DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF BUSINESS ADMINISTRATION
BUSINESS ADMINISTRATION PROGRAM
MASTER'S THESIS

A CASE STUDY FOR LEAGILE PERFORMANCE ASSESSMENT IN THE AUTOMOTIVE SUPPLIER INDUSTRY

Deniz ŞİMŞEK

Supervisor
Prof. Dr. Aysun KAPUÇUGİL İKİZ

2024

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İZMİR - 2024

APPROVAL PAGE

DECLARATION

I hereby declare that this master's thesis titled as "A Case Study for Leagile Performance Assessment in the Automotive Supplier Industry" has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

…../…../2024

Deniz ŞİMŞEK

ABSTRACT

Master's Thesis

A Case Study for Leagile Performance Assessment in the Automotive Supplier Industry

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Dokuz Eylül University

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Department of Business Administration

Business Administration Program

Lean is a management philosophy primarily developed to enhance efficiency in production and business processes, reduce waste, and maximize customer value. Lean philosophy focuses on simplification, efficiency, and customer satisfaction, helping organizations gain competitive advantage. Agility, on the other hand, aims to respond quickly to rapidly changing market demands, prioritize customer focus, ensure continuous improvement, and provide flexibility in business processes. The agile approach encourages being more adaptive, collaborative, and responsive to customer demands, unlike traditional production models. Leagile, which is formed by the combination of lean and agile concepts, refers to an approach that combines the principles of both simplicity (simplification and waste reduction) and agility (flexibility and customer focus) in production processes. Thus, by applying simplification and rapid adaptation together in an organization's production processes, it is aimed to increase efficiency and achieve the ability to respond quickly to customer demands. The leagile approach can provide organizations with an advantage in being more competitive in dynamic and changing market conditions by overcoming the limitations of traditional production models.

There are various studies in literature to evaluate the performance of lean, agile, and lean-agile practices. The studies were limited in scope and focused on defining general performance metrics. However, to better understand performance metrics and increase their applicability, it might be beneficial to

interpret and customize these metrics specific to the field where leagile applications are implemented. Based on this motivation, the study aimed to customize the lean, agile and leagile performance metrics in the literature for the automotive supplier industry and to define a leagile performance assessment system that considers these metrics together. While designing this performance assessment system, fuzzy logic method was used to transform performance metrics determined in different types and scales into a uniform score and to make comparisons between metrics. A holistic evaluation was made by visualizing strong and weak performance dimensions together with the help of the radar chart. In this way, it is aimed to provide a tool through which organizations can identify areas that are open to improvement in terms of leagile practices. The leagile performance assessment system was implemented in a company operating in the automotive supplier industry, and the experiences obtained from this implementation were included at the end of the study.

Keywords: Leagile Performance Assessment, Leagile, Lean, Agile, Performance Metrics.

ÖZET

Yüksek Lisans Tezi

Otomotiv Yan Sanayi Sektöründe Yalın-Çevik Performans Değerlendirmesine Yönelik Bir Örnek Olay Çalışması

Deniz ŞİMŞEK

Dokuz Eylül Üniversitesi
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Yalın, üretim ve iş süreçlerinde verimliliği artırmak, israfı azaltmak ve müşteri değerini maksimize etmek amacıyla geliştirilen bir yönetim felsefesidir. Yalın felsefesi, sadeleştirme, verimlilik ve müşteri memnuniyeti üzerine odaklanarak organizasyonların rekabet avantajı elde etmelerine yardımcı olmaktadır. Çeviklik ise, çabuk değişen pazar taleplerine hızlı yanıt verme, müşteri odaklılık, sürekli iyileştirme ve iş süreçlerinde esneklik sağlama amacını taşımaktadır. Çevik yaklaşım, geleneksel üretim modellerinin aksine daha adaptif, işbirlikçi ve müşteri taleplerine daha duyarlı olmayı teşvik etmektedir. Yalın ve çevik kavramlarının birleşmesi ile oluşan yalın-çevik (leagile) ise, üretim süreçlerinde hem yalınlık (sadeleştirme ve israfın azaltılması) hem de çeviklik (esneklik ve müşteri odaklılık) prensiplerini bir arada ele alan bir yaklaşımı ifade etmektedir. Böylelikle, bir organizasyonun üretim süreçlerinde sadeleşme ve hızlı adaptasyon birlikte uygulanarak hem verimliliğin hem de müşteri taleplerine hızlı yanıt verme yeteneğinin elde edilmesi hedeflenmektedir. Yalın-çevik yaklaşımı, geleneksel üretim modellerinin sınırlamalarını aşarak dinamik ve değişken pazar koşullarında daha rekabetçi olma yönünde organizasyonlara avantaj sağlayabilmektedir.

Literatürde yalın, çevik ve yalın-çevik uygulamalarının performansını değerlendirmek üzere çeşitli çalışmalar yer almaktadır. Yapılan çalışmalarda kapsam açısından kısıtlı ve genel performansa yönelik metriklerin tanımlanmasına odaklanılmıştır. Ancak performans metriklerinin daha iyi

anlaşılması ve uygulanabilirliğinin artması açısından özellikle yalın-çevik uygulamalarının gerçekleştirildiği alana özgü bu metriklerin yorumlanması ve özelleştirilmesi fayda sağlayabilir. Bu motivasyondan hareketle, çalışma literatürde yer alan yalın, çevik ve yalın-çevik performans metriklerini otomotiv yan sanayi sektörüne yönelik özelleştirmeyi ve bu metrikleri bir arada ele alan bir yalın-çevik performans değerlendirme sistemini tanımlamayı amaçlamaktadır. Bu performans değerlendirme sistemi kurgulanırken, farklı tür ve ölçekte belirlenen performans metriklerini tek tip skora dönüştürmek ve metrikler arasında karşılaştırma yapabilmek amacıyla bulanık mantık yönteminden yararlanılmış ve radar grafiği yardımıyla görselleştirilerek bütünsel bir değerlendirme yapılmıştır. Bu şekilde, organizasyonların yalın-çevik uygulamaları açısından iyileştirmeye açık yönlerini tespit edebilecekleri bir aracın sunulması hedeflenmiştir Yalın-çevik performans değerlendirme sistemi otomotiv yan sanayi sektöründe faaliyet gösteren bir firmada uygulanmış ve çalışmanın sonunda bu uygulamadan elde edilen deneyimlere yer verilmiştir.

Anahtar Kelimeler: Yalın-Çevik Performans Değerlendirme, Yalın-Çevik, Yalın, Çevik, Performans Metrikleri.

A CASE STUDY FOR LEAGILE PERFORMANCE ASSESSMENT IN THE AUTOMOTIVE SUPPLIER INDUSTRY

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ABBREVIATIONS

AFM	After Market
CS	Casual Silver
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
MCDM	Multi-Criteria Decision Making
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
PPM	Parts per Million
R&D	Research and Development
WCM	World Class Manufacturer

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INTRODUCTION

For businesses to be able to adapt to dynamically changing and evolving technological advancements and to survive in an increasingly competitive environment, they need to monitor their supply chain performance. Performance assessment systems are employed to efficiently utilize the supply chain, provide quick responses to customers, and track performance. Organizations, with the goal of enhancing their performances, experiment with supply chain philosophies that are suitable for their production structures. These supply chain philosophies can vary depending on factors such as company structure, strategy, product range, and customer expectations.

The lean strategy aims to eliminate all activities that do not add value for customers, intending to minimize production inefficiencies and reduce costs to a minimum. In other words, the lean concept not only optimizes traditional production processes but also strengthens organizations' ability to adapt to dynamic market conditions by introducing a perspective of learning and continuous improvement. This approach not only increases cost-effectiveness but also supports innovation by eliminating waste in business processes and encouraging employee participation. A distinctive feature of lean is that it goes beyond merely increasing profit margins; it also considers environmental sustainability and social impact. Therefore, the lean philosophy stands out as a strategy in the business world that aims not only for operational excellence but also for long-term sustainability, including environmental and social considerations.

The agile strategy stands out as the capability for organizations to sustain their presence in a competitive environment and respond rapidly to changes in customer demands. The success of agility is particularly dependent on factors such as service levels, customer sensitivity, customer satisfaction, or the extent to which customer goals are achieved. In this context, approaches that measure the success of agility focus on customer-centric elements such as understanding, analyzing, managing customer expectations, and effectively responding to complaints.

The concept of leagile represents a unique strategic approach in supply chain management, as it aims to achieve an effective balance in the supply chain by

combining both “lean” and “agile” principles. This approach seeks to integrate the section that focuses on improving efficiency with lean principles and the section that aims to meet various customer needs with agile principles. The fundamental goal of leagility is to bring together the advantages of the lean approach, to reduce costs, and the agile approach, which emphasizes the ability to respond quickly and flexibly to customer demands. This approach creates a strategic separation point in the supply chain called the “decoupling point,” integrating both the lean “push” and agile “pull” components.

The concepts of lean and agile may be fundamentally different, but they are closely interconnected. Leagile offers a unique advantage by bringing together the best of both worlds and focusing on both directions of the supply chain. This approach enables businesses to gain a competitive edge by serving the dual purpose of reducing costs and increasing customer satisfaction. Leagile provides a new perspective in supply chain management, aiming to quickly adapt to changing market conditions while enhancing operational efficiency. This strategic approach provides a unique balance that allows businesses to succeed in a dynamic and complex business environment.

Designing and managing a performance assessment system is crucial for organizations to gain a competitive advantage in the market. The leagile performance assessment system can be uniquely designed in a flexible structure that embodies both agile and lean elements. This adaptive feature enhances the organization's ability to effectively adapt to changing business conditions and strategic goals. The system can be customized, particularly focusing on the organization's strategic objectives, thus can identify performance indicators aligned with overall strategies through the integration of agile and lean goals. The leagile performance assessment system effectively balances agile and lean principles, providing the opportunity to successfully optimize agile principles such as customer focus and flexibility along with lean principles such as efficiency and waste reduction.

The leagile performance assessment incorporates the necessary metrics to support the goal of responding to customer demands quickly and effectively. This facilitates the continuous measurement of customer focus and rapid adaptation. Leagile performance assessment processes strengthen the organization's competitive

advantage by supporting the continual improvement of business processes and performance. The leagile approach facilitates organizations in adapting quickly to dynamic market conditions, providing significant advantages in terms of risk management and resilience.

There are various studies in literature to evaluate the performance of lean, agile and lean-agile applications. The studies are limited in scope and focused on defining general performance metrics. However, to better understand performance metrics and increase their applicability, it might be beneficial to interpret and customize these metrics specific to the field where leagile applications are implemented. Based on this motivation, the purpose of this study is to find out whether the leagile performance assessment system can be tailored to the field or industry in which it is used to improve understanding and applicability of the performance metrics. Specifically, the study aims to customize the lean, agile and leagile performance metrics in the literature for the automotive supplier industry and to define a leagile performance assessment model that considers these metrics together.

While designing this performance assessment model, the study uses fuzzy methodology to transform performance metrics determined in different types and scales into a uniform score and to make comparisons between metrics. A holistic evaluation is also targeted by visualizing strong and weak performance dimensions together with the help of the radar chart. In this way, it is aimed to provide a tool through which organizations can identify areas that are open to improvement in terms of leagile practices.

Therefore, the first chapter provides underlying background of this study based on the literature review. Then, the second chapter presents the methodology followed to address the research problem of this study and details the dimensions and metrics of leagile performance assessment model. The applicability of the proposed model is evaluated in a company operating in the automotive supplier industry. The third chapter explains the implementation of proposed leagile performance assessment model in a real company which produces aluminum alloy wheels, and discusses the experiences obtained from this implementation. Finally, the study concludes and suggests future works at the conclusion.

CHAPTER ONE
LITERATURE REVIEW

1.1. LEAN, AGILE AND LEAGILE

Within the scope of the lean production philosophy, one prominent figure who stands out as a pioneering leader is undoubtedly Taichi Ohno. The focus of Taichi Ohno was to create a system that would enhance productivity at the Toyota company (Christopher and Towill, 2001: 243-246). The lean philosophy is based on principles aimed at enhancing process efficiency, utilizing business resources effectively, and minimizing waste, forming a low-cost business strategy (Hallgren and Olhager, 2009: 976-999). The concept of lean is an approach that aims to increase efficiency and minimize waste. It seeks to reduce waste, excess inventory, and unnecessary activities by optimizing value-creating activities in all processes. In other words, lean supply chains intend to enhance customer satisfaction by reducing costs and providing faster and more effective supply chain management. The elimination of waste leads to a decrease in variable production costs (labor, energy, materials). This decrease contributes to an increase in the unit profitability of the manufactured products (Swink et al., 2011: 239). The core foundation of lean philosophy is formed by the concept of value. This value structure encompasses the production of high-quality products in the first instance and at the right time, meeting customer expectations by eliminating waste in processes (Womack and Jones, 2002:17).

The concept of agile manufacturing, proposed by a group of researchers at the Iacocca Institute in 1991, is a supply chain model aimed at quickly responding to the rapidly changing needs of the market. At its core lies the idea of regaining the manufacturing capability superiority that the American manufacturing industry had lost to its Far Eastern competitors. This model is widely recognized by many researchers and practitioners as one of the most effective strategic supply chain models that can be applied in rapidly changing dynamic market conditions. The primary goal of the system is speed and flexibility, aiming to provide flexibility through strategic collaboration to achieve common goals, considering market expectations for all

functions in the supply chain, and meeting customer expectations in a volatile market (Nagel and Dove, 1992: 215-758-5510).

Agile manufacturing requires the integrated work of skilled, motivated, and empowered teams. Additionally, it involves the effective use of advanced design, production, and management technologies. Alongside an engineering approach, knowledge management is also emphasized in agile manufacturing (Vazquez-Bustelo et al., 2007:1303-1332).

The concept of leagile emerged as a system that combines agile and lean philosophies, developed to explain production supply chains (Katayama and Bennett, 1999: 43-51; Naylor et al., 1999: 107-118; Mason-Jones et al., 2000: 54-61). Various authors have expressed different views on leagile. According to (Christopher (, 2000: 37-44), agility can be better embraced in situations where customer demands are variable and uncertain, and customer expectations are high, whereas the lean philosophy works better in situations with high volume and low variety. While agility evaluates opportunities in the market using market knowledge, leanness creates value flow to reduce waste. Naylor et al. (1999: 107-118), have pointed out an undefined gap between lean and agile concepts, and they have named this gap the "decoupling point." The decoupling point is where the effects of demand variability are felt, and it is the point where the product portfolio needs to be increased (Sun et al., 2008: 943-956).

1.2. PERFORMANCE ASSESSMENT

Performance measurements are a process used to determine and assess the extent to which organizations achieve their goals (Diaz et al., 2005: 781-799). This process assists organizations in monitoring, measuring, and managing their performances. Performance measurements ensure continuous monitoring of organizations reaching their set goals. Since performance measurements are based on concrete data, they enable more abreast decision-making, reducing uncertainty. Additionally, by examining and identifying improvement opportunities in organizational processes and practices, performance measurements contribute to operating with a mindset of continuous improvement.

Questions about how organizations should structure their performance have been asked by researchers and practitioners for years. Financial metrics are used to evaluate the performance of organizations. In the early 1980s, as the increasing complexity of the markets in which organizations compete was considered, thoughts began to emerge that financial metrics alone were not sufficient to measure success in performance assessment systems (Kennerley and Neely, 2002: 145-155).

Modern researchers and practitioners emphasize that financial concepts yield inadequate results in performance assessment systems. While "profit" as a performance metric stands as a robust performance target among financial metrics, it falls short as a performance measure. This is because performance metrics should be designed to maximize "profit." (Bruns, 1998:14). Moving away from the traditional approach, many authors have presented different studies on the construction of performance assessment designs. “Balanced Scorecard”, “The Performance Prism”, “The Performance Measurement Matrix”, “Smart Pyramid” and “The Results and Determinants Framework” are among the performance assessment systems.

Balanced Scorecard has emphasized the inadequacy of traditional performance assessment methods in fully reflecting the strategic objectives of organizations. In this context, a measurement framework based on four perspectives, called Balanced Scorecard, has been proposed. This framework consists of financial, customer, internal business processes, and learning and growth perspectives, aiming to assess the strategic objectives of organizations in a balanced manner. This approach guides organizations to focus on their strategic goals and measure their performance in alignment with their strategy. Thus, organizations can be managed more effectively, and their strategic success can be enhanced (Kaplan and Norton, 1992: 71-79).

The performance prism is a framework that offers an alternative approach to traditional performance assessment models. This model provides a more comprehensive perspective for measuring and managing the performance of businesses. The Performance Prism consists of five key components, including the business's strategic objectives, stakeholders, strategic management system, strategic management process, and performance outcomes. This framework enables businesses to achieve their strategic goals by considering the needs of both internal and external stakeholders, rather than solely focusing on financial results. In this way, businesses

optimize their financial and operational performance while also enhancing the value for all stakeholders. The performance prism allows businesses to adopt a more holistic and inclusive approach to managing their performance, providing a significant advantage for long-term success (Kennerley and Neely, 2000: 291-298).

The performance measurement matrix is a conceptual tool used to evaluate an organization's performance across various dimensions. Performance measurement matrix encompasses different dimensions such as financial metrics, customer satisfaction, internal processes, and learning and growth. Each dimension may include specific performance indicators or key performance indicators (KPIs). This matrix enables organizations to comprehensively analyze their performance, identify strengths and weaknesses, and develop strategies to improve their performance (Keegan et al., 1989: 45-50).

The smart pyramid is a comprehensive framework used to measure and manage business performance. This pyramid integrates an organization's strategic objectives, goals, measures, business processes, and resources. Strategic objectives reflect the organization's long-term vision, while strategic goals represent the prioritized objectives set to achieve these goals. Strategic measures are specific metrics used to monitor and measure performance, and business processes represent the operational activities conducted to achieve strategic objectives. Finally, resources and capabilities encompass the human, financial, technological, and other resources that impact the organization's performance (Lynch and Cross, 1991).

The Results and Determinants Framework is a conceptual tool used to assess business performance. This framework consists of two main components: results and determinants. Results represent the performance metrics targeted by the business, typically encompassing factors such as service quality, customer satisfaction, efficiency, and financial performance. On the other hand, determinants include the factors that influence these results. This framework helps businesses understand their performance, identify areas for improvement, and make strategic decisions. Additionally, it enables businesses to continuously monitor and manage their performance. The results and determinants framework is a significant tool used to guide performance management processes more effectively (Brignal and Ballantine, 1996).

In performance assessment systems, along with the evaluation method, the correct selection of performance assessment dimensions and metrics is highly important. Different authors in literature have focused on various aspects of performance assessment metrics. Among these authors, Gunasekaran et al. (2001:71-87) have identified three different types of metrics: strategic, tactical, and organizational. Chan et al. (2003: 209-223) have concentrated on customer sensitivity, costs, and productivity concepts. Wu et al. (2014: 122-132) have oriented towards financial and non-financial concepts.

1.2.1. Lean Performance Assessment

Lean provides a sustainable competitive advantage. Due to a lack of understanding of lean performance assessment in organizations, lean implementations often fail. Organizations adopting the lean philosophy may not achieve success unless they measure lean performances (Behrouzi and Wong, 2011: 388-395).

Organizations compete with different performance dimensions to achieve their goals. Various authors have attempted to identify lean performance dimensions. According to Gunasekaran and Ngai (2012: 687-701) and Jabbour et al. (2014:1070-1083), lean performance dimensions include delivery, quality, price, and flexibility. Karlsson and Ahlström (1996: 24-41), have indicated that dimensions showing lean performance should be productivity, quality, delivery time, and cost. Fullerton and Wempe (2009: 214-240), have defined the performance dimensions of a lean supply chain as setup time, production capacity, batch size, and employee participation, using profit as a financial performance dimension. Arif-Uz-Zaman and Nazmul Ahsan (2014: 588-612), have defined quality not only in terms of the quality of services or products provided to customers but also as a measure of the accuracy of the relationship between the person receiving the service or product and the supplier. They have also emphasized metrics such as total cycle time, order time, production time, and delivery time as important lean metrics.

