics.

CSFs	[6]	[3]	[7]	[5]	[81]	[82]	[90]	[91]	[83]	[84]	[85]	[86]	[88]	[89]	[87]
Organization															
Top management commitment and engagement	+			+		+		+	+		+	+		+	+

Table 2.2. Critical Success Factors of Ergonomics. (cont.)

CSFs	[6]	[3]	[7]	[5]	[81]	[82]	[90]	[91]	[83]	[84]	[85]	[86]	[88]	[89]	[87]
Organizational structure	+			+	+										+
Coordination, collaboration, and communication			+		+			+	+		+			+	+
Supervision and management styles	+			+	+						+				+
Performance evaluation, rewards, and incentives	+														+
Long-term strategy planning, tracking and reporting	+	+			+										
Employee															
Education, knowledge and skills	+					+			+	+	+	+	+	+	+
Physical characteristics		+				+	+			+			+	+	+
Psychological characteristics		+				+	+			+				+	+
Motivation and need of employees	+					+			+		+				+
Employee participation	+			+				+	+			+	+	+	+
Employee performance	+		+	+			+				+				+

Table 2.2. Critical Success Factors of Ergonomics. (cont.)

CSFs	[6]	[3]	[7]	[5]	[81]	[82]	[90]	[91]	[83]	[84]	[85]	[86]	[88]	[89]	[87]
Teamwork	+		+									+			+
Training for employees	+				+	+			+						+
Method, Tools & Technology															
Data-driven approach and data analysis	+	+								+					+
User friendly technology, hardware and software	+	+			+										+
Continuous Improvement (Kaizen)		+					+		+			+		+	+
Tasks															
Work demand (acceptable workloads)	+				+	+				+			+		+
Enriched work and job rotation					+	+			+	+			+		+
Enhancing the process, service, or product quality	+						+		+	+			+		
Employee health, safety and welfare	+					+	+			+					+

Table 2.2. Critical Success Factors of Ergonomics. (cont.)

CSFs	[6]	[3]	[7]	[5]	[81]	[82]	[90]	[91]	[83]	[84]	[85]	[86]	[88]	[89]	[87]
Use of personal protective equipment	+					+			+						+
Reducing employee health and safety risks	+				+	+									
Organizational culture and establishing a safety culture		+	+		+	+	+			+	+			+	+
Favorable environmental conditions (e.g. low noise, clean air, normal climatic conditions)					+	+			+						+
Ergonomic design of workstations, tools and equipment	+	+		+		+				+			+		+

Table 2.2 indicates that the following CSFs are the most important ones in order:

- Top management, commitment and engagement
- Coordination, collaboration and communication
- Education, knowledge and skills
- Employee participation
- Organizational culture and establishing a safety culture
- Ergonomic design of workstations, tools and equipment

2.7. Contributions of Ergonomics to Company Strategies

Ergonomics holds significant importance for company strategies across various sectors. Its contributions to company strategies include:

- (i) **Enhanced Productivity;** Ergonomic tools and work systems reduce employee fatigue, leading to increased productivity and profitability in companies focused on productivity [92].
- (ii) **Reduced Absenteeism and Work-Related Injuries;** Prioritizing ergonomics results in fewer work-related musculoskeletal disorders (WRMSDs) and injuries, enhancing employee well being, decreasing operational expenses and reducing absenteeism [93].
- (iii) **Improved Quality and Customer Satisfaction;** Ergonomic products and interfaces enhance customer satisfaction, leading to increased customer engagement and loyalty. This ultimately provides a competitive advantage through improved product and service quality [94].
- (iv) **Compliance with Regulations and Standards;** Adhering to ergonomic regulations ensures a safer work environment, minimizing legal issues, fines and reputational damage. Ergonomic practices foster a safer and more responsible work environment, ensuring compliance with regulations and standards [95].
- (v) **Talent Attraction and Retention;** Prioritizing ergonomics demonstrates a commitment to employee well being, aiding in attracting and retaining skilled workers. Ergonomic workspaces and policies differentiate companies in the competitive job market, assisting in effective recruitment and retention [96].
- (vi) **Innovation and Differentiation;** Ergonomics contributes to innovation in both product and process design, aiming to produce user-friendly products and improve production efficiency [97]. It fosters customer loyalty and helps establish companies' value in the marketplace through innovative approaches to design and problem-solving [98].
- (vii) **Sustainability and Corporate Social Responsibility (CSR);** Ergonomic design principles prioritize sustainability, aiming to reduce waste and efficiently utilize re-

sources. Integrating Corporate Social Responsibility (CSR) into ergonomic practices enhances companies' brand value in the market [99].

- (viii) Enhanced Organizational Performance; Macroergonomics enhances efficiency, productivity and overall company performance by aligning the organizational structure with employee needs [100]. Ergonomics helps achieve production-related and human-oriented workplace design goals, contributing to employee health, safety and overall system performance [101].
- (ix) Strategic Decision Making; Macroergonomics integrates employee performance and behavior with organizational structure and processes in strategic decision-making processes [102]. Ergonomics contributes to business strategy goals such as profit maximization, cost reduction, customer satisfaction, sustainability, innovation, product quality and employee satisfaction at every stage of products and processes.
- (x) Competitive Advantage; Companies adopting macroergonomic approaches gain a competitive edge through effective utilization of employees, innovation and adaptability [103]. Ergonomically designed workstations help companies achieve cost reduction goals by reducing employee risks and increasing productivity due to their convenient design.
- (xi) Change Management and Adaptability; Rapid adaptation to new processes and technologies, along with focusing on human factors to adapt to changing conditions, is crucial for companies emphasizing continuous development [58].
- (xii) Safety; Ergonomics significantly contributes to business strategies by designing workstations considering employees' characteristics and adopting a human-oriented philosophy [104]. It enhances employee well being and system performance, contributing to productivity, efficiency, quality, flexibility and cost reduction.
- (xiii) Customer-Oriented Approach; Ergonomics plays a crucial role in developing marketing strategies for product features such as usability, functionality, comfort and safety. It contributes to reaching customer satisfaction, enhancing competitiveness and ensuring the sustainability of company strategies [6].

- (xiv) Employee Involvement and Empowerment; Ergonomics integrates employees into all processes, increasing the quality of processes and products through employee involvement and empowerment.

2.8. Overview of Lean Philosophy

A Lean approach is a systematic methodology aimed at continuous improvement of workflow processes, involving active participation of employees at every stage and focusing on identifying and eliminating waste [105].

The historical evolution of the lean philosophy dates back to the late 19th century and follows a chronological development [106]:

- In the early 1890s, craft production was prevalent in the automobile industry, with skilled workers producing vehicles at significant cost. At that time, about a thousand vehicles were manufactured annually, primarily for wealthy individuals [106].
- By the end of the 20th century, Henry Ford introduced mass production, enabling the production of more vehicles in a shorter time by manufacturing individual car parts. Ford's introduction of the assembly line in 1913 further enhanced production efficiency [106].
- In the early 1930s, despite the dominance of mass production by Ford, Chrysler and General Motors in the American automobile market, issues began to emerge. Additionally, the Japanese market demanded a wider variety of vehicles, which mass production could not accommodate. During this period, Japanese companies such as Toyota and Nissan started developing new models. Taichii Ohno and Eiji Toyoda developed the Toyota Production System, focusing on continuous improvement and incorporating lean manufacturing values that give priority to employees and customers [106].

Lean manufacturing combines the positive features of craft production and mass production, aiming to reduce waste, eliminate errors, prevent overproduction, support innovation, increase quality, maintain customer and employee satisfaction and reduce costs. A fundamental aspect of lean production is the continuous improvement process, which utilizes approaches such as the "five whys" method to identify and address the root causes of errors, thereby increasing overall quality and efficiency in the long run. Lean manufacturing also employs a kanban delivery system, which establishes an advanced system with suppliers and eliminates the need for inventory space. While lean production originated in the automobile sector, it is now applied across various industries [106].

The primary objectives of lean philosophy include continuous improvement and enhanced efficiency across all institutional operations, aiming to minimize waste and maximize customer value [107].

Based on the principle of continuous improvement, the lean approach targets the elimination of non-value-added processes [108]. It emphasizes the active participation of employees in all processes and strives to integrate employee involvement into the corporate culture. By reducing inefficient processes, lean approaches aim to deliver services and products more effectively, with higher quality and at lower costs [109].

Non-value-added stages in the creation of services or products are identified as waste and targeted for elimination from the process. These wastes are categorized as follows: overproduction, defects, overprocessing, inventory (e.g., excess products, unread emails), waiting, transportation, motion (e.g., unnecessary movement), underutilization of employee skills, lack of knowledge, waste of resources and unused byproducts [110]. Originally referred to as "The 7 Wastes", the categories of waste have now been expanded to include 11 types:

- (i) Overproduction; Overproduction refers to the act of manufacturing more goods than are currently demanded.

- (ii) Inventory; Inventory waste occurs when there is an excess of stored goods, tying up capital and potentially leading to obsolescence.
- (iii) Waiting; Waiting waste encompasses delays in the production process, resulting in the inefficient use of time and resources.
- (iv) Transportation; Transportation waste involves the unnecessary movement of materials or products within the production process.
- (v) Motion; Motion waste refers to unnecessary movements of personnel or equipment, which can decrease efficiency.
- (vi) Defects; Defects occur when errors or mistakes in production necessitate rework or correction.
- (vii) Overprocessing; Overprocessing waste involves performing more work than is necessary to achieve the desired outcome, leading to inefficiency in the production process.
- (viii) Underutilization of Employee Skills; Underutilization of employee skills results in decreased productivity and missed opportunities for innovation and improvement within the organization.
- (ix) Lack of Knowledge; Waste due to a lack of knowledge occurs when employees do not have access to necessary information or training, leading to errors and inefficient resource utilization.
- (x) Waste of Resources; Waste of resources occurs when materials, time, or energy are used inefficiently, resulting in increased costs and reduced profitability.
- (xi) Unused Byproducts; Unused byproducts represent wasted opportunities for resource optimization and environmental sustainability, leading to increased waste disposal costs and environmental impact.

2.9. Lean Principles

The Toyota Production System (TPS) introduced lean principles, which have been widely adopted across various industries as a fundamental approach to business operations. Lean thinking has five principles [111, 113]. These lean principles, designed to minimize waste and maximize value, and include:

- (i) Value; Determining how the product or service will meet the customer's needs.
- (ii) Value Stream; Defining the process from production to delivery after determining the value of the product and service. By visualizing the value flow, non-value-added processes can be identified and improved.
- (iii) Flow; Removing interruptions to the value flow to eliminate waste. This involves reducing batch sizes, cycle times and eliminating bottlenecks.
- (iv) Pull; Enabling the consumer to pull value from the producer. This helps in reducing excess inventory, preventing overproduction and optimizing resource utilization.
- (v) Perfection; Embracing continuous improvement in every aspect of the organization and processes. It fosters a culture of excellence where employee participation is encouraged to identify and eliminate waste [4].

Consequently, companies employing the lean approach deliver higher quality products and services to their customers. They actively engage their employees in the process through training and empowerment, thereby ensuring both employee and customer satisfaction. The adoption of the lean approach also yields overarching benefits, including reduced production costs and the delivery of high-quality products and services [105].

2.10. Lean Tools

Lean tools encompass a set of techniques and principles utilized in process optimization within the lean methodology, aiming to reduce waste and enhance efficiency. These tools are applied in many industries [114]. Some of the key lean tools include:

- (i) Value Stream Mapping (VSM); VSM is a graphical tool that represents the steps, information and material flow involved in the production or service delivery process until it reaches the customer. It aims to identify waste through graphical analysis [115].

- (ii) 5S (now 6S) Methodology; The methodology organizes the business environment based on six principles: Sort, Set in Order, Shine, Standardize, Sustain and Safety. It ensures a clean and organized work environment to enhance safety and efficiency [116].
- (iii) Kaizen; Kaizen, meaning continuous improvement in Japanese, refers to the ongoing, incremental improvements made to processes to reduce waste and enhance quality and efficiency [117].
- (iv) Just-in-Time (JIT); JIT aims to minimize inventory levels by producing products or parts only when needed, reducing costs associated with excess inventory while also minimizing waste [118].
- (v) Kanban; Kanban is a visual planning system utilized for inventory management, employing signals or cards for workflow control and planning. It facilitates efficient resource utilization [119].
- (vi) Poka-Yoke (Mistake-Proofing); Poka-Yoke is an approach aimed at preventing errors and defects in processes before they occur, making it challenging to make mistakes [120].
- (vii) Total Productive Maintenance (TPM); TPM is an approach to machinery and equipment maintenance, aiming to maximize reliability, performance and usability. It encourages employee involvement in maintenance activities and proactive practices [121].
- (viii) Single Minute Exchange of Die (SMED); SMED aims to reduce machine setup times, increasing operational efficiency.
- (ix) Standard Work; Standard Work involves pre-documented procedures for processes or tasks, ensuring consistent, high-quality and efficient work processes through clear instructions provided to employees [108].
- (x) Root Cause Analysis (RCA); RCA is a problem-solving method that seeks to identify the underlying root cause of identified problems. It emphasizes addressing problems at their source, preventing their recurrence [122].
- (xi) Continuous Flow; Continuous Flow aims to achieve uninterrupted workflow by reducing cycle times and batch sizes, thereby minimizing inventory buildup, waiting times and bottlenecks [114].

Integration of multiple tools facilitates the streamlining of processes, elimination of waste and continuous improvement throughout organizational operations.

2.11. Critical Success Factors of Lean for Company Strategies

The lean philosophy, focusing on waste reduction, increased efficiency and continuous improvement, is widely employed in developing company strategies [107]. A number of critical success factors for integrating Lean into company strategies include:

- (i) Top Management Commitment; Active support and leadership from senior management are essential for managing Lean processes effectively [108]. Management should allocate resources, provide support and organize Lean initiatives.
- (ii) Employee Involvement and Empowerment; In line with lean principles, every employee should be involved in lean initiatives [123]. Employees are encouraged to actively participate in defining problems, proposing solutions and making decisions, fostering a culture of ownership and continuous improvement.
- (iii) Clear Communication and Vision; It is crucial that lean objectives are communicated throughout the organization [124]. Employees should understand the importance of lean initiatives within the company's vision. They need to recognize the integration between company goals and lean principles and how their roles contribute to achieving these goals.
- (iv) Training and Skill Development; Comprehensive training on lean principles and tools should be provided to all employees within the company [115]. These trainings help employees identify problems, reduce waste and streamline and improve processes.
- (v) Gemba (Go and See) Mentality; Gemba walks allow leaders to observe work in the actual work environment [125]. This enables closer monitoring of operations, a deeper understanding of operations and provides support to employees where necessary. Gemba walks also facilitate the analysis of problems where they occur and the generation of solutions.

- (vi) Continuous Improvement Culture; A culture of continuous improvement should permeate daily activities [126]. Encouraging the exploration of different methods, taking risks and learning from mistakes fosters a culture of continuous improvement.
- (vii) Visual Management; Visual management systems facilitate the tracking of current goals, processes and performance [127]. Tools such as Andon lights, Kanban boards and performance control panels are employed to monitor and communicate progress between teams, identifying areas for improvement.
- (viii) Standardized Processes; Standardized procedures are established in operations to enhance efficiency and consistency [128]. These procedures minimize variability and promote best practices, ultimately enhancing quality.
- (ix) Value Stream Mapping (VSM); VSM is utilized to identify and optimize value-creating processes in process flows, eliminating processes that do not add value [129]. It focuses on process improvements and streamlining workflows for increased efficiency.
- (x) Kaizen Events; Kaizen aims to drive regular improvements in processes. These activities are crucial for fostering teamwork, problem-solving and identifying areas for improvement [130].
- (xi) Supplier Collaboration; Active participation of stakeholders in the process is fundamental to Lean principles [131]. Collaborating closely with suppliers and stakeholders enhances the quality and efficiency of processes, while also reducing delivery times.
- (xii) Performance Measurement and Feedback; Key Performance Indicators (KPIs) are employed to measure performance and monitor processes [132]. Regular monitoring of performance through KPIs allows for timely identification of areas for improvement and the implementation of corrective actions.

By leveraging these lean success factors and incorporating them into their strategic frameworks, organizations can sustain their competitive edge in the market while executing their processes more efficiently and with higher quality.

2.12. Studies on Critical Success Factors of Lean for Company Strategies

The literature's most researched critical success factors, according to the references in Table 2.3, are categorized as;

- organization,
- person,
- tools and technology,
- environment,
- customer

These categories include factors such as;

- top management's involvement and commitment,
- employee involvement and participation,
- effective communication within the organization,
- leadership,
- policies and management methodology,
- understanding and implementation of lean tools,
- human engagement,
- organizational culture and competencies,
- customer-related factors,
- market and supplier factors,
- motivational approaches,
- job environment and satisfaction,
- the development of new behavioural patterns,
- strict implementation of lean tools and methods.

These success factors have been frequently studied and the analysis results have shown that they are the most important factors affecting company success and performance.

Summary of the related research are summarized in Table 2.3, Table 2.4 and Table 2.5 Table 2.3 summarizes the studies on finding the CSFs of Lean.

Table 2.3. Summary of the critical success factors of lean.

Study	Purpose	Method	Main Findings
[133]	This study aims to identify critical success factors for Lean Six Sigma implementation from the perspective of middle management.	A mixed-method approach was employed, utilizing surveys and interviews to collect both quantitative and qualitative data from middle management.	The primary findings indicate that employee participation, leadership commitment, training and organizational culture are the most critical factors for the success of Lean Six Sigma initiatives.
[134]	The objective of this study is to identify critical success factors for the successful implementation of Lean practices in Small and Medium Enterprises (SMEs).	Both qualitative and quantitative data collection techniques were employed, utilizing surveys and interviews.	The data was analyzed, revealing that top management commitment, training, employee involvement and supplier involvement are the most critical success factors.
[135]	This study conducts a comprehensive review of existing literature to identify critical success factors	The research synthesizes success factors from a wide range of sources through an extensive literature review.	Ultimately, critical success factors for longterm success in Lean implementations include leadership commitment, employee involvement, continuous

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	for long-term success in Lean implementations.		improvement culture, performance measurement systems, training and education and supplier collaboration.
[136]	The aim of this study is to identify critical success factors for Lean management through an extensive literature review.	The research synthesizes success factors from a wide range of sources through an extensive literature review.	The study identifies and categorizes critical success factors under the categories of leadership, people, process and technology. The most important success factors identified include top management commitment, employee involvement, effective communication, continuous improvement and performance measurement.
[137]	This study aims to identify Critical Success Factors (CSFs) for successful Lean operations in Nigerian manufacturing companies.	Surveys, interviews and case studies were utilized as research methods.	Critical success factors identified for successful Lean practices in Nigeria include leadership commitment, training and performance measurement, employee participation, effective communication and cultural adaptation.

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
[138]	This study aims to identify critical success factors for the successful implementation of Lean practices in the healthcare sector.	Data analysis methods included a literature review, establishment of inclusion and exclusion criteria and data extraction and analysis.	Critical success factors identified for the success of Lean applications in the healthcare sector include leadership commitment, employee involvement, continuous improvement, patient-centered focus and data-driven decision-making.
[139]	This exploratory study investigates Critical Success Factors (CSFs) for successful local Lean applications in the Saudi Arabian region.	Surveys, interviews and case studies were employed in the research.	Critical success factors identified for successful Lean applications in Saudi Arabia include leadership commitment, employee participation, organizational culture, supplier collaboration, performance measurement and monitoring and continuous improvement culture.
[140]	This study aims to identify critical success factors for successful Lean	Surveys, interviews and case studies were utilized as research methods.	The most important factors identified include leadership commitment, supplier collaboration,

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	applications in Australia.		employee participation, continuous improvement culture and comprehensive training programs.
[141]	The study aims to determine the critical success factors for companies that adopt a lean manufacturing approach.	Sixteen critical success factors were determined through a literature review; data collected through a questionnaire and statistically analyzed.	Customer performance and business project improvement are the main reasons motivating lean implementation. In addition, involvement and commitment of the top management, involvement and participation of employees and communication within the company (objectives, vision, goals, etc.), which are the factors of the human elements category, were found to be the most critical success factors.

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
[142]	The aim of this study is to determine and evaluate the success factors in lean applications for SMEs and to determine the critical factors.	In the study, 28 critical factors were determined and divided into five categories: leadership, policy and management; technic, funding and process; humans, culture and competencies; customers, market and suppliers and methodology and implementation. CSFs are prioritized using the analytical hierarchy process (AHP).	CSFs are prioritized as follows; leadership, policy and management, methodology, understanding and implementation, humans, culture and competencies, technique, funding and process, customers, market and suppliers
[143]	The study aims to determine which success factors are more critical for SMEs using varying degrees of lean practice.	12 success factors were determined. Necessary Condition Analysis was used for analysis.	While improvement training, learning focus and support congruence factors are critical for a company that has just started lean implementation, factors such as top management support, a shared improvement vision and a supplier link are critical for large companies.

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
[8]	The study compared the importance of 13 identical critical success factors between lean and six sigma methodologies.	Statistical methods are used to determine whether there were significant differences between lean and six sigma.	The most important success factors for lean and six sigma differ. While employee involvement and culture change are the most important factors for successful lean implementation; expertise and skills are the most critical factors for six sigma implementations.
[10]	The study aims to identify critical success factors for effective lean six sigma applications.	A comprehensive literature review was conducted and comparisons of case studies were presented to determine the CSFs for Lean six sigma.	Four critical factors were identified; management commitment, linking Lean Six Sigma to business strategy, cultural change and leadership styles.
[11]	The aim of this study was to identify the critical success factors (CSFs) for lean deployment in	The strategy employed in this study is an online survey to obtain data. The survey's findings were then put to use in developing a model	A culture of continuous improvement, the percentage of the company that has received lean training, the implementation

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	enterprises.	and testing a hypothesis. The forward stepwise technique, an automated search method, was used to build the model.	of a Kanban system and a focus on making modest improvements in processes were the top four CSFs.
[145]	The objective of this study is to determine the critical success factors (CSFs) for a system named Sustainable Lean Six Sigma (LSS), design a hierarchical structural model, compute the driver and dependence CSF and validate the model in detail.	The researchers combined different methods, including statistical analysis and an open-ended questionnaire survey. Additionally, they classified the CSFs using the FMICMAC method and created a hierarchical model of the interactions between them using the TISM methodology. Finally, they analyzed the relationships between the CSFs using structural equation modeling (SEM).	Top-level CSFs include management involvement in LSS implementation, structured LSS implementation training, clear and specific target-oriented objectives, sustainable project selection and prioritization and appropriate availability of funds, resources and their usage.
[146]	The study's objective is to assist industries in identifying the CSFs	The Analytic Hierarchy Process (AHP) is used to determine the critical success factors (CSFs)	According to the findings, four factors motivational approach, upgrade job environment and satisfaction;

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	required to successfully implement lean and decrease waste, which will lead to an improvement in production and profitability.	required for the effective use of lean.	leadership and responsibility; the development of new behavior patterns; and strict implementation of lean tools and methods.-are most crucial for successful implementation.
[10]	The objective of this paper is to analyze and construct a list of the critical success factors (CSFs) for the Lean Six Sigma application (LSS).	To find major CSFs, the affinity diagram tool is performed.	The most significant category of CSFs are defined as management commitment and leadership, Lean Six Sigma competency, training and education, organisational infrastructure and project management that link LSS to business strategy.
[147]	The goal of this study Is to indentify CSFs for LSS and generate a	An examination of the available research in the field was conducted to create a framework.	Dedicated management and employee, readiness of organization to

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	framework of the Green and Lean Six Sigma methodologies.	Data were collected from several firms through survey.	execute green and lean six sigma, selection and prioritize of projects, facilitate resources and skills for implementation, concentration on estimation and results of LSS projects are found as the most significant CSFs.
[148]	This study intends to identify and classify the Lean Six Sigma (LSS) framework's critical success factors (CSFs) of small and medium-sized enterprises (SMEs)	The study is the literature on CSFs, gathers data using an exploratory research and employs Pareto analysis to rank the CSFs.	The following CSFs are found as the most important ones: Training, Management Involvement and Commitment, Customer Satisfaction and Leadership.
[149]	This study intends to offer a method for assessing Lean Six Sigma's (LSS) critical	To evaluate CSFs, a graph theoretic technique is used. A literature review article [148] is used to build the CSF index.	This research offers recommendations for how to convert critical success factors (CSFs) into an index.

Table 2.3. Summary of the critical success factors of lean. (cont.)

Study	Purpose	Method	Main Findings
	success factors (CSFs) for small and medium sized enterprises (SMEs) in India.		
[150]	Finding the critical success factors (CSFs) for adopting Six Sigma in SMEs is the main objective of this study.	The AHP is used to rank CSFs.	The top three critical factors found are: management involvement, commitment and participation and training; Understanding the methodology, tools and techniques; Project management skills ; and linking Six Sigma to business strategy. Most critical categories are the project prioritization and selection, organizational infrastructure and resources, cultural change and linking Six Sigma to customers.

Table 2.4. Lean critical success factors. (cont.)

CFSs	[141]	[142]	[143]	[8]	[149]	[11]	[145]	[146]	[10]	[147]	[148]	[150]	[144]
Employee													
Education, knowledge and skills				+		+	+	+	+	+	+	+	+
Motivation and needs of employee		+						+					
Employee participation	+	+	+	+	+	+	+			+	+		
Employee performance	+						+						
Teamwork			+			+	+	+	+		+		
Training for employees		+	+	+	+								
Method, Tools and Technology													
Data-driven approach and data analysis							+	+			+	+	+
Implementing kanban system					+	+							
Implementing value stream mapping (VSM)						+				+			
Implementing the SMED approach						+		+					

Table 2.4. Lean critical success factors. (cont.)

CFSs	[141]	[142]	[143]	[8]	[149]	[11]	[145]	[146]	[10]	[147]	[148]	[150]	[144]
Implementing Total Productive Maintenance (TPM)					+			+					
Poka Yoke implementation						+							
Continuous Improvement (Kaizen)		+				+	+	+		+			
Tasks													
Gemba walks		+											
Flexibility, speed and efficiency increase		+						+			+		
Enhancing the quality of process, service or product		+						+			+		
Environment and Safety													
Employee health, safety and wellbeing							+						
6S implementation Reducing employee health and safety risks		+				+							

Table 2.4. Lean critical success factors. (cont.)

CFSs	[141]	[142]	[143]	[8]	[149]	[11]	[145]	[146]	[10]	[147]	[148]	[150]	[144]
Organizational culture and lean culture		+		+		+	+		+	+		+	
Safe and ergonomic design of workstations, tools and equipment		+							+				
Customer and Supplier													
Cooperating effectively with the supplier		+	+	+	+		+	+	+	+	+	+	+
Benefiting from customer feedback and complaints	+	+	+	+		+						+	+
Meeting customer/ stakeholder demands and expectations	+	+	+	+	+	+	+		+		+	+	

Table 2.5 lists the CSFs of Lean based on the relevant literature.

Table 2.5. Lean critical success factors 1.

CFSs	[133]	[134]	[135]	[136]	[137]	[138]	[139]	[140]
Organization								
Top management commitment and engagement	+	+	+	+	+	+	+	+
Organizational Structure	+				+			
Coordination, collaboration, and communication	+	+	+	+	+	+	+	+
Supervision and management styles			+	+				+
Performance evaluation, rewards and incentives		+	+	+			+	
Visual Management practices								
Long-term strategy planning, tracking and reporting	+	+	+	+		+		
Employee								
Education, knowledge and skills				+	+	+	+	+

Table 2.5. Lean critical success factors 1. (cont.)

CFSs	[133]	[134]	[135]	[136]	[137]	[138]	[139]	[140]
Motivation and needs of employee		+						+
Employee participation	+	+	+	+	+	+	+	
Employee performance	+						+	
Teamwork			+			+	+	+
Training for employees	+	+	+	+	+	+		
Method, Tools and Technology								
Data-driven approach and data analysis							+	+
Implementing kanban system	+		+		+	+	+	
Implementing value stream mapping (VSM)	+		+		+	+	+	
Implementing the SMED approach	+		+		+	+	+	+
Implementing Total Productive Maintenance (TPM)	+		+		+		+	+
Poka Yoke implementation	+		+		+	+	+	

Table 2.5. Lean critical success factors 1. (cont.)