Many authors have provided different perspectives on determining performance metrics. Pakdil and Leonard (2013:4587-4607), conducted a literature review and identified lean performance dimensions and metrics that can be used in

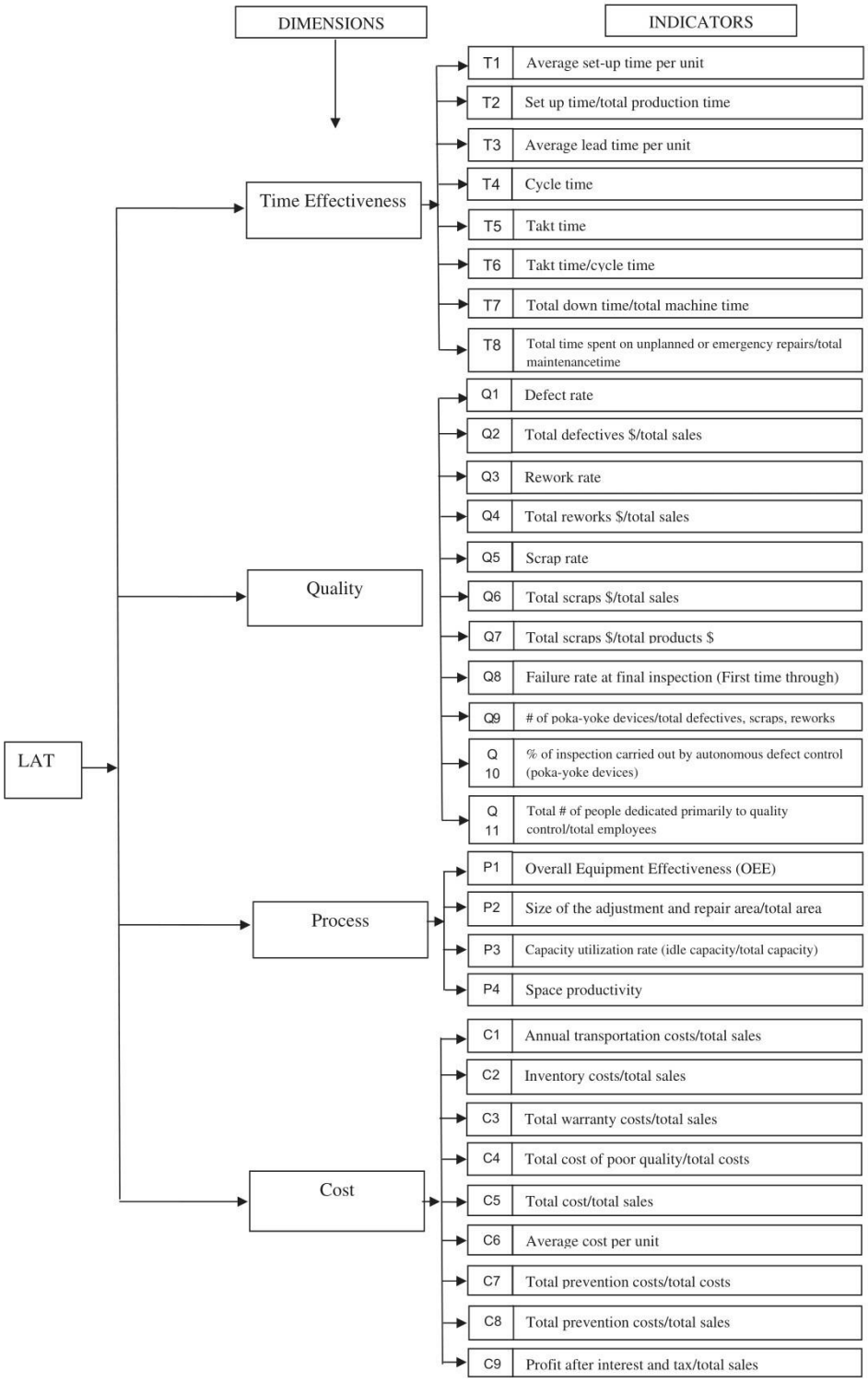
organizations (Figure 1). The lean performance dimensions they identified are “Time Effectiveness”, “Quality”, “Process”, “Cost”, “Human Resources”, “Delivery”, “Customer”, and “Inventory”. To measure the success of these performance dimensions, they developed a lean performance assessment tool using the fuzzy logic methodology.

1.2.2. Agile Performance Assessment

Organizations need to adapt to the globalized and changing world. The foundation of competition for manufacturing organizations is evolving from product quality and cost competitiveness to the ability to provide rapid responses to changing customer demands (Van Assen, 2000: 142-155). At this point, lean practices fall short in increasing customer satisfaction. To address the shortcomings of the lean philosophy, the concept of agile manufacturing, a new production paradigm, was introduced in 1991 (Nagel and Dove, 1992: 215-758). The concept of agility is defined as efficiently altering processes by adapting to changing customer demands and providing rapid feedback to customers (Narasimhan et al., 2006: 440-457). In defining agility, responsiveness, flexibility, and information technologies are the most used performance metrics (Soepardi et al., 2018: 95-126). Agility aims to establish a production management system that can provide quick responses to customers in terms of product type and volume, enabling rapid transitions between product models or product groups.

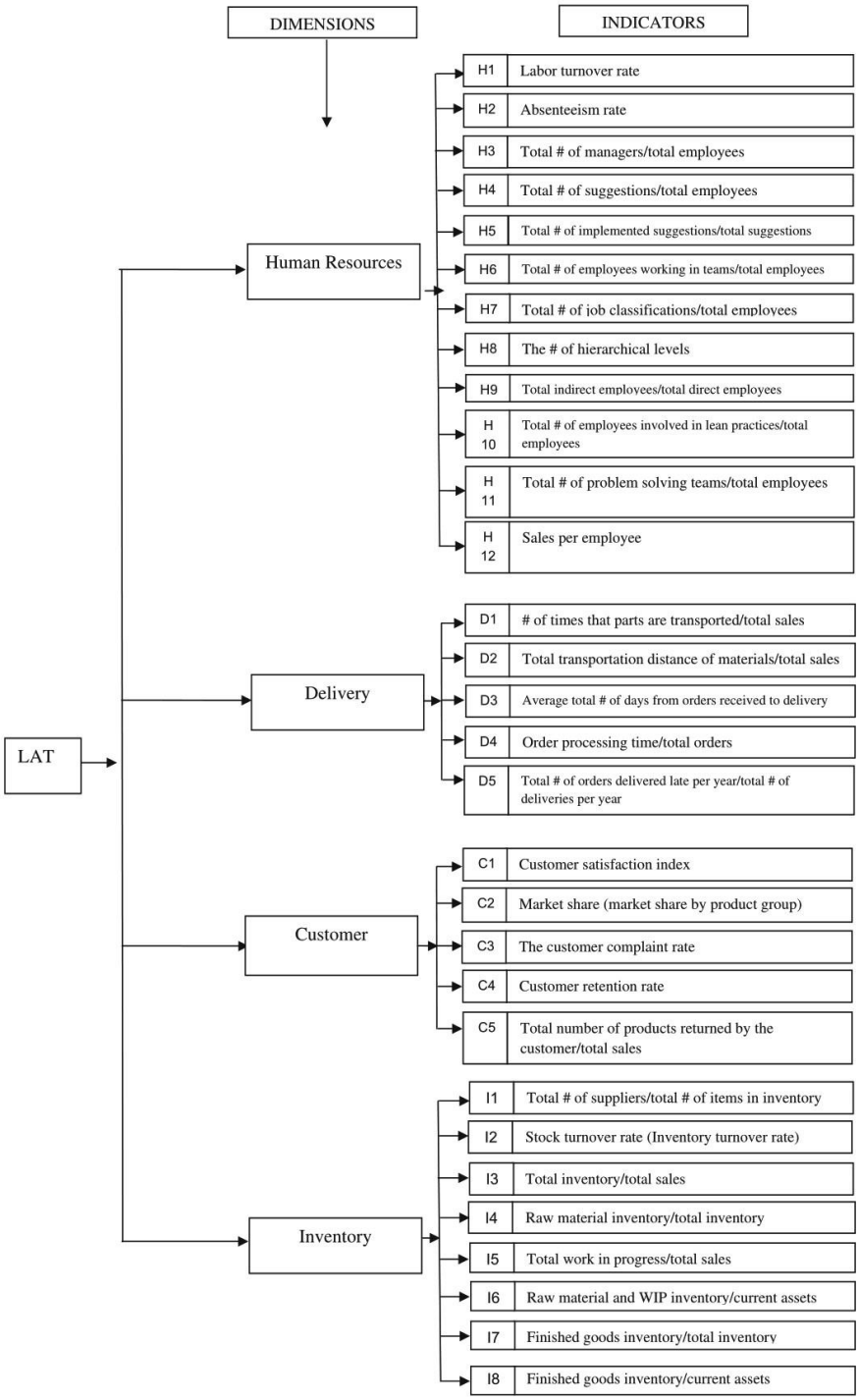
Agile philosophy can be effectively applied, and the performance capabilities of applications need to be comprehensively understood. In the structure outlined in Figure 2, agile performance metrics have been identified.

Figure 1: Lean Assessment Tool Performance Indicators



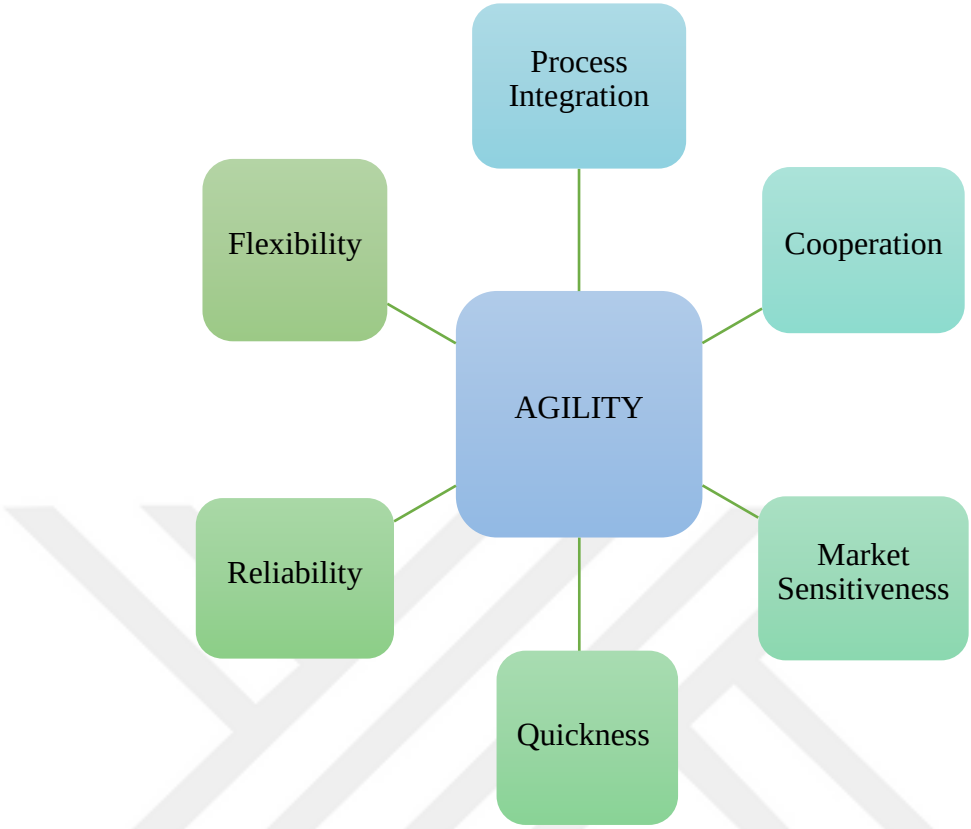
Source: Pakdil and Leonard, 2013: 4592.

Figure 1: Continued



Source: Pakdil and Leonard, 2013: 4593.

Figure 2: A Comprehensive Structure for Agile Concept



Source: Soltan and Mostofa, 2015: 480.

1.2.3. Leagile Performance Assessment

Although there have been numerous studies on the concepts of lean and agile, there is still confusion regarding their use in combination. Narasimhan et al. (2006: 440-457) argues that lean and agility are distinct but overlapping concepts. On the other hand, Haq and Boddu (2017: 1-12) assert that lean and agile may sound similar but are conceptually different. Prince and Kay (2003: 305-318) and Carlson (2003: 95-102) emphasize the need to use lean and agile methods together. Lean and agile approaches share common characteristics, including the elimination of waste, sensitivity, flexibility, quickness, and reliability. According to Womack and Jones (2002: 17), lean is more suitable when customer demand is stable and product variety is low, whereas agility is appropriate when there is high variability in demand and a wide range of products. Lean operations have a positive impact on metrics such as

cost, quality, and delivery speed. It positively influences the delivery speed metric under the agility heading. This situation can be exemplified as an intersection point where lean and agility overlap. According to the study conducted by Drew et al. (2004), both lean and agile management strategies have been proven as successful approaches for businesses, resulting in significant improvements in profitability, cash flow, customer satisfaction, and market share.

Although lean and agile concepts are conceptually different paradigms, they can be combined at the point of separation in supply chains. This combination is called flexibility. This junction point separates operational processes from customer processes. The presence of a split point is an indicator of flexibility. In a study by Moyano-Fuentes and Sacristan-Diaz (2012: 551-582), the necessity of a more agile approach in supply chains was emphasized, considering certain limitations of the lean concept. This is linked to the prediction that the extent of leanness in supply chains may weaken. The fundamental question is at what point within the supply chain the transition from lean to agility should occur. It aligns theoretically with Christopher and Towill (2002: 1-14) and Harrison (1997: 257-260) because the point of divergence ensures that lean and agile systems do not overlap in the same area; there is a boundary point between them. In organizations, the situation where agile and lean concepts converge is referred to as leagile. Similarly, Prince and Kay (2003: 305-318) defines a point of separation between the concepts of agile and lean.

Within the leagile philosophy, before the decoupling point, it is important to first focus on the lean criteria and then switch to the agility criteria (Shahin and Jaberi, 2011: 215-240). The decoupling point lies between production output and customer requirements. At this stage, a strategic inventory is used as a buffer (Hemalatha et al., 2015: 69-85; Naylor et al.,1999: 107-118). In other words, the decoupling point represents a critical point where demand variables show their effects and product diversity begins throughout the supply chain (Sun et al., 2008:943-956).

1.3 AUTOMOTIVE SUPPLIER INDUSTRY

One of the sectors where globalization occurs most frequently is the automotive industry. While the countries that dominated the automotive industry until

the 1980s included the USA, European countries such as Germany, France, Spain, and South Korea and Japan, towards the end of the 1980s, a large part of the production processes began to move outside these countries. Since 2001, the production share of other countries in the automotive industry has reached approximately 40 percent (Tuncay, 2001:27).

The automotive industry works in partnership with industries such as the automotive industry, iron and steel, petro-chemistry, automotive supplier industry, and tires, and carry out their processes with suppliers in these business lines. As cars became more widespread in the 20th century, consumption needs began to increase. Today, the automotive industry is in a leading position among the sectors that allocate high budgets to research and development studies to meet consumers' demands for security, comfort, speed, and social status (Teker and Felekoğlu, 2007: 30).

When Turkey's automotive industry is evaluated from a perspective that includes vehicle production as well as parts and raw material production, it has a significant development potential in terms of the sector's capacity, technological level, competitiveness of the products in the international market and qualified manpower in the sector (MEGEP, 2005: 243). The automotive industry continues to invest in technology continuously and rapidly. This industry functions as a leading dynamic of technological developments in Turkey and creates an important driving force with this structure (Yurdakul et al., 2003: 1-18).

The automotive supplier industry is an industrial enterprise that is dependent on automotive main industry customers. In the early 1980s, the foreign exchange problem and the decrease in imports of vehicles in the manufacturing sector caused the sector to return to the domestic market with domestic parts production. This situation positively affected the development of the automotive supplier industry and increased the domestic contribution rate to 90%. After the 1980s, export rates in Turkey began to rise with the increase in technological developments and the ability to offer quality products internationally. During this period, the automotive supplier industry transitioned from a “foreign currency spender” to a “foreign exchange earner” position. With the steady increase in demand in the automobile industry in the early 1990s, investments in the automotive supplier industry showed an increase. Organizations operating in the automotive supplier industry have started to make

technological investments to gain a competitive advantage as well as capacity-increasing activities in order to meet the increase in production demands (TUBITAK, 2023: 6).

Nowadays, although more than 1000 companies operate in the automotive supplier industry, the number of organizations that directly manufacture original parts in accordance with production standards and compete and export in international markets is approximately 300-350. When we look at the distribution of these organizations across Turkey in terms of location, it is observed that they are concentrated in Istanbul, Bursa, and Izmir regions (TUBITAK, 2023:1).

The automotive supplier industry is among the sectors that have managed to keep technology levels high by following technological developments. By using the power of technology, it has become capable of producing for Original Equipment Manufacturer (OEM) companies operating in developed western countries. In addition, 30% of the companies operating in the automotive industry have internationally accepted quality certificates such as ISO 9000, QS 9000, ISO 14000. The automotive supplier industry creates employment for approximately 150,000 people directly and 750,000 people indirectly (TUBITAK, 2023: 2-3).

CHAPTER TWO
METHODOLOGY

This section is focused on the methodology of the study. The purpose of this study is to find out whether the leagile performance assessment system can be tailored to the field or industry in which it is used to improve understanding and applicability of the performance dimensions and metrics. Specifically, the study aims to customize the lean, agile and leagile performance metrics in the literature for the automotive supplier industry and to define a leagile performance assessment model that considers these metrics together. The study will be conducted by following the stages outlined in Figure 3 to achieve this goal.

2.1. RESEARCH AIM

The main purpose of this study is to make a comprehensive compilation of the performance dimensions and metrics related to the leagile approach, in which lean and agile approaches are integrated, and then to present a case study in the relevant field by customizing the performance dimensions and metrics of the leagile performance assessment system for the automotive supplier industry.

2.2. LITERATURE REVIEW

Piotrowicz et al. (2023: 1560-1583) provide a literature review study and a general framework of dimensions for measuring the supply chains of organizations. In the study, a literature study was presented based on 62 articles published on lean, agile, and leagile dimensions from 1990 to 2020. It was stated that the study focused on time effectiveness, cost, profitability, productivity, efficiency, inventory management and quality metrics under the title of “lean”. Under the heading of “agile”, the focus is on flexibility, adaptability, cooperation, collaboration, integration, coordination, information system, market sensitivity, quickness, responsiveness and information sharing dimensions, and under the heading of “leagile”, the focus is on time, quality, customer satisfaction and service level metrics. Lean dimensions focus on business

processes, products produced, cost and productivity. They are more concrete dimensions and can be easily identified in organizations. Since agile dimensions vary depending on the needs of customers, they can be analyzed abstractly in organizations. Leagile dimensions include time, quality, and customer-based measurements. Leagile dimensions can be both concrete and abstract (Piotrowicz, et al.,2023: 1560-1583).

According to Qi et al. (2009: 667-695), it has been defined that lean and agile strategies are integrated with each other. Fadaki et al. (2019: 246-264) argue that focusing on lean and agile strategies together in supply chains will bring great profits. They stated that lean alone is insufficient to meet the needs of customers quickly and that it should be supported by agility (Aitken et al., 2005: 73-96).

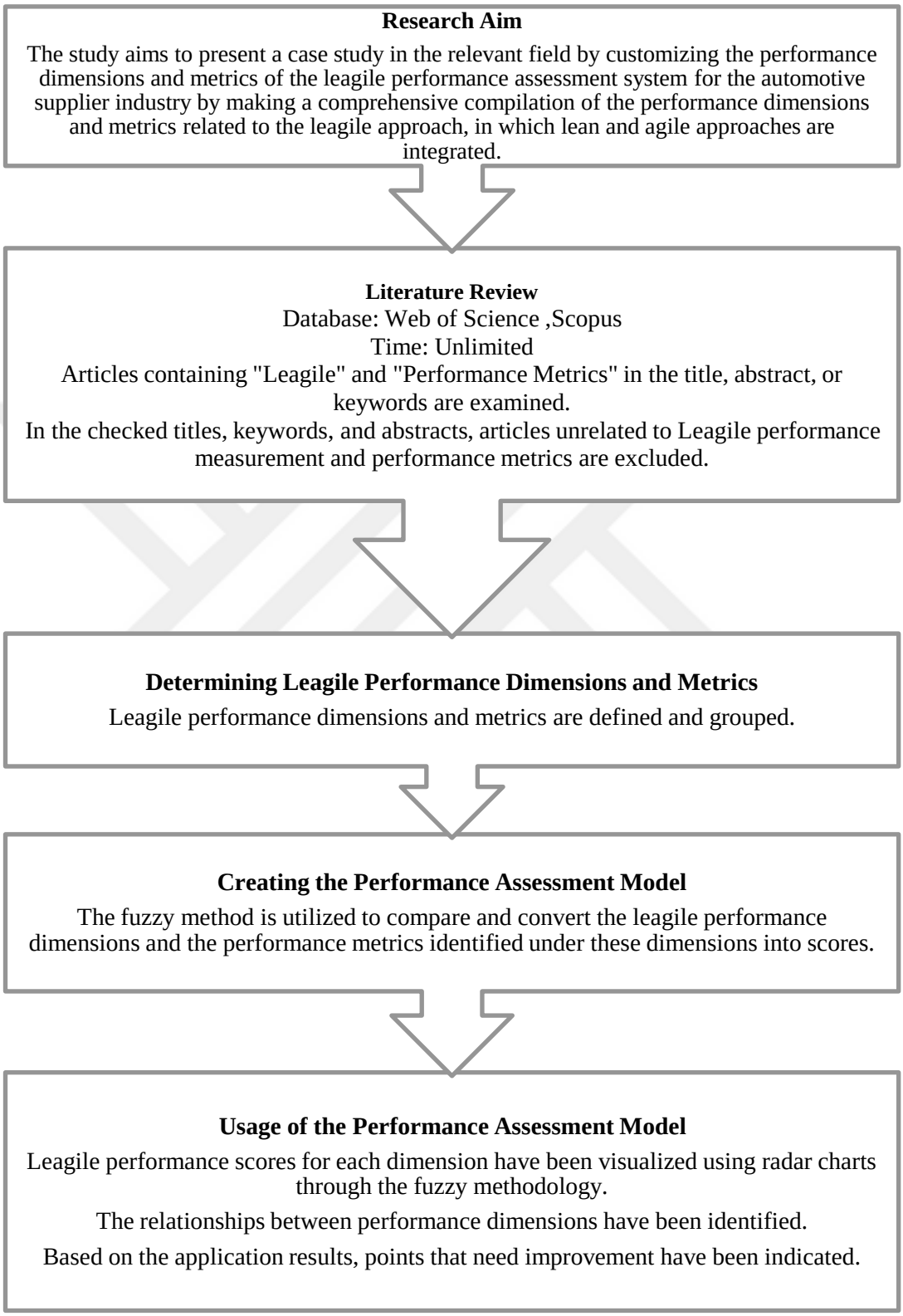
In this study, articles containing the terms leagile performance criteria, leagile performance metrics, leagile performance indicator, leagile performance measures, leagile performance requirements, leagile performance guidelines, leagile performance assessment, and leagile performance assessment in their titles, abstracts, or keywords were examined. The review was conducted without time constraints using the Web of Science and Scopus databases. Articles not related to leagile performance assessment and performance metrics in their titles, keywords, or abstracts were excluded from the analysis. Figure 3 also depicts the settings used to conduct the literature review.

According to the results of literature review, it has been determined that there are 123 studies on determining leagile performance metrics (Table 1). The number of repetitive articles among these 123 articles is 50. Therefore, a more detailed literature review has been conducted on 73 articles.

In the research, which deepened over 73 articles, performance dimensions and performance metrics under each performance dimension were determined in order to customize the leagile performance assessment system according to the automotive supplier industry. Then, a performance assessment system was designed using the fuzzy method. In the leagile performance assessment system, the leagile performance scores were determined with the fuzzy method. The scores of the performance dimensions were visualized using the radar chart. The relationships between the performance dimensions from which scores are calculated are shown, as well as the areas that need to be improved.

With this study, despite the existence of metrics specific to lean and agile approaches in the literature, the aim is to define the evaluation method that integrates these approaches. The study also aims to reveal the effects of applying the proposed method in an organization, demonstrating the combined use of lean and agile approaches.

Figure 3: The Methodology Adapted for the Study



Source: Created by the author.

Table 1: The Number of Articles by the Keywords in the Database

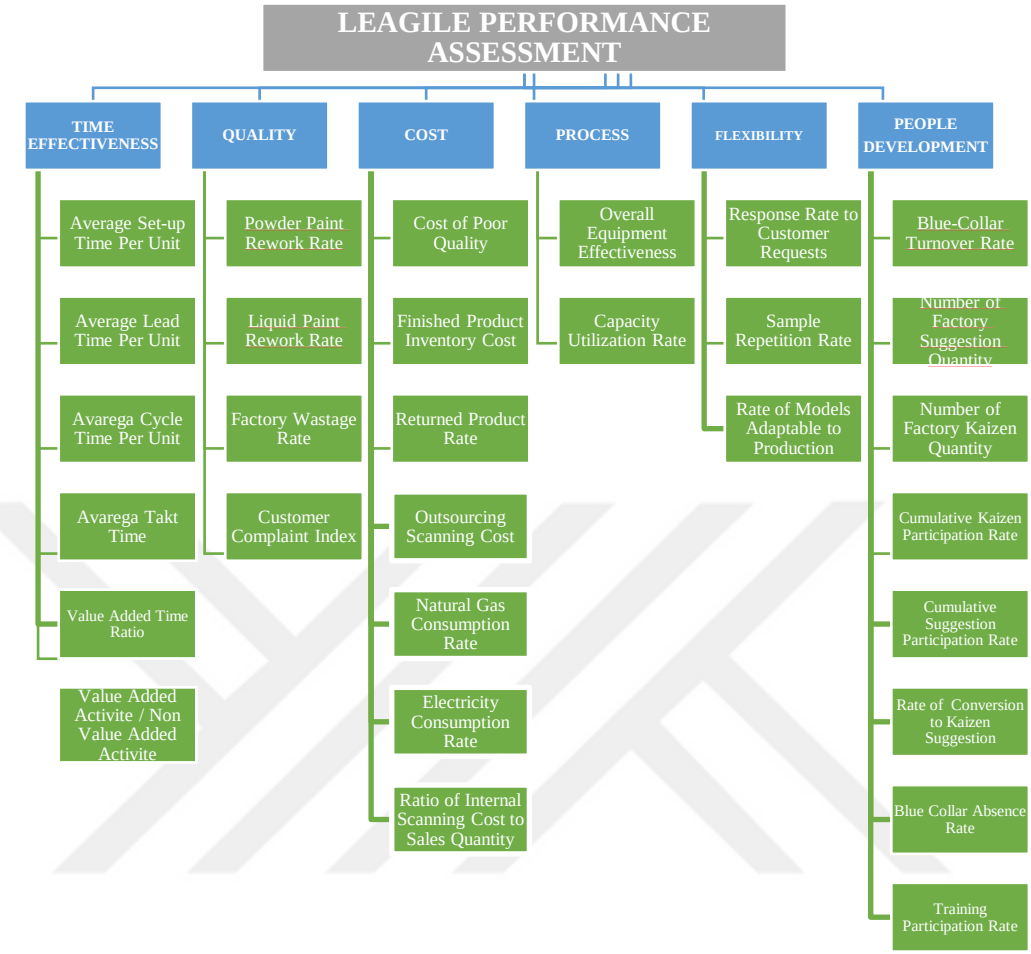
Searching Criteria	Number of Articles in the Database
″Leagile” AND ″Performance”	65
″Leagile” AND ″Performance Criteria”	4
″Leagile” AND ″Performance Metrics”	8
″Leagile” AND ″Performance Indicator”	1
″Leagile” AND ″Performance Measures”	14
″Leagile” AND ″Performance Requirements”	12
″Leagile” AND ″Performance Guidelines”	3
″Leagile” AND ″Performance Measurement”	6
″Leagile” AND ″Performance Assessment”	2
″Leagile” AND ″Performance Evaluation”	8

Source: Created by the author.

2.3. DETERMINING LEAGILE PERFORMANCE DIMENSIONS AND METRICS

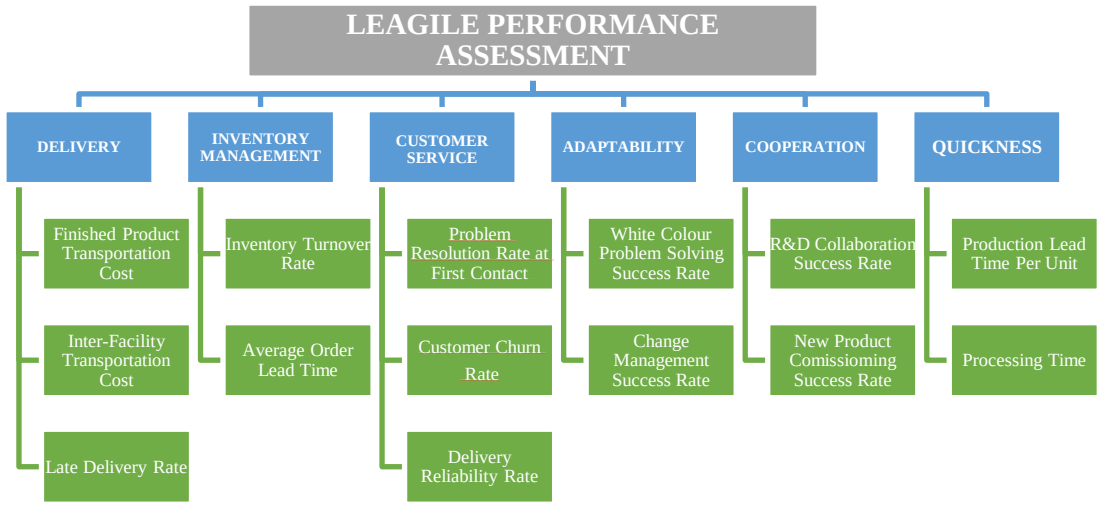
In line with the information obtained from the literature review, lean, agile, and leagile performance dimensions and performance metrics under each performance dimension, which can be analyzed in the automotive supplier industry, have been determined in Figure 4.

Figure 4: Leagile Performance Assessment



Source: Created by the author.

Figure 4: Continued



Source: Created by the author.

2.3.1 Time Effectiveness

Time efficiency refers to the ability to effectively use time. This concept defines how efficiently a process, activity, or task manages time to achieve goals that are set. Time efficiency measures how effectively business processes, projects, or tasks are completed within specified time frames. In organizations, the speed of delivery and the pace at which the product is formed are crucial for creating a competitive advantage (Devaraj et al., 2004: 313-333; Mazzuto et al., 2012: 4718-4733; Ward et al., 1996: 597-626).

Cycle time refers to the total time it takes to complete a process, a product, or a service (Letens et al., 2011: 69-25). This period includes the time from the beginning to the completion of the process of producing a product or providing a service. Cycle time is an important metric for evaluating, managing, and improving business processes.

Set-up time involves tasks performed to prepare machines for the next product and are not directly related to productivity. These operations generally include situations such as cleaning machines, correcting machine parts, configuring machines, changing molds, or switching to another work task (Pan et al., 2017: 89-112).

Takt time refers to the anticipated maximum time for completing a specific product. This duration is determined based on factors such as customer demands, production rates, and operating times. Takt time is a metric indicating how many times a production line or process should complete a particular product. This concept is a crucial component in efficiently managing the production process according to customer demands and ensuring timely delivery of products. Thus, it enables verification that the production rate aligns with customer demands (Monden, 1998: 16-168). In the time effectiveness dimension, metrics associated with ″average set up time per unit”, ″average lead time per unit”, ″average cycle time per unit”, ″average takt time”, ″value-added time ratio”, ″ratio of value-added activities to non-value-added activities” may be included.

2.3.2. Quality

Changes in competitive advantage and customer expectations, product-related and technological innovations, decreasing product life cycles and product diversity affect organizations. Organizations need to be shaped according to customer expectations to gain competitive advantage and be successful (Dehghani and Jafari, 2019: 2217-2236).

While being able to respond quickly to customers' expectations in line with the changing demands in the market is important for gaining competitive advantage, it is also extremely crucial that the quality processes of the products produced are within the specification values desired by the customers.

The quality dimension includes features such as durability, reliability, functionality, and aesthetics of the products. Production quality is of great importance in minimizing errors, maximizing customer satisfaction, and managing business processes effectively. Carvalho et al. (2010: 49-62), in their study on the operational and economic performance of supply chains, found that increased responsibility, flexibility, quality products and fast delivery times lead to customer satisfaction. Rework and waste metrics can be used to measure quality performance in organizations. These performance metrics represent internal quality errors (Dale, B. G., 1999: 265-282).

2.3.3. Cost

Organizations implement various techniques such as total quality management, lean production, and flexible manufacturing systems (agility) to gain a competitive advantage. All these techniques aim to minimize costs, improve quality, reduce cycle times, and enhance flexibility. However, support systems like cost management struggle to adapt quickly to operational changes (Modarress et al., 2005: 1751-1760).

Lean and agility represent two fundamental strategies that have significant effects on cost management in businesses. Lean aims to optimize business processes by minimizing waste and reducing costs. By reducing inventory, speeding up processes, and efficiently using resources, Lean increases the efficiency of businesses.

In other words, the primary focus of lean philosophy is to reduce costs (Christopher, 2000: 37-44). Agility, on the other hand, emphasizes the ability of businesses to adapt quickly to rapidly changing market conditions. An agile business sustains cost-effectiveness by responding rapidly to sudden changes in customer demands (Maskell, 2001: 5-11). While lean maximizes profits by reducing costs, agility maximizes profits by providing exactly what the customer needs promptly (Gurahoo and Salisbury, 2018: 1- 9). Leagile combines these two strategies, offering businesses the advantage of both cost-effectiveness and rapid adaptation. This approach establishes a balanced strategy that aims to respond quickly to customer demands while simultaneously minimizing costs.

When the literature is examined, authors advocating the traditional approach to quality costs state that an increase in quality will also increase quality costs. Traditional thinkers on quality costs argue that the implementation of state-of-the-art control mechanisms for quality assurance will raise costs. In today's understanding, it is prevalent that the cost generated by poor quality products far exceeds the costs incurred to ensure quality (Schmahl et al., 1997:58). The concept of quality costs can be defined as costs arising from activities aimed at preventing errors, as well as planned quality controls during the production process and costs that may arise after delivery to the customer (Yükçü, 1998:486). Quality costs are divided into two categories: prevention costs and failure costs. Prevention costs refer to the expenditure made to reduce errors in production systems. Failure costs are further divided into two subcategories. If a defect is detected during production before the product reaches the customer, it is referred to as internal failure cost. On the other hand, if the product reaches the customer and quality issues arise afterward, it is defined as external failure cost (Pasewark, 1991: 46-52). Performance assessment systems, the cost dimension for organizations can be assessed using metrics such as cost of poor quality, finished product inventory cost, returned product rate, external inspection cost, and others.

2.3.4. Process

By combining lean and agile strategies, the leagile philosophy aims to optimize cost, time and profitability while providing a rapid response to dynamic demands.

When practices are implemented after the adoption of lean, agile or leagile concepts, the performance indicator that shows that the production processes are successfully carried out is defined as Overall Equipment Effectiveness (OEE). OEE multipliers are tools generally used to measure 3 production performance indicators (availability, performance, and quality) (Puvanasvaran, et al., 2013: 507-524).

Another performance metric used to measure the performance of processes is capacity utilization. Capacity utilization is a performance indicator that indicates an organization's ability to effectively manage its production resources. The continuity of a manufacturing company depends on the effective determination of production capacity and production planning. Production capacity refers to the amount a business can produce by using existing production factors efficiently within a certain period of time (Bulut, 2004: 1-22). In performance assessment systems, capacity utilization rate and OEE metrics can be used for organizations under the process dimension.

2.3.5. Flexibility

Flexibility refers to the ability to respond appropriately to environmental changes and uncertainties. This capability contributes to the development of high-quality products or services (Allegre and Sard, 2015:375-385). The flexibility performance dimension has been identified as the most crucial performance criterion for distinguishing lean and agile business models (Narasimhan, et al., 2006:440-457). Lean production is a process that aims to eliminate non-value-added activities. While the concept of flexibility is not a prerequisite for lean production, the elimination of waste is a prerequisite for agility (Naylor, et al., 1999:107-118). In performance assessment systems, the flexibility dimension for organizations can be evaluated with metrics such as response rate to customer requests, sample repetition rate and rate of models adaptable to production.

2.3.6. People Development

Employee development management plays a critical role in supporting and implementing the leagile strategy. Human resources practices, such as teamwork,

continuous development, and employee development, commitment, continuous improvement, and recognition systems, support the strategic structure of organizations. The commonality between lean and agile structures lies in the ability to establish a flexible framework based on teamwork, by carrying the logic of continuous improvement from the highest to the lowest levels and involving employees in improvement activities (Denning, 2016:10-17). The birth of the Kaizen method took place in Japan. The Kaizen system is one of the most widely used methods in managing manufacturing businesses in Japan. The most effective way to make employees feel valued in businesses and to demonstrate that their ideas and suggestions are valued is to implement the Kaizen system within the organization. Collaboration forms the basis of the Kaizen concept (Brunet, 2000: 2).

When creating a performance assessment system in organizations, the dimension of people development can be assessed by measuring employee engagement through metrics such as turnover rate. To gauge the widespread adoption of a culture of continuous improvement, metrics like the number of suggestions provided by employees, quick and standard kaizen (continuous improvement) submissions, and the participation rate in quick and standard kaizen initiatives can be employed. Additionally, to measure the conversion rate of suggestions into kaizen, metrics such as the number of qualified suggestions can be utilized.

2.3.7. Delivery

In lean performance assessments, service levels and delivery times stand out as critical indicators providing a competitive advantage. However, their effectiveness is intricately linked to the stability of supply chain processes that involve product production, delivery, and information flow (Naim and Gosling, 2011: 342-354). Leagile aims to enhance delivery performance in inventory management and supply chain management by integrating lean and agile elements into production processes.

According to Karlsson and Åhlström (1996: 24-41), delivery performance in organizations is assessed as both internal and external activities. Internal activities encompass movements such as inter-station transportation, raw material transportation, and semi-finished goods transportation. In addition, the transportation

of semi-finished or finished products between facilities is considered a non-value-added task. Such transportation activities increase delivery times and consequently escalate costs within organizations. In this context, within performance assessment systems, the delivery dimension can be assessed using metrics such as finished product shipping cost, inter-facility transportation cost, and late delivery rate.

2.3.8. Inventory Management

Inventory management is crucial in responding to fluctuations in customer demands and preventing unplanned disruptions during the production process (Olhager, 2010:863-868). Lean inventory management considers stocks throughout the process from order creation to product delivery to the customer as non-value-adding activities from the customer's perspective, resulting in costs for organizations (Kumar et al., 2019: 67-100). Stock, in its literal sense, means producing more than necessary before it is needed. Overproduction before the actual demand leads to unnecessary use of labor, equipment, space, and energy.