CFSs	[133]	[134]	[135]	[136]	[137]	[138]	[139]	[140]
Continuous Improvement (Kaizen)	+		+	+	+	+	+	+
Tasks								
Gemba walks Flexibility, speed and efficiency increase				+				+
Enhancing the quality of process, service or product								+
Environment and Safety								
Employee health, safety and wellbeing 6S implementation		+				+	+	
Reducing employee health and safety risks								
Organizational culture and lean culture	+	+	+	+	+	+		+
Safe and ergonomic design of workstations, tools and equipment		+						

Table 2.5. Lean critical success factors 1. (cont.)

CFSs	[133]	[134]	[135]	[136]	[137]	[138]	[139]	[140]
Customer and Supplier								
Cooperating effectively with the supplier		+	+	+		+		
Benefiting from customer feedback and complaints	+	+	+	+	+		+	+
Meeting customer/stakeholder demands and expectations	+	+	+	+	+	+	+	+

These studies offer insights into both common and distinct critical success factors contributing to the effectiveness of Lean applications across diverse industries, geographical regions and organizational sizes.

Table 2.4 and Table 2.5 indicates that the following CSFs are the most important ones in order:

- Top management commitment and engagement
- Coordination, collaboration and communication
- Performance evaluation, rewards and incentives
- Education, knowledge and skills
- Employee participation
- Organizational culture and lean culture
- Cooperating effectively with the supplier
- Meeting customer/stakeholder demands and expectations

2.13. Lean Contributions to Company Strategies

The lean philosophy, fundamentally oriented towards waste reduction and efficiency enhancement, is underpinned by the principle of continuous improvement.

Consequently, Lean methodology is crucial in shaping corporate strategies across various sectors. The primary contributions of lean to corporate strategies include the following:

- (i) **Waste Reduction;** Within lean methodology, waste is identified as excess inventory, overproduction, unnecessary transportation, waiting time, over-processing, defects and underutilized talent. Companies strive to mitigate these forms of waste, thereby enhancing the quality and productivity of their operational processes [151].
- (ii) **Continuous Improvement;** Known as Kaizen, continuous improvement is the cornerstone of the lean approach. It involves companies consistently making incremental improvements to processes or systems, thereby continuously enhancing their services and products [117].
- (iii) **Customer Focus;** Lean methodology emphasizes a customer-centric approach. By aligning the service or product with the customer's needs and demands, companies aim to ensure customer satisfaction and loyalty [114].
- (iv) **Flexibility and Adaptability;** The lean approach promotes operational flexibility and adaptability within processes or business systems. This enables companies to swiftly respond to evolving market conditions, technological advancements and shifting customer demands, thereby enhancing their competitiveness and sustainability in the sector [152].
- (v) **Employee Engagement;** Lean methodology advocates for the active involvement of employees in all processes. This engagement fosters improved problem-solving, decision-making and initiative-taking skills among employees when faced with challenges. Consequently, employee loyalty, sense of ownership and responsibility are bolstered, alongside increased morale and motivation [153].

- (vi) Quality Improvement; The aim of lean is to deliver high-quality products and services with a zero-defect approach. Techniques such as error prevention (Poka-Yoke), root cause analysis, Jidoka, standard work, visual management and cellular layout are employed to minimize costs while ensuring reliable and high-quality outputs. Quality increase provides customer satisfaction, which helps the company increasingly remain competitive in the industry and meet customers' needs. By applying these tools to products and processes, Lean tries to minimize waste and meet customer requirements [154].
- (vii) Cost Reduction; Lean methodology seeks to reduce costs through various strategies, including enhancing efficiency and quality and eliminating waste. Since the purpose of Lean is to reduce waste, tools such as VSM, 6S, continuous improvement, standard work and kanban minimize wastes such as excess inventory and overproduction which directly contribute to achieving one of its strategic goals, cost reduction [156]. By refining systems and processes, reducing waste and optimizing resource utilization, companies can achieve significant cost reductions [155].
- (viii) Innovation; Innovation is an important strategic goal for companies to remain competitive in today's conditions. Because customers prefer companies that can adapt to constantly changing market conditions from a wide range of products, for this reason, it has adopted the cellular layout, a lean approach to innovation. Product development and continuous improvement are also prominent lean approaches for innovation [156].
- (ix) Operational Efficiency; Lean tools such as Just in Time (JIT), Value Stream Mapping (VSM), Single Minute Exchange of Die (SMED) and Pull Production/Kanban are designed to achieve shorter lead times, which is a critical goal for many companies. By minimizing non value added tasks in production or processes, these tools enhance operational efficiency and speed.
- (x) Sustainability; Sustainability and the enhancement of employee capability and satisfaction constitute key strategic objectives for companies, both of which are supported by lean practices. By aligning their primary goals and integrating

suitable lean tools into their processes, companies can effectively enhance their overall performance and achieve their objectives more efficiently.

- (xi) Long term Planning and Perspective; To maintain competitiveness within their respective industries, companies must embrace long term planning and perspective, while remaining receptive to changes in company culture. Similarly, significant cultural change is imperative when integrating lean practices into their operations [157].

Incorporating lean principles into company strategies is pivotal in achieving strategic objectives. The lean approach significantly enhances process performance, thereby enabling companies to maintain competitiveness within the industry. Organizations that adopt lean methodologies and utilize lean tools to refine operational processes aim to achieve improvements in quality, productivity, efficiency and cost reduction [158].

2.14. Linking Ergonomics and Lean

For many years, the production sector has pursued various company strategies, including customer satisfaction, cost minimization and profit maximization, to maintain competitiveness. In alignment with these strategies, the waste minimization-oriented lean approach and the ergonomics approach, which focuses on human health, safety and performance, have been significant contributors to the success of these strategies. Given that lean and ergonomics share similar strategic goals and are closely interrelated in their application, there is a growing need for companies to establish an integrated management system [159].

The theoretical principles of Lean philosophy, such as waste minimization and a people-oriented approach, were initially developed within the Toyota Production System. However, significant differences exist between the theoretical concepts of Lean and their practical applications. For example, while autonomy is highly valued in Lean theory, practical implementations often involve close monitoring of employees by

management [160]. Similarly, although empowerment is considered crucial for successful Lean implementation, its practical application varies depending on social relations within the organization. Employee participation, another essential component of Lean, is often limited in real-world applications within the sector [160].

Due to variations in Lean applications across industries, countries and companies, achieving the level of human factor integration valued by the Toyota Production System (TPS) targets can be challenging. This discrepancy may have adverse effects on employees, highlighting the close relationship between ergonomics and Lean applications. Studies have indicated that for Lean practices to achieve their intended purpose, they should be integrated with ergonomics. Furthermore, it has been found that unless due importance is given to the human factor, Just in Time practices can increase pressure and stress among employees [160].

Both the ergonomics and lean approach aim to optimize systems and processes, enhance productivity, and improve employee health and well being. Combining ergonomics and lean principles offers several key benefits:

- Improved Process Efficiency; Lean principles aim to cut waste and boost efficiency. When ergonomic factors are considered in process design, it helps eliminate waste caused by employee posture and movement issues. This integration reduces errors, injuries, and unnecessary movements, making operations smoother [151].
- Decreased Work-related Injuries; Integrating ergonomics with lean can prevent musculoskeletal disorders (MSDs). By addressing ergonomic concerns alongside lean strategies, repetitive movements, lifting, and posture-related problems are minimized, promoting employee health and safety. This approach also reduces costs related to compensation and healthcare [114].
- Optimized Production Flow; Ergonomic workstations optimize production flow and reduce bottlenecks by protecting employees from unnecessary strains. This aligns with lean goals of minimizing waste and improving business processes [151].

- **Cost Savings;** Integrating ergonomics and lean reduces risks, boosts productivity, and cuts down on health-related expenses and operational inefficiencies. By prioritizing employee well being, organizations can also save on recruitment and training costs, ensuring long-term employee retention. Overall, this integration leads to cost savings across various operational and human resource aspects [114].
- **Safety and Quality;** Ergonomics ensures safety by identifying workplace risk factors and mitigating these risks, which in turn reduces errors and enhances the quality of products and services [29]. Lean methodology also aims to reduce waste while employing tools and principles that bolster safety and quality [153]. By minimizing waste in processes, lean methodology enhances the quality of outputs. Consequently, the integration of ergonomics and lean practices can have a synergistic effect on increasing safety and quality [161].
- **Workstation Design;** Ergonomically designed workstations, which include optimal layout, tool placement and ergonomic seating arrangements, aim to facilitate efficient workflows. This aligns with lean's focus on reducing waste by optimizing workflow and minimizing unnecessary movements. Ergonomic designs contribute positively to employee health, productivity and well being, thereby supporting employee satisfaction, a fundamental aspect of the lean approach [162].
- **Employee Engagement;** Both ergonomics and lean methodologies encourage active employee participation in identifying, addressing and resolving problems [163]. Employee engagement is critical for continuous improvement, a core principle of lean [161]. In ergonomics, employees actively participate in designing their work environment and providing feedback on workstation setups, enhancing the functionality of ergonomic designs [17]. Stress, health, safety issues, morale, motivation and employee performance are important considerations for both ergonomics and lean. Therefore, an integrated approach of ergonomics and lean is required to address these aspects effectively [164].
- **Kaizen Events;** The principle of continuous improvement is shared by both ergonomics and lean, albeit with different focal points. Ergonomics emphasizes the incremental improvement of workstations and specific processes, while lean focuses on the ongoing enhancement of processes and systems. Integrating er-

gonomics with lean kaizen activities can foster productivity and employee well being, making these improvements more sustainable [165]. Since continuous improvement is a company strategy in both lean and ergonomics, simultaneous application is necessary to avoid duplicating similar steps and wasting time, resources and labor. These integrated applications have yielded significant benefits for employee health and job satisfaction [166].

- **Waste Reduction;** One of the basic principles of Lean is Muri, which refers to actions closely related to the human factor and means overburdening. Activities such as pushing, pulling and lifting heavy loads are closely related to ergonomics. To provide solutions based on the Lean philosophy, it is necessary to integrate Lean and ergonomics. This integration is essential for the success of the solution [167].

Integrating the ergonomics approach into the lean methodology supports ergonomic goals such as active employee participation, enhanced safety and quality and optimized work environments. This integration facilitates the achievement of operational excellence and continuous improvement, making it easier for companies to uphold these principles. Given this interrelated relationship, studies focusing on integrating lean and ergonomics competencies have been conducted. Consequently, given that the workforce is the most important asset of companies to realize their goals, there has been an increasing emphasis on integrating lean and ergonomic approaches across various scopes and dimensions, as discussed in the following section.

2.15. Studies on the Integration of Lean and Ergonomics

- (i) **Improving Ergonomics within Lean Manufacturing;** Numerous studies have examined the integration of ergonomics within lean manufacturing processes. Li (2017) highlighted how ergonomic principles contribute to reducing waste, enhancing process efficiency and improving employee satisfaction, which are fundamental aspects of lean manufacturing [168].

- (ii) **Enhancing Worker Safety;** Adopting a lean approach to ergonomics can significantly enhance workplace safety and productivity by optimizing processes and eliminating security vulnerabilities. Hignett (2018) found that ergonomic redesign of work environments not only boosts productivity but also reduces costs associated with musculoskeletal disorders (MSDs) and other injuries [169].
- (iii) **Employee Involvement and Engagement;** Employee participation is crucial for continuous improvement in lean manufacturing. Integrating ergonomics into lean practices fosters greater employee involvement in identifying ergonomic issues, analyzing problems and developing solutions [170].
- (iv) **Case Studies and Practical Applications;** Various companies have implemented ergonomics within their lean production processes, conducting case studies to analyze this integration. These studies document ergonomic transformations in lean processes, outline the challenges encountered, detail company strategies and highlight the positive outcomes achieved [171].
- (v) **Training and Education;** Training for employees and managers is essential to recognize ergonomic risks in lean applications and develop appropriate solutions. Effective integration of lean and ergonomics requires ongoing education to ensure proper practices and enhance productivity and efficiency [172].
- (vi) **Productivity and Ergonomics in Lean Environments;** Neumann (2016) investigated the relationship between ergonomics and productivity within lean environments [173]. Their study emphasized the importance of ergonomic practices in improving both the efficiency and well being of employees, thereby boosting overall productivity.
- (vii) **Cost-Benefit Analysis of Ergonomic Interventions;** Occhipinti and Colombini (2018) conducted cost-benefit analyses of ergonomic improvements in lean production settings [174]. They concluded that ergonomic interventions yield economic benefits by reducing turnover rates, absenteeism and healthcare costs.
- (viii) **Worker Satisfaction and Ergonomic Improvements;** Research by Bond (2019) demonstrated that integrating ergonomics into lean production environments significantly enhances employee satisfaction, morale and motivation [175]. Conse-

quently, ergonomic improvements lead to greater employee loyalty and job satisfaction in lean manufacturing.

- (ix) Integration of Lean and Ergonomics in Healthcare; The healthcare sector is increasingly adopting lean and ergonomics approaches to improve workflow efficiency, patient safety and staff satisfaction. Carayon (2015) studied the integration of these approaches in healthcare, highlighting their effectiveness in achieving these goals [176].
- (x) Long-Term Effects of Ergonomic Interventions; Gallagher (2017) explored the long-term effects of integrating ergonomic applications into lean production environments [177]. Their study provided insights into the sustainability and contributions of ergonomic interventions to lean production over time.
- (xi) Enhancing Efficiency and Safety in Lean Manufacturing through Ergonomics; Mahdi and Mahbubah [178] utilized lean and ergonomics methodologies along with their evaluation tools to reduce non-value-added activities, namely wastes. Value stream mapping (VSM), a lean tool, was employed to analyze the current situation and detect waste. The wastes identified after VSM analysis included waiting, excess processing and defects. A fishbone diagram was used to determine the causes of the waste. Subsequently, a Future State Map was developed. Following the implementation of the Future State Map, the total lead time decreased from 600 to 550 minutes. Additionally, the Nordic Body Map (NBM) method was employed to assess ergonomic risks, particularly work posture. The identified ergonomic risks included repetitive tasks, excessive workloads and fatigue. According to the NBM results, the operators faced medium to high risk levels, with complaints of pain in the shoulders, hands and wrists. Mahdi recommended ergonomic workplace design, personal protective equipment and adequate education and training to mitigate these risks [178].
- (xii) Quality Increase; Muzakir and Padang [179] utilized the Integration of Ergonomics and Lean Six Sigma methodologies to analyze the quality of shipbuilding manufacturing processes. This integration involved the application of both methodologies' tools to the DMAIC cycle stages [179].

- (xiii) Define; Work posture was analyzed from an ergonomic perspective to define the problem. In the Lean approach, the Supplier Input Process Output Customer diagram (SIPOC) was utilized.
- (xiv) Measure; Work posture analysis was conducted and Defects Per Million Opportunities (DPMO) were calculated using the Lean Six Sigma approach. This calculation resulted in a sigma level value of 1.7034, indicating the need for adjustments and improvements.
- (xv) Analysis; RULA scores were calculated and risk categories were determined. In the Lean Six Sigma approach, the causes of defects were identified using Cause and Effect Diagrams and Failure Mode and Effect Analysis (FMEA).
- (xvi) Improvement; Recommendations were made based on the results of FMEA and RULA analyses.
- (xvii) Control; The integrated approach aimed to sustain continuous improvement.
- (xviii) Workstation Design; Jazani, Sahlabadi and Mousavi [180] discussed the relationship between ergonomics and lean approaches in workstation design. The study emphasized the contributions of ergonomics to lean tools such as cellular design and standard work. It highlighted the importance of ergonomics in lean applications and the significance of lean principles in ergonomics applications.
- (xix) Safety; Heller-Ono [181] discussed the Lean Approach to Ergonomics Process approach to reduce work injuries. Utilizing principles of continuous improvement, macro ergonomics, lean thinking and participatory ergonomics, the study aimed to enhance workplace safety.
- (xx) Impact of Ergonomics on Lean Manufacturing in the Automobile Industry; Rao and Niraj [182] conducted a case study to measure ergonomics' contribution to lean application in the automobile industry. Following the application of lean ergonomic manufacturing systems, feedback was collected via a questionnaire. The results showed a significant decrease in absenteeism, annual cost loss, defect rates and accidents, coupled with significant increases in quality and productivity.
- (xxi) Waste Minimization; Umar, Tiong, Ahmad and Dahalan [183] developed a framework by integrating ergonomics into the Lean concepts of Mura, Muda and Muri. The study applied a semi-structured interview method to experienced engineers

to identify ergonomic components. Four ergonomic themes emerged: Human energy waste, uneven workload distribution, overburden of workers' physical and mental capacities and worker performance affecting work performance. These themes were integrated into Lean's Mura, Muda and Muri concepts, resulting in a validated framework through the Fuzzy Delphi Method [183].

- (xxii) The Mura Concept in Lean Integrated with Ergonomics; Alsaffar and Ketan [184] utilized Lean Six Sigma's Mura concept and the RULA ergonomics tool to examine assembly workstations. They employed DMAIC and RULA tools to integrate ergonomics and Lean Six Sigma approaches. Following ergonomics workstation design recommendations, the initial RULA score of 7 (red) was reduced to 3 (yellow). Additionally, the application resulted in a decrease in the Mura waste rate from 77% to 17% [184].
- (xxiii) Setup Time Reduction [185] conducted a workplace assessment study using the ErgoSafeCI tool. The study also employed the ErgoSMED tool, developed to integrate ergonomic aspects into SMED, one of the lean tools. The improvements suggested in the study led to a 15% reduction in setup time.
- (xxiv) Efficiency and Productivity Increase; Gibson and Mrugalska [186] conducted a case study integrating a lean thinking approach with ergonomics to enhance efficiency and productivity while reducing defects and waste. The study identified waiting, inventory, motion and defects as wastes according to Lean principles. A spaghetti diagram was employed to identify motion waste. In addressing inventory waste, the study concluded that a system operating according to Lean's pull system, producing in small batch sizes, would be ergonomic in terms of transportation, reduce the risk of musculoskeletal disorders and prevent overproduction.

2.16. Common Critical Success Factors of Ergonomics and Lean

Based on the findings from the literature (Table 2.2, Table 2.4 and Table 2.5) the common CSFs are determined Figure 2.2. This section explains the determined CSFs for integrated ergonomics and lean. The success factors for the organization,

employees, methods, tools and technology, tasks, environments and safety and customer and supplier categories are described.

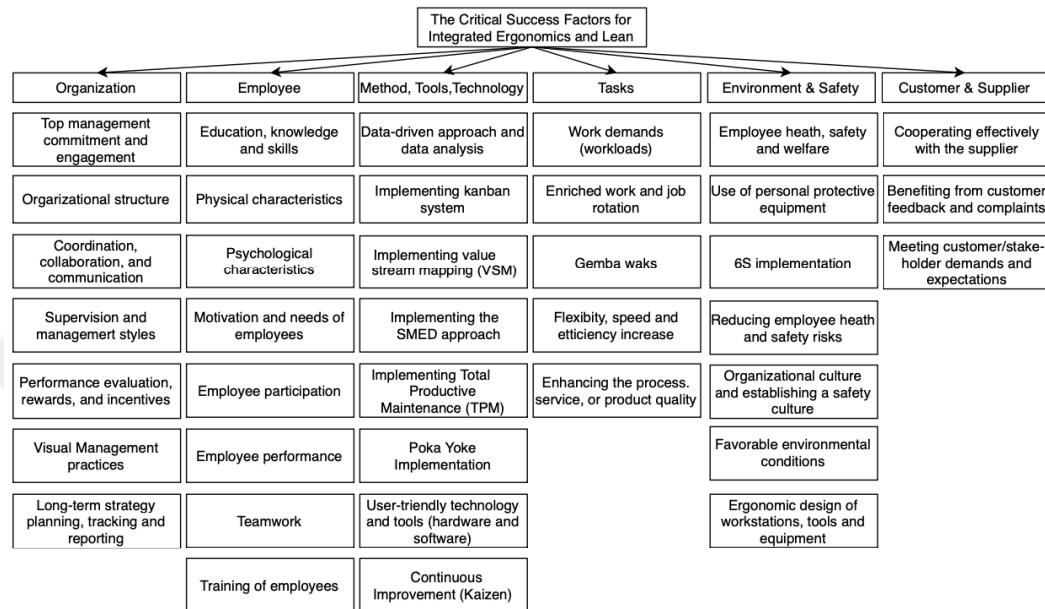


Figure 2.2. Integrated lean and ergonomics critical success factors.

2.17. Organization Category

Organization category consists of seven critical success factors: (i) Top management commitment and engagement, (ii) Organizational structure, (iii) Communication, coordination and cooperation among employees, (iv) Management and supervision style, (v) Rewarding, incentives and performance evaluation practices, (vi) Visual Management practices, (vii) Long term strategy planning, tracking and reporting.

2.17.1. Top Management, Commitment and Engagement

The success of ergonomics and lean programmes depends largely on top management, commitment and engagement. As top management adopts lean principles, corporate culture is formed. The commitment of the top management in this regard also sets an example for employees to adopt and apply lean principles. Additionally, lean practices need resources and support. Since this issue is related to financial decisions and the authority to make such decisions is only in the top management, it

is beneficial for the top management to provide resources for lean projects to increase business performance. Top management should determine long-term strategic goals for business continuity and ensure organization [5]. In addition, training is important in lean practices, so top management should encourage training that will enable development in lean principles. In addition, top management's commitment and engagement are very important for the sustainability of lean practices. In terms of ergonomics, top management's commitment and engagement play a very important role in issues such as employee health and safety, providing resources for ergonomic regulations, developing strategies in the field of ergonomics and encouraging employee participation in lean and ergonomic practices [6].

2.17.2. Organizational Structure

Organizational structure is a framework that organizes employee roles, responsibilities, hierarchy and collaboration. To implement lean principles, the organizational structure must develop practices encouraging teamwork and cooperation between teams. In lean production, there is more employee participation and empowerment, giving employees responsibility and initiative. In addition to all these, the organizational structure should support the development of lean and ergonomics strategies and setting goals. Employee involvement is also crucial in ergonomics practices [35].

Developing strategies regarding ergonomic practices, providing training on ergonomics and employee health and increasing employee awareness in this field, occupational health and safety practices, ergonomic working environment, tools, work processes and workstation design should be part of the organizational structure [87].

2.17.3. Coordination, Collaboration and Communication

Communication skills are critical in lean and ergonomics applications, as in all areas of business life. Effective team communication ensures that detected problems are quickly resolved, thus contributing to continuous improvement [143]. Cooperation

and coordination between teams help to optimize workflows, ensure good material flow and ultimately minimize waste. Teamwork and cooperation are very important to manage processes effectively and efficiently and the transfer of expertise as a result of teamwork is important for optimizing processes and identifying the root causes of problems more quickly [141]. In ergonomics, communication within the team is very important for rapidly detecting risks and ergonomic problems. The teams dealing with ergonomics and lean applications need to cooperate and coordinate with each other to manage the process effectively. At the same time, effective communication increases employee participation and awareness.

2.17.4. Supervision and Management Styles

Management and supervision style is a leadership approach and how employees are managed, monitored and supported. A good management and control style in Lean production can greatly contribute to business success [8]. Leaders should adopt lean principles and guide employees on this issue. The management style adopted should support employees' taking responsibility and active participation throughout the process. In Lean, flexibility, agility and the ability to adapt quickly to change are important elements of the management style [146]. Managers should participate in the process with their employees and cooperate with them by ensuring coordination for continuous improvement. The management style adopted should be focused on setting goals and achieving them, giving importance to training and development. In the field of ergonomics, management and supervision styles that prioritize employee health and safety, give importance to the ergonomic design of workstations, give importance to training and awareness, aim to benefit from employee feedback as much as possible and comply with OHS standards should be adopted.

2.17.5. Performance Evaluation, Rewards and Incentives

Particularly in the industrial sector, rewarding, incentives and performance evaluation practices are critical to success in lean and ergonomics applications. These incen-

tives and performance evaluations positively affect employee motivation and employee engagement. Performance based rewards have a great impact on employee performance. Incentives given to teams are also important for working more collaboratively towards common goals. Providing special incentives for training and programs and offering career opportunities increase employees' lean and ergonomics information and contribute to business success. Performance evaluations and receiving feedback from employees are also important to reveal any unnoticed problems and develop effective solutions to them. Employee participation can be increased by giving special rewards to encourage Occupational Health and Safety (OHS) practices [106]. The importance of having an improved reward mechanism to be recognized in the sector was emphasized and a significant relationship between reward and motivation was determined [87].

2.17.6. Visual Management Practices

Visual management aims to make everything visible and easily understood in the business environment. For example, information such as which task will be done, when by whom and how it will be done should be easily accessible and visible. The current status of the company or workflow should be displayed so that everyone can see and follow the current status [144]. This is also important so that problems can be noticed, known by everyone and acted upon accordingly. Placement, design and size of displays (visual or audial) require ergonomics.

2.17.7. Long-Term Strategy Planning, Tracking and Reporting

Since Lean and ergonomics applications are long-term projects, it is important to implement them successfully and ensure their continuity. Companies that adopt Lean principles should make long-term strategy planning and set goals. Continuous improvement, customer focus and waste reduction should be at the forefront when setting targets [141]. Problems that may be encountered should be anticipated through long-term strategy planning and intervention planning should be made. Determining the projects to be invested in, planning resource management, making regular reports

and monitoring performance outcomes are central elements of long-term planning for lean and ergonomics. In the field of ergonomics, it should also be included in the planning to protect long-term employee health and safety. Technical training, investments for improvements, employee incentives and ergonomic standards determination are issues that should be given importance in long-term planning, tracking and reporting [14].

2.18. Employee Category

Employee category includes eight CSF: (i) Knowledge, skills and experience of employees, (ii) Physical characteristics of employees, (iii) Behavior and psychological attitudes of employees, (iv) Employee morale and motivation, (v) Participation and empowerment of employees in improvements, (vi) Employee performance, (vii) Teamwork, (viii) Providing necessary lean, ergonomics and occupational health and safety.

2.18.1. Education, Knowledge and Skills

One of the most important issues to increase quality and efficiency in lean production is that employees have sufficient knowledge about lean tools and lean methodology. No matter how skilled an employee is, if he does not have adequate training in that technical subject, he cannot reach his full potential and therefore, the desired performance cannot be achieved [6]. Although occupational health and safety training is provided in companies to convey information about ergonomics, the scope of this training remains at a basic level and is not taken into consideration by employees. Since Lean adopts the philosophy of continuous improvement, great importance should be given to training to identify areas that need improvement in lean practices and implement improvements in these areas. Therefore, providing employees with the correct knowledge and skills is essential to effectively implement lean approaches and methods [8]. For this reason, training to increase employee skills and knowledge, which are indispensable in lean and ergonomics, should be periodically defined and monitored for employees. Today, companies that view training as an investment rather than an ex-

pense continue strengthening their position in the sector and increasing their business quality. Ergonomics knowledge on the correct use of the human body and correct use of tools, equipment and machines. Lean knowledge on, for example, 6S.

2.18.2. Physical Characteristics

The physical characteristics of employees are related to fitness, strength, flexibility and physical skills. Creating a working environment design according to the physical characteristics of employees will help protect employee health in the long term and thus positively affect employee performance. It has been seen in many studies in the literature that the physical characteristics of the employee have a significant effect on the performance of the work system [3]. At the same time, it has been observed that employee physical characteristics impact employee morale, motivation and psychological characteristics. Especially in lean applications, the harmony of the employee's physical characteristics with the working environment, stemming from the philosophy of lean, is of great importance. An ergonomic work environment provides employees with a safe work environment that is compatible with their physical characteristics, thus increasing employee satisfaction and, accordingly, employee performance. In addition, ergonomically designed work systems aim to reduce waste, which is a lean philosophy, as they reduce non-value-added movements in the work environment and the resulting time losses. In addition, since lean practices include standard work procedures, employees' physical characteristics are affected by this situation.

It aims to bring the workload of employees and the physical difficulties to an optimal level with the improvements identified thanks to the Kaizen approach.

2.18.3. Psychological Characteristics

Since employee psychological characteristics and attitudes are both affected by the work environment and directly affect the performance of the work environment, importance should be given to work system designs in lean and ergonomics applica-

tions. Employee psychological characteristics consist of many elements, such as stress management, emotional state management, perception style and internal motivation [7]. In companies that do not give due importance to employees' physical and psychological elements, an increase in the stress level of employees has been observed due to lean practices. Since lean tools aim to reduce waste, lean applications are carried out at an intense pace [3]. In this case, it becomes difficult for employees whose workload is not adjusted properly to cope with stress [3]. Therefore, paying attention to employees' psychological characteristics is critical to improving work efficiency and employee performance [5]. In addition, to ensure employee participation in the processes, the psychological attitude in the work environment must be positive. Thus, employees play a role in teamwork or take the initiative and contribute to improving system performance.