Achieving effective inventory management involves establishing a comprehensive system to monitor inventory processes, accessing reliable information about accurate demand and supply processes, making realistic forecasts for associated costs, and classifying inventory items. This process includes creating a prioritized system to guide inventory control efforts. Inventory management encourages optimizing cost reductions by efficiently utilizing internal resources. This strategic approach can contribute to sustainable success by enhancing the organization's competitive advantage (Alamri et al., 2016: 92-104).

The study by Vinodh and Aravindraj (2012:1186-1195) highlights the challenges faced by manufacturing companies in adapting to the dynamic changes in modern customer demand in the ever-changing business environment. Performance assessments were conducted based on lean and agile principles, relying on the zero inventory principle and safety inventory principles for variable market conditions. Agile inventory management is defined as the ability to respond to uncertainty and fluctuations (Sheffi, 2004: 51). According to the supply chain philosophy, production should be made in the right amount, at the right time and in the right places to minimize

the total cost throughout the system (Routroy and Kodali, 2005:7-17). In performance assessment systems, metrics such as inventory turnover rate and average order delivery time can be evaluated in the inventory management dimension.

Inventory turnover rate can be calculated as the ratio of products sold in a specific period to the average stock quantity during that period. A high inventory turnover rate indicates inventory shortages and reveals a competitive advantage in sales (Moyer et al., 2009: 105). A high turnover rate signifies that stocks are being efficiently utilized. Customer demand speed is a metric in the leagile approach that indicates how quickly customer demands are met. Average order delivery time is a metric measuring how quickly customer orders are delivered. The combination of both lean and agile strategies emphasizes fast and reliable delivery processes.

2.3.9. Customer Service

Customer service performance emerges as a crucial metric assessing an organization's interaction with its customers (Zelbst et al., 2010: 637-658). Traditional customer service has evolved beyond a focus solely on complaint management or issue resolution, transitioning towards a proactive service approach. Rapid response to customer demands, accurate and effective communication, solution-oriented work, and continuous monitoring of customer satisfaction are fundamental elements determining customer service performance. Research has identified various benefits of customer service, including increased customer loyalty, enhanced problem-solving processes, more effective understanding of customer needs, heightened sensitivity towards customers, strengthened ability to differentiate products, and increased market share (Abdallah et al., 2014: 13-27); (Wasti, and Jeffrey., 1999:245-257).

Customer service performance plays a key role in businesses achieving sustainable success. Organizations that respond quickly and effectively to customer expectations gain competitive advantage, while those integrated with league strategies both optimize their internal processes and increase customer satisfaction. Establishing correct customer relations and meeting customer expectations reduces costs, increases quality, provides improved product design with more flexibility, increases information exchange and improves delivery performance (Hsu, et al., 2009: 835-870).

In this context, in performance assessment systems, customer service dimension can be evaluated with performance metrics such as first contact problem resolution rate, customer churn rate, delivery reliability rate. These metrics can evaluate how leagile principles contribute to customer satisfaction and can be used to understand how your organization can adopt these principles.

2.3.10. Adaptability

Organizations must adapt to constantly changing customer expectations in order to ensure customer satisfaction and gain competitive advantage. Factors such as customer demands, market conditions and technological developments force businesses to constantly adapt and keep up with changes. Successful organizations create a flexible and highly adaptable structure in order to understand customer expectations and respond quickly to these expectations. Additionally, it adopts continuous improvement processes, taking into account customer feedback. The ability to adapt to changes allows organizations to expand not only to existing customers but also to new markets.

Managing cultural changes within an organization, ensuring the adaptation and adoption of employees, is crucial for organizational success and sustainability. In this process, support from top management and the commitment of employees to this change are important for establishing and maintaining organizational culture (Sawhney and Chason, 2005: 76-96); (Treville and Antonakis, 2006: 99-123). To achieve success in the cultural change process, factors such as leadership, communication, and participation need to be effectively managed (Sawhney and Chason, 2005: 76-96). In this context, within performance assessment systems, the adaptability dimension of organizations can be assessed through metrics such as problem-solving success rate and change management success rate.

2.3.11. Cooperation

Cooperation emphasizes interaction among stakeholders and sharing of information (Rigby et al., 2000: 178-186). Cooperations between organizations

contribute to more effective adaptation in operational processes and support a culture of cooperation, enabling them to reach market dynamics more efficiently (Guoquan, 2002: 39-44).

The Leagile cooperation perspective emphasizes a deeper interaction with the customer. Cooperation involving information sharing with customers enhances Research and Development (R&D) efforts for product or service improvement. Customer expectations and feedback provide valuable inputs in R&D processes (Yang and Zhang, 2013: 125-130). In this context, the cooperation dimension in performance assessment systems can be assessed through metrics such as R&D collaboration success rate and new product commissioning success rate.

2.3.12. Quickness

The literature on lean and agile strategies, manufacturing applications, and performance is characterized by significant complexity due to the temporal uncertainty associated with the contents and applications of these two paradigms (Narasimhan et al., 2006:440-457). Additionally, customers' increasing resistance to long lead times for products and services has become a critical factor for competitive advantage in today's industry environment. This situation has emphasized the importance of speed and sensitivity in today's industrial environment by some authors (Reichhart and Holweg, 2007: 1144-1172). In this context, it is seen that the boundaries of concepts such as agility (Goldman and Nagel, 1993: 18-38; Van Hoek et al., 2001: 126-147) and lean thinking are becoming increasingly blurred.

In this context, production lead time and processing time metrics can be used within the framework of the quickness dimension in performance assessment systems. Production lead time refers to the total time from the moment of request for a product or service until the completion of all production processes. This period consists of various stages such as material procurement, production, testing, packaging and transportation.

Azaron et al. (2006:150-168) and Perkgoz et al. (2007: 292-308) state that companies focus on customer response speed as well as cost and quality factors in their efforts to gain competitive advantage. They emphasize that short lead times play a

critical role in winning customer orders, especially in cases of make-to-order and engineered production. It is important to ensure reliable delivery times to increase customer satisfaction and attract more orders. Offering competitive delivery times and achieving reliable delivery performance is often as important as competitive pricing. At this point, while accurate and timely deliveries affect customer satisfaction, customer-oriented fast response times can contribute to companies' standing out in the market. In this context, responding to customer demands quickly, reliably, and effectively is an integral part of a successful competitive strategy.

Processing time is the time spent to complete a process or task and generally refers to the time from the beginning to the completion of a particular activity. In manufacturing organizations, processing time is always affected by various uncertain factors (e.g. processing time, unit failure, rush order) (Gomzalez-Neira, et al., 2017:399-426). Accurately measuring processing time allows processes to be optimized, resources to be used efficiently and a rapid response to customer demands. In this context, managing processing time can help organizations better adapt to competitive market conditions and focus on continuous improvement.

2.4. CREATING THE PERFORMANCE ASSESSMENT MODEL

While designing the performance assessment model, the fuzzy logic methodology is used to transform performance metrics determined in different types and scales into a uniform score and to make comparisons between metrics. Fuzzy logic is a mathematical approach used in the MCDM (Multi-Criteria Decision Making) technique to deal with uncertainty and imprecise decision-making. Instead of using exact numerical values to convey their opinions or preferences, decision-makers can use fuzzy logic, which is frequently more realistic and useful.

In general, MCDM techniques provide a structured and systematic approach to decision-making, allowing decision-makers to weigh multiple criteria (i.e., qualitative and quantitative criteria) and trade-offs when deciding between options. They are applicable to a wide range of decision-making problems from business and management to engineering, environmental decision-making, healthcare, and public policy, such as selecting the best location for a new facility, choosing the most cost-

effective solution for a project, or identifying the best investment opportunities (Sahoo and Goswami, 2023: 25-48). There are several types of MCDM methods that are developed or improved by different authors during the last decades (Taherdoost, H. and Madanchian M., 2023: 77-87). Traditional approaches, such as the Analytic Hierarchy Process, TOPSIS, and ELECTRE, have served as foundations for decision-making (Alvarez et al., 2021: 183). Nevertheless, new approaches have surfaced, such as fuzzy-based approaches for handling uncertainty and imprecision, data-driven models that use big data analytics and machine learning, hybrid approaches that combine several approaches, and multi-objective MCDM methods that take competing objectives into account (Sahoo and Goswami, 2023: 25-48). The main differences between these methods are related to the complexity level of algorithms, the weighting methods for criteria, the way of representing preferences evaluation criteria, uncertain data possibility, and finally, data aggregation type (Bączkiewicz et al., 2021: 417-425).

Fuzzy set theory formulated by Zadeh (1965: 338-353) represents an extended version of classical logic in a multivariate form. Fuzzy approaches have several advantages over clear approaches. The most important of these advantages is that they have more flexible decision limits, which are characterized by their ability to better adapt to a specific application area and reflect its characteristics more accurately (Tsipouras et al., 2008:447-458).

Fuzzy sets become more descriptive with vague words such as “many”, “very much”, “small number”, “large number”, “few”, “quite a few” (Zadeh, 1965:338-353). This approach reduces uncertainty and allows clearer results to be obtained. Behrouzi and Wong (2011:338-395) constructed the performance assessment structure using fuzzy methodology. The constructed performance assessment structure shows a comprehensive analysis of the applications of determined performance metrics in organizations. The study is described as user-friendly for organizations.

Fuzzy theory, the α-cut of a set represents a specific crisp range determined by the α value, which denotes a particular level of uncertainty. The fundamental definitions involved in fuzzy logic methodology are explained below.

- A universe X, the fuzzy set A is defined with a membership function $\mu_{\hat{A}}(x)$ associating each element x with a real number in the interval [0,1].

$\mu_{\hat{A}}(x)$ function value represents the degree of membership of x in the fuzzy set A (Zadeh 1965:338-353).

- A is a fuzzy set, and $\mu_{\hat{A}}(x)$ is the membership function of x in set A.

$\mu_{\hat{A}}(x)$ function is defined as in Equation (1). The expressions a and b in this function represent the best and worst performance metrics (Behrouzi and Wong 2011: 338-395).

$$\mu_{\hat{A}}(x) = \begin{cases} 1, & if x_i \leq a \\ 0, & if x_i \geq b \\ 1 - \frac{(x_i - a)}{(b-a)}, & if a < x_i < b \end{cases} \quad (1)$$

After calculating the metrics under each dimension using Equation (1), Equation (2) is utilized to compute the performance score for the respective dimension. The expressions in Equation (2) are detailed below.

$$\frac{\sum_{j=1}^{m} \sum_{i=1}^{n_j} \frac{\mu_{\hat{A}}(x)ij}{n_i}}{m} \text{x}100 \quad (2)$$

m: number of dimensions

n_j:performance metric in each dimension, j = 1,2,…, m

$\mu_{\hat{A}}(x)_{ij}$: fuzzy membership value of the *i*-th performance metric in the *j*-th dimension, j =1 ,2,….,m, i = 1,2…,n_j

Fuzzy membership values are calculated for each metric. To form the overall performance score, the average of the performance assessment scores for each dimension is taken (Pakdil and Leonard, 2013: 4587-4607). To achieve a high performance score, fuzzy membership functions should be close to 100. Organizations, through a fuzzy-based measurement system, can identify areas for improvement by measuring performance effectiveness (Bayou and De Korvin, 2008:285-304).

In the time effectiveness dimension, metrics associated with ″average set up time per unit”, ″average lead time per unit”, ″average cycle time per unit”, ″average

takt time", ″value-added time ratio", ″ratio of value-added activities to non-value-added activities" may be included.

To facilitate a clearer understanding of the application of the fuzzy method, an example of its usage is provided. Firstly, performance dimensions and the performance metrics under each performance dimension need to be identified. In the example, under the time effectiveness dimension, six performance metrics are defined as "average set up time per unit", "average lead time per unit", "average cycle time per unit", "average takt time", "value-added time ratio", "ratio of value-added activities to non-value-added activities". For each performance metric, values representing the best (A) and worst (B) outcomes have been identified. For example, in the company operating in the automotive supplier industry where this study has been implemented, these best and worst values are the targets set by the company in line with its strategic decisions. For the performance metric "average set up time per unit" under the time effectiveness dimension, the best and worst performance metrics have been determined as 0.61 and 0.68, respectively, in accordance with the company's strategy. Another value that needs to be determined is the actual performance level ($\boldsymbol{X_i}$). This value represents the current status of the relevant performance metric. After determining the current status as 0.67 for "average set up time per unit," and establishing the best (A), worst (B), and actual performance level values ($\boldsymbol{X_i}$), Equation 1 is utilized. With Equation 1, the $\boldsymbol{\mu_{\widehat{A}}(x)}$ value of the relevant performance metric is determined. Upon examining Equation 1, it is found that x_i = 0,6 lies between the best (0.61) and worst (0.68) values. Therefore, using the equation $1 - \frac{(x_i - a)}{(b-a)}$, a value of 0.14 is obtained. These procedures are repeated for all six performance metrics. After determining the $\boldsymbol{\mu_{\widehat{A}}(x)}$ values for all performance metrics, Equation 2 is utilized. In Equation 2, the $\boldsymbol{\mu_{\widehat{A}}(x)}$ values of each performance metric are summed up and then divided by the number of performance metrics. The resulting value is multiplied by 100 to obtain the score of the "time effectiveness" performance dimension.

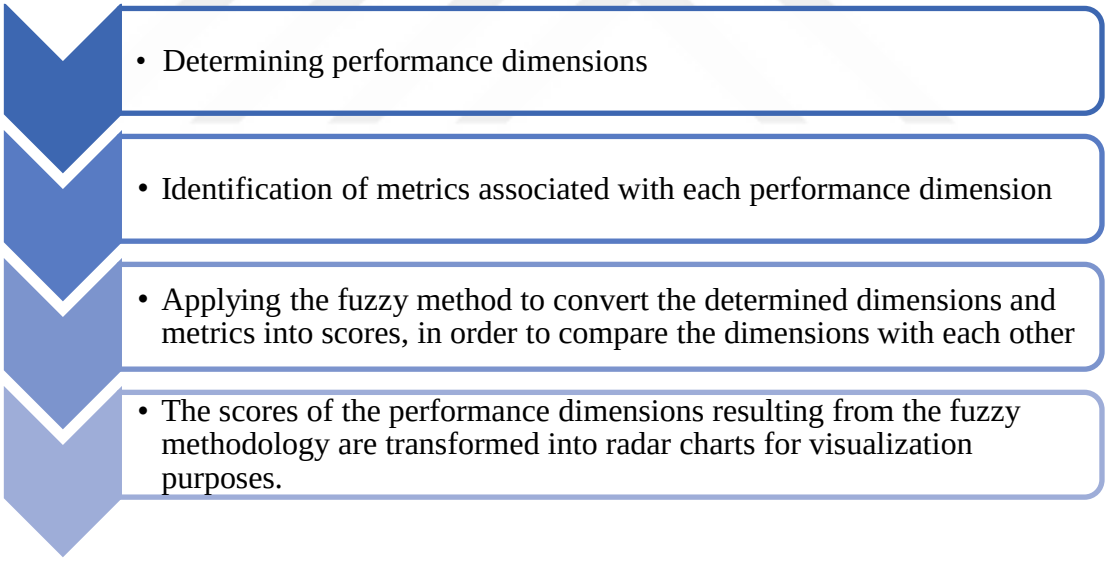
Through a literature review, it has been observed that various authors express different perspectives on the leagile performance assessment system. While there are studies compiling lean, agile, and leagile performance metrics, no study measuring the applicability of these metrics could be found. Within the scope of this research, after determining leagile performance dimensions and metrics, these metrics will be

transformed into scores using fuzzy methodology, and comparisons or relationships will be established among the metrics.

2.4.1. Usage of the Performance Assessment Model

The leagile performance assessment is a system that assesses businesses in creating a unique production and operational model by combining both lean and agile strategies. This system evaluates the performance of enterprises in enhancing both cost-effectiveness and gaining a competitive advantage by embracing agility principles such as customer focus, speed, and flexibility. Organizations that employ both lean and agile philosophies can use the proposed model to design and measure the leagile performance assessment system as outlined in Figure 5.

Figure 5: Key Steps of the Performance Assessment Model



Source: Created by the author.

Leagile performance scores for each dimension have been visualized using radar charts through the fuzzy methodology. The relationships between performance dimensions have been identified, and based on the application results, points that need improvement have been indicated. A holistic evaluation is targeted by visualizing

strong and weak performance dimensions together with the help of the radar chart. In this way, it is aimed to provide a tool through which organizations can identify areas that are open to improvement in terms of leagile practices.

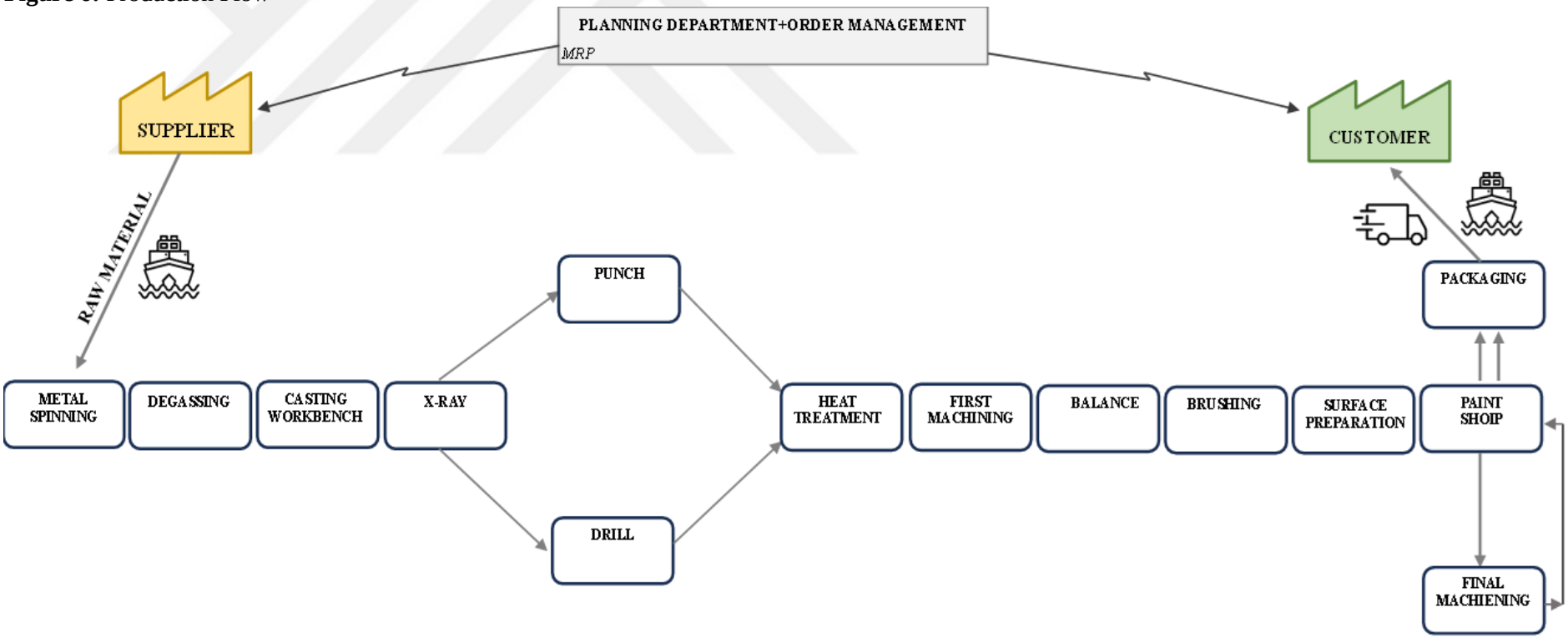
CHAPTER THREE
CASE STUDY

The case study was conducted in a company operating in the automotive supplier industry. The company specializes in producing aluminum alloy wheels for both passenger and commercial vehicles in the automotive industry. With over 3000 employees, the company conducts its operations in four different locations in Izmir. The approximate production capacity of the facilities is 8 million units. The company has two different customer groups: After Market (AFM) and Original Equipment Manufacturer (OEM). Products manufactured and sold under the company's own brand constitute the After Market group. The Original Equipment Manufacturer (OEM) group includes customers such as BMW Group (BMW, Mini), Daimler Group (AMG, Mercedes), Fiat Group (Alfa Romeo, Fiat, and Lancia), Ford, Honda, Lada, Renault Group (Renault, Nissan, Dacia), Toyota Group (Toyota and Lexus), VW AG Group (Audi, Bentley, Seat, Skoda, Porsche, and Volkswagen). In a general sense, the company has a total of 22 customer portfolios. This customer portfolio consists of customers who dominate the automotive industry and have high volume ordering capacity.