2.18.4. Motivation and Needs

Employee morale and motivation are critical for seeing the positive effects of lean and ergonomics practices. Keeping employees' motivation high depends on their job satisfaction and, accordingly, their commitment to the institution they work increases [5]. It has been observed that motivated employees exhibit more positive attitudes toward work participation, initiative and teamwork. In this way, improvements in business performance were observed. Therefore, companies need to support employees and meet their needs so that employees maintain morale and motivation [7]. Since lean practices require rapid changes, highly motivated employees can quickly adapt. For this reason, high morale and motivation of employees in lean applications are in a very critical position to achieve positive results on business performance and achieve goals.

2.18.5. Employee Participation

Employee participation and empowerment are other factors critical to achieving the desired performance outcomes in lean and ergonomics applications. Participation and empowerment of employees are closely related to collaboration, kaizen, problem-

solving, flexibility and adaptation in lean. In ergonomics, since it is closely related to efficiency, performance, job satisfaction, employee morale and stress reduction, the participation and empowerment of the employee in the process from beginning to end is critical to achieve the desired results [88]. As long as this issue is given importance, employee complaints will decrease and their commitment to the job and the institution will increase [6].

2.18.6. Employee Performance

Employee performance is essential in optimizing processes, achieving high business performance, protecting employee health, improving the overall system and achieving business success. In Lean, it is important to have high employee performance to reduce waste and increase efficiency. Employee performance is affected by many factors, such as employee motivation, physical characteristics, psychological characteristics, employee morale and motivation and ultimately affects business success. Highperforming employees participate and cooperate in processes. Since the lean philosophy supports giving initiative to employees, empowerment and awareness of responsibility are also important. Employee performance is one of the most important issues in ergonomics. The suitability of workstations to employee physiology directly affects employee performance [6]. Additionally, workload is another important factor affecting employee performance [5]. Adjusting the workload according to employee capacity is important in increasing employee performance.

2.18.7. Teamwork

Teamwork refers to more than one worker performing the job together, work in which people with different perspectives, knowledge and skills come together and implement practices aimed at a common goal. Teamwork ensures effective improvement and review of processes. Since reducing waste is one of the main goals of Lean, more effective results can be achieved by analyzing processes with methods such as teamwork and brainstorming. Additionally, teams can adapt to changes more efficiently

with effective communication. In addition, each team member's knowledge, skills and opinions differ when it comes to determining the root causes of problems. By taking advantage of this difference, teams can effectively identify the root causes of problems. In addition, teams can identify ergonomic risks in the work environment and contribute to effectively implementing regulations [7]. In groups with cooperation and solidarity, employees' job satisfaction, morale, motivation and performance are high [87]. Therefore, business success and performance increase are positively affected by teamwork.

2.18.8. Training of Employees

Although providing the necessary lean, ergonomics and occupational health and safety training falls within the scope of the Knowledge, skills and experience of employees factor, being specific in these areas of expertise is of great importance to understand all aspects of the job and find fast, practical solutions to problems. These trainings will be beneficial for waste reduction as they will allow employees to evaluate business processes from a more professional perspective. Thanks to the training, they can adapt to the culture of continuous improvement, recognize opportunities for improvement, take action in this regard and adapt to changes more quickly [142]. As each employee will be informed about Employee Health and Safety as a result of the training, they will be able to identify risks and take necessary actions to reduce them [143]. Thus, they can have safer work environments. All of these will contribute positively to increasing the performance of the system. In addition, as a conscious work culture will be formed, employees will work in postures appropriate to their physiology and ultimately, work accidents and injuries will be prevented.

2.19. Method, Tools and Technology Category

Method, Tools and Technology category consists of eight critical success factors: (i) Data driven approach and data analysis, (ii) Implementing kanban system, (iii) Implementing value stream mapping (VSM), (iv) Implementing the SMED approach,

(v) Implementing Total Productive Maintenance (TPM), (vi) Poka Yoke implementation, (vii) Ease of learning and use of technology and software, (viii) Continuous Improvement (Kaizen)

2.19.1. Data Driven Approach and Data Analysis

In lean and ergonomics applications, insights obtained from data are used in decision making processes. Thus, since the decisions taken are made from the analyzed data, more accurate, effective and faster decisions are made in process optimization. Especially in lean applications, data analysis results are used to reduce waste and improvements are made in observed cases [150]. In addition, determined performance metrics are monitored with a data-oriented approach and necessary actions are taken. Future production planning is also made by analyzing historical data. Data is also used to optimize material flow. In the field of ergonomics, safety risks are determined as a result of the analysis of recorded and collected data. Various environmental factors such as temperature, noise, lighting and humidity in the working environment can also be improved as a result of related data analysis [6].

2.19.2. Implementing Kanban System

Kanban means visual card in Japanese and is a visual tool that aims to control the material flow and make the pull system work properly. Moreover, the Kanban card may contain information such as the provider's brand, the stores' locations, or the use of that component. In addition, kanban cards are used for material flow and inventory control. Since containers in the standards determined between the two sources are used and this situation is controlled with kanban cards, there cannot be more inventory than determined in the sources, which ensures inventory control. Kanban card types are used for many different purposes, such as production cards, move cards, capacity kanbans, emergency kanbans and signal kanbans. Whether it is an electronic or physical Kanban board, or a physical Kanban card the interface design should be user-friendly, easy to understand, learn and remember. They should appeal to the five senses and cognition.

Therefore, Kanban system requires ergonomics. For example, the choice of color and font size should be appropriate and the card's design should be helpful in a way that does not create confusion [11].

2.19.3. Implementing Value Stream Mapping (VSM)

VSM is one of Lean's tools that aims to improve the process by analyzing the current state of any process or flow. It starts from the beginning of the process, from the procurement stage to the delivery to the customer. VSM helps improve the process by revealing situations such as excessive inventory, restraints, delay, excessive set up times, long cycle times, poor quality/rework and low uptime. When creating a future state value stream map, some improvements are made due to the analysis, such as eliminating waste, balancing the workload, reducing cycle time, minimizing wait time and lead time, reducing unnecessary hand-offs and reducing set ups / reducing batches. While VSM evaluates the system's performance in lean manufacturing and aims to increase productivity, efficiency and quality of the system, integrating lean and ergonomics becomes more profitable for companies as ergonomics is based on the well being and satisfaction of employees [11]. For this reason, a tool called ErgoVSM was developed and ergonomics was added to the VSM processes [187]. It aims to identify and improve risks affecting human health at workstations.

2.19.4. Implementing the SMED Approach

Set up is required to produce different parts. Thus, the set up is essential for flexibility. Demand for a wide variety of products is increasing day by day. For this reason, increasing the capacity, reducing the inventory and providing flexibility in production is of greater importance for companies to remain competitive [11]. Production is usually performed in batches to reduce set up time. Therefore, The Single Minute Exchange of Die (SMED) approach was developed by Shigeo Shingo to increase capacity and flexibility and reduce set up time.

There are two types of set up, internal set up when the machine is not running and external set up when the machine is running. the SMED approach consists of six steps. These are:

- (i) measure the entire changeover time
- (ii) determine internal and external processes
- (iii) move external steps outside the actual changeover process
- (iv) reduce internal steps
- (v) enhance external steps to eliminate waste
- (vi) standardize the new changeover strategy

During these stages, various process improvement options are considered. For example, eliminating unnecessary steps, making it faster, externalizing and paralleling are some options that improve the process. However, a few issues related to ergonomics should be noted. It is necessary to pay attention to issues such as the suitability of the equipment used for these works, the suitability of the working environment for human physiology and anthropometry and the ergonomic design of tools and equipment [146]. For example, ErgoSMED tool has emerged due to the integration of the SMED approach with the ergonomics approach to reduce ergonomic risks and increase productivity, reduce setup time and improve the workstation layout [185].

2.19.5. Implementing Total Productive Maintenance (TPM)

Total productive maintenance is an approach that contributes to lean production by preventing equipment and machine failures. TPM consists of autonomous maintenance, which aims to carry out simple maintenance works by the machine and equipment operator without needing expert personnel; predictive maintenance, which aims to predict failures before they occur; and preventive maintenance, which includes routine maintenance that must be done to prevent failures. In addition, TPM aims to prevent emergency maintenance [146].

The TPM consists of eight pillars: Initial Phase Management, Health and Safety, Education and Training, Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Focused Improvement and Support Systems.

Initial Phase Management deals with new product ideas and selection, customer needs and demands and manufacturability.

Health and safety try to prevent accidents. In doing so, it deals with issues such as risk assessment and ensuring safety during maintenance. Similarly, Ergonomics prevents health and safety issues.

Education and training deal with issues such as trainee, trainer selection and the budget spent on training.

Autonomous maintenance encompasses expanding the competencies of operators and technicians without the need for a maintenance team.

Planned maintenance aims to establish standards that will ensure planned maintenance to avoid breakdowns.

Quality Maintenance aims to reduce product variations with maintenance. Focused Improvement aims to provide solutions to problems.

Support Systems emphasizes that the support process will continue at every stage of TPM, in every department, until the problem is resolved.

In addition to these eight pillars, ergonomic workstation design can be added because it focuses on possible accidents and risk situations in the Health and Safety section. The workstation, unsuitable for the worker, is not focused on the long-term harm to human health. This is an important point that affects employee well being and system performance [149]. Maintaining activities that involve using tools and

workstations should consider employee fit. Maintenance activity should be designed concerning employee capacity and limitations.

2.19.6. Poka Yoke Implementation

Poka-yoke is the method that aims to reduce defects and, accordingly, increase the productivity of the processes [188]. Poka-yoke aims to find the root cause of the problems so that employees can avoid wrong parts installation and selection. According to Shigeo Shingo, there are two types of Poke-Yoke: the regulating function consisting of the control and warning type and, secondly, the Setting (Forcing) Function consisting of contact, fixed value and motion step [188]. In addition, human errors play a significant role in poka-yoke. According to Norman [189], human error is caused by bad design. For this reason, one of Lean's goals is to understand the causes and types of errors and develop error-resistant systems. In addition, the poka-yoke is a fundamental method for ergonomics since it provides higher worker performance and less training. According to Reason and Hobbs, some human error types are a misapplication of rules, cognitive failure, misapplication of procedure and forgetting, while some of the causes that cause human errors are: using improper tools and equipment, time pressure and lack of communication. As a result, poke yoke increases safety as it reduces the training time to be given to the jobs and protects the employee from any risky situation; that is, it is closely related to ergonomics as it increases human health than safety and worker performance. In addition, the poka-yoke is an important method for lean and ergonomics as it reduces waste, increases productivity and contributes to continuous improvement. Thus, these efforts should work together to support the common goals of lean and ergonomics.

2.19.7. Ease of Learning and Use of Technology and Software (Ergonomic)

Ease of learning and use of technology and software is very important because it provides ease of use and reduce errors in lean and ergonomic applications. In Lean, rapid adaptation to new applications or processes is very important. Therefore, soft-

ware and technologies must be easy to learn to shorten the learning process. It also ensures uninterrupted progress of workflow processes and rapid access to data in decision-making processes. Since the possibility of users making mistakes increases in complex software with complex designs, they may be exposed to physical effects such as work accidents and psychological effects such as stress [6]. For this reason, the user-friendly and ergonomic design of software and technologies increases work efficiency and employee morale and motivation.

2.19.8. Continuous Improvement (Kaizen)

The Toyota Way 2001 by Toyota Motor Corporation consists of two critical principles. The first is Continuous Improvement, which includes Challenge, Kaizen and Genchi gembutsu; the second is Respect for People, which includes Respect and Teamwork. In 2004, Dr. Jeffrey Liker offered a different approach to the Toyota way consisting of 14 Management Principles. In addition, 4P model includes long-term thinking philosophy, waste elimination process, people and partners and problem-solving (i.e., continuous improvement). The Toyota Way, which consists of 14 principles presented by Liker, emphasizes the lean production. At the same time, The Toyota Way 2001 has a scope that gives great importance to the customer with its respect for the people component. Liker's 14 Management Principles consist of the following;

- Long-term Philosophy
- Continuous flow usage to identify problems Pull system usage to minimize over-production
- Workload balance
- Jidoka culture to reduce defects Standardized process
- Visual control usage Reliable technology usage Grow leaders
- Develop people
- Respect for stakeholders Genchi gembutsu culture
- Slow decision making Continuous improvement

Furthermore, kaizen, a continuous improvement tool, was developed by Dr. Imai Masaaki and became famous. Kaizen aims to offer rapid development for process improvement and problem solving. The solutions presented aim to improve the current situation. Hence, continuous improvement, common in lean and ergonomics, contributes excellently to improving processes.

2.20. Tasks Category

Tasks category consists of critical success factors: Work demands (workloads), Enriched work and job rotation, Gemba walks, Flexibility, speed and efficiency increase, Enhancing the process, service, or product quality.

2.20.1. Work Demands (Workloads)

Compatibility of physical and mental workloads with employee capacity increases efficiency and performance in the long term. Lean increases production efficiency and contributes to process improvement. By defining the appropriate workload for the employee, the employee's participation in the processes, loyalty to the institution and motivation increase. The employee is not burdened with a heavy physical and mental workload. Ergonomics plays a major role in ensuring physically and mentally balanced working conditions in the workplace. Appropriate physical workload reduces health problems and accidents in the workplace [82]. Adjusting the workload to employee capacity also helps protect mental health and reduce stress [6]. As a result, the suitability of physical and mental workload to employee capacity positively affects workplace and employee performance, sustainable success, employee satisfaction and health.

2.20.2. Enriched Work and Job Rotation

Enriched work is giving responsibility for different tasks of the same job and job rotation is systematically changing jobs between employees within a team for employees. Since enriched work and job rotation balance employee workload, they positively

affect employee performance, safety and system efficiency [81]. Enriched work and job rotation provide employees with new, diverse skills and impose different responsibilities. Thus, their work ceases to be monotonous and employee job satisfaction, participation and commitment increases. Enriched work and job rotation contribute to the corporate culture's continuous improvement and innovation perspective. Enriched work and job rotation make great contributions to the field of ergonomics because as job variety increases, the work becomes less monotonous. In addition, workers in physical jobs work with different muscle groups and are protected from musculoskeletal disorders in the long term [82]. Job rotation also reduces exposure time to hazardous conditions, so it is safety-critical. This also protects mental health and reduces certain risk factors.

2.20.3. Gemba Walks

Gemba walks are performed by managers and lean experts, observing, understanding, asking questions and learning about the real process/event on site. Gemba means “a real place” in Japanese. Gemba walks are of great importance for on-site and rapid detection of problems. It contributes to detecting inefficiencies and developing a culture of continuous improvement by detecting non-value-added activities in business processes. Active visits of managers to the field positively affect employee participation and performance [142]. In ergonomics, field visits by ergonomists and safety professionals are of great importance for detecting and improving risky situations in occupational health and safety, observing whether the work environment meets ergonomic design standards, understanding the level of employee awareness and benefiting from employee feedback.

2.20.4. Flexibility, Speed and Efficiency Increase

Flexibility, speed and increased productivity are the main goals that every organization wants to achieve. Flexibility, especially in Lean production, is very important to respond to changing customer demands. Flexibility enables rapid integration into change requests and reduces inventory accumulation. In addition, fast and efficient pro-

duction increases customer satisfaction and competition and reduces costs and waste. In the field of ergonomics, flexibility, speed and productivity increase have positive aspects for employees who can adapt quickly. Efficiency increases employee satisfaction as it increases employee participation in processes [34]. The balanced integration of flexibility, speed and efficiency into business processes contributes to the improvement of processes and the company's sustainable success.

2.20.5. Enhancing the Process, Service, or Product Quality

Increasing product and service quality is indispensable for lean and ergonomics studies to increase business success and performance. In Lean, when quality problems are encountered, the problem is expected to be solved at the point by getting to the root cause. According to Lean's Muda principle, efforts should be made to increase the efficiency of processes and reduce errors to reduce waste [142]. As a result, there is an increase in product and service quality. Since customer satisfaction is one of the goals that companies strive to achieve, providing quality products and services is one of the premises for ensuring customer satisfaction. Since ergonomic workstations provide suitable working environments for employees, their performance increases and as a result, errors in products and services decrease, thus increasing the quality of the products and services obtained [14].

2.21. Environment and Safety Category

Environment and Safety category consists of critical success factors: Employee health, safety and welfare, Use of personal protective equipment, 6S implementation, Reducing employee health and safety risks, Organizational culture and establishing a safety culture, Noise, lighting, temperature, humidity, air quality, etc. environmental factors are at normal levels, Safe and ergonomic design of workstations, tools and equipment.

2.21.1. Employee Health, Safety and Welfare

Since the most valuable asset of a business is its manpower, its employees, employee health, safety and welfare are very important for the sustainability of business success. A safe work environment increases employee performance, motivation and work efficiency. A healthy and safe work environment reduces possible risks, prevents accidents and contributes to business continuity. Particularly from an ergonomics point of view, it is necessary to attach critical importance to employee health, safety and well being for a company's success [6].

The ergonomic design of workstations, tools and equipment contributes positively to employee health and prevents employees from suffering from musculoskeletal disorders in the long term [14]. Ergonomic designs also prevent misunderstandings and errors. Technical training in the field of Lean and ergonomics also plays an important role in protecting employees' health.

2.21.2. Use of Personal Protective Equipment

The use of personal protective equipment to protect employees from possible physical accidents, which is within the scope of occupational health and safety training given in the field of lean and ergonomics and providing the necessary training on the use of this equipment ensures employee safety and health. It increases employee performance in the long term.

The use of equipment increases employee comfort and reduces errors and accidents. Thus, it contributes to business continuity and increased business performance and quality [6].

2.21.3. 6S Implementation

6S is an extended version of 5S by adding safety, one of the lean tools developed in the 1950s with the aim of process development. It is one of the workplace organization methods and is also related to visual management. It is a systematic method aimed at sustainability in workplace organizations. The stages constituting this method are respectively; sort, set in order, shine, standardize, sustain and safety [11].

Sort: aims to contain only the necessary tools and equipment in the working environment. There are some details that are not taken into account at this point. Ergonomics can contribute to these points. For example, the workplace should be suitable for the human physiology and anthropometry of the workers. The tools used must be ergonomic.

In addition, tools and equipment must be designed in such a way that they do not harm human health and safety.

Set in order: The aim is to implement a method that can be standardized for materials, tools and equipment used and stored. It is necessary to determine the permanent locations of the selected materials after the sorting stage. Similarly, ergonomics can contribute too. For instance, tools and equipment used in a workstation should be placed in such a way that employees can work in a neutral posture during working hours. It is also important when placing materials that the worker should not bend or twist while trying to reach the materials. In this sense, the application of ergonomics is important.

Shine: The aim is to keep the workplace clean and tidy. This stage ensures that the materials and equipment remain clean and that no problems are encountered as they are maintained. Some examples of this stage are: monitoring the oil level in equipment and tightening belts, hoses, nuts and bolts. However, it is also essential that not only the maintenance of the instruments used but also the suitability of the

instruments used for human physiology and anthropometry, the noise level while being used and whether the instrument is ergonomically designed or not. This should be taken into consideration and ergonomics can contribute at this point.

Standardized: The aim is to develop standards to ensure the sustainability of 6S for the organized workplace. It aims to ensure that these stages are valid and continuous for every employee, from manager to worker, every day. Visual management is of great importance as well. The standards should be easy to understand and visual to be sustainable. The use of red tags, well-labeled tools and checklists for inspection, safety and maintenance can be given as examples.

Sustain: It aims to implement and maintain the standards created for the 6S application.

Safety: It aims to protect the employee health and safety of the work environment. At this point, the workstation must be ergonomically designed and comply with occupational health and safety rules. In order to ensure health and safety, signs that will increase visual communication, ergonomic software and hardware should be used and regular training should be given on this subject [142]. The 6S is also valued by ergonomics for employee performance and well being.

2.21.4. Reducing Employee Health and Safety Risks

Preidentifying, analyzing and reducing risks that will affect employee health and safety is one of the common factors of lean and ergonomics studies. Eliminating the identified risks aims to reduce waste caused by accidents and errors in the workplace and reduce costs. Contributes to Lean's culture of continuous improvement. It increases employee participation because employees can help take action on the risks they identify [6]. Thus, employee participation in processes increases, ultimately contributing to business performance and success. Training employees and ergonomically designing workstations reduce risks and errors and increase process efficiency [82].

2.21.5. Organizational Culture and Establishing A Safety Culture

Establishing a safety culture is about the organization's values, norms and practices regarding employee performance and well being. Adopting this culture in the organization encourages continuous improvement. For the risks identified during the process not to cause any security vulnerabilities, a security culture must be adopted by institutions that want to make their success sustainable [3]. Adoption of this culture can be facilitated through awareness training. It is important for every employee to feel responsible for security and to participate in the processes for the security culture to be established in the institution. Safety culture is more common in institutions that attach importance to ergonomics. Safety culture should have an important place in institutions to protect employees' physical and psychological health.

2.21.6. Noise, Lighting, Temperature, Humidity, Air Quality, Etc. Environmental Factors are at Normal Levels

Environmental factors such as noise, lighting, humidity level, air quality and temperature directly impact employee health, safety and performance. Therefore, the optimum level of environmental factors impacts business success. Suitable environmental conditions positively affect the concentration of employees and employees can work more efficiently. Continuous detection and monitoring of environmental factors help ensure business continuity. Appropriate air quality, temperature and correct lighting are among the ergonomic improvements made in the workplace. Providing healthy working conditions reduces stress on employees and increases performance [87]. Awareness of this issue can prevent many work accidents from occurring. Even if it is not noticed at the moment, negative working conditions cause diseases in the human body in the long run [83]. Therefore, providing appropriate environmental factors to protect employee health is very important.

2.21.7. Ergonomic Design of Workstations, Tools and Equipment

The ergonomic design of workstations, tools and equipment is one of the most critical factors affecting employees' work performance in the short and long term. These designs give employees a comfortable, efficient and sensitive working environment. Thus, the possibility of accidents and errors decreases and the quality of the products increases. Ergonomically designed tools and equipment increase the speed of processes.

As a result of ergonomic design, workstations can be easily adjusted for different employees, thus providing flexibility in production. Thanks to ergonomic tools, tables, chairs and screens, the physical health of employees is protected in the long term and the likelihood of contracting musculoskeletal diseases decreases [87]. In addition, it is essential for those who work with repetitive movements to work in the correct positions and to regulate the frequency of repetitive work according to the employee [34]. With these practices, employee health satisfaction increases and ultimately, an increase in the quality and efficiency of work is observed.

2.22. Customer and Supplier Category

Customer and Supplier category consists of critical success factors: Cooperation effectively with the supplier, Benefiting from customer feedback and complaints, Meeting customer / stake holder demands and expectations.

2.22.1. Cooperation Effectively with the Supplier

Effective collaboration with suppliers helps optimize supply chain processes. Effective cooperation with suppliers considerably benefits companies in inventory management and reduces stocking costs and waste [144]. Lean's Just in Time principle ensures that materials are provided in enough quantity and at the right time and suppliers have an important role in this process [145]. At the same time, with the supply

of quality materials, there is a decrease in quality control processes. Cooperation with suppliers also plays a significant role in ergonomics because supplying materials that comply with standards is important. Suppliers' participation in the process and being seen as stakeholders is beneficial for a safe working environment and increasing product quality.

2.22.2. Benefiting from Customer Feedback and Complaints

Benefiting customer feedback is essential in improving product and service quality, business processes and customer satisfaction. Customer feedback can be used for Lean's continuous improvement principle because customer feedback can be used to improve product quality and operations [144].

It is highly beneficial to benefit from customer feedback to minimize waste in production carried out according to the just in time principle [150]. User experiences, demands and feedback should be considered for effective product or service design in ergonomics. The compliance of the product or service with ergonomic regulations is determined as a result of the analysis of data obtained from customer feedback. By utilizing customer complaints, areas for improvement can be identified and processes can be improved, thus ensuring customer satisfaction.

2.22.3. Meeting Customer/Stakeholder Demands and Expectations

Since Lean production focuses on customer satisfaction, it aims to meet customer demands and expectations. Production according to customer demand reduces stock levels and increases efficiency and customer satisfaction. With a flexible approach in Lean production, customer expectations and demands can be met quickly. Ensuring customer satisfaction is one of the main goals of the total quality management approach, which constantly aims to improve product and service quality.

From an ergonomics point of view, the user-friendliness of the products or services offered increases customer satisfaction; that is, it tries to meet customer expectations. In addition, user and customer feedback is used in the design processes and this feedback is used in ergonomic improvements [14]. Thanks to the flexibility approach of Lean and ergonomics, special products or services can be created for customers and suitable and healthy working environments for employees.

As can be seen, ergonomics and lean have some common ground and ergonomics can significantly contribute to companies' lean efforts.

2.23. Business Strategies

In 1996, Kaplan and Norton published *The Balanced Scorecard*, a comprehensive and systematic book on business strategies aimed at translating company strategies into actions and measuring company performance[192]. These perspectives are in a causal relationship with each other and these four perspectives are carried out to create the framework for the balanced scorecard.

The financial perspective aims to identify key performance indicators to achieve financial goals such as growing revenue, decreasing risk, enhancing productivity and improving asset use.

The customer perspective aims to identify, analyze and develop the target customer group that will enable financial goals to be achieved. Customer satisfaction, loyalty, profitability and market share are the main interests it aims to achieve.

The internal business process perspective defines, develops and analyzes the processes that will enable to achieve customer and shareholder objectives, namely innovation in products and services, actions that can be taken in operations to be competitive and improvements that can be made in after-sales services. It is based on quality, cost and response time. The learning and growth mindset gives importance to the devel-

opment of topics such as employee capabilities, motivation, alignment, empowerment and information system availability in order to reach growth objectives in the long term [192]. Up to now, many studies have tried to integrate sustainability into the balanced scorecard method. However, due to the different organizational cultures of the companies, sustainability continued to be conducted differently for each company. In this thesis, six objectives for company strategies were determined considering the four perspectives of the balanced scorecard and the findings obtained from the literature on this subject. These ultimate goals can be listed as follows [193], [194]:

- (i) Revenue Growth
- (ii) Cost reduction
- (iii) Customer Satisfaction
- (iv) Improving employee capability and satisfaction
- (v) Sustainability of business strategies
- (vi) Market share improving
- (vii) Innovation and product quality improvement

After conducting a literature review, the Business Strategy Objectives were determined and presented in Figure 2.3 as a Balanced Scorecard.

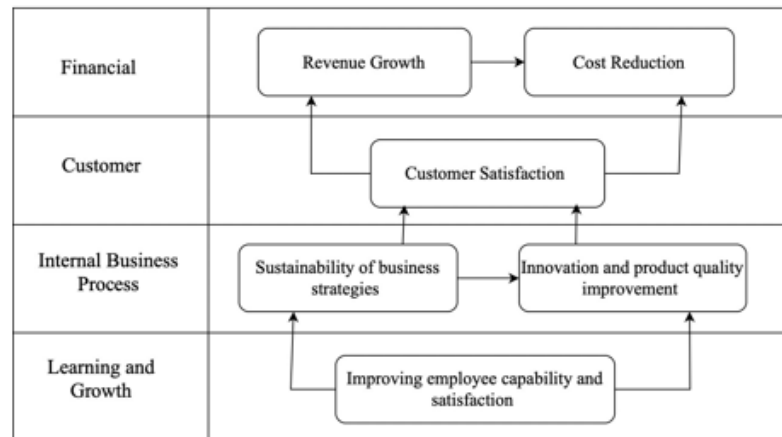


Figure 2.3. Developed balanced scorecard business strategy objectives (source adapted from [192]).

3. RATIONALE AND OBJECTIVES OF THE STUDY

3.1. Rationale of the Study

This study is about integrating ergonomics and lean approaches. In industries where lean methods are used to streamline operations by minimizing waste, the human aspect is very important. Numerous studies examine the success factors of lean and ergonomics applications, exploring their impact on the business success and performance of both production and service sectors separately. However, these studies predominantly measure the effects of lean and ergonomics “critical success factors” on “business performance” independently, overlooking their combined impact concerning critical success factors. Therefore, no studies have been identified that concurrently examine the success factors of both lean and ergonomics. In addition, when the studies on lean and ergonomics integration were examined, it was determined that this integration was achieved due to ergonomic analyses of lean tools. Even though it is known that use of ergonomics in lean applications provides significant benefits in both production and service sectors, studies have yet to be conducted to measure the effects of lean and ergonomics integrated success factors on business success. Therefore, this study focused on developing a model that will enable integration of ergonomics and Lean. The developed successful integration models will assist companies in making informed decisions.

3.2. Objectives

Based on the rationale provided, this study aims to achieve two main objectives:

- (i) Identify the critical factors necessary for businesses to develop a strategic plan that integrates ergonomics and lean methodologies for fostering simultaneous growth across the organization.

- (ii) Construct a hypothetical model illustrating the relationship between integrated categories of Lean and Ergonomics and business success. (This involves determining the direct, indirect, and overall effects of these integrated categories on business success using a developed hypothetical model.)

To further elucidate these objectives, four research questions have been formulated:

RQ1: What critical factors are essential for the successful implementation of ergonomics and lean methodologies?

RQ2: What are the most important factors for developing a sustainable business strategy considering both ergonomics and lean methodologies?

RQ3: What are the impacts of integrated categories of critical success factors on business success, and how are these categories interrelated?

RQ4: Which categories of ergonomics and lean methodologies hold the greatest significance for business success, and what are the significant relationships between these categories?

While the first and second research questions aim to address the first objective, focusing on understanding critical factors and strategic planning, the third and fourth research questions are oriented towards achieving the second objective, which involves examining the relationships between integrated categories and business success.

4. METHODOLOGY

4.1. An Overview

In this section, a detailed exposition of the methodologies employed for data analysis and the assessment of the proposed model is presented. A step-by-step explanation is provided regarding the execution of descriptive statistics, reliability analysis, explanatory factor analysis and confirmatory factor analysis, respectively, offering detailed insights into each procedure.

4.2. Study Steps

The details of the study steps are listed below.

- (i) To achieve the objectives of the study, a comprehensive literature review was conducted to determine the success factors of ergonomics and lean. After identifying the common factors between the two through a detailed literature review, they were categorized to examine their impact on the business success of companies. A business success category was also created after conducting a literature review.
- (ii) To gather data on which category has a greater impact on business success and test hypotheses that express relationships between factors, a three-part survey was conducted by directing managers to participate.
- (iii) The survey was designed to collect information on the common critical success factors and analyze the data gathered. The questionnaire was distributed to professionals working in the area of ergonomics and lean; and demographic data was also collected to determine the demographic characteristics of the participants.
- (iv) Descriptive statistics were used to determine the distribution, normality and reliability of the sample.

- (v) Reliability analysis was conducted to determine the reliability of the survey and data used. Cronbach's Alpha method was used to test reliability for internal consistency.
- (vi) Explanatory factor analysis (EFA) was applied to express the relationships in the created model with fewer items. Bartlett Test, Kaiser Meyer-Olkin values and total variance explained values were used for explanatory factor analysis.
- (vii) Convergent validity and divergent validity values were determined for the validity of the structure. Confirmatory factor analysis (CFA) was used to test the suitability of the hypotheses and structure established in the model.
- (viii) Structural equation modeling was used to determine which categories have a greater impact on business success. Structural equation modeling was used for the SEM method and model fit indices were determined to determine whether the data fit the model. To achieve the second objective of the study, the direct, indirect and total effects of the lean and ergonomic categories on business success were calculated. 16 hypotheses were created in the study to express relationships between factors.

4.3. Hypothesis Model

This study aimed to create a hypothesis model for measuring the impact of common factors of Lean and ergonomics on business success. In this model, six categories were determined: "Employee"; "Organization"; "Method, Tools and Technology"; "Tasks"; "Environment and Safety" and "Customer and Supplier".

There were a total of 38 critical success factors in these categories. A total of 6 success factors have been determined as business success factors: Revenue growth, Cost reduction, Customer satisfaction, Sustainability of business strategies, Innovation and improving product quality and Increasing employee performance and satisfaction. Hypotheses were created using the critical success factors information from the literature study.

Using these hypotheses, a model was created regarding the relationship between the business success category obtained from business success factors as the dependent variable and the six categories obtained from critical success factors as the independent variable.

The developed hypothesis model is shown in Figure 4.1. Each hypothesis created is represented by its hypothesis number. The employee is represented as EMP; Organization is represented as ORG; Method, Tools and Technology is represented as TOOL; Tasks is represented as TASK; Environment and Safety is represented as ENV; and Customer and Supplier category is represented as CUST.

The developed hypothesis model consists of 6 categories, namely Employee, Organization, Method, Tool and Technology, Tasks, Environment and Safety, Customer and Supplier and one business success category obtained from the critical success factors identified as a result of the literature review.

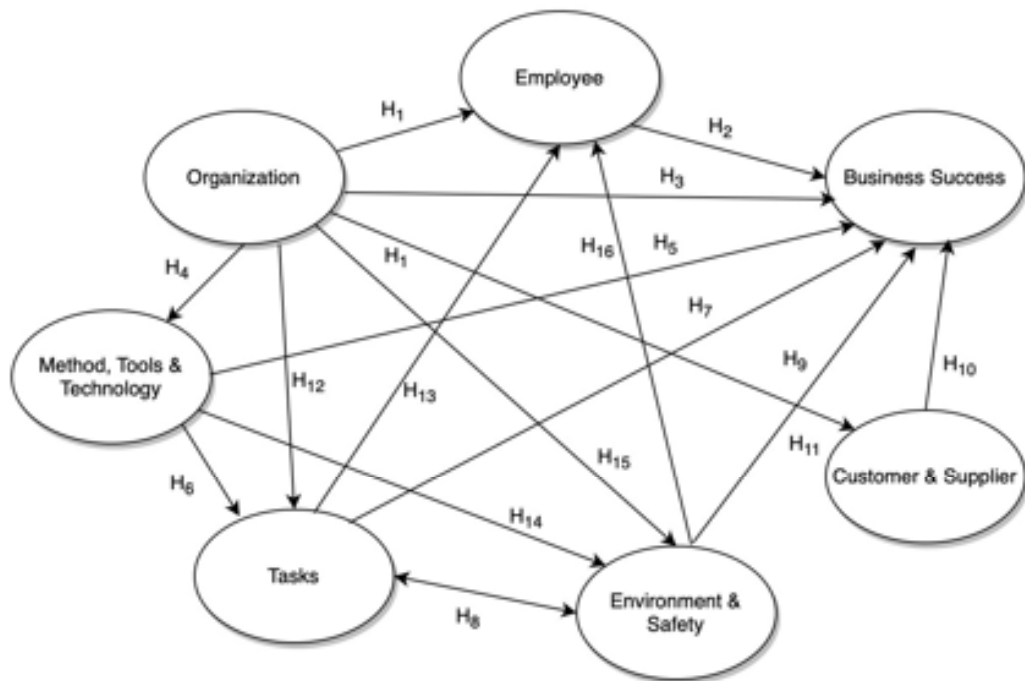


Figure 4.1. Developed hypothesis model.

To achieve the objectives of the study (Section 3), the research questions in section 3 and the hypotheses were created by considering the existing literature. The hypotheses are presented below.

H1: There is a significant relationship between the Organization and Employees.

H2: There is a significant relationship between the Employees and the Business Success.

H3: There is a significant relationship between the Organization and the Business Success.

H4: There is a significant relationship between Organization and Method, Tools and Technology.

H5: There is a significant relationship between Method, Tools and Technology and the Business Success.

H6: There is a significant relationship between Method, Tools and Technology and Task.

H7: There is a significant relationship between Task and the Business Success.

H8: There is a significant relationship between the Task and Environment and Safety.

H9: There is a significant relationship between Environment and Safety and the Business Success.

H10: There is a significant relationship between Customer and Supplier and the Business Success.

H11: There is a significant relationship between the Organization and Customer and Supplier.

H12: There is a significant relationship between Organization and the Task.

H13: There is a significant relationship between the Task and Employees.

H14: There is a significant relationship between Methods, Tools and Technology and Environment and Safety.

H15: There is a significant relationship between Organization and Environment and Safety.

H16: There is a significant relationship between Environment and Safety and Employees.

This hypothesis model is constructed to measure the direct, indirect and total effects of various categories on business success. Structural Equation Modeling (SEM) was used to test these effects. As a result of Exploratory Factor Analysis; categories as independent latent variables and business success as dependent latent variables were analyzed.

4.4. Data Collection

A questionnaire was developed to test the hypothesized model aimed at determining the relationships between factors. The questionnaire focused on the predetermined Lean and Ergonomics common factors and gathered input from company employees regarding their thoughts on these topics. This instrument was designed to gather opinions from individuals in various managerial positions across different companies, specifically targeting respondents who are 25 years of age or older. The participants were selected randomly and the goal was to reach at least 200 individuals [195].

For statistical analysis SPSS and AMOS software were utilized. AMOS (Analysis of Moment Structures) is a software application utilized in structural equation modeling (SEM) analysis to investigate complex relationships among variables. Specifically, it is employed for model specification, parameter estimation and the evaluation of model fit.

4.4.1. The Questionnaire

The questionnaire developed in the study consisted of 3 main parts:

- First part; Collect demographic characteristics of the participants for descriptive analysis, including gender, age, education level, company's industry, participant's area of expertise, participant's total work experience, participant's position in the company, managerial experience, experience in the current role, experience in the current company. This part consists of 10 questions in total.

- Second part; Consists of questions about the goals of the companies. Participants were asked to evaluate how important achieving these goals was for their company. Participants were asked to assess the importance of the certain goals to the success of the company/institution they work for. The 5-point Likert scale used in this section reflects increasing importance from 1 to 5. These goals consist of revenue growth, cost reduction, customer satisfaction, sustainability of business strategies, innovation and improving product quality and increasing employee performance and satisfaction. This part consists of 6 questions.
- Third part; Participants were asked to evaluate the importance of the factors common to Ergonomics and Lean on a scale of relative importance in terms of their contribution to achieving their company's strategic goals. These factors are grouped under six main categories. These categories are "Employee"; "Organization"; "Method, Tools and Technology"; "Tasks"; "Environment and Safety" and "Customer and Supplier". This part consists besides demographic questions of 38 questions. A total of 44 questions were asked to the participants in the survey.

Table 4.1 consists of demographic questions in the first part of the survey. Multiple predefined options were created by literature review and participants were asked to mark the option that best suits them.

Table 4.1. The first section of the questionnaire.

Demografic Questions
Gender
Age
Education Level
In what industrial sector does your company belong?
What is your area of expertise?
How many years of work experience do you have in total?
What is your position in the company?
How many years of management experience do you have?
How many years of experience do you have in your current position?
How many years of experience do you have in the current company?

Table 4.2 includes the questions about the factors in the second part of the survey and the Likert scale used in the survey can also be observed in the table.

Table 4.2. The second part of the questionnaire.

Please evaluate the importance of the following goals to the success of the company/institution you work for.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Business Success Category					
Revenue growth					
Cost reduction					
Customer satisfaction					
Sustainability of business strategies					
Innovation and improving product quality					
Increasing employee performance and satisfaction					

Table 4.3 includes the some part of the questions about the factors in the third part of the survey and the Likert scale used in the survey can also be observed in the table. The entire survey can be accessed in the appendices section.

Table 4.3. The third part of the questionnaire.

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Employee					

Table 4.3. The third part of the questionnaire. (cont.)

Knowledge, skills and experience of employees					
	Unimportant -1	Slightly Important -2	Moderately Important -3	Important -4	Very Important -5
Physical characteristics of employees (fitness, strength, flexibility, physical skills)					
Behavior and psychological attitudes of employees					
Organization					
Top management commitment and engagement					
Organizational structure (Framework that organizes employee roles, responsibilities,					
hierarchy and collaboration)					
Method, Tools and Technology					
Data-driven approach and data analysis					
Kanban applications /Material flow					

Table 4.3. The third part of the questionnaire. (cont.)

	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Tasks					
Suitability of physical and mental workload to employee capacity					
Enriched work (giving responsibility for different tasks of the same job) and job rotation (systematically changing employees between jobs within a team) instead of monotonous work for employees					
Gemba walks (managers observing, understanding, asking questions and learning about the real process/event on site)					
Environment and Safety					
Employee health, safety and welfare					
Use of personal protective equipment					

Table 4.3. The third part of the questionnaire. (cont.)

	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Periodic implementation of 6S practices					
Customer and Supplier					
Cooperating effectively with the supplier					
Benefiting from customer feedback and complaints					
Meeting customer /stakeholder demands and expectations					

4.4.2. The Procedure of Administrating the Questionnaire

The developed questionnaire was first sent to 15 lean or ergonomics professionals accessed via LinkedIn and a pilot study of the survey was carried out. According to the feedback of the pilot study participants, changes and updates were made to the factors used in the survey and to clarify the survey language. Then, a second pilot study was conducted on the updated survey with 20 people and since there was no need for any changes at the end of this study, the actual survey study started.

The most commonly used rating scale to evaluate participants' opinions in surveys is the Likert scale. A 5 point Likert scale was used in the study as follows:

(1) Unimportant, (2) Slightly Important, (3) Moderately Important, (4) Important, (5) Very Important.

The created survey was delivered to the participants as a LinkedIn message and in groups of various online platforms created for lean and ergonomics. The opinions of B, C and D level managers; Presidents and Vice Presidents; Project managers, engineers and consultants aged 25 and over working in various companies were consulted. Participants working in many sectors, especially in the automotive, textile, service and fast-moving consumer goods (FMCG) sectors, participated in the survey. A total of 512 surveys in Turkish were sent via message and shared in 4 different Lean groups. In total, 224 people answered the survey in Turkish.

4.5. Data Analysis Phases

Structural equation modeling was used to verify the goodness of fit and to conduct confirmatory factor analysis. Covariance, correlation and regression coefficients were used to test research hypotheses within the framework of the created structural equation model for the relationships between variables. The research model, hypotheses and measurement scales are based on the comprehensive literature review in Section 2. The steps utilized in the data analysis for this study are outlined below.

- (i) Descriptive statistics is calculated to determine the distribution, normality and reliability of the data.
- (ii) Reliability analysis is performed to determine whether the measurement tool, the survey, reflects the purpose of the study.
- (iii) Explanatory factor analysis (EFA) was applied to test data suitability. By testing the validity and reliability of the factor structure resulting from the analysis, the analysis of the collected data was completed and its suitability for applying confirmatory factor analysis (CFA) was determined.
- (iv) It was decided to apply the most commonly used structural equation modeling (SEM) for CFA. 16 hypotheses were created to determine the relationships between categories. Model fit indices were checked to determine the fit of SEM to the data.

- (v) The direct, indirect and total effects of the categories consisting of lean and ergonomics integrated factors on business success were calculated.

4.5.1. Descriptive Statistics

The summary statistics of survey data such as mean, standard deviation, variance, skewness, kurtosis and Cronbach's alpha were calculated. These statistical measures were used to determine the distribution, normality and reliability of the sample.

4.5.1.1. Normality Analysis.

- According to George and Mallery, kurtosis and skewness values between -2 and +2 are accepted for a normal univariate distribution [196].
- Bryne and Hair suggest that if the skewness is between -2 and +2 and the kurtosis is between -7 and +7, the assumption that the data is normally distributed is accepted [197].
- Kline suggests that the kurtosis value should not be greater than 10 for the assumption of normality [198].
- According to other studies, the ranges that skewness and kurtosis values should take to comply with normal distribution are as follows: between -1.50 and +1.50, between -2.00 and +2.00 and between -1.96 and +1.96 [199] [200].

4.5.1.2. Reliability Analysis. Reliability is a measure of how accurately survey data measures a particular attribute. There are several functions that a measuring tool must have for it to be considered reliable. These include producing stable and consistent results, being as sensitive as possible and being unbiased or objective. Stability, consistency, sensitivity and objectivity are all important characteristics for reliability [201]. Validity, on the other hand, refers to achieving the intended measurement without adding any additional parts. A measurement tool can be valid even if it is unreliable, but validity is affected by unreliability and decreases as a result. Therefore,

reliability limits validity and validity should not exceed the square root of the reliability coefficient.

It should be noted that a reliable measurement tool may not necessarily be valid. Therefore, reliability is only important if the measurement tool or measurement is valid.

Various methods are available to determine the degree of reliability, including the test-retest, parallel forms, split-half, Kuder Richardson, Cronbach Alpha, item score reliability, item discrimination method and objectivity method [201].

- The test-retest method involves administering the same survey again after a certain period. Reliability is determined by the correlation between the results of the two different applications. The ideal time to apply the survey at two different times varies between 3-4 weeks. Results above 0.70 are considered reliable.
- The parallel forms method involves preparing two different surveys that are similar to each other. These surveys are administered once after a certain time. The difference between this and the test-retest methods is that the measurement tool changes. This change allows the second survey to be administered in a shorter time because there is no suspicion to memorize the answers. Similar to the test-retest method, the correlation of these two different applications is examined and a finding about reliability is reached.
- The split-half method involves a single survey application, where the questions are divided into two and internal consistency is achieved with the correlation between these two halves. Reliability is achieved with internal consistency using the formula that converts the correlation obtained into a reliability coefficient.
- The Kuder Richardson method (KR-20 and KR21) is a single survey application that is based on the internal consistency of the items. In this test, the harmony of each question with all other questions is checked. It is used in two-choice answers.
- The Cronbach Alpha method is based on internal consistency and uses a Likert-type scale in answers. A coefficient value varying between 0.00-1.00 is obtained,

and in general, the alpha coefficient is expected to be above 0.7. Cronbach's Alpha (CA) is calculated using the following formula

$$\alpha = \frac{N \times \bar{c}}{\bar{v}(N - 1) \times \bar{c}}. \quad (4.1)$$

In this formula, N represents the number of items, $\bar{c}$ denotes the average covariance among item pairs, and $\bar{v}$ signifies the average variance [202].

- The item score reliability method is based on internal consistency, where a correlation is made between each item and the total score. Items with a correlation coefficient of $r = 0.30$ and above are determined as discriminatory.
- The item discrimination method involves separating the lower and upper two groups of 27% of the data and comparing the averages. A significant difference ($p < 0.05$) indicates the internal reliability of the test. In multidimensional structures, each sub-dimension should be examined separately.
- The objectivity method involves evaluation of the survey by more than one expert to determine consistency and the correlation between expert evaluations is used to determine reliability.
- Inter-Rater Reliability: Inter-rater reliability is used to determine whether different survey raters give consistent estimates of the same items, assessing the compatibility of the raters' evaluations.
- Cohen's Kappa: Cohen's Kappa, developed by Jacob Cohen, is a statistical measure used to evaluate the reliability of categorical items. This coefficient accounts for random agreement within the fit. The Kappa value obtained from the analysis ranges from -1 to $+1$. A value of -1 indicates complete disagreement between the evaluators, a value of 0 indicates that the agreement is due to chance, and a value of 1 indicates perfect agreement between the evaluators. The closer the Kappa value is to 1 , the better the fit [203].

Evaluation Criteria:

According to McHugh (2012) [204]:

0.00-0.20: No fit

0.21-0.39: Minimal compliance

0.40-0.59: Weak agreement

0.60-0.79: Moderate agreement

0.80-0.90: Strong agreement

0.90: Almost perfect agreement

According to Landis and Koch (1977) [205]:

<0.00: Poor agreement

0.00-0.20: Slight agreement

0.21-0.40: Fair agreement

0.41-0.60: Moderate agreement

0.61-0.80: Substantial agreement

0.81-1.00: Almost perfect agreement

4.5.1.3. Composite Reliability(CR). Composite reliability(CR), which provides information about the internal consistency or reliability of the factors, measures the reliability of the factors in the model among the indicators. As the CR value increases, the internal consistency among the items included in the factors increases.

CR takes values between 0 and 1; as this value approaches 1, reliability increases. It is stated that the CR value should be greater than 0.7 to ensure reliability [206]. The formulas are used to compute CR and AVE, as presented in Table 4.4. Reliability is divided into two:

- (i) Internal Reliability
- (ii) Construct Reliability

To ensure Internal Reliability, the Cronbach's alpha (CA) value is expected to be greater than 0.6. To ensure Construct Reliability, the CR value is expected to be greater than or equal to 0.6 [201].

Table 4.4. Formula and parameters of CR and AVE.

	Formulan	Parameters
CR	$(\sum K)^2 / [(\sum K)^2 + (\sum 1 - K^2)]$	K= Standardized estimate (loading) of each factor
AVE	$\sum K^2 / n$	n = number of factors in a model

4.5.2. Validity

Validity is the ability of a measurement tool to express the quality it is intended to measure accurately. There are four types of validity to determine whether a measurement is valid. These are Content validity, which measures whether the measurement tool correctly evaluates the situation it measures; criterion validity, which assesses how compatible the measurement tool or test is with a specific criterion such as performance or output; construct validity, which measures how accurately the measurement tool evaluates the theoretical structure that is intended to be measured and discriminant validity measures the ability to distinguish concepts from each other [207].

4.5.2.1. Convergent and Discriminant Validity. Campbell and Fiske proposed the analysis of convergent validity. For convergent validity to be within acceptable limits, questions about latent variables (critical success factors in this study) must be understood and answered by participants as intended by those who defined the survey. To ensure convergent validity, it is recommended that the p values associated with the loadings be less than 0.05 and that the loadings be equal to or greater than 0.5. [149]. AVE values obtained in the analysis are used to test Discriminant validity with the correlation values of the latent variables. The accepted AVE threshold to ensure discriminant validity is 0.5 [208].

4.6. Factor Analysis

Factor analysis was first developed and used in the 1900s. The primary purpose of factor analysis is to explain the observed variables with a smaller number of factors by

revealing the structure of many variables in a complex structure and the relationships between the variables [209]. Factor extraction and factor rotation are used in the factor analysis stages to express the variables with a smaller number of factors and detect relationships. The Factor Extraction method aims to determine the main factors and the principal component analysis (PCA) technique is commonly used for this. Factor rotation is used to interpret and give meaning to the factor structure. As a result of factor analysis, factor loadings are obtained and these loadings show which specific factors the variables are related to and then enable us to make sense of the structure. Factor analysis consists of two analyses: Exploratory factor analysis and confirmatory factor analysis. However, to use these analyses, it is necessary to know the data distribution, have appropriate data quality and type and have sufficient sample size to perform the analysis [209].

Exploratory factor analysis aims to make sense of the relationships between variables and identify the main factors that define these relationships. On the other hand, confirmatory factor analysis aims to determine the suitability of a theoretical model based on the hypotheses determined in the study [210]. In this analysis, the predetermined factor structure, for example, the structure reached as a result of EFA in this study, is tested and its suitability for the structure is tried to be determined.

Both factor analyses were used to test the hypotheses created in this study since the structure formed as a result of EFA needed to be tested with CFA.

4.6.1. Exploratory Factor Analysis (EFA)

EFA is used to identify key factors in a relatively large and complex data set. It has an exploratory nature as it aims to define the structure; it has no verification purpose. In EFA, the suitability of the data for analysis is first tested. For this, sample size, Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity values are checked. KMO evaluates whether the data is suitable for factor analysis by examining the strength of the correlations between variables. KMO value

is between 0 and 1 and is expected to be greater than 0.05 [201]. The equation used to calculate the Kaiser-Meyer-Olkin (KMO) test is

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}}. \quad (4.2)$$

In the context where is $R = [rij]$ represents the correlation matrix, where $i, j = 1, 2, \dots, n$, is the $U = [uij]$ denotes the partial covariance matrix, where $i, j = 1, 2, \dots, n$ [199].

KMO value is between 0 and 1 and is expected to be greater than 0.05 [201]. Bartlett test, like KMO, is used to test the suitability of the data before performing factor analysis. It tests the statement that there is no correlation between variables in the H_0 hypothesis. In order to perform factor analysis as a result of the test, the H_0 hypothesis must be rejected; that is, the correlation between variables must be determined. Since the p-value is taken as 0.05 in this study, to reject the hypothesis, a statistically significant result must be obtained; that is, the p-value must be lower than 0.05. Afterward, factor extraction is performed. Principal component analysis (PCA), the most used factor extraction method in the literature, was used for extraction. PCA was preferred as the extraction method because it reduces the factors according to the largest variance explained in the data set without removing the success factors in the data set from the evaluation [199]. Then, factor rotation is used to obtain a more meaningful factor structure and increase interpretability. It has three methods. Varimax Rotation, one of the most widely used factor rotation methods, reveals strong relationships between factors and variables by minimizing the correlation between factors. Promax Rotation benefits from the correlation between factors; Oblique Rotation is used in theory when there is correlation between factors [199]. In the next step, the validity of the structure obtained is checked using convergent and divergent validity. Finally, the obtained factor structure is interpreted.

For the EFA example, the structure consisting of two factors (latent variables) is shown in Figure 4.2. In addition, to perform factor analysis, each factor must have at least two variables. While the arrow between the factors represents the covariance, the

phrases expressed with 8 Y's represent the indicator. The arrows going from factors to indicators indicate the factor loadings that will occur due to the analysis. In addition, unexplained error terms of unknown origin appear in each indicator, expressing the variable's variance that cannot be explained by fundamental factors [211]. The factors in this study are seven categories created in the study (organization, employee, tasks, environment and safety, tools and technology, customer and supplier and business success). The variables are critical success factors obtained from the literature review.

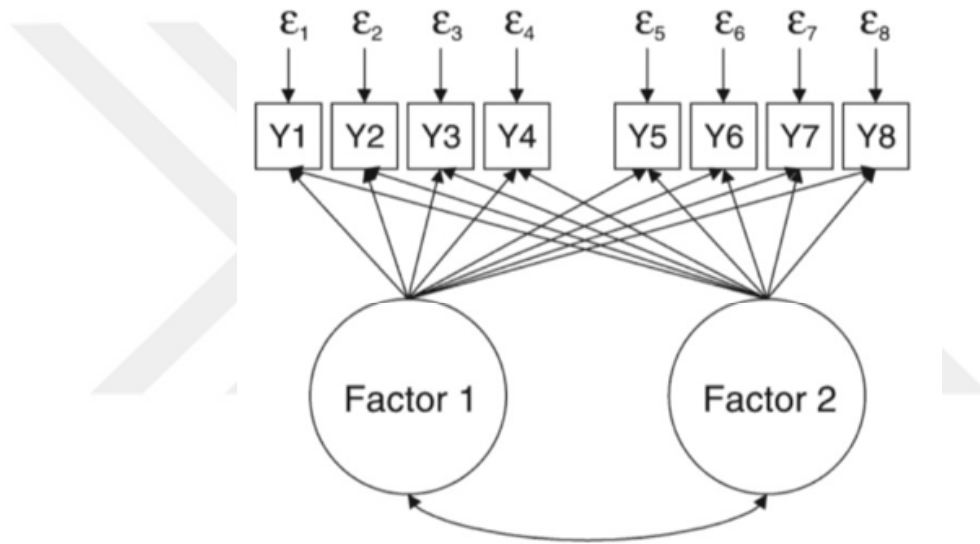


Figure 4.2. EFA Representative model structure (source adapted from [211]).

4.6.2. Confirmatory Factor Analysis (CFA)

CFA is a factor analysis method that aims to verify the model structure established from predetermined hypotheses. The factor structure obtained as a result of EFA is verified with CFA. It tests the model in which it is known in advance which variables affect which factors. As a result of the analysis, it determines the measurement errors and factor loadings, which are called deviations of the variables from their actual values. In addition, the suitability of the theoretical model to the data can be understood by looking at the model fit indices. If the model fit indices are close to the desired values but do not provide the values accepted in the literature, the model fit indices can be improved by using the standardized residuals and modification indices

obtained as a result of CFA and the model fit indices can be improved. Compliance can be achieved [212].

CFA is performed with the help of the AMOS (Analysis of Moment Structures) program, which uses the Maximum Likelihood statistic as the default method. According to Kline, for the validity of the structure, first EFA should be performed and then CFA should be performed [213].

Figure 4.3 shows an example CFA model. In the model consisting of 2 factors and 8 indicators, similar to the sample structure in EFA, error terms express variances that factors cannot explain, while the covariance between factors indicates that the factors have a common variance. In the example model, the 1st factor (categories created in the study) is measured with the variables Y1, Y2, Y3 and Y4 (success factors in the study), while the 2nd factor is measured with Y5, Y6, Y7, Y8. The arrows leading from the factor to the indicators indicate the direct effect: the factor loadings consisting of standardized or unstandardized regression coefficients. In this example model, indicators are called endogenous variables; dependent variables, while independent variables, for example error terms, are called exogenous variables [213].