The company has communication points and warehouses in different countries and cities. Customers can conduct their purchasing transactions through communication points in Oxfordshire, Paris, Frankfurt, Munich, Turin, Barcelona, and Izmir. The company has warehouses in Bremen, Sunderland, Middlesex, and Zaragoza. Product shipments to customers are provided through both road and sea transportation.

The company produces two types of products: Casual Silver (CS) and Diamond model wheels. The difference between the two models is distinguished by the variability in the wheel style surface. Additionally, the production process for the Diamond model takes longer than the production process for the Casual Silver (CS) model. Figure 6 illustrates the production process sequentially, depicting the casting, machining, and paint shop processes.

Figure 6: Production Flow



Source: Created by the author.

3.1. ORDER MANAGEMENT, PLANNING, AND LOGISTICS ACTIVITIES

In accordance with the requests from customers, the order management department ensures the timely and quantity-specific organization of customer shipments and deliveries. The order management department serves as a bridge between customers and departments by coordinating with production planning, logistics, and customer relations. Orders from customers are created using the Enterprise Resource Planning (ERP) system. Original Equipment Manufacturer (OEM) customers' orders are periodically received through Electronic Data Interchange (EDI), and they are entered into the ERP system based on the delivery date requested by the customer. With the definitions in this module, sales schedules based on delivery date and shipment plans based on shipment date are automatically created. As a result of the transfer of customer orders, the requested quantity, shipment and delivery date information is controlled within the scope of production and material planning supply functions. If order variability differs from the mold capacity values agreed with customers and there are restrictions in production planning activities, customers are notified via e-mail or web portal and critical delivery dates and quantities are discussed. If there is an overcapacity order, additional mold investment is evaluated with the customer. If all quantities and dates can be met, the shipment and delivery plan is determined according to the quantity and date information transferred to the ERP system. Orders transferred to the ERP system in line with current customer demands can be viewed on the ERP screens and orders to be shipped daily and weekly can be viewed. The location, time and delivery date of transportation are planned. On the last business day of the week, the shipment forecast plan covering the next week is published to the logistics operations unit in Excel format on a customer basis. In the published table, the loading day, vehicle type, number and desired delivery date for each customer destination are entered. According to customer orders, the delivery document and transportation number for the next day's final shipment are created in the ERP system until 11:00 every day. The published daily shipment plan data is used by the logistics operations department and entered the ATLAS program, and requests are automatically forwarded to contracted transportation companies. The company that will provide the shipment approves the requests according to the loading location,

time, equipment type, quantity and delivery point, reservations are finalized and loading plan lists are created. The order management specialist monitors the shipment of customer orders in the correct quantity and on time, according to the desired shipment and delivery method. In case of disruption of shipment, it ensures coordination with relevant departments such as production, logistics and foreign trade.

In summary, Electronic Data Interchange (EDI) program is utilized during demand forecasting. The EDI system represents electronically transmitted orders from customers. EDI data is employed for weekly forecasts. Monthly and annual demand forecasts, on the other hand, use customer nomination information in the proposals made with customers. Nomination is the document where the features of the product and the sales forecast are made during the proposal stage with the customer. Customers have the flexibility to request orders based on increasing demand outside of annual order plans. Production plan scenarios that can quickly respond to increases in demand in the market and adapt the production process to this change are being studied. If such an increase in customer demands is met, the shipment of the products can be met by road. Road transportation is divided into two: transportation by truck and transportation by fast vehicles with small capacities. Transportation in small batches is a faster but higher cost type of transportation. While transportation by truck is more costly than sea transportation, it is lower cost compared to transportation in small batches.

3.2. PRODUCTION PROCESSES

The wheel manufacturing process initially starts with the preparation for the die casting process. The casting process involves the melting of aluminum ingots in a mould connected to a low pressure die casting machine. The melted metal is subjected to a degassing process to remove air bubbles from the liquid aluminum. This step is carried out to ensure that there are no unwanted air bubbles in the cast wheel, as this can affect the durability of the wheel.

After degassing, the liquid metal is directed to the low-pressure casting machine and cast into the mould. This casting process takes approximately 5.2 minutes. After casting, operators perform visual checks on the wheels. If there are

visually detected casting defects, these wheels are separated into scrap and sent to the melting furnace. The intact wheels are subjected to a marking process as indicated in the facility where they are produced.

After the marking process, the gross wheels are subjected to X-Ray inspection. This inspection is carried out to detect defects caused by the casting process. If defective wheels are detected, the melting process is repeated. Wheels that receive "Okey" from the X-Ray control proceed to the hub drilling process. The core drilling process involves drilling the runner area of the wheel. After the core drilling process, the wheel is transported to the stacking area.

Depending on the model that is ordered, the wheels pulled from the stacking area enter the heat treatment process. This process is carried out to increase the durability of the gross rim and varies depending on customer demands. The heat treating process takes approximately 7 hours for one wheel. After heat treating, the wheels are marked with a marking process indicating that they have been treated and are taken to the stacking area.

According to the order model, wheels taken from the stacking area enter the machining process. In this process, the gross rim is shaped by machining removal operation in accordance with the specification values requested by the customer. After the completion of the machining process, the wheels are subjected to leveling by the operators and the lug holes, hub depth and diameter and tyre surface thickness are measured. If undesirable values are detected in the measurements, the wheels are transported to the rework stacking area. After detailed measurements are made here, whether rework process will be applied or not is decided. If the rework process is applicable, the wheels are processed again and put into production. Processed wheels are transported to the air tunnel with the help of a conveyor, where the machining adhered to the wheel are removed. Wheels coming out of the air tunnel pass to the balancing operation. The balancing operation measures the oscillation of the wheel and checks whether it is in line with the specification values determined by the customer. If unwanted values are detected as a result of the controls, the wheels are moved to the rework area. These wheels are checked again by applying balance rework process. After the balance rework process, the wheels enter the MD860 measuring device. This device checks whether the hub, lug and runout dimensions of the

processed wheel are in accordance with the values specified by the customer. After the MD860 measuring device, the wheels move towards the leveling operation with the help of a conveyor. The burrs on the wheel are cleaned by the leveling operator with the help of sandpaper.

After the leveling operation, the wheel moves towards the brushing machine. In the brushing machine, the burrs and sharp edges remaining on the wheel are cleaned. After the brushing operation, the wheel is directed to the washing machine. The wheel, which is subjected to washing operation to remove the boron oil on the surface of the wheel, then enters the helium machine. Before the helium process, the operators put a plug in the valve hole of the wheel and a gasket on the style surface of the wheel. During the helium process, a leak test is performed to check whether the wheel leaks air when the tyre is connected. After the tightness test, the wheel is directed to the final leveling process. In this process, the burrs on the rim are cleaned again with the help of sandpaper. The cleaned wheels are taken to the stacking area and stacked.

According to the models whose order is approaching, the wheels that are taken from the stacking area enter the paint shop process. Wheels without front surface treatment (Casual Silver) are sent to the logistics warehouse after packaging. Diamond model products are transported to the front surface treatment operation. Here, machining is removed from the front surface of the wheel and processed. Processed wheels enter the paint shop process again, where they are washed and varnished. The varnish process is carried out to make the wheel visually bright. After the paint shop, visual controls are carried out in the final control step.

After visual controls, the wheels are directed to the packaging area, where palletizing is carried out according to the model type. The wheels stacked in the packaging area are planned according to the shipment date to be sent to the logistics warehouse.

3.3. LEAGILE PERFORMANCE ASSESSMENT FOR THE AUTOMOTIVE SUPPLIER INDUSTRY

Performance dimensions, performance metrics, best (A) target values, worst (B) target values, and actual performance level (X_i) values were determined for an

organization operating in the automotive supplier industry. Based on the determined target and current values, the $\boldsymbol{\mu_{\widehat{A}}}(\boldsymbol{x})$ values for each performance and the scores for each performance dimension were calculated as shown in Table 2. The best (A) and worst (B) target values were determined according to the organization's strategic roadmap. The actual performance level (X_i) value represents the current state of the organization. Fuzzy membership functions were evaluated according to the distance of each dimension to 100. In the radar chart in Figure 7, the closeness of the dimensions to 100 was visually expressed. Dimensions with a leagile performance score closer to 100 indicate that they are better in terms of performance. Depending on the closeness of the dimensions to 100, points that need improvement can be identified.

In radar charts, the size of the areas represents the high or low scores on that performance dimension. A large area represents a high performance, while a small area represents a low performance. As seen in Figure 7, the performance dimension with the smallest area and the lowest performance score is the delivery performance dimension with 13 points, while the performance dimension with the largest area and the highest performance score with 85 points is the cooperation performance dimension.

Table 2: Leagile Performance Assessment Dimensions and Performance Metrics

Leagile Performance Assesment Dimensions and Performance Metrics					Results			
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
Time Effectiveness	Average Set-up Time Per Unit	Average set up time in all processes per 1 product / avarage batch size	Production	Min	0,67	0,61	0,68	0,14
	Average Lead Time Per Unit	Total average lead time per 1 product / avarage batch size	Production	Day	20,12	16,70	23,05	0,46
	Average Cycle Time Per Unit	Total average cycle time per 1 product / average batch size	Production	Min	0,30	0,25	0,34	0,44
	Average Takt Time	Workable Time / Daily Customer Demand	Production	Min	0,76	0,67	0,85	0,50
	Value Added Time Rate	Value Added Time / Total Working Time	Operational Excellence	%	78,18	85,00	75,00	0,32
	Value Added Activite / Non Value Added Activite	Actual production quantity*average lead time / Total Working Time	Operational Excellence	%	75,48	85,00	70,00	0,43
Score								**38,17**
Quality	Powder Paint Rework Rate	Number of Products Entering Powder Coating for the Second Time / Total Number of Products Entering the Paint Shop Process	Production Quality	%	2,96	0,00	3,12	0,05
	Liquid Paint Rework Rate	Number of Products Entering Liquid Coating for the Second Time / Total Number of Products Entering the Dye Shop Process	Production Quality	%	2,23	0,00	2,45	0,09

Source: Created by the author

Table 3: Leagile Performance Assessment Dimensions and Performance Metrics

Leagile Performance Assesment Dimensions and Performance Metrics					Results			
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
	Factory Wastage Rate	Amount of Waste*100/Gross Casting Quantity	Production	%	18,67	9,12	15,67	0
	Customer Complaint Index	Number of Customer Complaints*1000000 / Number of Sales	Production Quality	ppm	10,49	9,15	14,78	0,76
Score								**22,50**
Cost	Cost of Poor Quality	Wastage Cost + Internal Scanning Cost + External Scanning Cost	Production Quality	Euro	13.004.803	2.000.000	15.000.000	0,15
	Finished Goods Inventory Cost	Finished Product Unit Cost*Number of Finished Products in Stock	Production Planning	Euro	1.191.740	803.332	1.606.664	0,52
	Returned Product Rate	Customer Return Items / Total Production Run	Sales	%	0,17	0	0,13	0
	Outsourcing Scanning Cost	Cost of Screening by 3rd Party Company	Production Quality	Euro	38.562	45.600	60.000	1
	Natural Gas Consumption Rate	Natural Gas Consumption (kWh) / Weight of Product Produced (kg)	Energy	kwh/kg	2,66	1,98	2,15	0
	Electricity Consumption Rate	Energy Consumption (kWh) / Weight of Product Produced (kg)	Energy	kwh/kg	3,95	3,05	4,51	0,39
	Ratio of Internal Scanning Cost to Sales	Total Time Spent for Internal Scanning * Labor Cost / Number of Sales	Energy	%	0,03	0	0,05	0,37
Score								**34,71**
Process	Overall Equipment Efficiency	Usability*Performance*Quality /	Production	%	69,52	85,00	68,12	0,08
	Capacity Utilization Rate	(1-Planned Maintenance - Planned Sample - Planned Break Time)*100	Production Planning	%	76,19	90,00	70,00	0,30

Source: Created by the author.

Table 2: Continued

Leagile Performance Assesment Dimensions and Performance Metrics					Results			
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
Score								**19,00**
Flexibility	Response Rate to Customer Requests	(Number of Responses to Customer Requests / Total Customer Requests)*100	Order Management	%	87,56	100	80,00	0,38
	Sample Repetition Rate	Number of Models Entering the Sample Process for the 2nd Time / Total Number of Sample Models	Ar-Ge	%	12,56	0	20	0,37
	Ratio of Models Adapted to Production	Number of Models Adapted to Production / Total Number of Models	Production Planning	%	68,75	75	60	0,58
Score								**44,33**
People Development	Blue Collar Turnover Rate	Cumulative Number of Personnel Quitted / Number of Personnel in the Relevant Month *100	Human Resources	%	38	10	30	0
	Number of Factory Suggestions	Total Number of Suggestions Entered into the System	Operational Excellence	Item	1958	2100	1500	0,74
	Number of Factory Kaizen	Total Number of Kaizens Entered into the System	Operational Excellence	Item	655	660	562	0,95
	Cumulative Kaizen Participation Rate	Number of Kaizens with Completed Status / Number of Personnel	Operational Excellence	%	56,19	75	50	0,25
	Cumulative Suggestion Participation Rate	Number of Suggestions with Completed Status / Number of Personnel	Operational Excellence	%	65,12	75	50	**0**,61

Source: Created by the author.

Table 2: Continued

Leagile Performance Assesment Dimensions and Performance Metrics					Results			
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
	Rate of Conversion to Kaizen Suggestions	Total Number of Kaizen / Total Number of Suggestions	Operational Excellence	%	53,11	75	50	0
	Blue Collar Absenteeism Rate	Total Absenteeism Hours / Total working hours - paid leave hours	Human Resources	%	5,44	2	6	0,14
	Training Participation Rate	Total Number of Personnel with Training Plans / Total Personnel Attending Training	Human Resources	%	85	100	75	0,40
Score								**38,63**
Delivery	Finished Product Transportation Cost	Shipment Cost of Finished Products	Logistics and Warehouses	Euro	8.836.083	7.000.000	10.000.000	0.38
	Inter-factory Transportation Cost	Number of Transportation Between Plants * Transportation Cost	Internal Logistics	Euro	1,190,411	500.000	1.000.000	0,0
	Late Delivery Rate	Number of Products Delivered Late / Total Sales /	Logistics and Warehouses	%	0,34	0	0,50	0,32
Score								**23,33**
Inventory Management	Inventory Turnover Ratio	Number of Products Sold / [(Inventory at the Beginning of the Period + Inventory at the End of the Period)/2]	Internal Logistics	%	15,16	12	18	0,47
	Average Order Lead Time	Average Order Lead Time	Logistics and Warehouses	Day	11,68	10,12	10,19	0
Score								**23,50**

Source: Created by the author.

Table 2: Continued

Leagile Performance Assesment Dimensions and Performance Metrics				Results				
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
Customer Service	Problem Resolution Rate at First Contact	Number of Customer Complaints Resolved at First Contact / Total Number of Customer Complaints /	Order Management	%	88	90	82	0,75
	Customer Churn Rate	Number of Lost Customers / Total Number of Customers	Sales	%	0,5	0	0,8	0,38
	Delivery Reliability Rate	Number of Orders Delivered on Time and Accurately / Total Number of Orders * 100	Order Management	%	78,65	100	70	0,29
Score								**70,75**
Adaptability	White Collar Problem Solving Success Rate	Number of White Collars Scoring 80 points and above in the Problem Solving Competency Exam / Total Number of White Collars	Operational Excellence	%	87	90	80	0,7
	Change Management Success Rate	Number of Pillars Scoring 70 points from the Pillars in the Production Management System / Total Number of Pillars	Operational Excellence	%	88,02	90	80	0,8
Score								**75,00**
Cooperation	R&D Collaboration Success Rate	Number of Successful R&D Studies / Total Number of R&D Studies Conducted with Customers	Ar-Ge	%	67	60	40	1
	New Product Commissioning Rate	Number of New Products that can be Produced / Total Number of New Products specified by the Customer	Ar-Ge	%	78	90	50	0,7

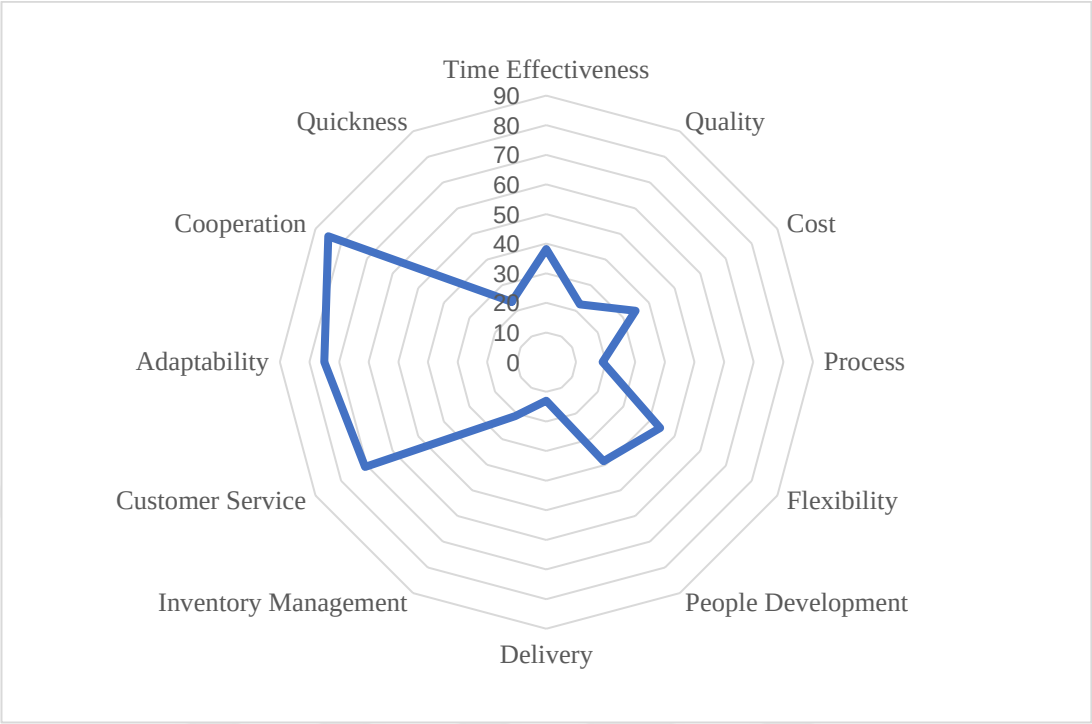
Source: Created by the author.

Table 2: Continued

Leagile Performance Assesment Dimensions and Performance Metrics					Results			
Dimensions	**Performance Metrics**	**Formulation**	**Data Sources**	**Unit**	**Actual Performance Level (X_i)**	**Best (a)**	**Worst (b)**	$\mu_{\tilde{A}}(x)$
Score								**85**
Quickness	Production Lead Time Per Unit	Time from the time the customer places an order for 1 product to the completion of production processes	Production and Operational Excellence	Day	17,22	11,68	10,19	0
	Processing Time	Time required for the creation of 1 product (value added time)	Production and Operational Excellence	Day	0,69	0,78	0,61	0,47
Score								**23,50**
Total Score								**41,28**

Source: Created by the author.

Figure 7: Radar Chart of Leagile Performance Assessment Scores



Source: Created by the author.

3.4. INTERPRETING THE RESULTS OF THE PERFORMANCE ASSESSMENT MODEL

Leagile performance assessment in the automotive supplier company was performed using the fuzzy methodology in Table 2. The total score in the leagile performance assessment system carried out in the automotive supplier company was found to be 41.28. The score value of each dimension and the resulting scores will be evaluated.

The time effectiveness dimension achieved a leagile performance assessment score of 38.17. Within the time effectiveness dimension, metrics include “average set-up time per unit,” “average lead time per unit,” “average cycle time per unit,” “average takt time,” “value-added time ratio,” and “ratio of value-added activities to non-value-added activities. Among these metrics, the average set up time per unit metric has the lowest score, with a score of 0.14. The organization has facilities in four different

locations. However, customer groups and product ranges vary across factories. Especially when the first two facilities were being established, the layout and investment activities of the factories were carried out according to the product range. While the first two facilities serve the customer group in the “After Market” group, where demand for small volume products (Casuel Silver model) is high, the other two facilities serve the market in which he original equipment manufacturer (OEM) group, where large volume products (Diamond model) are generally demanded. Nowadays, the increase in the demand for high-volume vehicles in the automotive sector has increased the popularity of large-volume products. For this reason, customer demands tend towards large volume products. To adapt to this situation, to meet customer expectations and to work with optimum capacity in all facilities, flexible production approach is tried to be adopted by trying to expand the model range of each facility. Since this situation increases the number of existing models on a plant basis, the number of model changes also increases during the transition to mass production. The increase in the number of model changes leads to an increase in set-up times.

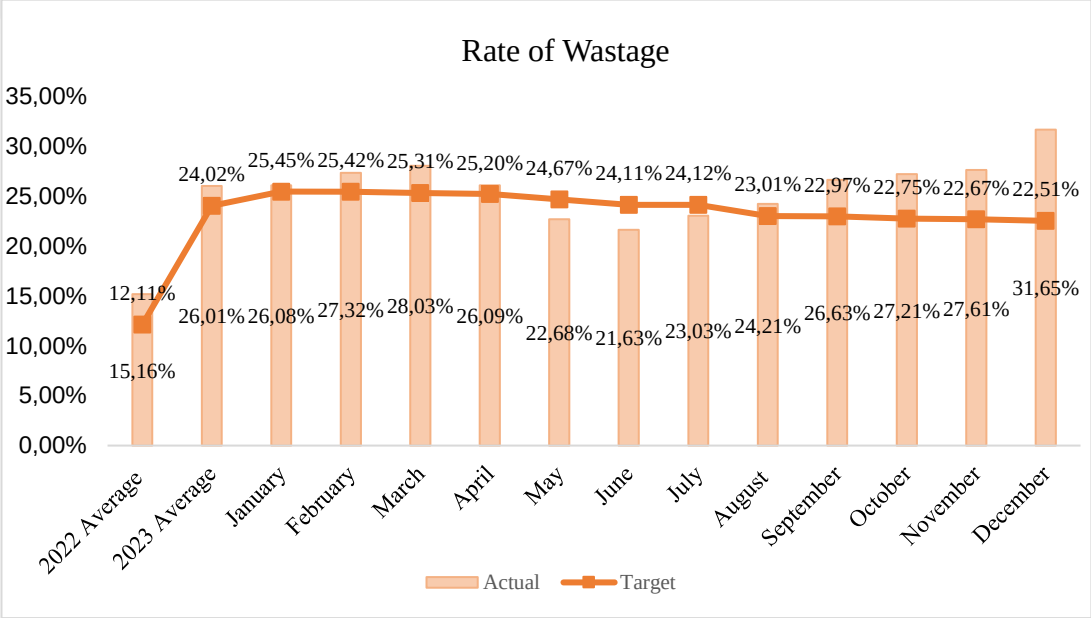
The average set up time per unit metric under the time effectiveness dimension can affect different dimensions. Especially in foundry and machining processes, the increase in set up times, which is most frequently experienced, increases the lead time, which is the total time from the production process until the products reach the customer. However, it also increases the Production lead time under the Quickness dimension. The products used in the mould changes in the foundry process and the first adjustment operations in the manufacturing process are separated as waste. While the processing time per unit within the organization is 0.67 days, the negativities caused by long set up times, high intermediate stocks, high number of non-value added movements such as transportation between processes, and adaptation of sudden orders from customers to production processes increase the average lead time per unit to 20.12 days and the Production lead time to 17.22 days.

The effect of the set-up time performance metric under the time effectiveness dimension has a negative effect on the performance assessment system as it causes an increase in the duration of the production lead time metric under the quickness performance dimension. In summary, the effect of the set-up time performance metric under the time effectiveness dimension negatively affects the cumulative factory waste

rate under the quality dimension and the production lead time under the quickness performance dimension.

The leagile performance assessment score of the quality dimension was realized as 22,50. Under the quality dimension, there are factory cumulative wastage rate, powder rework rate, liquid rework rate and customer complaint index metrics. The lowest score among these metrics is the factory wastage rate metric with a score of 0. The monthly target and actual values of the waste rates and the breakdown of the waste rate are shown in Figure 8 and Figure 9, respectively.

Figure 8: Monthly Wastage of Rate



Source: Created by the author.

Looking at the month-based wastage rate graph in Figure 8, the average wastage rate in 2023 was 26.01%. In Figure 9, the breakdowns of the 26.01% wastage rate are shown on a month basis. When the waste rate breakdowns in Figure 9 are sorted from the highest waste rate breakdown to the lowest waste rate breakdown, the average waste rate due to set up is 10.03%, the average waste rate due to machinery is 5.65%, the average waste rate due to human error is 3.96%, the average waste rate due to stock management is 2.37%, the average waste rate due to planning is 1.40%, the

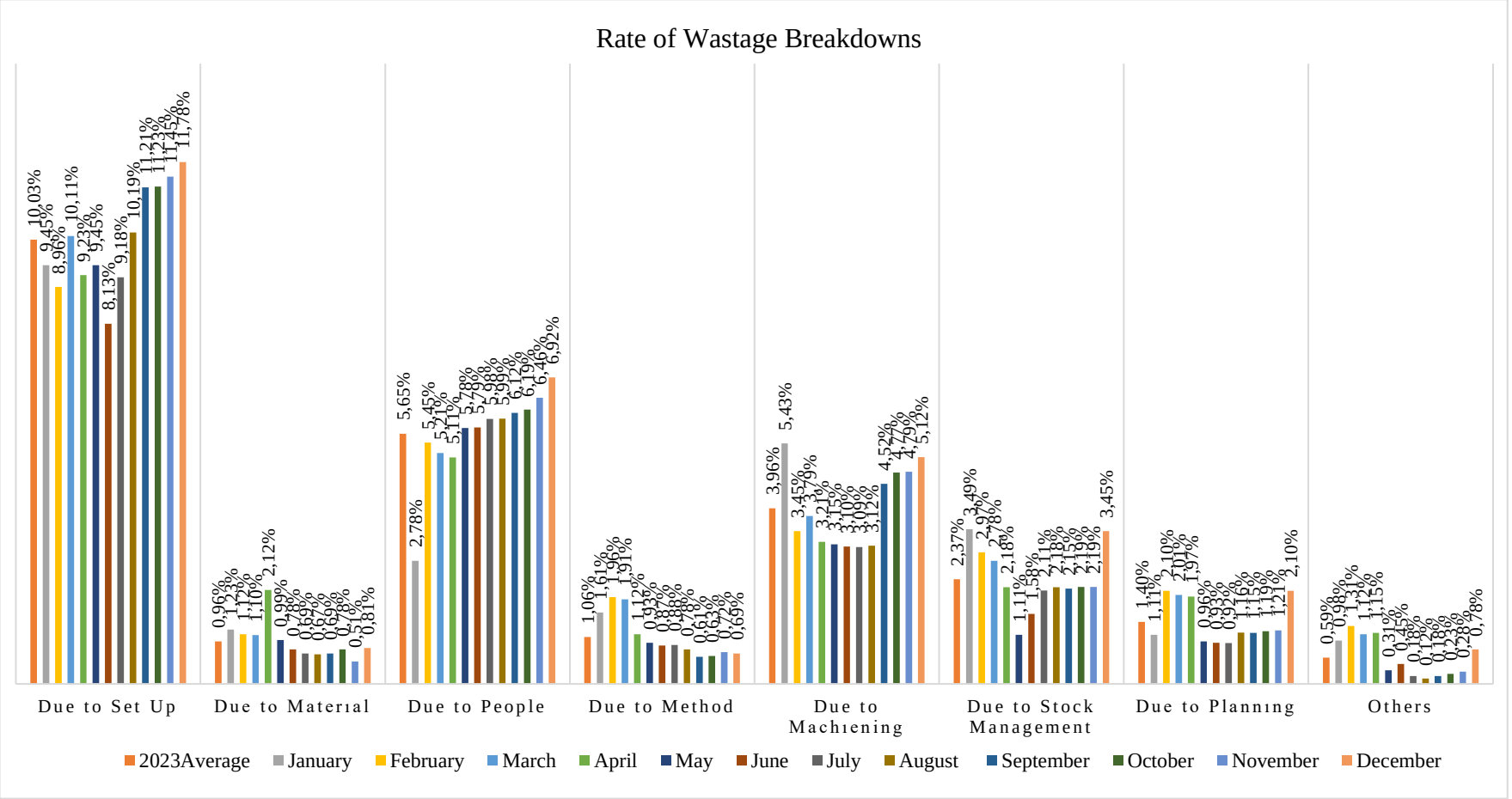
average waste rate due to method is 1.06%, the average waste rate due to materials is 0.96%, and the average waste rate other than the reasons under 7 main headings is 0.56%. As can be seen from the breakdown of the wastage rate shown in Figure 9, it is stated that the biggest reason that increases the wastage rate is due to set-up. It has been observed that the high set-up time, the long duration of special adjustment processes during model transitions and the products used during these adjustment processes are separated into wastage and therefore the wastage rates increase. In addition, trying to expand the product model range on a plant basis and integrating an unusual process may increase the wastage rates.

As can be seen in Figure 9, the second highest factor that increases the wastage rate is machine related. The high failure rate of the machines that perform the core drilling process in the machining process increases the machine-related wastage rate. In order to manage this process, the organization performs core drilling by increasing the cycle time in the first machining operation. The reason for the core drilling process is that an aluminum filter is placed on the core part of the product in order to ensure that the liquid metal does not fill the core part of the product while the liquid metal fills the mould during the foundry process. The aluminum filter has to be removed by drilling in the core drilling machines while the casting process of the finished product proceeds towards the machining process after the casting process. Due to the continuous malfunction of the core drilling machine, core drilling is performed on the first machining machines during the machining process. Performing this operation in the first machining operation increases the cycle time by 15% on average. Performing the core drilling process in the first machining operation causes the pieces of the carrot separated from the middle of the product to mix into the boron oil channels and mix among the machining collected in the central system. This machining goes to the foundry process as raw material and mix into the new product to be formed. The mixing of the carrot pieces in this process increases the metal ratio and the metal ratio is out of the specification value requested by the customer and the products are separated into wastage.

Another reason affecting the wastage rate is that after the casting process is completed in the casting machines, the quality control process is carried out in X-Ray machines, which is the first quality gate in production. Especially, the products cast

after the mould changes in the casting machines are of great importance for the quality of the batch to be cast. For this reason, after the mould changes, the products of the casting process must quickly enter the X-Ray control. However, the distance between the casting benches and X-Ray control benches in the facility is high and the products that have completed the casting process overcome this distance with a conveyor system, which increases the time for a product to enter X-Ray control by approximately 30-35 minutes. During this time, in order not to reduce the capacity of the casting machines, the casting process of the product continues to be carried out without receiving feedback from the quality gate. The fact that the X-Ray machine, which is the quality control gate, notifies the casting machines of a possible error situation after such a long time causes the products that the casting machine performs the casting process until the notification arrives to be wasted and the wastage rate increases.

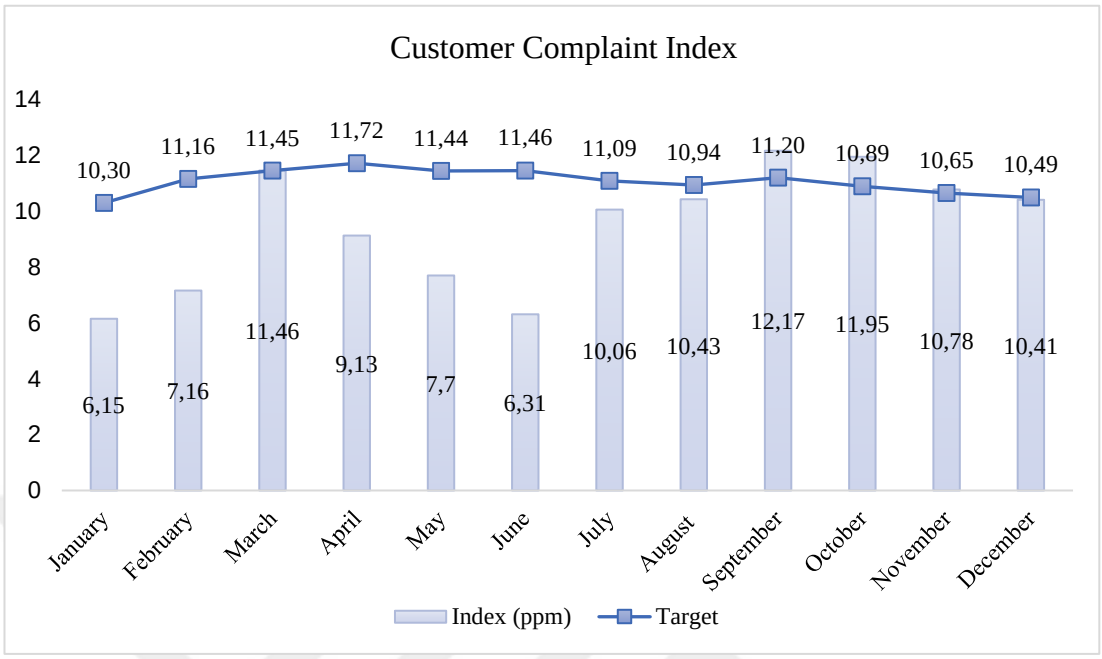
Figure 9: Rate of Wastage Breakdowns



Source: Created by the author.

Another metric under the quality dimension is the customer complaint index. The customer complaint index is calculated by dividing the number of customer complaints *1000000/ by the number of sales. The unit of customer complaint index is defects per million per piece (PPM). Defects Per Million Parts (PPM) is a widely used metric for measuring quality performance and is frequently applied, especially in the automotive industry. This metric is used to characterize the defects that occur in each production or supply process. For example, if only 1 defective part is detected out of 1 million parts purchased, the PPM value is set to 1. PPM is an important tool in assessing the stability and quality of a production process or supply chain. If the PPM value is low, this may indicate that the production process is more reliable and of higher quality. However, high PPM values indicate the presence of potential quality problems or inconsistencies in production processes. Figure 10 shows the organization's customer complaint index by month. When the customer complaint index in Figure 8 is analyzed, it is seen that there are realizations above the target especially towards the last months of the year. Trying to increase the number of models in the factories affects the production flow. Increasing the number of models also increases the set-up time. In the organization, due to the increase in the set-up time, planned stoppages are used in order to achieve the targeted number of productions. Failure to make planned stoppages increases the failure rates of the machines. Likewise, failure to perform planned maintenance increases quality defects.

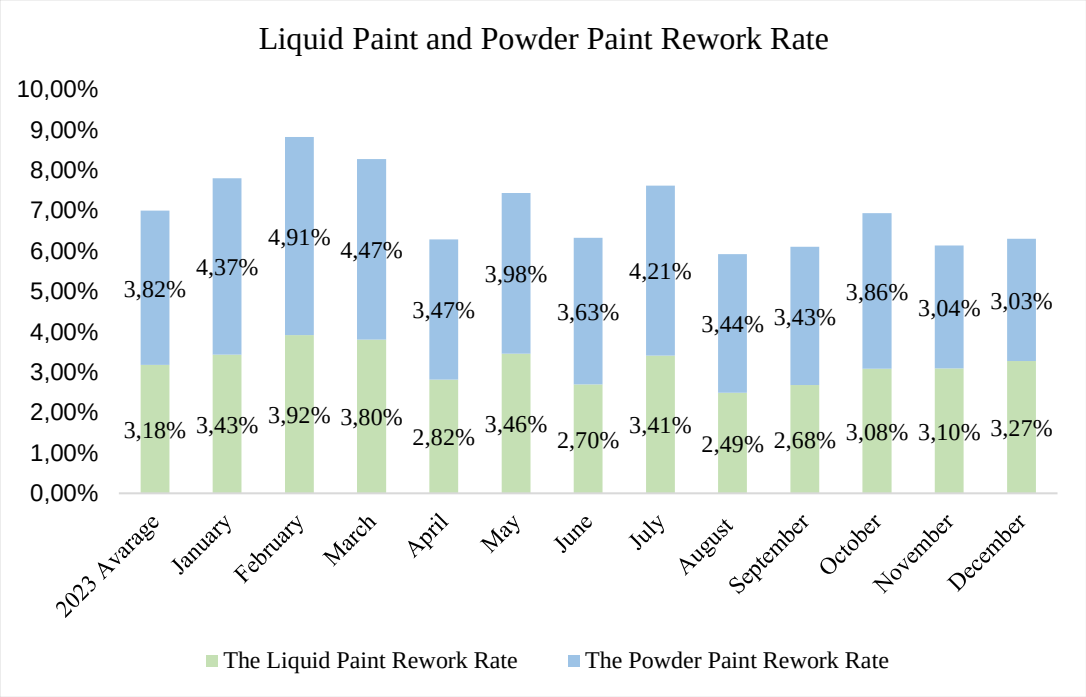
Figure 10: The Monthly Customer Complaint Index for the Year 2023



Source: Created by the author.

Other critical parameters monitored under the quality dimension are powder and liquid rework rates. Figure 11 shows the rework rates of liquid and powder coatings. Liquid and powder rework rates are calculated by dividing the number of products entering the dyeing process for the second time by the total number of products entering the paint shop process. Looking at the results of the graph in Figure 11, the average liquid rework rate was 3.18%, while the powder rework rate was 3.82%. After the product passes through the dye-house in the last process, the number of errors caught in the final quality control affects the powder and liquid rework rates. To eliminate the error caught, the product enters the dyeing process for the second time after the leveling process. Since this is a repetitive process and the product is caught in the last step, the cost per unit is much higher than the quality error caught in the first process.

Figure 11: Liquid Paint and Powder Paint Rework Rate



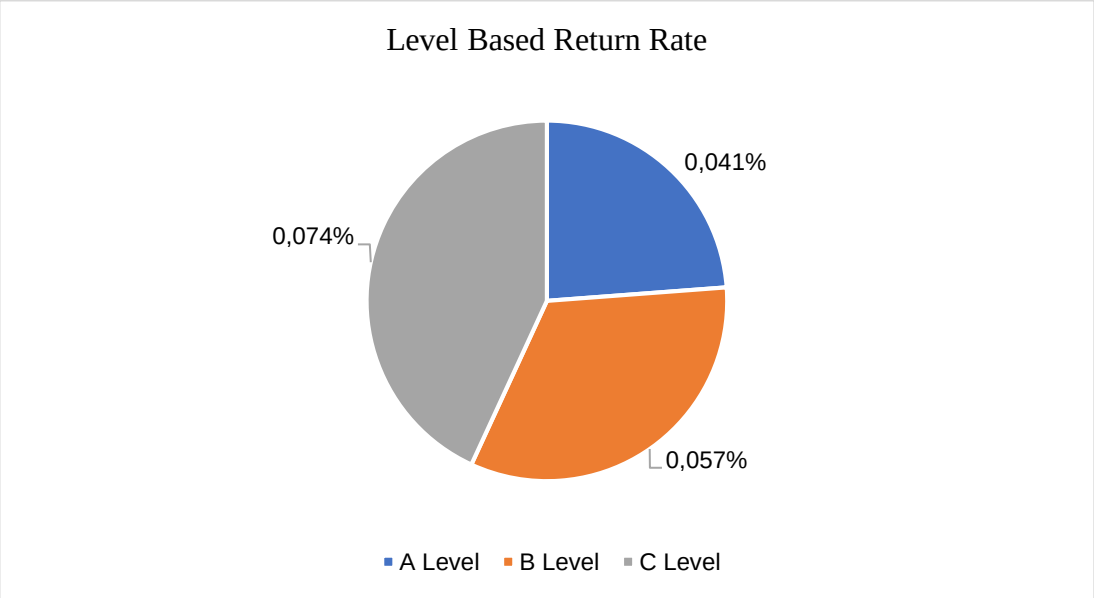
Source: Created by the author.