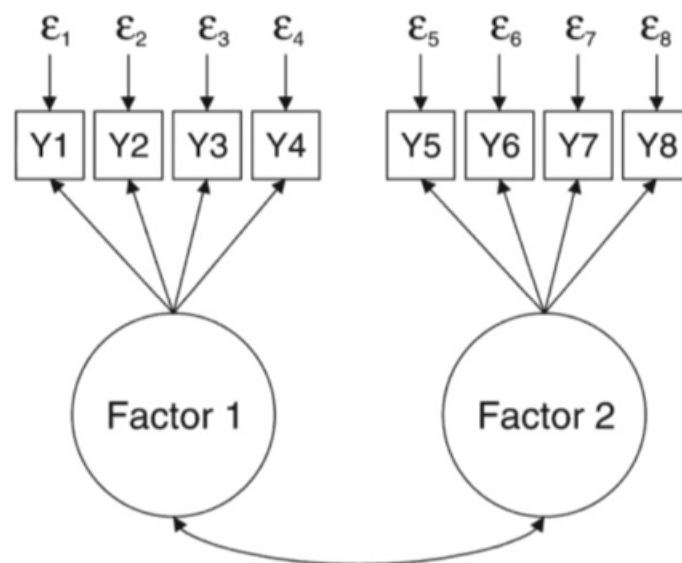


Figure 4.3. CFA representative model structure source adapted from [211].

4.6.3. Structural Equation Modelling (SEM)

SEM analysis, which started to be used in the 1970s, is the most used CFA method in the literature. It examines the causal relationship between variables in the model and verifies the presented theoretical model [214]. Since the method reveals multiple relationships in a single analysis, it is frequently used by researchers in multivariate model structures. In addition, it is a very comprehensive method as it includes many analyses such as regression analysis, factor analysis and discriminant analysis. This method has two types of variables: dependent variables, called endogenous variables and independent variables, called exogenous variables [212]. Before starting the analysis, the relationship between the dependent and independent variables in the model must be defined through a literature study. Hypotheses should have been created before this stage. The model structure resulting from EFA can provide input to SEM analysis and be used to test hypotheses. Afterwards, path analysis is carried out. In this analysis, the relationship between the dependent and independent variables in the model is examined. In order to determine the relationships between the variables, the relationship between variables is interpreted through the Unstandardized Coefficient values, which express the direct effects on the original scale and the Standardized Coefficient values, which represent the strength and direction of the relationship, allowing the relationship to be compared. Unstandardized Coefficients are called regression coefficients because they express the effect of a unit change in one variable on the other variable. Standardized coefficients express the characteristics of the relationships between variables, such as strength and direction, according to standard deviations. After determining the factor loadings, Convergent validity and divergent validity values are checked to review model validity. Lastly, the suitability of the model to the data is checked.

The model consists of latent variables (which cannot be measured and observed) and observed variables, which express the factors created to define the hidden variables.

Unlike the regression model, SEM solves more complex relationships. For example, relationships between multiple dependent and independent variables can be tested simultaneously. In addition, the use of SEM by researchers is increasing in studies because it can effectively solve much more complex structures than basic statistical methods can solve. It takes into account latent, observable variables and model estimation error terms and it successfully analyzes complex theoretical models with the maturity it has reached in recent years [212].

In 1934, Sewall Wright used the path diagram and developed the calculation of indirect, direct and total impacts. By performing multiple regression analysis, path analysis determines the magnitude of the relationship between variables and the significance of the relationship by allowing the hypotheses created to be tested. Figure 4.4 represents a simple path diagram. In this model, the total effect of A on C is found with the help of the direct effect of A on C and the indirect effect of A on B and B on C.

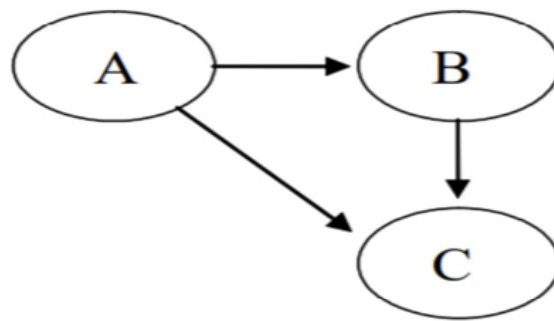


Figure 4.4. Path diagram representative model structure source adapted from [225].

4.6.3.1. Model Fit Indices. Model fit indices are used in SEM analysis to evaluate the model's compatibility with observations. These indices show how well the model represents its theoretical structure and compatibility with the data. They are divided into 3: Absolute Fit indices, Incremental Fit indices and Parsimonious Fit indices [215].

Chi-square (X^2), Root Mean Square Error of Approximation (RMSEA) and The goodness of Fit Index (GFI) are the most commonly used Absolute Fit indices. Chi-Square (X^2) is based on the assumption that the fit of the model and data is perfect, in which the expected and observed frequency difference is measured. To obtain a significant result, it is necessary to reach $p < 0.05$ [215].

However, this model fit index may reach high values depending on the structure complexity if the sample is large, which alone does not give definitive results about model fit. Root Mean Square Error of Approximation (RMSEA) measures how representative the model is of the population. RMSEA values are expected to be between 0.05 and 0.08 for an acceptable fit. As this value decreases, model fit increases [216]. The goodness of Fit Index (GFI) shows the model's fit with observations; it takes values between 0 and 1 and the closer it gets to 1, the better the model fit.

Adjusted Goodness of Fit (AGFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI) and Normed Fit Index (NFI) are the most commonly used Incremental Fit Indices. Adjusted Goodness of Fit (AGFI) makes a correction on the Goodness of Fit Index (GFI); it takes a value between 0 and 1 and the closer it is to zero, the better fit the model is. The accepted limit value for this index is 0.9 and above [217]. Similarly, the closer the Comparative Fit Index (CFI) value is to 1, the better the model fit with observations. Values of 0.95 and above indicate a perfect fit [218]. It is concluded that the closer the Tucker-Lewis Index (TLI) and Normed Fit Index (NFI) are to 1, the better the fit of the model with observations [219]. The Tucker-Lewis Index (TLI) may be preferred, especially in cases where the number of samples is small. Chisq/df is the most commonly used Parsimonious Fit index. This index evaluates the relationship between model complexity and fit by favoring simple models over complex models. The Chisq/df ratio, a chi-square value corrected for model complexity, analyzes model fit versus model complexity. A ratio of 3 or lower indicates a good fit [220]. It takes into account model complexity and achieves reliable results in large samples. As a result, no model fit index alone can reach a definitive conclusion about the model's compatibility, as it analyzes different aspects of model compatibility. For this reason, it is essential to

evaluate the most commonly used fit indices in the literature, CFI, NFI, TLI, RMSEA, Chisq/df together, to determine model fit.



5. RESULTS

5.1. Preliminary Analysis

The six categories of success factors to be used in the SEM analysis, named “Employee”, “Organization”, “Method, Tools Technology”, “Tasks”, “Environment Safety” and “Customer Supplier”, are independent latent variables. The “Business Success” category, which consists of business strategy objectives, is latent dependent variable.

In the study, the survey data of $n=224$ people were evaluated, and since all items were necessary, data cleaning was performed on the obtained data. First, 3 survey data were removed because the participant gave the same answer to all questions. Second, 7 survey data were removed for accepted responses, which were flagged for any participant who used the same Likert score in more than 85% of their responses. Finally, raw scores of all measurements were converted to z scores to examine outliers. If any z-score was greater than +1.98 or less than -1.98, it was considered for removal of survey data [199]. A total final sample size of $n=224$ was obtained. In this study, the AMOS program was used for the structural equation model. The most commonly used method for parameter estimation in SEM analysis is Maximum Likelihood (ML) in this program.

5.2. Demographic Analysis

In this survey’s demographic data analysis section, in which 224 people participated, the distributions regarding gender, age, education level, type of industry, field of expertise, work experience and position are as follows Table 5.1.

Table 5.1. Demographic data analysis results.

	Frequency	Percent
Gender		
Female	73	32.6
Male	151	67.4
Total	224	100
Participants' Age		
25-30 years old	52	23.2
31-40 years old	89	39.7
41-50 years old	64	28.6
51+	19	8.5
Total	224	100
Participants' Education		
Undergraduate	113	50.4
Graduate	97	43.4
PhD	14	6.3
Total	224	100
Participants' Sector		
Automotive	51	22.8
Service	48	21.4
Glass, plastic and metal	35	15.6
Fast Moving Consumer Goods (FMCG)	18	5.1
Other	72	35.1
Total	224	100
Participants' Total Work Experience		
0 to 5 Years	45	20.1
6 to 10 Years	35	15.6
11 to 20 Years	92	41.1
Over 20 Years	52	23.2
Total	224	100

Table 5.1. Demographic data analysis results. (cont.)

	Frequency	Percent
Participants' Position		
C-Level Executive	22	9.8
President	4	1.8
D-Level Executive	18	8.0
B-Level Executive	90	40.2
Top Managers	17	7.6
Project Manager	7	3.1
Engineer	46	20.5
Advisor	11	4.9
Other	9	4.0
Total	224	100
Participants' Total Managerial Experience		
0 – 2 Years	72	32.1
2 – 5 Years	38	17.0
5 – 10 Years	54	24.1
10 – 20 Years	40	17.9
20 + Years	20	8.9
Total	224	100
Participants' Total Experience in the Current Position		
1 to 2 Years	56	25.0
3 to 5 Years	78	34.8
6 to 10 Years	50	22.3
11 + Years	40	17.9
Total	224	100
Participants' Total Experience in the Current Company		
1 to 5 Years	135	60.3
6 to 10 Years	43	19.2
11 to 20 Years	37	16.5
Over 21 Years	9	4.0
Total	224	100

- Of 224 participants, 151 (67.4%) were male and 73 (32.6%) were female. Males were the majority in the research group.
- Of 224 participants, 151 (67.4%) were male and 73 (32.6%) were female. Males were the majority in the research group.
- It was determined that n=89 people (39.7% of the participants) were between the ages of 31-40, there were n=64 people (28.6%) in the 41-50 age range, and n=52 people (23.2%) in the 25-30 age range. According to this result, it can be said that the sample consists of young age group participants.
- It was determined that most participants were n=113 people (50.4%) at the undergraduate level, n=97 people with 43.3% at the master's level and n=14 people with 6.3% at the doctoral level.
- It was determined that 22.8% of the participants were (n=51) people in the automotive sector, 21.4% (n=48) people were in the service sector, 15.6% (n=35) people were in the glass, plastic and metal sector, and 5.1% (n=18) people were in the Fast Moving Consumer Goods (FMCG) sectors. It is understood that the number of people in other sectors is 12.1% (n=27) people.
- When the work experience of the participants is examined, it is understood that the majority of the sample has 11-20 years of work experience with n=92 (41.1%).
- According to the distribution of position in the company of the participants, it is understood that the maximum of 40.2% of the participants (n=90) people are in the B-Level Manager (Mid Level) position.
- It is understood that n=72 people (32.1% of the participants) have 0-2 years of managerial experience.
- It is understood that n=78 people (34.8% of the participants) have 3-5 years of experience in their position.
- It is understood that n=135 people, (60.3% of the participants), have 1-5 years of experience in the current company.

5.3. Descriptive Statistics

Table 5.2 represents descriptive statistics of the data (mean, standard deviation, Cronbach's alpha).

5.3.1. Reliability Analysis

In this study, there are seven different categories, namely "Business Success", "Employee", "Organization", "Method, Tools and Technology", "Task", "Environment and Safety" and "Customer and Supplier". Cronbach alpha method was used for reliability analysis. The reliability and basic component analyses of these categories have been determined. The Cronbach alpha (CA) value of each category is checked. This value being greater than 0.7 is a valid coefficient for reliability. A value greater than 0.8 indicates that the survey has high reliability. After conducting a reliability analysis that included all survey questions, it was found that the CA value reached 0.966. In addition, the tables below provide the descriptive statistics and reliability coefficient of the data values collected for the seven separate categories used in the study.

Table 5.2. Descriptive statistics and reliability coefficient of the business success category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
BS1	4.46	0.733	0.300	0.208	0.823
BS2	4.50	0.868	0.378	0.164	0.815
BS3	4.74	0.566	0.664	0.471	0.761
BS4	4.32	0.833	0.710	0.686	0.733
BS5	4.36	0.819	0.680	0.551	0.741
BS6	4.21	0.922	0.702	0.669	0.733
Cronbach's Alpha $\alpha = 0.802$					

The questionnaire includes six questions pertaining to “business success”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations for each question take values between 0.300 and 0.710. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated as 0.802. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.3. Descriptive statistics and reliability coefficient of the employee category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
EMP1	4.26	0.828	0.545	0.334	0.869
EMP2	2.89	1.099	0.354	0.185	0.899
EMP3	4.05	0.843	0.651	0.463	0.858
EMP4	4.32	0.822	0.768	0.696	0.847
EMP5	4.41	0.831	0.817	0.821	0.841
EMP6	4.38	0.735	0.655	0.439	0.859
EMP7	4.41	0.837	0.733	0.673	0.850
EMP8	4.37	0.888	0.692	0.629	0.854
Cronbach's Alpha $\alpha = 0.875$					

The questionnaire includes 8 questions pertaining to “Employee”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength

of the relationship between each observed variable and the total scale, are included. The item total correlations for each question take values between 0.354 and 0.817. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated as 0.875. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.4. Descriptive statistics and reliability coefficient of the organization category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
ORG1	4.63	0.691	0.660	0.463	0.883
ORG2	4.14	0.846	0.661	0.472	0.882
ORG3	4.41	0.770	0.732	0.563	0.874
ORG4	4.35	0.844	0.756	0.596	0.870
ORG5	4.09	0.916	0.601	0.372	0.890
ORG6	4.32	0.919	0.723	0.569	0.874
ORG7	4.28	0.915	0.742	0.592	0.872
Cronbach's Alpha $\alpha = 0.893$					

The questionnaire includes 7 questions pertaining to "Organization". As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations of each question are between 0.601 and 0.756. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated

as 0.893. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.5. Descriptive statistics and reliability coefficient of the method, tools and technology category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
TOOL1	4.51	0.781	0.590	0.381	0.902
TOOL2	3.72	1.044	0.672	0.510	0.895
TOOL3	3.98	1.092	0.732	0.610	0.889
TOOL4	3.89	1.151	0.781	0.699	0.884
TOOL5	3.94	1.121	0.770	0.712	0.886
TOOL6	4.04	1.089	0.742	0.571	0.888
TOOL7	4.03	0.862	0.541	0.348	0.905
TOOL8	4.30	0.986	0.745	0.621	0.888
Cronbach's Alpha $\alpha = 0.905$					

The questionnaire includes 8 questions pertaining to “Tool and Technology”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations for each question take values between 0.541 and 0.781. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated as 0.905. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.6. Descriptive statistics and reliability coefficient of the tasks category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
TASK1	4.04	0.936	0.682	0.504	0.830
TASK2	3.87	0.989	0.670	0.509	0.835
TASK3	4.35	0.978	0.725	0.538	0.819
TASK4	4.46	0.797	0.681	0.551	0.832
TASK5	4.54	0.714	0.665	0.521	0.838
Cronbach's Alpha $\alpha = 0.860$					

The questionnaire includes 5 questions pertaining to “Task”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations of each question take values between 0.665 and 0.725. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated as 0.860. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.7. Descriptive statistics and reliability coefficient of the environment and safety category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
ENV1	4.09	1.281	0.507	0.307	0.812
ENV2	3.97	1.346	0.503	0.272	0.817
ENV3	4.38	0.895	0.612	0.429	0.788
ENV4	4.32	0.822	0.617	0.652	0.790
ENV5	4.41	0.831	0.691	0.700	0.779
ENV6	4.27	0.873	0.579	0.642	0.794
ENV7	4.42	0.843	0.588	0.642	0.793
Cronbach's Alpha $\alpha = 0.820$					

The questionnaire includes 7 questions pertaining to “Environment”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations of each question are in the range of 0.503 to 0.691. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. The scale’s reliability analysis yields a Cronbach alpha value of 0.820. The analysis of reliability results indicates that the scale has good internal consistency.

Table 5.8. Descriptive statistics and reliability coefficient of the customer and supplier category.

Item	Mean	Std. Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach’s Alpha if Item Deleted
CUST1	4.35	0.789	0.740	0.550	0.868
CUST2	4.58	0.723	0.806	0.657	0.804
CUST3	4.59	0.702	0.778	0.622	0.831
Cronbach’s Alpha $\alpha = 0.883$					

The questionnaire includes 3 questions pertaining to “Customer”. As a result of the analysis of the data collected from the Likert-type survey, the mean and standard deviation values for each observed variable are presented in the table above. Additionally, the Corrected Item-Total Correlation values, which demonstrate the strength of the relationship between each observed variable and the total scale, are included. The item total correlations for each question take values between 0.550 and 0.657. The Squared Multiple Correlation (SMC) values, indicating the proportion of variance for each observed variable explained by other variables, are also provided in the table above. As a result of the reliability analysis, the Cronbach alpha value of the scale was calculated as 0.883. The analysis of reliability results indicates that the scale has good internal consistency.

As a result, It was observed that CA values were between 0.802 and 0.905 on a category basis. Therefore, it was concluded that the scale and survey used were reliable.

Inter-rater reliability is employed to determine whether different survey respondents provide consistent estimates of the same items, thereby assessing the compatibility of the respondents' evaluations.

Considering the Cohen's Kappa value for the inter-rater reliability analysis, a value of 0.51 was obtained. According to the criteria established by Landis and Koch (1977), this value indicates a moderate agreement [203, 205]. Additionally, the p-value was found to be less than 0.05, signifying that the agreement between raters is statistically significant. Consequently, it was determined that there is significant agreement between the raters, thereby achieving inter-rater reliability.

5.4. Inferential Statistics

In this study, Structural Equation Modeling (SEM) will be employed to test the relationships within the hypothesized model. For parameter estimation, SEM utilizes Maximum Likelihood Estimation (MLE) as the most common method to identify the model parameters that best fit the observed data. MLE aims to maximize the likelihood function, which represents the probability of the observed variables under the given model parameters. To appropriately apply the MLE method in SEM, the assumption of multivariate normal distribution must be satisfied. Therefore, a normality analysis was conducted at the outset of the analysis to ensure the assumption of multivariate normality required by SEM [201].

5.4.1. Normality Analysis

As explained in the method section of the study, skewness and kurtosis values are used to estimate the data distribution. Different limits have been determined for these

values in various studies. In various studies, these values between -1.50 and + 1.50, between -2.00 and +2.00, and between -1.96 and 1.96 are interpreted as complying with normal distribution [199], [200]. If the skewness and kurtosis values fall within the range of -2 to +2 and -7 to +7, respectively, the data is assumed to be normally distributed [201].

Outliers at the scale level were evaluated and normality was evaluated. It is not uncommon to find anomalous data [221], and structural equation modeling is relatively robust to violations of normality [199]. Since parcel development is a technique that allows for more effective analysis by breaking down data sets consisting of many measurement indicators into more manageable pieces, parcel development can partially resolve the anomaly, as elements combined or averaged generally reduce the undue influence of any one element.

Parcels are created according to the following measures. “Business Success”, “Employee”, “Organization”, “Method, Tools, and Technology”, “Tasks”, “Environment and Safety”, and “Customer and Supplier”. Each measure contains three to eight randomly assigned items. This method of random assignment has been accepted by past research [222]. In the examinations made after the product parcels were created, it was observed that some parcels were significantly flattened. Thus, the remaining variables were closely monitored throughout all analyses and no additional concerns were raised.

The normal distribution assumption is accepted based on the skewness and kurtosis values of the data included in the Appendix B. Ultimately, it was decided to perform SEM analysis in the AMOS program using the Maximum Likelihood (ML) method.

5.5. Factor Analysis

Factor analysis is a multivariate statistical technique used to establish construct validity, reduce the number of variables by expressing them with fewer underlying factors, and identify relationships among variables. This method is divided into two types: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

5.5.1. Assumptions

In order to perform factor analysis effectively, several assumptions must be met, ensuring the robustness and validity of the analysis. Below are the key assumptions and their confirmation within the present study:

- (i) Ensuring Multivariate Normality; This assumption was evaluated through the examination of multivariate skewness and kurtosis values. The obtained values fell within the acceptable range of -2 to +2 for skewness and -7 to +7 for kurtosis [201], thus confirming the adherence to the Multivariate Normality assumption (Normality analysis section).
- (ii) Linearity (Linear Relationship Among Variables); Linearity among variables is essential for factor analysis, indicating that the relationships between variables are linear. This assumption was assessed using the Pearson correlation matrix, which provides insights into the linear associations between variables. Notably, Pearson correlation coefficients of 0.5 or higher were observed, suggesting a strong indication of linearity within the data [197]. This data is presented in the Table 5.12.
- (iii) Adequate Sample Size; Adequate sample size is paramount to ensure the reliability and validity of factor analysis results. As per recommendations in the literature, it is advised that the number of participants exceeds 5-10 times the number of factors analyzed [197]. In our study, data were collected from a sample of 224 participants, thereby meeting the requisite sample size criteria.

- (iv) Correlation Between Variables; There must exist sufficient correlation between factors to justify their grouping within the factor analysis framework. High correlation values between factors indicate their potential grouping into a single structural dimension. In our analysis, correlation coefficients exceeding 0.3 were observed [199], aligning with the expected threshold for factor analysis. This data is presented in the Table 5.12.

5.5.2. Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis (EFA) was conducted to uncover the factor structure of the study scale and to determine its construct validity. In this analysis, principal component analysis was used as the extraction method, and the direct oblimin method was employed for rotation. Since Principal component analysis is a fast and simple analysis to understand the structure and structural relationships, it is the most commonly used technique to identify factor structures. Direct oblimin method was chosen due to the expected correlations between variables. In instances where there is no correlation between factors, direct oblimin rotation can still be applied. However, the decision to utilize direct oblimin rotation in this context was predicated upon the perceived logical relationship between the factors, inferred from theoretical research findings [199, 197, 198].

- Suitability for Exploratory Factor Analysis; The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy values, calculated for each factor structure individually, are presented in Table 5.9. A KMO value above 0.5 indicates that the sample size is sufficient for EFA [223]. Additionally, the significance level obtained from the Bartlett's test of sphericity for each factor structure must be significant ($p < 0.05$). This result demonstrates that the correlations among items are sufficiently large for EFA.

Table 5.9. KMO and bartlett's test results.

Item	KMO	Bartlett's Test
Business Success	0.798	p<0.05
Employee	0.893	p<0.05
Organization	0.905	p<0.05
Tool	0.887	p<0.05
Task	0.819	p<0.05
Environment	0.899	p<0.05
Customer	0.737	p<0.05

- Exploratory Factor Analysis Results; The EFA revealed that the scale, comprising a total of 44 items, has a structure with 7 sub-dimensions (factors) as determined through the literature review. The table provides information on the percentage of the total variance explained by each factor. Based on these results, the scale and its structure were deemed valid. Consequently, the Confirmatory Factor Analysis (CFA) part of the study commenced using the 7-factor structure established through the literature review. These seven categories are “Business Success”, “Employee”, “Organization”, “Method, Tools and Technology”, “Task”, “Environment and Safety” and “Customer and Supplier”.

Table 5.10. Total variance explained values.

Item	Total Variance Explained (Cumulative % for one factor structure)
Business Success	53.115
Employee	57.019
Organization	61.655
Tool	60.142
Task	64.927
Environment	71.863
Customer	81.286

The Total Variance Explained values indicate the proportion of the overall variance in the entire scale that is accounted for by the relevant factor (latent variable). With over 50% of the total variance accounted for by a single factor, the single-factor structure stands as valid [198]. As illustrated in Table 5.10, the single-factor structure comprising;

- 6 questions for business success accounts for 53.1% of the total variance
- 8 questions for employee accounts for 57.1% of the total variance
- 7 questions for organization accounts for 61.7% of the total variance
- 8 questions accounts for tool 60.1% of the total variance
- 5 questions accounts for task 64.9% of the total variance
- 7 questions accounts for 71.9% of the total variance
- 3 questions accounts for 81.2% of the total variance

The questions included in this survey are detailed in the Method section.

Table 5.11. EFA results.

Factor	Item	Factor Loadings	Number of Questions	Number of Factors Extracted
Business Success	SB1	0.421	6	1
	SB2	0.503		
	SB3	0.783		
	SB4	0.855		
	SB5	0.832		
	SB6	0.849		
Employee	emp5	0.903	8	1
	emp4	0.862		
	emp7	0.837		
	emp8	0.803		
	emp6	0.746		
	emp3	0.727		
	emp1	0.626		
	emp2	0.426		

Table 5.11. EFA results. (cont.)

Factor	Item	Factor Loadings	Number of Questions	Number of Factors Extracted
Organization	org4	0.836	7	1
	org7	0.821		
	org3	0.816		
	org6	0.803		
	org2	0.759		
	org1	0.755		
	org5	0.699		
Tool and Technology	tool4	0.843	8	1
	tool5	0.836		
	tool8	0.817		
	tool6	0.814		
	tool3	0.802		
	tool2	0.752		
	tool1	0.679		
	tool7	0.634		
Task	task3	0.837	5	1
	task4	0.814		
	task5	0.798		
	task1	0.795		
	task2	0.783		
Environment	env5	0.905	7	1
	env4	0.895		
	env2	0.858		
	env1	0.856		
	env7	0.819		
	env6	0.807		
Customer	env3	0.787	3	1
	cust2	0.919		
	cust3	0.904		
	cust1	0.881		

Based on the Exploratory Factor Analysis (EFA) results, a seven-factor structure was identified, informed by the factor loadings and the total variance explained. The

factors are delineated in Table 5.11. For instance, under the factor labeled “Business Success”, the observed variables SB1-SB6 are included. The remaining factors are similarly interpreted. The factor naming was consistent with the theoretical expectations, and the factors were thus renamed as shown in the table. In the subsequent section, the validity of this structure derived from EFA will be tested using Confirmatory Factor Analysis (CFA).

- Validity; Table 5.12 presents the correlation analysis, which illustrates the direction and magnitude of the relationships between the categories of Business Success, Employee, Organization, Tool, Task, Environment, and Customer (SB, EMP, ORG, TOOL, TASK, ENV, CUST), to assess discriminant validity. The table combines the AVE matrix with this correlation matrix. The diagonal entries in the table represent the square root of the construct AVE. Discriminant validity is confirmed when the diagonal values are greater than the corresponding row and column values. Additionally, the table includes Pearson correlation coefficients, which range from -1 to +1. An acceptable discriminant validity is indicated when these correlations fall between 0.1 and 0.9 [197], suggesting a positive correlation. Based on the results obtained, discriminant validity was successfully established.

In Table 5.12, it is understood that the composite reliability (CR) and Mean Variance AVE values are good for model success considering the item factor loads created in the model framework. The definitions and validity thresholds for AVE, MSV, and MaxR (H) values presented in the table are as follows:

- Composite Reliability (CR) assesses the internal consistency of observed variables, indicating how reliably they represent the underlying latent construct they are intended to measure. It should be greater than 0.7 for acceptability [197].
- AVE (Mean Variance Extracted), utilized for assessing convergent validity, signifies the portion of variance in latent variables attributed to measurement error, with thresholds typically set at values exceeding 0.5 for acceptability [197].

- MSV (Maximum Shared Variance), employed to evaluate discriminant validity, denotes the maximum correlation observed among latent variables, with thresholds typically set at values below 0.5 for acceptability [197].
- MaxR (H) (Maximum Redundancy of an Indicator) quantifies the extent to which each observed variable contributes to the variance of its corresponding latent variable, with thresholds typically set at values surpassing 0.7 for acceptability [197].

The CR coefficients ranged from 0.837 to 0.927 and the AVE coefficients ranged from 0.631 to 0.761. According to the analysis, the assumptions that the CR coefficients are expected to be greater than 0.70 [222]. According to the CR, AVE, model fit indices values obtained as a result of the analysis, all seven categories in the research model will be used in Confirmatory factor analysis.

Table 5.12. Model validity measures.

[illegible]

5.5.3. Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis was performed on this study model using AMOS (Analysis of Moment Structures) to evaluate the measurement model fit and the observed variable factor loads. According to the results the goodness of fit of the scales is evaluated based on various indices.

- The most basic criterion used to evaluate the goodness of fit is the Chi-square statistic. This statistic evaluates the compatibility of the model and the data (the difference between the realized covariance matrix and the expected covariance matrix). The case in which perfect harmony is achieved is $\text{Chi-square} = 0$.
- In the evaluation of model fit, the ratio of Chi-square / degrees of freedom (dof) presents the difference between the model's covariance matrix and the observed covariance matrix, correcting for complexity. A Chi-square / degrees of freedom (dof) ratio between 0 and 2 indicates a good fit, while a ratio between 2 and 3 indicates an acceptable fit [197].
- RMSEA explains the difference between the model and observed data. RMSEA values less than 0.08 indicates good fit.
- CFI examines the fit of the structural model to a base model. CFI indices range from 0 to 1. 0 is interpreted as no fit at all, 0.90 is a good fit, and 0.95-1.0 is a perfect fit [224].
- NFI examines the difference between the observed covariance matrix and the covariance matrix of the model. The acceptable range for NFI values lies between 0.9 and 0.94.
- TLI compares model fit to a null model. A TLI value exceeding 0.9 indicates a good fit.

There are those who state that the value of 0.75 can also be taken as a sub-value for these indices [219]. In addition to the chi-square statistic, a number of different fit indices that evaluate the model from different angles are used in the evaluation of the model.

The data obtained as a result of the confirmatory factor analysis were found to be compatible with the theoretical model Table 5.13.

Table 5.13. Model fit indices values Hair (2014).

Fit Criterion	Good Fit	Acceptable	Model CFA Fit Values
CFI	$0.97 \leq \text{CFI} \leq 1$	$0.95 \leq \text{CFI} \leq 0.97$	0.95
NFI	$0.95 \leq \text{NFI} \leq 1$	$0.90 \leq \text{NFI} \leq 0.94$	0.90
TLI	$0.95 \leq \text{TLI} \leq 1$	$0.90 \leq \text{TLI} \leq 0.94$	0.94
RMSEA	$0 \leq \text{RMSEA} \leq 0.05$	$0.05 \leq \text{RMSEA} \leq 0.08$	0.06
(x^2/dof)	≤ 3	$\leq 4-5$	1.857

The results of the Confirmatory Factor Analysis performed on the success factors used in the study are presented in Figure 5.1. In the Confirmatory Factor Analysis (CFA), a seven-factor structure was evaluated. The model fit criteria were assessed and found to be within acceptable limits. Items that were not statistically significant or had a covariance connection with the observed variables under other factors were systematically removed from the scale and re-analyzed. Consequently, the path coefficients of all observed variables within the factor structures were found to be statistically significant ($p < 0.001$). The factor loadings obtained from the analysis revealed that the following factors significantly contribute to the model:

- SB4, SB5, and SB6 in the business success category;
 - SB4: Sustainability of business strategies
 - SB5: Innovation and improving product quality
 - SB6: Increasing employee performance and satisfaction
- emp4, emp5, emp7, and emp8 in the employee category;
 - emp4: Motivation and need of employees
 - emp5: Employee participation
 - emp7: Teamwork
 - emp8: Training for employees

- org3, org4, org6, and org7 in the organization category;
 - org3: Communication, coordination and cooperation
 - org4: Management and supervision style
 - org6: Visual Management practices
 - org7: Long-term strategy planning, tracking and reporting

- tool4, tool5, and tool8 in the tool category;
 - tool4: SMED applications
 - tool5: Total Productive Maintenance practices
 - tool8: Continuous improvement (kaizen) practices

- env1, env2, env4, and env5 in the environment category;
 - env1: Employee health, safety and wellbeing
 - env2: Use of personal protective equipment
 - env4: Reducing employee health and safety risks
 - env5: Organizational culture and lean culture

- task3, task4, and task5 in the task category;
 - task3: Gemba walks
 - task4: Flexibility, speed and efficiency increase
 - task5: Increase in service and/or product quality

- cust1, cust2, and cust3 in the customer category.
 - cust1: Cooperation effectively with the supplier
 - cust2: Benefiting from customer feedback and complaints
 - cust3: Meeting customer/stakeholder demands and expectations

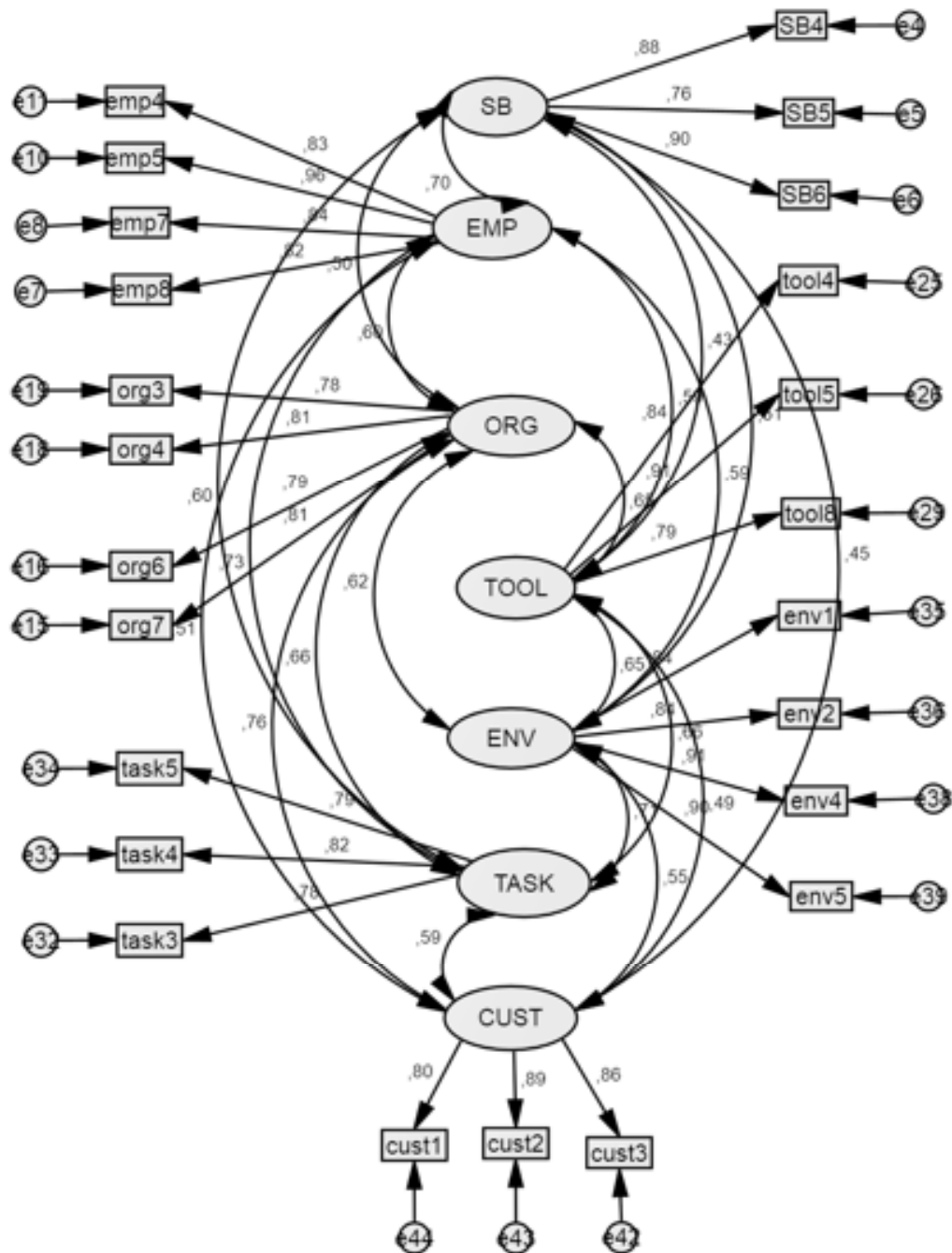


Figure 5.1. Measurement model of study.

Org: Organization; Tool: Method, Tools and Technology; Task: Task; Env: Environment; Emp: Employee; Cust: Customer and supplier; Sb: Business Success

Figure 5.1 illustrates the measurement model obtained from the Confirmatory Factor Analysis (CFA). The measurement model evaluates the relationships between latent variables and observed variables. Latent variables, which cannot be directly measured, are inferred through observed variables and represent the seven categories (SB, EMP, ORG, TOOL, TASK, ENV, CUST) in this thesis study. Observed variables, measured directly through survey questions (e.g., emp4, emp5), provide data for these latent constructs. The factor loadings resulting from the CFA are shown in Figure 5.1 and in Table 5.14, represented by the arrows between the latent and observed variables,

$$\beta = \frac{bx\sigma_x}{\sigma_y}. \quad (5.1)$$

β is the standardized beta coefficient (factor loadings), b refers to the unstandardized regression coefficient; σ_x , standard deviation of the latent variable, σ_y , standard deviation of the observed variable [197].

In the SEM, where all latent variables are denoted as Y_i all observed variables are denoted as x_i . The regression equation showing the relationship between the latent variable and its observed variables is as follows

$$Y = \sum_{i=1}^n (\beta_i x_i) + error. \quad (5.2)$$

For instance, “cust2” (Benefiting from customer feedback and complaints) has a high factor loading ($\beta=0.89$), indicating that this observed variable strongly represents the Customer latent variable. The linear regression equation explaining this relationship is as follows

$$Customer = 0.89 \times cust2 + error_{customer}. \quad (5.3)$$

According to the formula, a one standard deviation increase in “cust2” (benefiting from customer feedback and complaints) results in a 0.89 standard deviation increase in the customer category. This indicates a strong positive relationship between the two variables, suggesting that improvements in utilizing customer feedback and addressing complaints significantly enhance overall customer satisfaction.

Table 5.14. Standardized estimate (factor loads) of the significant factors.

Categories	Critical Success Factors of Integrated Ergonomics and Lean	Standardized estimate (standardized β coefficient)
Customer and Supplier	Benefiting from customer feedback and complaints	0.89
	Meeting customer/ stakeholder demands and expectations	0.86
	Cooperating effectively with the supplier	0.80
Organization	Long-term strategy planning, tracking and reporting	0.81
	Management and supervision style	0.81
	Visual Management practices	0.79
	Communication, coordination and cooperation	0.78
Employee	Employee participation	0.96
	Teamwork	0.84
	Satisfaction of the needs of employees	0.83
	Training for employees	0.82

Table 5.14. Standardized estimate (factor loads) of the significant factors. (cont.)

Categories	Critical Success Factors of Integrated Ergonomics and Lean	Standardized estimate (standardized β coefficient)
Method, Tools and Technology	Total Productive Maintenance practices	0.91
	SMED applications	0.84
	Continuous improvement (kaizen) practices	0.79
Tasks	Flexibility, speed and efficiency increase	0.82
	Increase in service and/or product quality	0.79
	Gemba walks	0.78
Environment and Safety	Reducing employee health and safety risks	0.91
	Organizational culture and lean culture	0.90
	Employee health, safety and wellbeing	0.84
	Use of personal protective equipment	0.84

The standardized estimate quantifies the strength and direction of the relationship between variables. By examining the standardized estimate values, or factor loadings, of the critical success factors within the categories presented in the Table 5.14, insights can be gained regarding the contribution of this category to business success.

The impacts within the Customer and Supplier category are ranked from most to least influential as follows:

- Benefiting from customer feedback and complaints ($\beta = 0.89$)
- meeting customer/stakeholder demands and expectations ($\beta = 0.86$)
- Cooperating effectively with the supplier ($\beta = 0.80$)

The impacts within the “Organization” category are ranked from most to least influential as follows:

- Long-term strategy planning, tracking and reporting
- Management and supervision style
- Visual Management practices
- Communication, coordination and cooperation

The impacts within the “Employee” category are ranked from most to least influential as follows:

- Employee participation
- Teamwork
- Motivation and need of employees
- Training for employees

The impacts within the “Method, Tools and Technology” category are ranked from most to least influential as follows:

- Total Productive Maintenance practices
- SMED applications
- Continuous improvement (kaizen) practices

The impacts within the “Tasks” category are ranked from most to least influential as follows:

- Flexibility, speed and efficiency increase
- Increase in service and/or product quality
- Gemba walks

The impacts within the “Environment and Safety” category are ranked from most to least influential as follows:

- Reducing employee health and safety risks,
- Organizational culture and lean culture
- Employee health, safety and wellbeing
- Use of personal protective equipment

As a result of the Confirmatory Factor Analysis (CFA), the hypothesized seven-factor model was confirmed. This finding indicates that the observed variables are robust indicators of their respective latent constructs.

5.6. Structural Equation Model (SEM)

Structural Equation Modeling (SEM) is a statistical technique used to test relationships between latent and observed variables.

The structural model illustrates the relationships between latent variables, with path coefficients indicating the direction and strength of these relationships. In this section, SEM was used to examine the direct, indirect, and total effects between latent variables. For example, in Figure 5.3, the arrow between Organization and Business Success represents the direct relationship between these two latent variables. Additionally, the arrows from Organization to Employee and from Employee to Business Success depict the indirect effect of Organization on Business Success through Employee. Total

effects are calculated as the sum of both direct and indirect effects. The expression for the total effects formula is as follows

$$\beta_{direct} + \beta_{indirect} = \beta_{total}, \quad (5.4)$$

$$\beta_{indirect} = \beta_{c'} = \beta_a \beta_b. \quad (5.5)$$

In the depicted scenario, the $\beta_{indirect}$ can be denoted as c' as illustrated in Figure 5.2 below. Additionally, β_a and β_b represent the standardized coefficients of paths a and b , respectively.

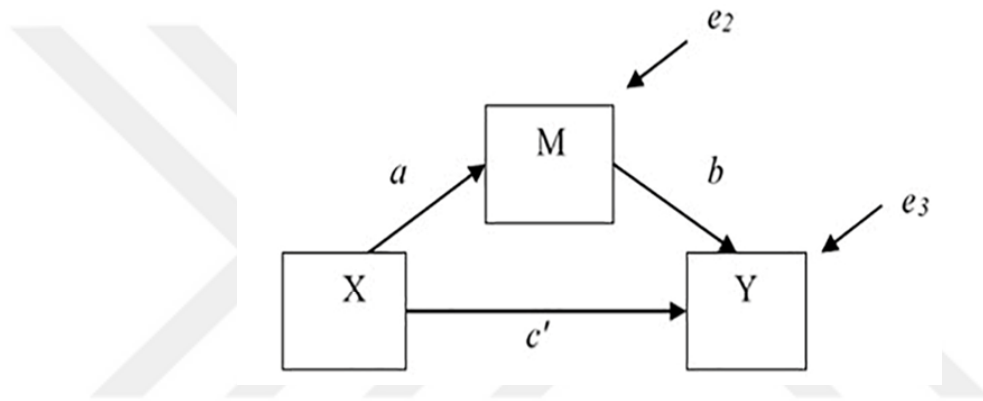


Figure 5.2. Model of the indirect effect mediated by M_i [226].

16 hypotheses were examined using Structural Equation Modeling (SEM). These hypotheses are presented in Table 5.16. The results derived from the structural model indicate that the model demonstrated an acceptable fit, with the model fit index values falling within acceptable limits. The specific model fit indices are detailed in Table 5.15. The accepted and rejected hypotheses based on these results are summarized in Table 5.16.

Table 5.15. SEM analysis model fit indices values Hair, (2014).

Fit Criterion	Good Fit	Acceptable	Model SEM Fit Values
CFI	$0.97 \leq \text{CFI} \leq 1$	$0.95 \leq \text{CFI} \leq 0.97$	0.95
NFI	$0.95 \leq \text{NFI} \leq 1$	$0.90 \leq \text{NFI} \leq 0.94$	0.90
TLI	$0.95 \leq \text{TLI} \leq 1$	$0.90 \leq \text{TLI} \leq 0.94$	0.94
RMSEA	$0 \leq \text{RMSEA} \leq 0.05$	$0.05 \leq \text{RMSEA} \leq 0.08$	0.06
(X^2/dof)	≤ 3	$\leq 4-5$	1.857

Direct Effects: The results of the Structural Equation Modeling (SEM) performed on the categories are presented in Figure 5.3.

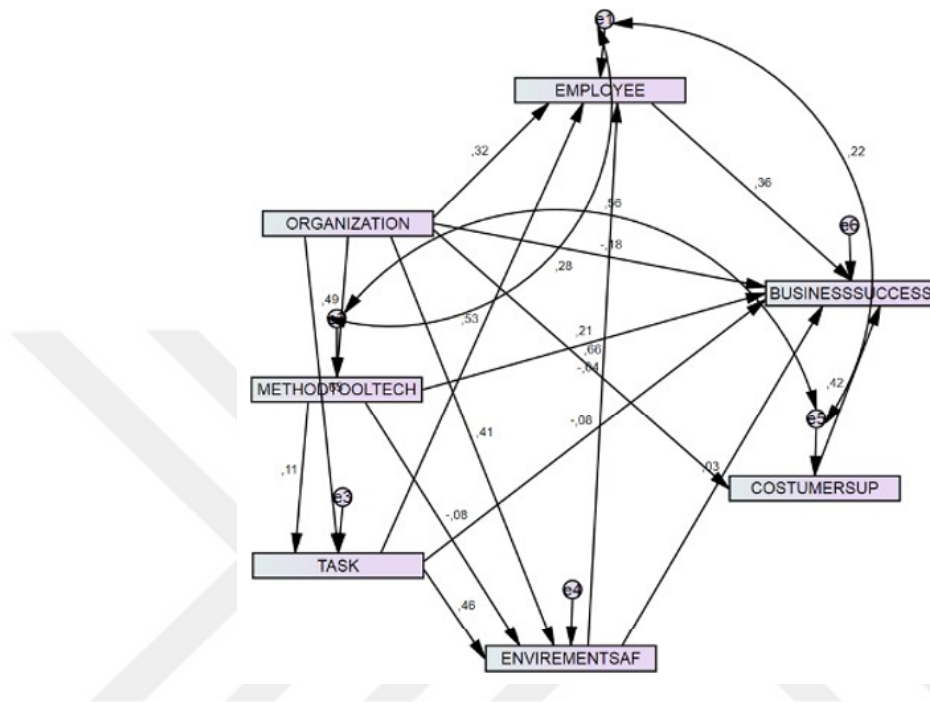


Figure 5.3. Structural model.

This figure displays the direct effects and relationships in the research model. Standardized β coefficients can be accessed from the Figure 5.3 and Table 5.16. The most noteworthy outcome is that the Customer category has the strongest effect on Business success, with a standardized β coefficient of 0.42.

Table 5.16. Hypothesis testing.

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.492	0.377	0.045	8.430	H4 Accepted	***
Task	< ...	Tool	0.109	0.142	0.070	2.017	H6 Accepted	0.044*

Table 5.16. Hypothesis testing. (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Task	< ...	Org	0.649	0.644	0.054	11.972	H12 Accepted	***
Env	< ...	Task	0.464	0.476	0.062	7.664	H8 Accepted	***
Env	< ...	Tool	-0.081	-0.108	0.066	-1.647	H14 Rejected	0.100
Env	< ...	Org	0.411	0.418	0.064	6.535	H15 Accepted	***
Emp	< ...	Org	0.316	0.314	0.064	4.935	H1 Accepted	***
Cust	< ...	Org	0.661	0.425	0.032	13.161	H11 Accepted	***
Emp	< ...	Task	0.531	0.533	0.066	8.109	H13 Accepted	***
Emp	< ...	Env	-0.040	-0.039	0.063	-0.615	H16 Rejected	0.539
SB	< ...	Emp	0.361	0.254	0.055	4.613	H2 Accepted	***
SB	< ...	Org	-0.184	-0.129	0.059	-2.164	H3 Accepted	0.030*
SB	< ...	Task	-0.077	-0.054	0.061	-0.878	H7 Rejected	0.380
SB	< ...	Env	0.032	0.22	0.052	0.418	H9 Rejected	0.676
SB	< ...	Cust	0.418	0.455	0.085	5.370	H10 Accepted	***
SB	< ...	Tool	0.209	0.191	0.063	3.047	H5 Accepted	0.002*
*** $p < .01$. * $p < .05$								

According to Table 5.16, the regression loads for the relationship between the variables “Business Success”, “Employee”, “Organization”, “Method, Tools Technology”, “Tasks”, “Environment Safety” and “Customer Supplier” are statistically significant because their p values are less than 0.05. As a result, except for the H7, H9, H14 and H16 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed.

It was determined that there was a positive and moderate effect between the Employees and Organization and this relationship was statistically significant ($\beta=0.316$; $p < 0.01$). It is observed that the participants think that the organization is in a correct structure and that this structure is created according to the employees. The H1 hypothesis was accepted. The structure of the organization is suitable for employees.

It was determined that there was a positive and moderate effect between the employees (EMP) and the success of the company (SB) and this relationship was statistically significant ($\beta =0.361$; $p < 0.01$). The H2 hypothesis was accepted.

It was determined that there was a negative and weak effect between the organization (Org) and the success of the company/institution (SB) and this relationship was statistically significant ($\beta=-0.184$; $p= 0.03$). The H3 hypothesis was accepted.

It was determined that there was a positive and strong effect between the organization (Org) and the thoughts of the participants about Method, Tools and Technology (Tool) and this relationship was statistically significant ($\beta= 0.492$; $p < 0.01$). The H4 hypothesis was accepted.

It was determined that there was a positive and weak effect between the thoughts of the Method, Tools and Technology (Tool) and the success of the company/institution (Sb) and this relationship was statistically significant ($\beta= 0.209$; $p < 0.05$). The H5 hypothesis was accepted.

It was determined that there was a positive and weak effect between the participants' thoughts about Methods, Tools and Technology (Tool) and the Task and this relationship was statistically significant ($\beta= 0.109$; $p=0.04$). The H6 hypothesis was accepted.

It was determined that there was a negative and very weak effect between Task and the success of the company/institution (Sb) and this relationship was not statistically significant ($\beta = 0.077$; $p > 0.05$). The H7 hypothesis is not accepted.

It was determined that there was a positive and strong effect between the Task and environment (Env) and this relationship was statistically significant ($\beta = 0.464$; $p < 0.01$). The H8 hypothesis is accepted.

It was determined that there was a positive and very weak effect between environment (Env) and the success of the company/institution (Sb) and this relationship was not statistically significant ($\beta = 0.032$; $p > 0.05$). The H9 hypothesis is not accepted.

It was determined that there was a positive and strong effect between effective cooperation with the customer and supplier (Cust) and the success of the company/institution (Sb) and this relationship was statistically significant ($\beta = 0.414$; $p < 0.01$). The H10 hypothesis is accepted.

It was determined that there was a positive and very strong effect between organization (Org) and customer and supplier (Cust) and this relationship was statistically significant ($\beta = 0.614$; $p < 0.01$). The H11 hypothesis is accepted.

It was determined that there was a positive and very strong effect between organization and the task and this relationship was statistically significant ($\beta = 0.649$; $p < 0.01$). The H12 hypothesis was accepted.

It was determined that there was a positive and strong effect between the task and the employee and this relationship was statistically significant ($\beta = 0.531$; $p < 0.01$). The H13 hypothesis is accepted.

It was determined that there was a negative and very weak effect between Methods, Tools and Technology and environment and this relationship was not statistically significant ($\beta = -0.081$; $p > 0.05$). The H14 hypothesis is not accepted.

It was determined that there was a positive and strong effect between organization and the Task and this relationship was statistically significant ($\beta = 0.411$; $p < 0.01$). The H15 hypothesis is accepted.

It was determined that there was a negative and very weak effect between the Method, Tools and Technology and employees and this relationship was not statistically significant ($\beta = 0.040$; $p > 0.05$). The H16 hypothesis is not accepted.

5.6.1. Indirect Effects

The following table shows the indirect effects as explained in the methodology section. The indirect effects (standardized regression coefficient) obtained as a result of the analysis are displayed in the table.

Table 5.17. Sum of indirect effects.

To	From			
	Org	Tool	Task	Env
Task	0.054***			
Env	0.286***	0.051 n.s		
Emp	0.346***	0.059 n.s	-0.018***	
Sb	0.587*	0.012*	0.200 n.s	-0.014 n.s
*** $p < .01$, * $p < .05$, n.s not significant				

It was determined that there was a positive and strong indirect effect between the organization and the success of the company/institution (SB) and this relationship was statistically significant ($\beta = 0.587$; $p < 0.05$). It is observed that this effect

increases due to the fact that the relationship in question is obtained through the employee variable. Accordingly, a positive increase in standard deviation towards the organization will result in an increase of 0.587 standard deviations in the success of the company/institution.

5.6.2. Total Effects

The following table shows the total effects (sum of direct effect and indirect effect) as explained in the methodology section. The total effects obtained as a result of the analysis are displayed in the table.

Table 5.18. Total effects.

	Org	Tool	Task	Env	Cust	Emp
Tool	0.492***					
Task	0.703***	0.109*				
Env	0.697***	-0.031 n.s.	0.464***			
Cust	0.661***					
Emp	0.661***	0.059 n.s.	0.513***	-0.040 n.s.		
Sb	0.403*	0.222*	0.123 n.s.	0.017 n.s.	0.418***	0.361***
*** $p < .01$, * $p < .05$, n.s : not significant						

It was found that the most important effect task and environment was due to organization characteristics. Similarly, it was understood that customer and supplier had the most important impact on the employees due to the organization characteristics.

In summary, based on the results obtained from SEM analysis, the most significant contributors to business success are customer satisfaction, organization, employee, tool, task, and environment categories, in that order.

5.7. Analyses According to Sociodemographic Variables

This section includes the analysis of SEM analysis according to sociodemographic variables. These analyses were made according to gender, education level and age. These analyses are performed to understand the impact of social variables on the research, to make comparisons between different sociodemographic groups, and to evaluate model fit according to demographic variables.

5.7.1. Gender

In this section, Structural Equation Modeling (SEM) analysis was employed to investigate the relationships among factors, considering the gender variable as a grouping factor. The study aimed to discern difference in the relationships among latent constructs based on data collected from male and female participants. This analytical approach offers insights into the influence of gender on the associations between latent variables.

5.7.1.1. Male. SEM was used to examine the direct, indirect, and total effects between latent variables according to male participants.

5.7.1.2. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM). The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values.

This detailed information for male participants allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.19. Hypothesis testing (male).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.543	0.412	0.075	5.499	H4 Accepted	***
Task	< ...	Tool	0.046	0.058	0.112	0.516	H6 Rejected	0.606
Task	< ...	Org	0.740	0.703	0.085	8.245	H12 Accepted	***
Env	< ...	Task	0.390	0.404	0.119	3.397	H8 Accepted	***
Env	< ...	Tool	-0.166	-0.215	0.114	-1.892	H14 Rejected	0.058
Env	< ...	Org	0.519	0.510	0.120	4.247	H15 Accepted	***
Emp	< ...	Org	0.102	0.092	0.105	0.880	H1 Rejected	0.379
Cust	< ...	Org	0.681	0.473	0.060	7.925	H11 Accepted	***
Emp	< ...	Task	0.688	0.657	0.109	6.056	H13 Accepted	***
Emp	< ...	Env	0.059	0.055	0.100	0.551	H16 Rejected	0.582
Sb	< ...	Emp	0.450	0.307	0.100	3.079	H2 Accepted	0.002*
Sb	< ...	Org	-0.147	-0.091	0.103	-0.882	H3 Rejected	0.378
Sb	< ...	Task	-0.292	-0.190	0.113	-1.684	H7 Rejected	0.092
Sb	< ...	Env	0.543	0.203	0.085	2.396	H9 Accepted	0.017*
Sb	< ...	Cust	0.046	0.219	0.124	1.759	H10 Rejected	0.079
Sb	< ...	Tool	0.740	0.228	0.100	2.281	H5 Accepted	0.023*
*** $p < .01$. * $p < .05$								

According to Table 5.19, except for the H6, H1, H14, H16, H3, H7 and H10 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the male participants, it was

found that the category of tools and technology has the most significant impact on business success, with a standardized $\beta = 0.740$.

5.7.1.3. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for male participants.

Table 5.20. Statistical results of BP and CM.

To	From			
	Org	Tool	Task	Env
Task	0.025***			
Env	0.208***	0.018 n.s		
Emp	0.570 n.s.	0.023 n.s	0.023***	
Sb	0.632 n.s.	-0.051*	0.445n.s	0.027*
*** $p < 0.01$, * $p < 0.05$, n.s : not significant				

According to the male participants, it was determined that there was a positive direct effect between the environment and the success of the company/institution (SB) and this relationship was statistically significant ($\beta = 0.027$; $p < 0.05$). Accordingly, a positive increase in standard deviation towards the organization will result in an increase of 0.027 standard deviations in the success of the company/institution.

5.7.1.4. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects, as outlined in the methodology section. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for male participants.

Table 5.21. Total effects (male).