The leagile performance score of the cost performance dimension was 34.71. Under this dimension, metrics associated with “cost of poor quality”, “finished product inventory cost”, “returned product rate”, “outsourcing scanning cost”, “ratio of internal scanning cost to sales”, “natural gas consumption rate”, “Electricity Consumption Rate” are included.

Under the cost dimension, it is seen that the returned product rate metric is at critical level. Returned product rate represents the defective product detected by the customer. This rate is formulated by dividing the number of returned products by the number of production units. Figure 12 shows the level-based returned product rate. Each level has its own meaning. Level A represents the critical defect level. At this level, an escalation process should be initiated. When there is a quality problem at level A, the customer has the right to cancel the sales contract in accordance with the contract. A level A quality defect can lead to customer losses. B level error is a level of error where the customer expects an explanation by using various problem-solving tools (e.g. 8D, Six Sigma, Kaizen, etc.) to understand the cause of the problem and

solve the problem. At this level, systematic solution strategies are expected to be implemented by reaching the root of the problems. Level C is a level where smaller errors are usually detected, or single errors are detected. Again, it is expected to solve the problems with standard and rapid kaizens in the problem-solving tools. When the graph of the rate of returned products in Figure 12 is analyzed, it is seen that the customers detect most of the errors at level C.

Figure 12: Level-Based Return Rate

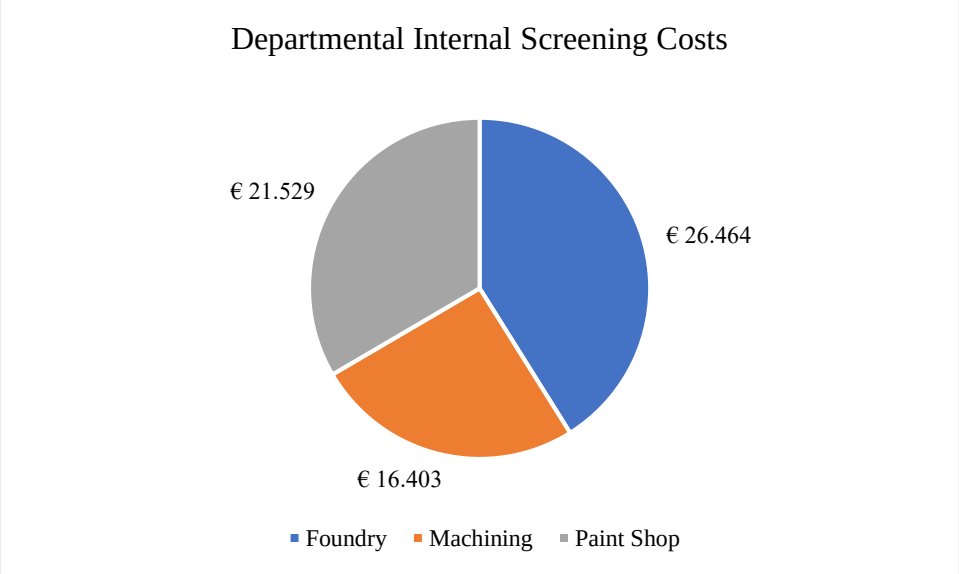


Source: Created by the author.

After the returned product rate metric, the cost of poor-quality metric appears to be critical. The cost of poor quality includes the sum of wastage cost, internal screening cost and external screening activities. Internal screening activities are defined as the separation of defective products detected at the quality gates located at certain points of the organization's production processes and the re-screening of the separated critical defective products. These screening activities are performed manually. In Figure 13, department-based screening activities are illustrated. Looking at the department-based internal screening activities, the department with the highest internal screening cost appears to be the foundry. Another reason for the increase in

the cost of poor quality is related to the Factory waste rate metric under the quality dimension. The increase in wastage rates indirectly increases the cost of poor quality.

Figure 13: Departmental Internal Screening Costs



Source: Created by the author.

The delivery to the customer of the products which are not caught during the production phase, which are out of the specification values requested by the customer, and the return of the product after the poor-quality product is caught by the customer increase the rate of returned products. At the same time, due to the factory-based expansion of the model range, experiencing quality problems in production processes and sending defective products to the customer without being noticed increases the cost of poor quality of the organization. Experiencing quality problems in production or delivery processes decreases the reputation of the organization in the eyes of the customer. In order to check whether the products delivered when the customer's trust decreases are within the desired quality specification values, customers apply to third party companies to have quality control of the products. The cost of this quality control process is reflected in the manufacturer company. In the applied organization, a total of 64.396 € was spent for external screening activities in 2023. Another critical reason

for the increase in the poor-quality performance metric under the Cost dimension is the increase in the factory waste rate. In 2023, € 12,898,460 was spent as wastage cost.

The leagile performance assessment score of the process dimension was 19. “Overall equipment efficiency (OEE)” and “capacity utilization rate” under the process dimension performance metrics are included. Among these metrics, the OEE metric appears to have the lowest score. The OEE performance parameter is formed by multiplying the availability, performance and quality metrics. When the sub-fractions of the OEE parameter are analyzed, the availability performance value, which is one of the multipliers, is lower than the other multipliers. The reason for the low availability is that sudden increases in customer demands increase production quantities. In order to meet the production quantities, planned maintenance stops are used. Failure to make planned maintenance stops can lead to unplanned stops. Unplanned maintenance stoppages adversely affect the performance, quality and availability of multipliers.

Another performance measure in the process dimension is the capacity utilization rate. The trend in the automotive sector is shifting towards larger and higher volume vehicles. This trend indicates that the volumes of products to be produced by the companies in the automotive supplier industry sector will increase. All four plants of the applied organization are not able to produce high volume products. Due to the shift of customer demand towards high volume products, capacity losses occur in two plants, while an increase in the number of production units is observed in the other two plants. At this point, transport between factories is made in order to optimize the capacity of 4 plants. While some of the processes involved in the formation of a product are carried out in different plants, the remaining processes can be carried out in different plants. This situation negatively affects the inter-factory transport cost performance metric under the delivery performance dimension.

The leagile performance assessment score for the flexibility dimension was 44.33. Under this dimension, metrics associated with “return rate to customer demands”, “sample repeat rate”, “model rate adaptable to production” are included. The reason for the low performance metric of the ratio of models that can be adapted to production under the flexibility dimension is determined as the volumetric size of the products. The organization has 4 facilities. 2 of these facilities are the facilities

where it is easy to produce large-scale products. When the plants were in the establishment phase of the organization, customer demands were mostly for small diameter wheels; however, today, due to the increase in the demand for high volume vehicles in the automotive sector, the popularity of large volume products has increased. As this situation could not be foreseen during the establishment phase of the plants, each plant of the organization does not have the flexibility to produce large diameter wheels. Therefore, the score for the performance metric of type of product that can be adapted to production is low. The organization is trying to adapt the production of large-volume products to the third and fourth plants in order to increase the flexibility of large-volume products in order to meet customer demands and not to reduce customer reputation. In this adaptation process, the wastage rate of large-volume models increases. However, capacities of the plants are tried to be used by transporting between the plants. Negativities experienced during the transport of the products between the plants may cause the products to be wasted. The risks of this process are quite high. If the quality problems probable to occur during transportation between the facilities are delivered to the customer without being noticed, the reliability of the organization on the customer side starts to decrease.

People development dimension, leagile performance assessment score was actualized in 38.63%. Under the mentioned dimension, performance metrics such as “blue collar turnover rate”, “number of factory suggestions”, “number of factory kaizen”, “cumulative kaizen participation rate”, “cumulative suggestion participation rate”, “rate of turnover of suggestions into kaizen”, “blue collar absenteeism rate” and “training participation rate” were present.

The opinions of the employees are given great importance within the organization and in this context, employees express their opinions through suggestion and kaizen systems. Blue- and white-collar employees working within the company have suggestion and kaizen targets. Departments carry out the process with their efforts to achieve kaizen targets and to generalize the process. When the number of suggestions and kaizen performance metrics under the people development performance dimension are analyzed, it is seen that the number of suggestions and kaizen is below the best score but close to it. When the cumulative suggestion and kaizen participation rate performance metrics are analyzed, their distance to the best

score is quite high. This is because not all employees in the organization are involved in the process. This is because not all employees in the organization are involved in the process. The main purpose of the continuous improvement philosophy is to disseminate the process to all employees and to ensure that they have this perspective.

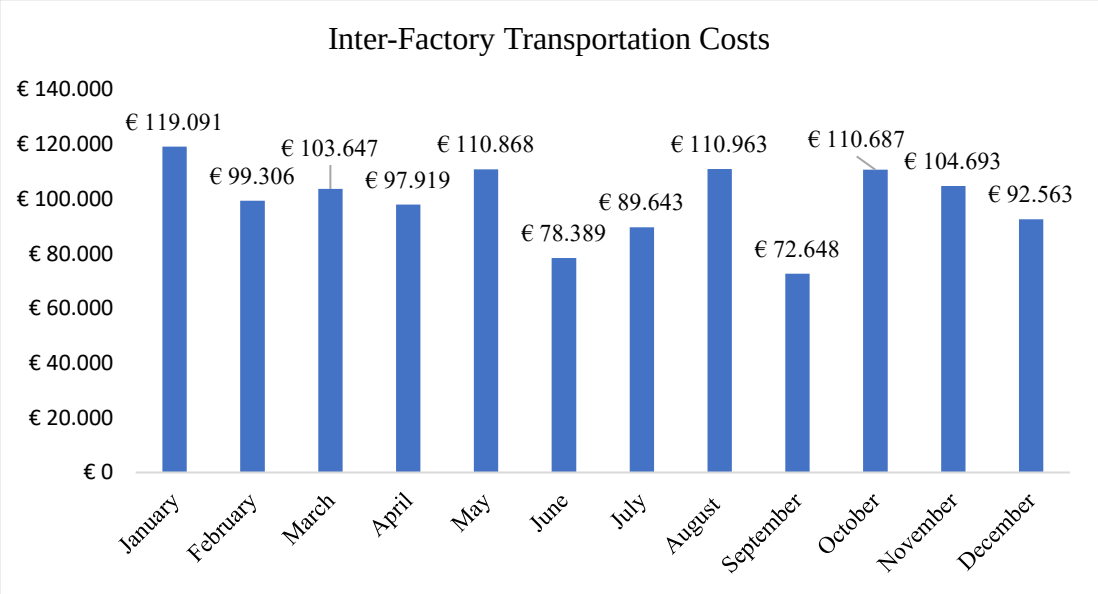
The high turnover rate, which is another performance metric, also negatively affects this process. As of 2022, the organization has made a reduction in labour costs based on the economic situation of the country. It has decided to work with subcontractors by dismissing employees with strong technical knowledge but with high age. This action for reducing labor costs returns to the company in the form of waste rate, cost of poor quality, work accidents and employees who do not adopt the company culture.

Delivery dimension, leagile performance assessment score. 23,33. Under the delivery performance dimension, “finished product transport cost”, “transport cost between factories” and “late delivery rate” performance metrics are included. One of the reasons for the high finished product transport cost is due to the fact that annual order forecasts are scenarioized in terms of transport charges by sea and in some cases by road trucks. However, the dynamic nature of the automotive industry causes rapid demand variability among customers. In order to adapt to this rapid variability, the organization has to adapt to short-term deadlines. Therefore, the strategy of more frequent deliveries in small batches is adopted. However, this type of delivery is three times more costly than sea transport. Although the delivery processes are passed on to the customers, the profitability per unit deviates from the annual plans. In small batch transport, delivery delays may occur due to production-related problems. This causes the vehicle to wait and thus increases the cost of transport.

Transport between factories is an internal activity in terms of delivery performance in the company. Inter-factory transport is considered as a process that covers the internal activities of the company's delivery performance. In terms of lean philosophy, transport between factories is considered as non-value added work. In order to manage the variability in customer demands and to provide fast responses to customers, it becomes mandatory to carry out inter-factory transport in order to keep the capacity utilization rate at the optimum level for each facility due to facility-based constraints. In Figure 14, in order to meet the demands of customers, the cost of

transport between factories on a monthly basis in 2023 is shown. The total cost of transport between factories in 2023 was € 1,190,411.

Figure 14: Inter-Factory Transportation Costs



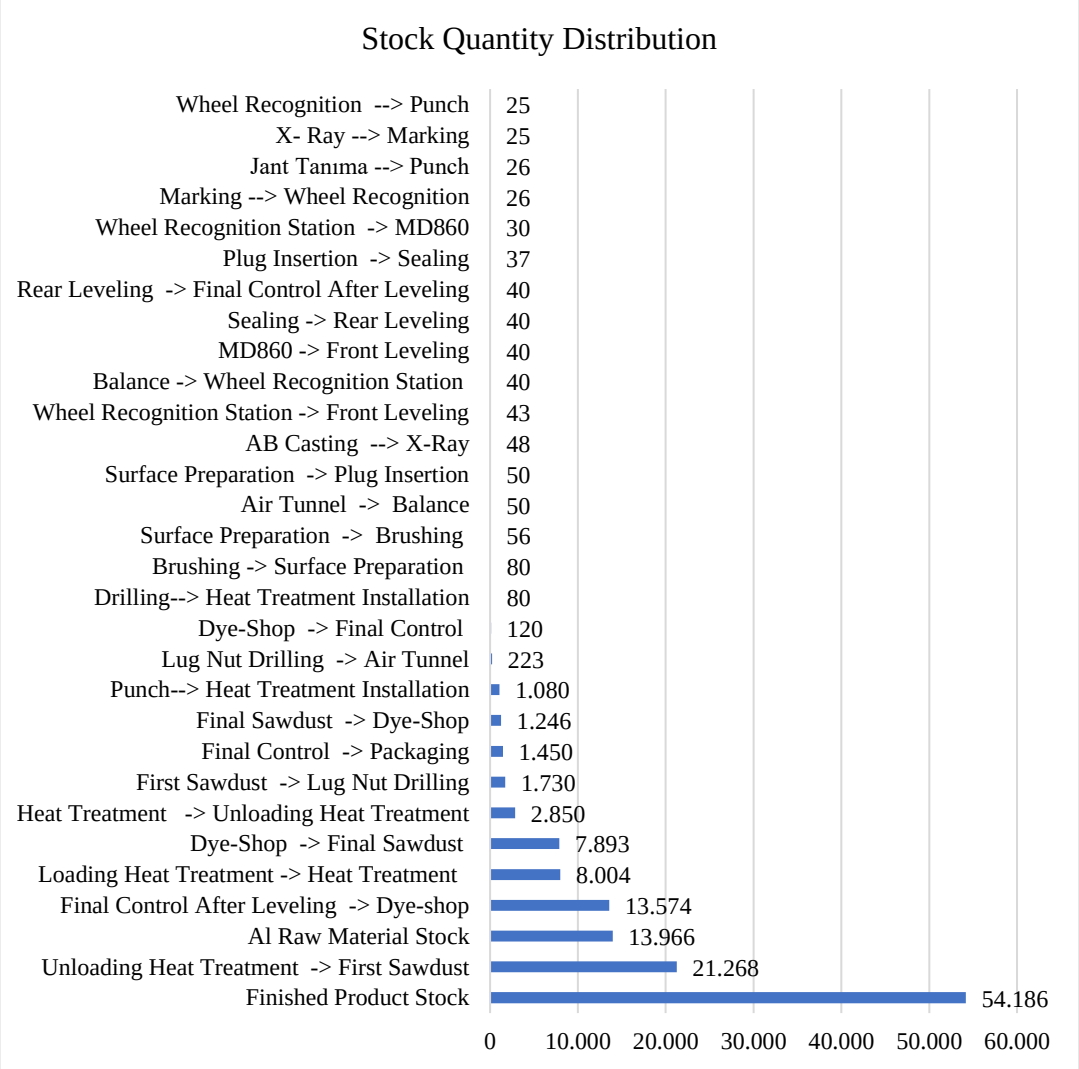
Source: Created by the author.

During transportation between factories, quality problems may occur in the transported products during transportation. In 2023, a total of 12,683 products were separated due to scratch and impact quality defects during transportation between factories. The cost of the separate products was € 253,660. The inter-factory transportation activity under the delivery performance dimension, the factory waste rate performance metric under the quality performance dimension and the cost of poor-quality performance metric under the cost performance dimension have a negative impact.

The leagile performance assessment score of the inventory management performance dimension is realized as 23.50. Under the delivery performance dimension, “inventory turnover ratio” and “average order lead time” performance metrics. When the performance metrics under the inventory management dimension are analyzed, it is shown in Table 3 that the average order delivery time performance metric is low. In this context, the value stream mapping workshop was conducted

inventory turnover rate is an important indicator that shows how fast the stocks turn and the inventory management performance of the business. The automotive supplier industry is often characterized by rapidly changing demands, innovation and technological developments. Therefore, it is important that the inventory turnover rate is in line with the dynamics in the sector. Figure 15 depicts the average finished product stock amount, average inter-process stock amounts and raw material stock data for 2023. Figure 15 depicts the average finished product inventory, average inter-process inventory and raw material inventory data for 2023. The inventory turnover rate is realized as 15.16 days. Customer order variability increases both finished goods inventory and inter-process inventory, leading to cost, performance and productivity losses. The organization had to rent an extra warehouse in 2023 due to customer order variability. Inventory management performance dimension negatively affects the performance metric of finished goods inventory cost under the cost performance dimension.

Figure 15: The Quantity of Raw Materials, Intermediate Stocks between Processes, and Finished Product Stocks



Source: Created by the author.

Customer service dimension, leagile performance assessment score. was realized as 81.75. Under the customer service performance dimension, “solution rate at first contact”, “customer loss rate” and “delivery reliability score” performance metrics.

Among these three performance metrics, the delivery reliability score appears to have the lowest score. In order to keep delivery reliability at a high level, it effectively utilizes the quality gates at the delivery points. After passing through the

production processes, the product is subjected to visual inspection at the quality gates in the warehouses before being shipped to the relevant warehouses. This process aims to maintain product quality and increase customer satisfaction. After the detection of defective products, replacements of defective products are kept in warehouses as safety stocks to prevent sending defective products to the customer. The cost of returning a finished product to the production facility after it has passed through all production processes and has been shipped is quite high. While the organization ensures delivery reliability, it has to bear the inventory cost due to the positioning of trust stocks in warehouses, supply cost due to the return of defective products to the production facility, and waste cost due to the evaluation of the products arriving at the production facility as waste.

Another critical performance parameter is the first contact problem resolution rate. This is the rate at which customer complaints are resolved within the time given by the customer to correct the error. 88% of customer complaints were resolved within the first contact period.

The customer service performance dimension is negatively related to the factory waste rate performance metric under the quality performance dimension, the finished product inventory cost performance metric under the cost performance dimension, and the finished product transportation cost performance metric under the delivery performance dimension.