	Org	Tool	Task	Env	Cust	Emp
Tool	0,543***					
Task	0,765***	0,046 n.s.				
Env	0,727***	-0,148 n.s.	0,390***			
Cust	0,681***					
Emp	0,671n.s.	0,023 n.s.	0,711***	0,059 n.s.		
Sb	0,485 n.s.	0,229*	0,153 n.s.	0,349 n.s.	0,245***	0,450***
*** $p < .01$, * $p < .05$, n.s : not significant,						

According to the male participants, it was found that the most important effect task and environment was due to organization characteristics. Similarly, it was understood that customer and supplier had the most important impact on the tool due to the organization characteristics.

5.7.1.5. Female. SEM was used to examine the direct, indirect, and total effects between latent variables according to female participants.

5.7.1.6. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for female participants. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.22. Hypothesis testing (female).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.459	0.352	0.056	6.324	H4 Accepted	***
Task	< ...	Tool	0.143	0.190	0.089	2.133	H6 Accepted	0.033
Task	< ...	Org	0.605	0.617	0.068	9.012	H12 Accepted	***
Env	< ...	Task	0.486	0.495	0.073	6.814	H8 Accepted	***
Env	< ...	Tool	-0.038	-0.051	0.080	-0.632	H14 Rejected	0.527
Env	< ...	Org	0.374	0.388	0.076	5.134	H15 Accepted	***
Emp	< ...	Org	0.406	0.424	0.079	5.397	H1 Accepted	***
Cust	< ...	Org	0.648	0.393	0.038	10.426	H11 Accepted	***
Emp	< ...	Task	0.479	0.491	0.079	6.237	H13 Accepted	***
Emp	< ...	Env	-0.103	-0.104	0.077	-1.345	H16 Rejected	0.179
Sb	< ...	Emp	0.276	0.198	0.065	3.053	H2 Accepted	0.002
Sb	< ...	Org	-0.173	-0.129	0.069	-1.869	H3 Rejected	0.062
Sb	< ...	Task	0.015	0.011	0.070	0.156	H7 Rejected	0.876
Sb	< ...	Env	-0.147	-0.105	0.062	-1.709	H9 Rejected	0.087

Table 5.22. Hypothesis testing (female). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Sb	< ...	Cust	0.552	0.679	0.107	6.329	H10 Accepted	***
Sb	< ...	Tool	0.195	0.189	0.076	2.492	H5 Accepted	0.013
*** $p < .01$. * $p < .05$								

According to Table 5.22, except for the H14, H16, H3, H7 and H9 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the female participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.552$.

5.7.1.7. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for female participants.

Table 5.23. Sum of indirect effects (female).

To	From			
	Org	Tool	Task	Env
Task	0.067***			
Env	0.321***	0.094 n.s		
Emp	0.262***	0.089 n.s	-0.051***	
Sb	0.402*	0.015*	0.035n.s	-0.021 n.s
*** $p < .01$. * $p < .05$. n.s : not significant				

According to the female participants, it was determined that there was a positive and strong indirect effect between the organization and the success of the company/institution (SB) and this relationship was statistically significant ($\beta = 0.402$; $p < 0.05$). It is observed that this effect increases due to the fact that the relationship in question is obtained through the environment variable. Accordingly, a positive increase in standard deviation towards the organization will result in an increase of 0.402 standard deviations in the success of the company/institution.

5.7.1.8. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for female participants.

Table 5.24. Total effects (female).

	Org	Tool	Task	Env	Cust	Emp
Tool	0.459***					
Task	0.671***	0.143*				
Env	0.683***	0.032 n.s.	0.486***			
Cust	0.648***					
Emp	0.657***	0.065 n.s.	0.429***	-0.103 n.s.		
Sb	0.336*	0.21**	0.062 n.s.	-0.175 n.s.	0.552***	0.276***
*** $p < .01$. * $p < .05$. n.s : not significant						

According to the female participants, it was found that the most important effect task and environment was due to organization characteristics. Similarly, it was understood that customer and supplier had the most important impact on the employee due to the organization characteristics.

5.7.2. Education

In this section, Structural Equation Modeling (SEM) analysis was employed to investigate the relationships among factors, considering the education variable as a grouping factor. The study aimed to discern difference in the relationships among latent constructs based on data collected from undergraduate, graduate and PhD participants. This analytical approach offers insights into the influence of education on the associations between latent variables.

5.7.2.1. Undergraduate. SEM was used to examine the direct, indirect, and total effects between latent variables according to undergraduate participants.

5.7.2.2. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) specifically for undergraduate participants. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.25. Hypothesis testing (undergraduate).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.518	0.413	0.065	6.404	H4 Accepted	***
Task	< ...	Tool	0.018	0.023	0.101	0.225	H6 Rejected	0.822
Task	< ...	Org	0.671	0.67	0.081	8.303	H12 Accepted	***

Table 5.25. Hypothesis testing (undergraduate). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Env	< ...	Task	0.386	0.381	0.084	4.532	H8 Accepted	***
Env	< ...	Tool	-0.13	-0.16	0.09	-1.779	H14 Rejected	0.075
Env	< ...	Org	0.491	0.484	0.091	5.297	H15 Accepted	***
Emp	< ...	Org	0.275	0.276	0.092	3.007	H1 Accepted	0.003
Cust	< ...	Org	0.705	0.5	0.048	10.513	H11 Accepted	***
Emp	< ...	Task	0.562	0.565	0.089	6.332	H13 Accepted	***
Emp	< ...	Env	-0.031	-0.031	0.092	-0.337	H16 Rejected	0.736
Sb	< ...	Emp	0.329	0.221	0.078	2.844	H2 Accepted	0.004
Sb	< ...	Org	-0.108	-0.073	0.092	-1.797	H3 Rejected	0.426
Sb	< ...	Task	0.007	0.005	0.086	0.055	H7 Rejected	0.956
Sb	< ...	Env	0	0	0.076	0	H9 Rejected	1
Sb	< ...	Cust	0.355	0.337	0.119	2.829	H10 Accepted	0.005
Sb	< ...	Tool	0.151	0.128	0.091	1.403	H5 Rejected	0.161
*** $p < .01$. * $p < .05$								

According to Table 5.25, except for the H6, H14, H16, H3, H7, H9 and H5 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the Undergraduate participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.355$.

According to the Undergraduate participants, it was found that the most important effect customer and environment was due to organization characteristics. Similarly, it was understood that task had the most important impact on the employee due to the organization characteristics.

5.7.2.5. Graduate. SEM was used to examine the direct, indirect, and total effects between latent variables according to graduate participants.

5.7.2.6. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for graduate participants. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.28. Hypothesis testing (graduate).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.424	0.294	0.064	4.589	H4 Accepted	***
Task	< ...	Tool	0.209	0.292	0.111	2.621	H6 Accepted	0.009
Task	< ...	Org	0.592	0.573	0.077	7.417	H12 Accepted	***
Env	< ...	Task	0.535	0.571	0.097	5.874	H8 Accepted	***
Env	< ...	Tool	-0.067	-0.100	0.110	-0.908	H14 Rejected	0.364
Env	< ...	Org	0.339	0.350	0.092	3.792	H15 Accepted	***

Table 5.28. Hypothesis testing (graduate). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Emp	< ...	Org	0.389	0.379	0.089	4.250	H1 Accepted	***
Cust	< ...	Org	0.587	0.321	0.045	7.114	H11 Accepted	***
Emp	< ...	Task	0.502	0.504	0.098	5.121	H13 Accepted	***
Emp	< ...	Env	-0.097	-0.091	0.089	-1.029	H16 Rejected	0.304
Sb	< ...	Emp	0.368	0.267	0.079	3.397	H2 Accepted	***
Sb	< ...	Org	-0.183	-0.129	0.073	-1.779	H3 Rejected	0.075
Sb	< ...	Task	-0.139	-0.101	0.086	-1.180	H7 Rejected	0.238
Sb	< ...	Env	-0.136	-0.093	0.069	-1.351	H9 Rejected	0.177
Sb	< ...	Cust	0.571	0.737	0.129	5.689	H10 Accepted	***
Sb	< ...	Tool	0.202	0.206	0.089	2.314	H5 Accepted	0.021
*** $p < .01$. * $p < .05$								

According to Table 5.28, except for the H14, H16, H3, H7 and H9 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the Graduate participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.571$.

5.7.2.7. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for graduate participants.

Table 5.29. Sum of indirect effects (graduate).

To	From			
	Org	Tool	Task	Env
Task	0.089***			
Env	0.336***	0.112 n.s		
Emp	0.276***	0.101 n.s	-0.052***	
Sb	0.480 n.s.	0.002 *	0.093 n.s	-0.036 n.s
*** $p < .01$, * $p < .05$, n.s : not significant				

According to the Graduate participants, it was determined that there was a positive indirect effect between the tool and the success of the company/institution (SB) and this relationship was statistically significant ($\beta=0.002$; $p < 0.05$). Accordingly, a positive increase in standard deviation towards the tool will result in an increase of 0.002 standard deviations in the success of the company/institution.

5.7.2.8. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects, as outlined in the methodology section. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for graduate participants.

Table 5.30. Total effects (graduate).

	Org	Tool	Task	Env	Cust	Emp
Tool	0.424***					
Task	0.592***	0.209 n.s.				
Env	0.339***	-0.045 n.s.	0.535***			
Cust	0.587***					
Emp	0.666*	0.101 n.s.	0.450***	-0.097 n.s.		
Sb	0.297 n.s.	0.204 n.s.	-0.046 n.s.	-0.172 n.s.	0.571***	0.368***
*** $p < .01$, * $p < .05$, n.s : not significant.						

According to the Graduate participants, it was found that the most important effect task and employee was due to organization characteristics. Similarly, it was

understood that customer and supplier had the most important impact on the tool due to the organization characteristics.

5.7.2.9. PhD. SEM was used to examine the direct, indirect, and total effects between latent variables according to PhD participants.

5.7.2.10. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for PhD participants. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.31. Hypothesis testing (PhD).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.608	0.567	0.199	2.852	H4 Accepted	0.004
Task	< ...	Tool	0.081	0.096	0.125	0.771	H6 Rejected	0.441
Task	< ...	Org	0.900	1.001	0.116	8.593	H12 Accepted	***
Env	< ...	Task	0.858	0.840	0.386	2.177	H8 Accepted	0.030
Env	< ...	Tool	0.002	0.002	0.184	0.011	H14 Rejected	0.991
Env	< ...	Org	0.033	0.036	0.421	0.085	H15 Rejected	0.932
Emp	< ...	Org	0.889	0.980	0.456	2.146	H1 Accepted	0.032

Table 5.31. Hypothesis testing (PhD). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Cust	< ...	Org	0.753	0.522	0.122	4.265	H11 Accepted	***
Emp	< ...	Task	0.057	0.056	0.463	0.121	H13 Rejected	0.904
Emp	< ...	Env	-0.157	-0.159	0.278	-0.570	H16 Rejected	0.569
Sb	< ...	Emp	0.161	0.124	0.171	0.727	H2 Rejected	0.467
Sb	< ...	Org	0.262	0.222	0.316	0.703	H3 Rejected	0.482
Sb	< ...	Task	-0.919	-0.702	0.295	-2.381	H7 Accepted	0.017
Sb	< ...	Env	0.698	0.544	0.179	3.043	H9 Accepted	0.002
Sb	< ...	Cust	0.257	0.316	0.216	1.464	H10 Rejected	0.143
Sb	< ...	Tool	0.559	0.509	0.165	3.091	H5 Accepted	0.002
*** $p < .01$. * $p < .05$								

According to Table 5.31, except for the H6, H14, H15, H13, H16, H2, H3 and H10 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the PhD participants, it was found that the category of task has the most significant impact on business success, with a standardized $\beta = 0.919$.

5.7.2.11. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for PhD participants.

Table 5.32. Sum of indirect effects (PhD).

To	From			
	Org	Tool	Task	Env
Task	0.049***			
Env	0.815 n.s.	0.069 n.s		
Emp	-0.079*	-0.007 n.s	-0.135 n.s.	
Sb	0.384 n.s.	-0.026 *	0.586*	-0.025*
*** $p < .01$. * $p < .05$. n.s : not significant				

According to the PhD participants, it was determined that there was a positive and strong indirect effect between the task and the success of the company/institution (SB) and this relationship was statistically significant ($\beta=0.586$; $p < 0.05$). Accordingly, a positive increase in standard deviation towards the task will result in an increase of 0.586 standard deviations in the success of the company/institution.

5.7.2.12. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects, as outlined in the methodology section. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for PhD participants.

Table 5.33. Total effects (PhD).

	Org	Tool	Task	Env	Cust	Emp
Tool	0.608***					
Task	0.949***	0.081 n.s.				
Env	0.848 n.s.	0.071 n.s.	0.858*			
Cust	0.753***					
Emp	0.810*	-0.007 n.s.	-0.078 n.s.	-0.157 n.s.		
Sb	0.646 n.s.	0.533*	-0.332*	0.673*	0.257 n.s.	0.161 n.s.

*** $p < .01$. * $p < .05$. n.s : not significant

According to the PhD participants, it was found that the most important effect task and employee was due to organization characteristics. Similarly, it was understood that customer and supplier had the most important impact on the tool due to the organization characteristics.

5.7.3. Age

In this section, Structural Equation Modeling (SEM) analysis was employed to investigate the relationships among factors, considering the age variable as a grouping factor. The study aimed to discern difference in the relationships among latent constructs based on data collected from different age group participants. This analytical approach offers insights into the influence of age on the associations between latent variables.

5.7.3.1. Between 25-30 Years. SEM was utilized to explore the direct, indirect, and total effects between latent variables among participants aged 25-30 years old.

5.7.3.2. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for participants aged 25-30 years old.

The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values.

This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.34. Hypothesis testing (25-30 years).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.516	0.352	0.081	4.317	H4 Accepted	***
Task	< ...	Tool	0.299	0.472	0.206	2.294	H6 Rejected	0.022
Task	< ...	Org	0.389	0.419	0.140	2.989	H12 Accepted	0.003
Env	< ...	Task	0.464	0.469	0.135	3.466	H8 Accepted	***
Env	< ...	Tool	-0.080	-0.128	0.209	-0.610	H14 Rejected	0.542
Env	< ...	Org	0.308	0.335	0.147	2.272	H15 Accepted	0.023
Emp	< ...	Org	0.214	0.230	0.096	2.392	H1 Accepted	0.017
Cust	< ...	Org	0.497	0.305	0.074	4.102	H11 Accepted	***
Emp	< ...	Task	0.825	0.824	0.098	8.448	H13 Accepted	***
Emp	< ...	Env	-0.204	-0.202	0.091	-2.229	H16 Accepted	0.026
Sb	< ...	Emp	0.366	0.215	0.111	1.937	H2 Rejected	0.053
Sb	< ...	Org	-0.242	-0.153	0.085	-1.807	H3 Rejected	0.071
Sb	< ...	Task	0.045	0.027	0.120	0.223	H7 Rejected	0.824

Table 5.34. Hypothesis testing (25-30 years). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Sb	< ...	Env	0.141	0.082	0.076	1.085	H9 Rejected	0.278
Sb	< ...	Cust	0.358	0.370	0.127	2.914	H10 Accepted	0.004
Sb	< ...	Tool	0.219	0.204	0.120	1.699	H5 Rejected	0.089
*** $p < .01$. * $p < .05$								

According to Table 5.34, except for the H6, H14, H2, H3, H7, H9 and H5 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the Ages 25-30 participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.358$.

5.7.3.3. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for participants aged 25-30 years old.

Table 5.35. Sum of indirect effects (25-30 years).

To	From			
	Org	Tool	Task	Env
Task	0.154*			
Env	0.211*	0.139 n.s		
Emp	-0.342*	0.235 n.s	-0.095***	
Sb	0.592 n.s.	0.108 *	0.333 n.s.	-0.075 n.s.
*** $p < .01$. * $p < .05$. n.s : not significant				

According to the Ages 25-30 participants, it was determined that there was a positive indirect effect between the tool and the success of the company/institution (SB) and this relationship was statistically significant ($\beta=0.108$; $p < 0.05$). Accordingly, a positive increase in standard deviation towards the tool will result in an increase of 0.108 standard deviations in the success of the company/institution.

5.7.3.4. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects, as outlined in the methodology section. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for participants aged 25-30 years old.

Table 5.36. Total effects (25-30 years).

	Org	Tool	Task	Env	Cust	Emp
Tool	0.516***					
Task	0.543*	0.299 n.s.				
Env	0.519*	0.059 n.s.	0.464***			
Cust	0.497***					
Emp	0.556*	0.235 n.s.	0.731***	-0.204*		
Sb	0.350 n.s.	0.327*	0.378 n.s.	0.066 n.s.	0.358*	0.366 n.s.
*** $p < .01$, * $p < .05$, n.s : not significant						

According to the Ages 25-30 participants, it was found that the most important effect task and employee was due to organization characteristics. Similarly, it was understood that environment had the most important impact on the tool due to the organization characteristics.

5.7.3.5. Ages 31-40. SEM was utilized to explore the direct, indirect, and total effects between latent variables among participants aged 31-40 years old.

5.7.3.6. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for participants aged 31-40

years old. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.37. Hypothesis testing (31-40 years).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.470	0.362	0.073	4.995	H4 Accepted	***
Task	< ...	Tool	0.018	0.025	0.094	0.261	H6 Rejected	0.794
Task	< ...	Org	0.802	0.824	0.072	11.363	H12 Accepted	***
Env	< ...	Task	0.290	0.296	0.107	2.765	H8 Accepted	0.006
Env	< ...	Tool	0.008	0.010	0.095	0.108	H14 Rejected	0.914
Env	< ...	Org	0.561	0.587	0.114	5.135	H15 Accepted	***
Emp	< ...	Org	0.441	0.469	0.124	3.779	H1 Accepted	***
Cust	< ...	Org	0.699	0.444	0.048	9.164	H11 Accepted	***
Emp	< ...	Task	0.453	0.469	0.107	4.391	H13 Accepted	***
Emp	< ...	Env	-0.058	-0.059	0.102	-0.575	H16 Rejected	0.565

Table 5.37. Hypothesis testing (31-40 years). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Sb	< ...	Emp	0.179	0.128	0.091	1.407	H2 Rejected	0.159
Sb	< ...	Org	0.160	0.122	0.118	1.029	H3 Rejected	0.303
Sb	< ...	Task	-0.085	-0.063	0.101	-0.624	H7 Rejected	0.533
Sb	< ...	Env	-0.334	-0.243	0.087	-2.779	H9 Accepted	0.005
Sb	< ...	Cust	0.417	0.499	0.159	3.148	H10 Accepted	0.002
Sb	< ...	Tool	0.350	0.346	0.107	3.217	H5 Accepted	0.001
*** $p < .01$. * $p < .05$								

According to Table 5.37, except for the H6, H14, H16, H2, H3 and H7 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the Ages 31-40 participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.417$.

5.7.3.7. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for participants aged 31-40 years old.

Table 5.38. Sum of indirect effects (31-40 years).

To	From			
	Org	Tool	Task	Env
Task	0.009***			
Env	0.239***	0.005 n.s.		
Emp	0.321***	0.008n.s.	-0.017***	
Sb	0.257 n.s.	-0.005*	0.019 n.s.	-0.010*
*** $p < .01$, * $p < .05$, n.s : not significant				

According to the Ages 31-40 participants, it was determined that there was a positive and strong indirect effect between the organization and employee and this relationship was statistically significant ($\beta = 0.321$; $p < 0.01$). It is observed that this effect increases due to the fact that the relationship in question is obtained through the environment variable.

5.7.3.8. Total Effects. The following table shows the total effects, which are the sum of direct and indirect effects, as outlined in the methodology section. The total effects obtained from the analysis are presented in the table, providing a comprehensive view of the relationships within the model for participants aged 31-40 years old.

Table 5.39. Total effects (31-40 years).

	Org	Tool	Task	Env	Cust	Emp
Tool	0.470***					
Task	0.811***	0.018 n.s.				
Env	0.800***	0.013 n.s.	0.290*			
Cust	0.699***					
Emp	0.762***	0.008 n.s.	0.436***	-0.058 n.s.		
Sb	0.417 n.s.	0.346*	0.104 n.s.	-0.344*	0.417*	0.179 n.s.
*** $p < .01$. * $p < .05$. n.s : not significant						

According to the Ages 31-40 participants, it was found that the most important effect task and environment was due to organization characteristics. Similarly, it was

understood that customer and supplier had the most important impact on the employee due to the organization characteristics.

5.7.3.9. Ages 41-50. SEM was utilized to explore the direct, indirect, and total effects between latent variables among participants aged 41-50 years old.

5.7.3.10. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for participants aged 41-50 years old. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.40. Hypothesis testing (41-50 years).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.613	0.453	0.073	6.179	H4 Accepted	***
Task	< ...	Tool	-0.002	-0.003	0.130	-0.022	H6 Rejected	0.983
Task	< ...	Org	0.723	0.630	0.096	6.563	H12 Accepted	*1**
Env	< ...	Task	0.571	0.610	0.113	5.413	H8 Accepted	***
Env	< ...	Tool	-0.145	-0.183	0.116	-1.569	H14 Rejected	0.117
Env	< ...	Org	0.378	0.352	0.112	3.153	H15 Accepted	0.002
Emp	< ...	Org	0.341	0.287	0.113	2.527	H1 Accepted	0.011

Table 5.40. Hypothesis testing (41-50 years). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Cust	< ...	Org	0.765	0.529	0.056	9.442	H11 Accepted	***
Emp	< ...	Task	0.235	0.227	0.146	1.551	H13 Rejected	0.121
Emp	< ...	Env	0.198	0.179	0.135	1.328	H16 Rejected	0.184
Sb	< ...	Emp	0.527	0.385	0.082	4.701	H2 Accepted	***
Sb	< ...	Org	-0.597	-0.367	0.095	-3.879	H3 Accepted	***
Sb	< ...	Task	0.009	0.007	0.097	0.068	H7 Rejected	0.945
Sb	< ...	Env	0.135	0.090	0.089	1.003	H9 Rejected	0.316
Sb	< ...	Cust	0.863	0.767	0.148	5.191	H10 Accepted	***
Sb	< ...	Tool	-0.187	-0.156	0.115	-1.357	H5 Rejected	0.175
*** $p < .01$. * $p < .05$								

According to Table 5.40, except for the H6, H7, H14, H16, H13, H9 and H5 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the Ages 41-50 participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized $\beta = 0.863$.

5.7.3.11. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression coefficients, are displayed as a result of the analysis for participants aged 41-50 years old.

According to the Ages 41-50 participants, it was found that the most important effect task and customer was due to organization characteristics. Similarly, it was understood that environment had the most important impact on the employee due to the organization characteristics.

5.7.4. 51 Years and Older

SEM was employed to investigate the direct, indirect, and total effects between latent variables among participants aged 51 years and older.

5.7.4.1. Direct Effects. The following table presents the direct effects of latent variables as derived from Structural Equation Modeling (SEM) for participants aged 51 years and older. The table includes dependent variables, paths, independent variables, standardized beta coefficients, unstandardized beta coefficients, standard errors, critical t-values, hypothesis testing results, and p-values. This detailed information allows for a comprehensive understanding of the relationships and the statistical significance of the effects within the model.

Table 5.43. Hypothesis testing (51 years and older).

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical t values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Tool	< ...	Org	0.262	0.288	0.245	1.177	H4 Rejected	0.239
Task	< ...	Tool	0.266	0.286	0.183	1.567	H6 Rejected	0.117
Task	< ...	Org	0.586	0.693	0.201	3.455	H12 Accepted	***
Env	< ...	Task	0.648	0.593	0.122	4.881	H8 Accepted	***
Env	< ...	Tool	-0.385	-0.379	0.102	-3.708	H14 Accepted	***

Table 5.43. Hypothesis testing (51 years and older). (cont.)

Model								
<i>Dependent variables</i>	<i>Path</i>	<i>Independent variables</i>	<i>Standardized Beta (β_0)</i>	<i>Beta (β)</i>	<i>Std. E.</i>	<i>Critical values</i>	<i>Hypothesis testing</i>	<i>P value</i>
Env	< ...	Org	0.436	0.472	0.135	3.492	H15 Accepted	***
Emp	< ...	Org	0.387	0.370	0.217	1.703	H1 Rejected	0.089
Cust	< ...	Org	0.449	0.227	0.104	2.179	H11 Accepted	0.029
Emp	< ...	Task	0.470	0.380	0.239	1.590	H13 Rejected	0.112
Emp	< ...	Env	-0.068	-0.060	0.301	-0.200	H16 Rejected	0.842
Sb	< ...	Emp	0.163	0.167	0.214	0.777	H2 Rejected	0.437
Sb	< ...	Org	0.200	0.196	0.230	0.852	H3 Rejected	0.394
Sb	< ...	Task	-0.757	-0.627	0.236	-2.653	H7 Rejected	0.008
Sb	< ...	Env	0.606	0.549	0.280	1.960	H9 Rejected	0.050
Sb	< ...	Cust	0.420	0.812	0.275	2.956	H10 Accepted	0.003
	< ...						H5	
Sb		Tool	0.551	0.491	0.169	2.902	Accepted	0.004
*** $p < .01$. * $p < .05$								

According to Table 5.43, except for the H6, H1, H14, H13, H16, H2, H3, H7 and H9 hypotheses determined in the model dimensions, all other hypotheses were statistically confirmed. After conducting the analysis, according to the 51 Years and older participants, it was found that the category of customer and supplier has the most significant impact on business success, with a standardized β value of 0.420.

5.7.4.2. Indirect Effects. The following table presents the indirect effects as described in the methodology section. The indirect effects, expressed as standardized regression

According to the 51 Years participants, it was found that the most important effect task and environment was due to organization characteristics.

Overall, according to the male participants, the organization factor have the highest impact on task, environment and employee factors.

According to the female participants, the organization factor have the highest impact on environment and employee factors.

According to the education levels of the participants, the organization factor have the highest impact on task factor. For graduate participants, the organization factor have the highest impact on environment factor. For PhD participants, the organization factor have the highest impact on task factor.

According to the age differences of the participants, the organization factor have the highest impact on employees factor. In those between the ages of 31-40, the organization factor have the highest impact on task factor. In those aged 41-50 years, the organization factor have the highest impact on customer and supplier factor. For 51 and over participants, the organization factor have the highest impact on environment factor.

5.8. Main Findings

In line with the purpose of the study, after data was collected through a survey, demographic analysis and then reliability analysis were performed.

As a result of CFA, it was determined that the following factors were the factors that most explained the relationships in the categories.

In the Employee category;

- Employee morale and motivation
- Participation and empowerment of employees in improvements
- Teamwork
- Providing necessary lean, ergonomics and occupational health and safety training to employees success factors,

In the Organization category;

- Communication, coordination and cooperation among employees,
- Management and supervision style,
- Visual Management practices,
- Long-term strategy planning, tracking and reporting success factors

In the Method, Tools Technology categories;

- SMED applications,
- Total Productive Maintenance practices,
- Continuous improvement (kaizen) practices success factors,

In the Task category,

- Gemba walks,
- Flexibility, speed and efficiency increase in production and service,
- Increase in service and product quality success factors,

In the Environment Safety category;

- Employee health, safety and welfare,
- Use of personal protective equipment,

- Reducing employee health and safety risks,
- Establishing a safety culture success factors,

In the Customer Supplier category;

- Cooperation effectively with the supplier,
- Benefiting from customer feedback and complaints,
- Meeting customer/stakeholder demands and expectations success factors

SEM was performed to test the hypotheses, and as a result of SEM analysis, direct, indirect and total effects, which define the relationships between categories, were calculated.

Except for four relationships, other direct effects were statistically significant. These four relationships are between;

- (i) Method, Tools and Technology and Environment and Safety
- (ii) Employee and Environment and Safety
- (iii) Task and Business Success
- (iv) Environment and Safety and Business Success

Since the p-value of these relationships is greater than 0.05 at the 95% confidence level, the relationship between them was not found to be statistically significant.

The hypothesis model conducted showed that the indirect effects were significant for all relationships, except for the four. The P-values for these four relationships were lower than 0.05 at a 95% confidence level. The four relationships that weren't significant were between environment and tool, employee and tool, task and business success, and environment and business success.

On the other hand, the total effects were significant for all relationships, except for the five. The p-values for these five relationships were lower than 0.05 at a 95% confidence level. The five relationships that weren't significant were between;

- (i) Environment and Safety and Method, Tools and Technology
- (ii) Employee and Method, Tools and Technology
- (iii) Employee and Environment and Safety
- (iv) Task and Business Success
- (v) Environment and Safety and Business Success

6. DISCUSSION

The hypothesis model in the study consists of 7 categories. These categories are Business Success, Employee, Organization, Tool, Task, Environment, and Customer (SB, EMP, ORG, TOOL, TASK, ENV, CUST). Under these categories, integrated lean and ergonomics critical success factors are included. In this section, the results obtained from the analysis will be discussed.

To positively impact business success, the organization's success is necessary for all other categories, including tool, task, environment, employee, and customer. The success of the organization is therefore crucial to the success of the business as a whole. Direct effects in the hypothesis model showed that the organization significantly affects the customer. Indirect effects in the hypothesis model showed that the organization has the highest impact on business success, followed by employees and the environment. To conclude, total effects indicated that the organization category considerably affects the other categories and performance indicators, namely business success. Organizations play a crucial role in the success of a business and the performance of its work system since they impact all categories containing critical success factors. Based on the findings of Hendrick's study, which was conducted similarly to this one, it was concluded that organizational factors are among the top three important factors for the success of ergonomic interventions [6]. Similarly, Realyvasquez's study revealed that organizational components, such as organizational communication and culture, have a direct impact on customers and an indirect impact on the growth of companies and manufacturing processes. Therefore, the most important conclusion drawn from his study is that the organizational factor plays a critical role in achieving success [7].

Employees are necessary for organization and task categories to impact business success positively. On the contrary, the study found that the environment did not positively affect the employee. Based on Chahal and Narwal's study, four factors, including upgrading the job environment and satisfaction factor, are crucial for suc-

successful implementation to enhance production and profitability. Chahal and Narwal's study concluded that, unlike these thesis findings, the environment positively affects employees [146].

In addition, the employee's success is important to the business's success since the employee has been found to significantly impact business success. Direct effects in the hypothesis model showed that the employee significantly affects the task. Indirect effects in the hypothesis model showed that the employee has the highest impact on business success. To conclude, total effects indicated that the employee category considerably affects the performance indicator, namely business success.

The tool category is necessary to achieve high system performance for the task and business success. However, it was determined that the tool had no significant effect on the environment, rejecting the hypothesis created. Direct effects in the hypothesis model showed that the tool significantly affects the business success. Indirect effects in the hypothesis model showed that the tool also affects the business success indirectly. Overall, the total effects in the hypothesis model showed that the tool effects were higher for business success than for the task.

The total effects of the hypothesis model showed that customer and organization categories have approximately the same effect on business success. Then, the employee category has a relatively lower effect on business success, and the tool category has the most negligible impact on business success. In addition, task and environment categories do not significantly affect business success. These results indicate that customer and organization categories are more important than employee and tool categories for the success of the companies' business.

Tasks are necessary for both the environment and employees to achieve high business performance. Direct effects in the hypothesis model revealed that the task has a significant impact on the employee, slightly less so on the environment, but not on the success of the business. Additionally, the indirect effects demonstrated that

the task has a significant impact on the employee. Overall, the total effects in the hypothesis model confirm that the task has a significant impact on both the employee and the environment.

Customer is necessary to achieve high business performance. Direct effects in the hypothesis model revealed that the customer significantly impacts a business's success. Furthermore, the total effects in the hypothesized model confirm that the customer has the most significant impact on the success of the business when compared to other categories. However, according to the hypothesis model's direct, indirect and total effects, no significant effect of the environment on employee and business success was detected.

All categories except two task and environment are crucial for achieving business success. The most critical and necessary category for achieving business success is the customer, which has a higher total impact than the organization. After the customer category, the impact ranking for business success is as follows: organization, employee, and tool.

Although the obtained outputs support the relationship between Method, Tools and Technology and Environment and Safety, the reason why the relationship is not significant may be affected by many factors, such as the inadequacy of lean tools in practice, the lack of top management support, the lack of motivation of employees, the lack of a continuous improvement culture in the institution, and the lack of a systematic approach in practice.

The reason why the effect of Environment and Safety on Employees is not significant in the outputs can be evaluated as the problem of employee participation, lack of communication, adverse and inadequate working conditions, not giving due importance to employee health and the negative effects of stress and workload.

The reasons why the Task category does not have a significant effect on Business Success may be due to the compatibility of the tasks with the physical and mental capacities of the employees, the lack of enriched work, the lack of sufficient field observations by the senior management, that is, the lack of Gemba walks.

The reasons why the Environment does not have a significant effect on Business Success may be that the necessary importance is not given to employee health, employee health and safety risks cannot be reduced sufficiently, safety principles cannot be applied as a corporate culture, and the quality of the working environment is not sufficient.

Upon examining the business success results, it is evident that the Customer category has the most significant impact with a $\beta = 0.418$. This result shows that involving customers in the process, benefiting from customer feedback, and meeting customer demand is important for the company to achieve sustainable success. While the customer category has the highest impact on company success, the effects of Task and Environment and Safety categories on company success were not found to be statistically significant.

12 of the 16 hypotheses presented in the study were accepted. Except for Task and Environment and Safety, all other categories have been found to have a positive impact on Business Success. Relationships between categories were found to be significant, except for the relationship between Method, Tools and Technology and Environment and Safety and between Employee and Environment and Safety.

It was found that the customer category has the most significant impact on business success. Secondly, the organization category has a high impact, with a $\beta = 0.403$. The Employee category comes in third place with a $\beta = 0.316$. Lastly, the Tool category is effective on business success with a $\beta = 0.222$. As a result of the analysis, no significant effect of environment and task categories on business success was observed.

When analyzing the data based on different sociodemographic variables such as gender, age and education level, the results showed that among male participants, the employee category had the highest $\beta = 0.450$, followed by the customer category with a $\beta = 0.245$. The category of tools ranks third with a $\beta = 0.229$. It has an impact on business success. Based on the analysis of data obtained from female participants, it was found that customer category has the highest impact on business success, with a $\beta = 0.552$, followed by the organization category with a $\beta = 0.336$, employee category with a $\beta = 0.276$, and finally the tool category with a $\beta = 0.21$. It was also determined that the task and environment categories have no significant effect on business success.

According to the analysis of data obtained from participants with undergraduate education level, customer and employee categories have the highest impact on business success, respectively. According to the analysis of data obtained from participants with graduate education level, customer and employee categories have the highest impact on business success, respectively. According to the analysis of data obtained from participants with PhD education level, environment, tool and task categories have the highest impact on business success, respectively. The results indicate that there is a clear variation in perceptions based on the level of education.

After analyzing data from the 25-30 age group, it was found that the customer and tool categories have the highest impact on business success, respectively. According to the analysis of data obtained from the 31-40 years group, customer, tool and environment categories have the highest impact on business success, respectively. According to the analysis of data obtained from the 41-50 years group, customer, employee and organization categories have the highest impact on business success, respectively. According to the results obtained from the 51 Years and older group, customer and tool categories have the highest impact on business success, respectively. Based on the results, participants in each age group perceived that the customer category has the greatest effect on business success.

According to the literature, especially in the industrial sector, the categories of organization, tool, employee, task, environment, customer and the success factors contained in these categories have an impact on business performance [6, 3, 87, 7]. The results of this study support the existing literature in some aspects, but also differ in others. Specifically, the study found that task and environment categories did not have a significant impact on business success, which contrasts with certain previous findings. However, sociodemographic data analysis using SEM revealed that task and environment categories significantly impact business success for some groups.

This study has unique aspects that differentiate it from previous research and strengthen its findings. The study's scope is distinct in terms of its target audience, as no other research has identified common factors between lean and ergonomics studies and observed their impact on business success and performance indicators through SEM analysis. To ensure more reliable data, the survey was directed towards middle and senior level managers, the majority of whom are B level managers. Additionally, the validity of the factor structure was checked with different methods.

Study outcomes can be used to provide guidance on which factors companies should prioritize to increase business performance and success. The hypothesis model that has been created provides guidance on the categories and success factors that should be focused on to improve the productivity and efficiency of companies that follow lean and ergonomics practices. It also helps in enhancing the quality of service they offer, making their success sustainable, ensuring employee satisfaction, and increasing the quality and satisfaction by strengthening the integration between ergonomics and lean efforts.

For this reason, it aims to facilitate system improvement to ensure that the direct, indirect and total effects of the categories obtained from the common factors of lean and ergonomics for the industrial sector are adopted and thus make the systems more developed and integrated.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusion

Based on the study results, the following conclusions can be stated:

- (i) A hypothesis model consisting of 16 hypotheses based on six categories representing business success was developed.
- (ii) The customer and supplier category has been identified as the most effective element for business success, followed by organization, employee, tool and technology. Effective cooperation with the supplier, benefiting from customer feedback and complaints, and meeting customer/stakeholder demands and expectations are the most critical factors to increase business performance.
- (iii) The factor loads for the relationship between the variables “Business Success”, “Employee”, “Organization”, “Method, Tools and Technology”, “Tasks”, “Environment and Safety” and “Customer and Supplier” are found statistically significant. As a result, all other hypotheses were statistically confirmed except for the H7, H9, H14 and H16 hypotheses determined in the model dimensions. The relationships between Method, Tools and Technology and Environment and Safety, secondly, Environment and Safety and Employee, thirdly, Tasks and Business Success, and Environment and Safety and Business Success were not found to be statistically significant at the 5% significance level.
- (iv) The results revealed that the categories had significant effects on business success and that the relationships between the categories were also statistically significant. Except for the relationships between Tools and Technology and Environment and Environment and Safety and Employee, all relationships defined in the hypothesis model were statistically significant at the 5% significance level. It was found that the most important effect of task and environment was due to organization characteristics. Similarly, it was understood that the customer had the most important impact on the employee due to the organization’s factors.

- (v) Companies should embrace continuous improvement and innovation to remain competitive in their industry, leveraging the maximum benefits that lean and ergonomic practices can offer. When designing business systems, it is crucial to consider the impact of the human factor in lean applications and to integrate ergonomics at every stage of the system.

As a result, the study aimed to identify the integrated success factors of lean and ergonomics and determine the effects of the categories of these success factors on business success and the relationships between these categories. Ultimately, the results are intended to guide professionals working in these fields and contribute to the decision-making processes of decision-makers.

7.2. Recommendations for Companies

This study is important in bringing a new dimension to the perception of the holistic system in companies in terms of ergonomics and lean applications where lean practices are based. Although lean and ergonomics aim to achieve similar goals separately, this study is unique as it seeks to determine the integrated effect of both on business success by providing integration through success factors.

By integrating ergonomics and lean practices, companies can reduce the effort spent on these two methods and benefit from the contributions of this integration. These recommendations can provide a basic framework for starting and sustaining your company's "integrated lean and ergonomics" effort. Each recommendation can be tailored to the specific needs and goals of the business. These recommendations are as follows, according to the results obtained:

- (i) Companies should prioritize customer satisfaction: Benefiting from customer feedback and complaints, meeting customer/stakeholder demands and expectations, cooperating effectively with the supplier, integrated lean and ergonomics applications should be provided.

- (ii) The organizational structure should be examined and analyzed and the philosophy of continuous improvement should be adopted: Long-term strategy planning, tracking and reporting, Management and supervision style, Visual Management practices, Communication, coordination and cooperation are the success criteria that should be given the most importance.
- (iii) Employee satisfaction should be kept at a high level and their needs should be met: Employee participation, Teamwork, Training for employees should be encouraged.
- (iv) The principle of continuous improvement should be adopted by giving importance to Method, Tools and Technology used in business processes: Total Productive Maintenance practices, SMED applications, Continuous improvement (kaizen) practices tools are the main lean tools that ergonomics should be integrated into.

Since this study only includes data obtained from those working in the field of lean and ergonomics in Türkiye, participants from other countries can also be included to obtain more global results. Thus, the results achieved may have more universal values. Additionally, in addition to increasing the number of participants, the study can be sector-specific if a sector is of particular interest.

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APPENDIX A: QUESTIONNAIRE

The appendix section includes the questionnaire that was used in this study. Also, this section includes forms such as invitation, necessary information, and privacy policy.

Table A.1 presents the questionnaire questions in English.

Table A.1. Questionnaire questions in English.

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Employee					
Knowledge, skills and experience of employees					
Physical characteristics of employees (fitness, strength, flexibility, physical skills)					
Behavior and psychological attitudes of employees					
Employee morale and motivation					
Participation and empowerment of employees in improvements					
Employee performance					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Teamwork					
Providing necessary lean, ergonomics and occupational health and safety training to employees					
Organization					
Top management commitment and engagement					
Organizational structure (Framework that organizes employee roles, responsibilities, hierarchy and collaboration)					
Communication, coordination and cooperation among employees					
Management and supervision style (Leadership approach and the way employees are managed, monitored and supported)					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Rewarding, incentives and performance evaluation practices					
Visual Management practices (information, processes and key performance indicators (KPIs) being easily understood and accessible through visual representations)					
Long-term strategy planning, tracking and reporting					
Method, Tools and Technology					
Data-driven approach and data analysis					
Kanban applications/Material flow					
Value Stream Mapping (VSM) applications					
SMED (minimizing machine installation and work process times) applications					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Total Productive Maintenance practices (purpose: to keep equipment and machines in constant working order)					
Poka-yoke (preventing human errors in production and service processes) practices					
Ease of learning and use of technology and software (ergonomic)					
Continuous improvement (kaizen) practices					
Tasks					
Suitability of physical and mental workload to employee capacity					
Enriched work (giving responsibility for different tasks of the same job) and job rotation					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
(systematically changing employees between jobs within a team) instead of monotonous work for employees					
Gemba walks (managers observing, understanding, asking questions and learning about the real process/event on site)					
Flexibility, speed and efficiency increase in production and service Increase in service and/or product quality					
Environment and Safety					
Employee health, safety and welfare					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Use of personal protective equipment					
Periodic implementation of 6S practices					
Reducing employee health and safety risks					
Establishing a safety culture (the organization's values, norms and practices regarding employee performance and well being)					
Noise, lighting, temperature, humidity, air quality, etc. environmental factors are at normal levels					
Safe and ergonomic design of workstations, tools and equipment					

Table A.1. Questionnaire questions in English. (cont.)

Please evaluate how important these factors are in achieving your company/institution's strategic goals.					
	Unimpor- tant -1	Slightly Impor- tant -2	Moderately Impor- tant -3	Impor- tant -4	Very Impor- tant -5
Customer and Supplier					
Cooperation effectively with the supplier					
Benefiting from customer feedback and complaints					
Meeting customer/stakeholder demands and expectations					

A.1. Invitation Mail to the Questionnaire

The section explains the content and purpose of the email sent to participants, inviting them to complete the questionnaire.

Merhaba Hanım/Bey,

Boğaziçi Üniversitesi Endüstri Mühendisliği bölümünde yürütmekte olduğum yüksek lisans tezimin bir parçası olarak bu ankete vereceğiniz yanıtlara ihtiyacım var. Anket, Ergonomi ve Yalın yaklaşımlarının entegrasyonu için gerekli olan ortak faktörlerin önem sırasını belirlemeyi amaçlamaktadır. Çalışmanın nihai amacı oluşturulacak başarılı entegrasyon modeliyle uygulayıcı şirketlerde bu konuda karar vermeye destek olmaktır. Anket üç bölümden oluşmaktadır: 1. Demografik bilgilerle ilgili sorular; 2. İş stratejisi hedefleri hakkında sorular; ve 3. Ergonomi ve Yalın'ın ortak faktörleriyle ilgili sorulardan oluşmaktadır.

Bu çalışma ile ilgili herhangi bir sorunuz varsa benimle veya danışmanımla iletişime geçebilirsiniz. Verilen tüm yanıtlar anonimdir. Tüm kişisel bilgilerin gizli tutulacağını ve yalnızca istatistiksel sonuçların paylaşılacağını temin ederim. Anketin tamamlanması yaklaşık 10 ila 15 dakika sürecektir. Bu bilimsel çalışmaya sağlayacağınız katkı için şimdiden teşekkür ederim.

Saygılarımla,

A.2. Questionnaire Template

Section A.2 displays screenshots of the questionnaire template.

Figure A.1 shows the information page of the questionnaire in English.

Lean and Ergonomics Survey for Company Strategies

Title of the master's thesis: ErgoLean: Ergonomics and Lean Integration

Dear Participant,

I need your answers to this survey as part of my master's thesis that I am conducting at Boğaziçi University Industrial Engineering Department (Turkey). The survey aims to determine the order of importance of common factors necessary for the integration of Ergonomics and Lean approaches. The ultimate aim of the study is to support decision-making in implementing companies on this issue with the successful integration model to be created.

The survey consists of three parts: 1. Questions about demographic information; 2. Questions about business strategy objectives; and 3. It consists of questions about the common factors of Ergonomics and Lean.

If you have any questions about this study, you can contact me or my advisor. All responses provided are anonymous. I assure you that all personal information will be kept confidential and only statistical results will be shared.

The survey will take approximately 10 to 15 minutes to complete. Thank you in advance for your contribution to this scientific study.

Kind regards,

Kübra Uyar
Graduate Student
Master of Science - Industrial Engineering
Boğaziçi University, İstanbul, Türkiye
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Advisor:
Prof. Dr. Mahmut Ekşioğlu
Department of Industrial Engineering
Boğaziçi University, İstanbul, Türkiye
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* Necessary

Figure A.1. Questionnaire information page in English.

Figure A.2 shows the general directions part of the questionnaire in English.

E-mail address (optional)

Yanıtınız

I have read the above statement and in this context I agree to participate in this context. *

☐ Yes, I agree

☐ No, I do not agree

General Directions

You can fill out the survey from your smartphone (IOS or Android) or computer, depending on your preference.

According to the survey rating scale provided, please rate each statement according to its relative importance.

Survey ratings: **(1) Unimportant, (2) Slightly Important, (3) Moderately Important, (4) Important, (5) Very Important**

1 represents the lowest importance and 5 represents the highest importance. Please rate each item according to this scale.

Questions with a red asterisk (*) must be answered; otherwise you will receive an error message.

Figure A.2. Questionnaire general directions part in English.

Figure A.3 provides information about the first section of the questionnaire in English.

Part 1

This section consists of demographic questions. Please read each item on this form carefully, except the optional ones, and answer all of them. Please respond to this survey anonymously.

Figure A.3. Questionnaire part 1 information section in English.

Figure A.4 provides information about the second section of the questionnaire in English.

Part 2

This section consists of questions about the goals of the companies. You will be asked to evaluate how important it is to achieve these goals for your own company.

Figure A.4. Questionnaire part 2 information section in English.

Figure A.5 provides information about the third section of the questionnaire in English.

Part 3

In the third section, you are asked to evaluate the importance of the factors common to Ergonomics and Lean in terms of their contribution to achieving your company's strategic goals, on a scale of relative importance. These factors are grouped under six main categories. These categories are **"Employee"**; **"Organization"**; **"Method, Tools & Technology"**; **"Tasks"**; **"Environment & Safety"** and **"Customer & Supplier"**.

Figure A.5. Questionnaire part 3 information section in English.

Figure A.6 presents the privacy policy section of the questionnaire in English.

Privacy Policy

We respect the respondent's right to privacy. The identity of each survey participant and any other information you provide in this survey is kept completely confidential. No information will be shared with your manager or company. The sole reason for using this study is for academic purposes.

No one at your company will receive a copy of your survey. Additionally, no one at your company will be notified of the responses to your questions. Your answers will not be used to identify you personally in any way. Only summaries, tables and reports containing survey results will be made public. Any information obtained for this survey cannot be used for purposes other than the purpose for which it was collected.

Your answers will be combined with those of others for reporting requirements. Reports will include results for all participants. Once the reports are finished, you can request an electronic copy of the results of the investigation.

Figure A.6. Questionnaire privacy policy section in English.

Figure A.7 shows the information page of the questionnaire in Turkish.

Şirket Stratejileri için Ergonomi ve Yalın Anketi

Yüksek lisans tezinin başlığı: ErgoLean: Ergonomi ve Yalın Entegrasyonu

Sayın Katılımcı,

Boğaziçi Üniversitesi Endüstri Mühendisliği bölümünde yürütmekte olduğum yüksek lisans tezimin bir parçası olarak bu ankete vereceğiniz yanıtlara ihtiyacım var. Anket, Ergonomi ve Yalın yaklaşımlarının entegrasyonu için gerekli olan ortak faktörlerin önem sırasını belirlemeyi amaçlamaktadır. Çalışmanın nihai amacı oluşturulacak başarılı entegrasyon modeliyle uygulayıcı şirketlerde bu konuda karar vermeye destek olmaktır. Anket üç bölümden oluşmaktadır: 1. Demografik bilgilerle ilgili sorular; 2. İş stratejisi hedefleri hakkında sorular; ve 3. Ergonomi ve Yalın'ın ortak faktörleriyle ilgili sorulardan oluşmaktadır.

Bu çalışma ile ilgili herhangi bir sorunuz varsa benimle veya danışmanımla iletişime geçebilirsiniz. Verilen tüm yanıtlar anonimdir. Tüm kişisel bilgilerin gizli tutulacağını ve yalnızca istatistiksel sonuçların paylaşılacağını temin ederim.

Anketin tamamlanması yaklaşık 10 ila 15 dakika sürecektir. Bu bilimsel çalışmaya sağlayacağınız katkı için şimdiden teşekkür ederim.

Saygılarımla,

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* Gerekli

Figure A.7. Questionnaire information page in Turkish.

Figure A.8 presents the general directions part of the questionnaire in Turkish.

E-mail adres (isteğe bağlıdır)

Yanıtınız

Yukarıdaki beyanı okudum ve bu bağlamda araştırmaya katılmayı kabul ediyorum. *

☐ Evet, kabul ediyorum.

☐ Hayır, kabul etmiyorum.

Genel Talimatlar
Anketi, tercihinize göre akıllı telefonunuzdan (IOS veya Android) veya bilgisayarınızdan doldurabilirsiniz.

Sağlanan anket derecelendirme ölçeğine göre, lütfen her bir ifadeyi görelî önem derecesine göre değerlendirin.

Anket derecelendirme: (1) **Önemsiz**, (2) **Biraz Önemli**, (3) **Orta Derecede Önemli**, (4) **Önemli**, (5) **Çok Önemli**

1 en düşük önemi ve 5 en yüksek önemi temsil etmektedir. Lütfen her öğeyi bu ölçek doğrultusunda değerlendirin.

Kırmızı yıldız işareti (*) olan sorular mutlaka yanıtlanmalıdır; aksi takdirde bir hata mesajı alırsınız.

Figure A.8. Questionnaire general directions part in Turkish.

Figure A.9 shows the information section for part 1 of the questionnaire in Turkish.

1. Bölüm

Bu bölüm demografik sorulardan oluşmaktadır. Lütfen bu formdaki isteğe bağlı olanlar dışındaki her bir maddeyi dikkatlice okuyunuz ve hepsini cevaplayınız. Lütfen bu ankete anonim/isimsiz olarak yanıt verin.

Figure A.9. Questionnaire part 1 information section in Turkish.

Figure A.10 presents the information section for part 2 of the questionnaire in Turkish.

Bölüm 2/3

2. Bölüm

Bu bölüm, şirketlerin hedefleri ile ilgili sorulardan oluşmaktadır. Sizden kendi şirketinizle ilgili bu hedefleri gerçekleştirmenin ne derece önemli olduğunun bilgisi istenecektir.

Figure A.10. Questionnaire part 2 information section in Turkish.

Figure A.11 provides the information section for part 3 of the questionnaire in Turkish.

Bölüm 3/3

3. Bölüm

Üçüncü bölümde, Ergonomi ve Yalın'da ortak olan faktörlerin, göreceli önem ölçeğine göre şirketinizin stratejik hedeflerine ulaşmadaki katkıları açısından önemini değerlendirmeniz istenmektedir. Bu faktörler altı ana kategori altında toplanmıştır. Bu kategoriler "Çalışan"; "Organizasyon"; "Metot, Araçlar & Teknoloji"; "Görevler"; "Çevre & Güvenlik" ve "Müşteri & Tedarikçi"dir.

Figure A.11. Questionnaire part 3 information section in Turkish.

Figure A.12 presents the privacy policy section of the questionnaire in Turkish.

Gizlilik Politikası

Yanıt verenin gizlilik hakkına saygı duyuyoruz. Her anket katılımcısının kimliği ve bu ankette sağladığınız diğer bilgiler tamamen gizli tutulmaktadır. Yöneticiniz veya şirketinizle herhangi bir bilgi paylaşılmayacaktır. Bu çalışmanın kullanılmasının tek nedeni akademik amaçlardır.

Firmanızdaki hiç kimse anketinizin bir kopyasını almayacaktır. Ek olarak, şirketinizdeki hiç kimse, sorularınıza verilen yanıtlardan haberdar edilmeyecektir. Yanıtlarınız hiçbir şekilde sizi kişisel olarak tanımlamak için kullanılmayacaktır. Yalnızca anket sonuçlarını içeren özetler, tablolar ve raporlar kamuoyuna açıklanacaktır. Bu anket için elde edilen hiçbir bilgi, toplanma amacı dışında kullanılamaz.

Yanıtlarınız, raporlama gereklilikleri için başkalarının yanıtlarıyla birleştirilecektir. Raporlar, tüm katılımcılar için sonuçları içerecektir. Raporlar bittiğinde, araştırmanın sonuçlarının elektronik bir kopyasını isteyebilirsiniz.

Figure A.12. Questionnaire privacy policy section in Turkish.

APPENDIX B: NORMALITY ANALYSIS AND PERMISSIONS

This appendix provides the skewness and kurtosis values of the data.

Table B.1. shows the skewness and kurtosis values for different categories or groups within the data.

Table B.1. Skewness and Kurtosis values of categories.

ID	Descriptives	Statistic	Std. Error
SB	Skewness	-1.088	0.163
SB	Kurtosis	0.562	0.324
EMP	Skewness	-0.957	0.163
EMP	Kurtosis	0.311	0.324
ORG	Skewness	-0.792	0.163
ORG	Kurtosis	0.511	0.324
TASK	Skewness	-0.273	0.163
TASK	Kurtosis	-0.337	0.324
CUST	Skewness	-1.816	0.163
CUST	Kurtosis	2.197	0.324
ENV	Skewness	-0.374	0.163
ENV	Kurtosis	-0.704	0.324
TOOL	Skewness	-1.378	0.163
TOOL	Kurtosis	1.956	0.324
<i>Org: Organization</i>			
<i>Tool: Method, Tools and Technology</i>			
<i>Task: Task</i>			
<i>Env: Environment</i>			
<i>Emp: Employee</i>			
<i>Cust: Customer and supplier</i>			
<i>Sb: Business Success</i>			



Brown, Timothy

Re: Permission Request to Use Visual Material in Master's Thesis

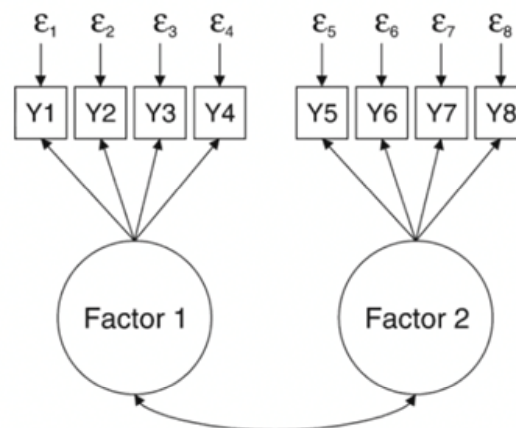
To: Kübra Uyar

Yes, please feel free to use this figure.

Sent from my iPhone

[See More from Kübra Uyar](#)

Model A: Confirmatory Factor Model (all measurement error is random)



Model B: Exploratory Factor Model (oblique rotation)

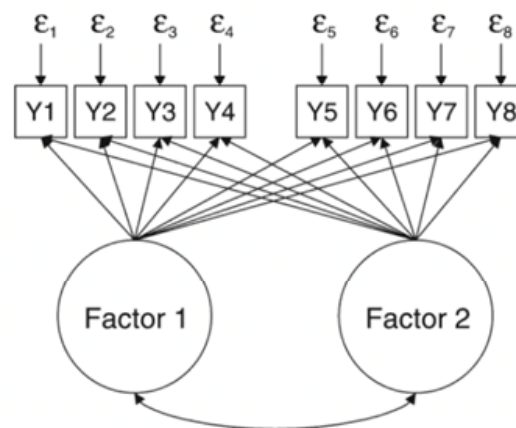


Figure B.2. The response received via email.

Figure B.3. presents another mail template for requesting permission to use visual materials.