Adaptability dimension, leagile performance assessment score. 75%. Under the Adaptability performance dimension, “white-collar problem-solving success rate” and “change management success rate” performance metrics are included. The organization focuses on the professional development of its employees and aims to support their career journeys. In this context, it aims to train employees with problem-solving skills within the company. In line with this strategy, the organization adopts the approach of supporting case analysis practices after the training organized to increase employees' problem-solving competencies. These practices play an important role in developing employees' ability to apply their theoretical knowledge in practice and adapt to real-world scenarios. The organization adopts this strategy, which aims to increase adaptation, in order to strengthen employees' problem-solving skills and to create a wide range of competencies within the company.

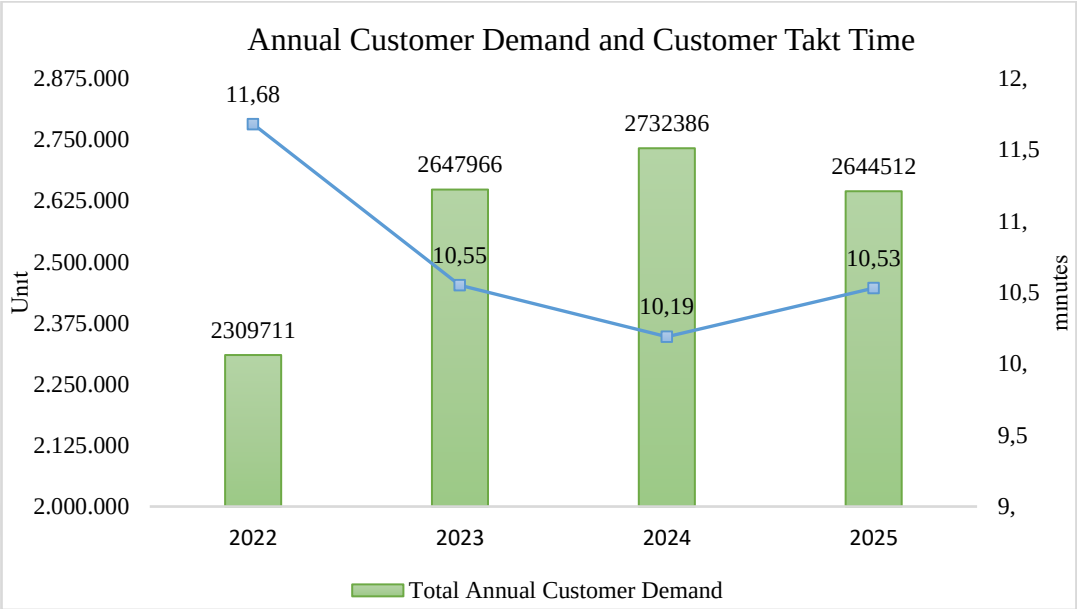
Major customers in the automotive sector have adopted the World Class Manufacturer (WCM) philosophy and established their methodologies within this framework. The supplier development departments of the customers expect their suppliers to adopt the World Class Manufacturer (WCM) perspective and conduct periodic WCM audits in this direction. This process is an important factor in business relationships with customers, and the applied organization has started to organize its own production management systems from this perspective. By combining their own needs and the literature, a production management system house was built. This house has 11 pillars. These pillars are occupational health and safety and environment, autonomous maintenance, professional maintenance, demand driven production, energy, new product introduction and termination, cost deployment, focused improvement, quality and workplace organization. Each pillar carries out its own work on the subject it is related to. The main purpose of establishing this structure is to align 4 different facilities, to solve problems with the right methods and to look at processes from a more systematic perspective. At the beginning of 2022, the organization took the first step towards a major change. The success of each pillar is monitored.

Cooperation dimension, leagile performance assessment score. 85%. Under the cooperation performance dimension, “R&D collaboration success rate” and “new product commissioning rate” performance metrics are included. The organization attaches great importance to R&D activities. With a team of 110 people, it continues its various activities to develop competitive products and ideas in the automotive industry, increase the efficiency of energy and resource utilization, and design new production methods. Since 2010, the Company has achieved successes such as 10 TÜBİTAK projects, 5 R&D projects carried out in cooperation with universities and industry, 1 Manufacturing Network project, 17 patents and 29 design registrations. The commissioning of new products parallel to customer specifications sustained within the framework of the organization's production management systems, especially under the leadership of new product commissioning pillars. The organization can offer its own designs to customers. It is also able to collaborate with customers to create joint designs.

Quickness dimension, leagile performance assessment score. was realized as 23.50. Under the quickness performance dimension, there are “production lead time per unit” and “processing time” performance metrics. Production lead time represents the total time from the beginning to the end of the production process of a product. Processing time refers to the time from the start to completion of a specific task or process and is a term often used to measure the effectiveness and performance of a job. This concept serves as an important metric for evaluating and optimizing the completion of a process, a project or a task. Processing Time plays a critical role in supporting businesses' efforts to effectively manage their processes, increase their ability to respond quickly and utilize resources efficiently. The main difference between processing time and production lead time: processing time refers to the value-added time it takes for a raw material to become a finished product, while production lead time is the total time it takes for a raw material to become a finished product. This time includes the waiting time of the semi-finished or finished product in stock.

Within the organizational framework, a value stream mapping study was conducted and customer takt times for the current year and future years were compared with production forecasts (Figure 16). In order to meet these customer demands, a bottleneck analysis was conducted to see the current situation (Figure 17). Bottleneck analysis is a strategic analysis methodology used to identify the most critical, weakest or slowest step in a process or system. This methodology aims to identify focal points to improve organizational effectiveness and performance of business processes. In this context, by examining the internal dynamics of a business, bottleneck analysis has the potential to guide efforts to use resources more efficiently and overcome performance barriers in processes.

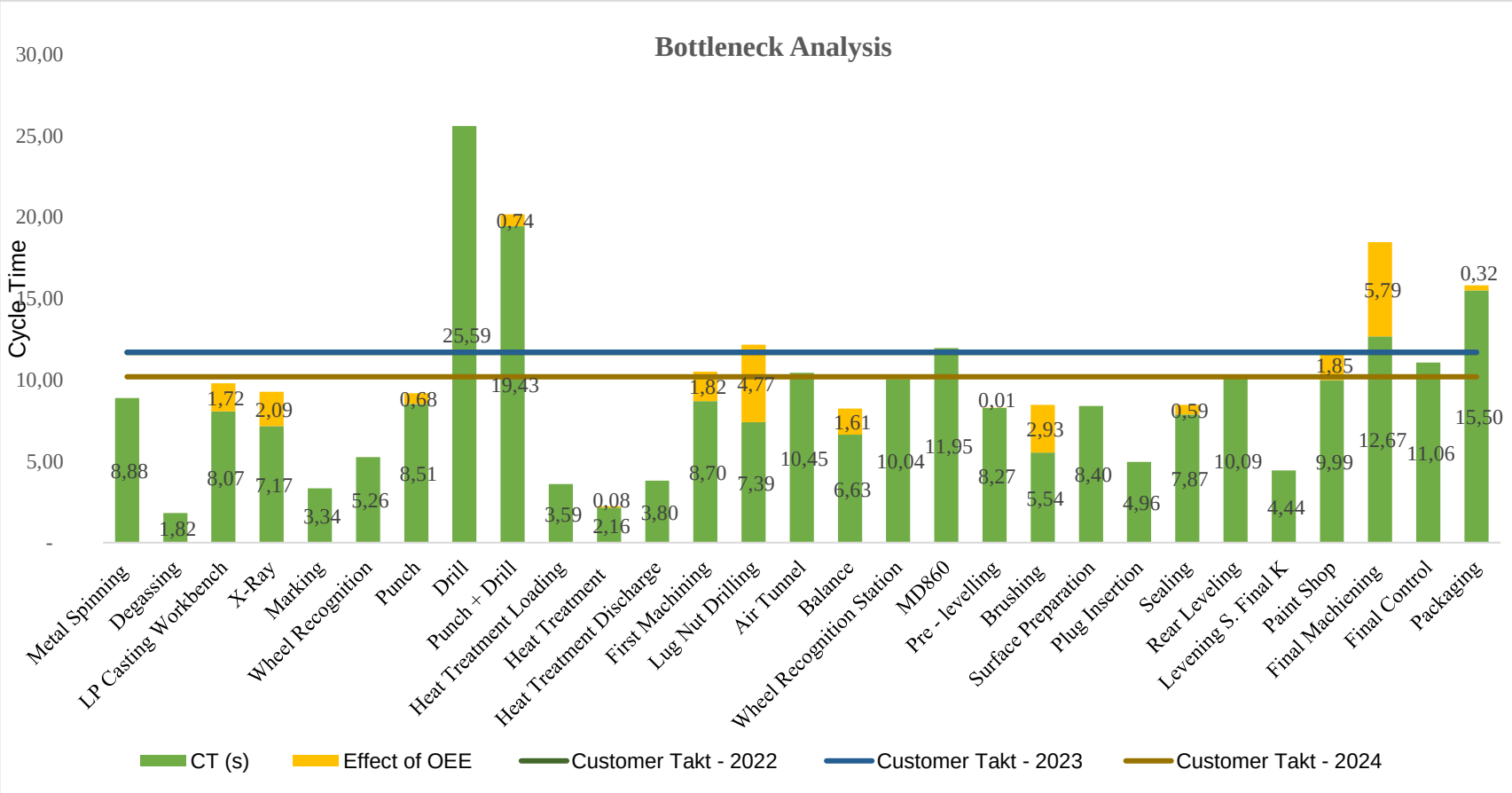
Figure 16: Annual Customer Demand and Customer Takt Time



Source: Created by the author.

Bottleneck analysis evaluates each step in a process in detail and determines which of these steps is the most critical point in the overall process. The identified bottleneck point is usually the step that determines the total duration of the process and does not have the most capacity. Process-based bottleneck analysis was performed in the organization. While performing the bottleneck analysis, another analysis was carried out regarding the impact of Overall Equipment Efficiency (OEE) concept. OEE is a performance measure used to evaluate a production system and understand the overall effectiveness of the process. OEE is calculated as the product of three key factors.

Figure 17: Bottleneck Analysis



Source: Created by the author.

During the bottleneck analysis in Figure 17, if there is a loss of quality performance or equipment efficiency of the relevant process, it is reflected in the analysis results. According to Figure 16, while the customer will demand 11.62 minutes for 1 product in 2022, it will demand 10.55 minutes in 2023 and 10.19 minutes in 2024. While customer takt time decreases with each passing year, production volumes remain approximately the same.

Leagile performance assessment system was created using fuzzy methodology for the automotive supplier industry. The total leagile performance score of the organization operating in the automotive supplier industry sector was 41.28. When the literature is examined, performance dimensions such as time, cost, quality, process, delivery, delivery, people development/human resources are dominant in lean performance assessment systems, while performance dimensions such as quickness, cooperation, flexibility, adaptability, customer service, inventory management are included in agile performance assessment systems. Leagile performance assessment system includes both lean and agile metrics. It includes cost, quality, customer service and time effectiveness dimensions.

The interactions between the performance dimensions in the leagile performance assessment system designed in the automotive supplier industry are presented in Table 3.

When the literature is examined, the performance metrics defined in leagile performance assessment systems are evaluated as time effectiveness, customer service quality and cost. In the leagile performance assessment system designed in the automotive supplier industry, the performance dimensions that affect each other are depicted in Table 3. The influencing performance dimension is the performance dimension that affects different dimensions positively or negatively. The affected performance dimension refers to the performance dimension that is positively or negatively affected by different dimensions. The most influential performance dimensions are time effectiveness and customer service performance dimensions. Among the performance dimensions, the most affected performance dimensions are quality, cost and delivery performance dimensions. In the leagile performance assessment system, the interaction among performance dimensions has been elucidated for each individual performance dimension.

Table 4: Interaction Between Dimensions

Dimensions Affecting	**Dimension of Effect**											
	Time Effectiveness	Quality	Cost	Process	Flexibility	People Development	Delivery	Inventory Management	Customer Service	Adaptability	Cooperation	Quickness
Time Effectiveness		X	X				X					X
Quality												X
Cost												
Process							X					
Flexibility		X					X					
People Development		X	X									
Delivery		X	X									
Inventory Management			X									
Customer Service		X	X				X					
Adaptability												
Cooperation												
Quickness							X					

Source: Created by the author.

Under time effectiveness performance dimension, there are performance metrics customized for the automotive supplier industry such as “average set-up time per unit”, “average lead time per unit”, “average cycle time per unit”, “average takt time”, “value added time ratio” and “the ratio of value added activities to non-value added activities”. The main reasons that negatively affect this performance dimension arise from the presence of 2 product groups and 2 different customer portfolios in the organization. Original Equipment Manufacturer (OEM) customer groups generally prefer diamond model products, while After Market customer groups prefer Casual Silver (CS) product group. OEM customers can also demand CS product group. However, since customer demands in the automotive sector tend towards diamond model products, the demand amount of CS model product is quite low by OEM customer groups. The applied organization has 4 facilities. While 2 of these facilities were designed for the production of CS model products with high customer demand in the first years of establishment, the other 2 facilities established in the following years were designed for the production of diamond model products, which appeal more to the OEM customer group. The change in the expectations of customers in the automotive sector has led the organization towards a flexible working perspective. In order to respond to customer expectations and to make optimum use of the production capacity of 4 plants, the organization is working to expand its model range to all plants by adopting a flexible production approach. Trying to expand the production model range to different facilities with the agile philosophy brings many problems. The first of these problems can be recognized by the low score of the set-up time metric under the time effectiveness dimension. In order for a model range to start mass production, it must be within the specification values required by the customers. For this reason, adjustment processes are carried out before mass production starts. While the increase in the number of models in the plants where the model range is tried to be increased increases the number of initial set-ups, production with unusual models also increases the initial set-up times. The high number of set up times and quantities increases the wastage rate due to the wastage of the adjusted products. We can see the effect in the performance assessment system in the factory cumulative waste rate metric under the quality dimension. In addition, the increase in set-up times increases the lead time. The effect in the performance assessment system has a negative effect on the production lead

time metric under the quickness performance dimension, as it affects the production lead time to increase negatively.

Quality performance metrics customized for the automotive supplier industry under the quality dimension are “powder rework rate”, “liquid rework rate”, “factory cumulative rate” and “customer complaint index”. When the conditions that negatively affect the factory wastage rate are listed, firstly, the set up times under time effectiveness can be said to be long. Secondly, the high failure rate of the machine that performs the core drilling process in the machining process and the fact that the core drilling process is performed on the first machining benches, which is the next process due to the continuous failure of the machine, negatively affects both the cycle time and set up time under the time effectiveness dimension and the waste rate under the quality performance dimension. Another reason is that after the foundry process, due to the fact that the core drilling process is carried out in the first machining operations, the pieces of metal coming out of the middle of the product whose core is drilled as a result of mixing into the boron oil channels, the metal coming out of the core part mixes between the machining to be collected in the central system and used as raw material and increases the metal ratio of the product to be formed, increasing the waste rate in the foundry process.

The last reason that negatively affects the factory wastage rate is the quality control process in X-Ray benches, which is the first quality gate in the foundry process. Especially the products to be cast after the mold (model) changes in the casting machines are of great importance for the quality of the batch to be cast. For this reason, the products that are cast after the mold change must quickly enter the X-Ray quality control bench. However, the fact that the distance between the casting benches and the X-Ray control benches in the plants is very long and the products that have completed the casting process move this distance with a conveyor system increases the time for a product to enter the X-Ray control by approximately 30-35 minutes. During this time, the casting machine performs the casting process of the product without receiving feedback in order to avoid downtime and capacity loss. The fact that the X-Ray machine notifies the casting machines of a possible waste situation after such a long time causes the wheels that the casting machine casts until the notification arrives to be wasted and the waste rate increases.

Other critical parameters monitored under the quality dimension are customer complaint index, powder and liquid rework rates. The average liquid rework rate of the organization in 2023 was 2.23% and the average powder rework rate was 2.96%. After the product passes through the paint shop, which is the last process, the number of errors caught in the final quality control affects the powder and liquid rework rates. After the leveling process, the product enters the dyeing process for the second time in order to eliminate the error caught. Since this is a repetitive process and the product is caught in the last step, the cost per unit is much higher than the quality error caught in the first process.

The wastage rate under the quality performance dimension interact with the time effectiveness, cost, process and quickness performance dimensions in the leagile performance assessment system. The increase in the set-up time, which is under the time effectiveness dimension, causes the products that are set up to be wasted. Time effectiveness dimension negatively affects quality dimension. Increasing the waste rate metric under the quality dimension increases the cost of poor quality under the cost dimension. An increase in the wastage rate negatively affects the consumption rate of natural gas and electricity resources spent during the formation of the product under the cost dimension. An increase in the wastage rate indicates poor quality. Therefore, an increase in the wastage rate negatively affects the quality multiplier of the Overall Equipment Efficiency (OEE) performance metric under the process dimension. Finally, an increase in the wastage rate leads to an increase in the production lead time. Therefore, an increase in the wastage rate negatively affects the production lead time under the quickness performance dimension.

Under the cost dimension, “cost of poor quality”, “finished product inventory cost”, “returned product rate”, “outsourcing screening cost”, “ratio of internal screening cost to sales volume”, “natural gas consumption rate”, “electricity consumption rate” - metrics are included. When the scores of the performance metrics under this dimension are analyzed, it can be said that the returned product rate performance metric is critical. After the production processes of the product are completed and shipped to the customer, the quality defects caught by the customer represent the returned product rate. This ratio is calculated by dividing the number of returned products by the number of production units. In the applied organization, the ratio of the number of returned products to the

number of production was 0.17%. Since the manufactured products are shipped to different countries, the organization has warehouses in common locations. In these warehouses, trust stocks are kept for each product group. The reason for this is that the organization is a supplier of the automotive main industry, and there is a risk of stopping production in the main industry. In the event of a negative situation such as production stoppage, all costs incurred are reflected to the supplier company. In order to avoid such bad scenarios, the organization keeps stocks in some locations.

The other critical performance metric under the cost dimension is the cost of poor quality. The cost of poor quality includes the sum of waste cost, internal screening cost and external screening activities. Internal screening activities are defined as the separation of defective products detected at the quality gates located at certain points of the organization's production processes and the re-screening of the separated defective products. External screening activities are considered as the quality controls of the products that are produced by 3rd party companies due to the decrease in the customer's trust in the organization which is a result of negative situations experienced with the customer. The cost of this quality control process is reflected to the organization producing the product. The realization of these screening activities is carried out manually. In 2023, the organization spent 42.888 € on internal screening and 38.562 € on external screening activities. Another critical reason for the increase in the poor quality performance metric under the cost dimension is the increase in the factory waste rate. In 2023, €12,898,460 was spent as waste cost.

The cost of poor quality, electricity and natural gas consumption rate performance metrics under the cost performance dimension are negatively affected by the high factory waste rate under the quality performance dimension.

“Overall Equipment Efficiency (OEE)” and “capacity utilization rate” under the “process” dimension performance metrics are included. Among these metrics, the OEE performance metric appears to have the lowest score. The OEE performance metric is formed by multiplying the availability, performance and quality multipliers with each other. When the sub-fractions of the OEE parameter are analyzed, the availability performance value, which is one of the multipliers, is lower than the other multipliers. The reason for the low availability is that sudden increases in customer demands increase production quantities. In order to respond to sudden production increases, planned

shutdowns are used. This increases the failure rates of the machines and indirectly affects the wastage rate. Another performance measure in the Process dimension is the capacity utilization rate. The customer trend in the automotive sector is shifting towards larger and higher volume vehicles. This trend indicates that the volumes of products to be produced by companies in the automotive supplier industry will increase. All four plants owned by the applied organization cannot produce high volume products. Due to the shift in customer demand towards high-volume products, capacity losses occur in two plants, while production volumes increase in the other two plants. At this point, in order to use the capacity of the 4 plants in an optimum way, transportation between the plants is carried out. While some of the processes involved in the formation of a product are carried out in different plants, the remaining processes can be carried out in different plants. This situation negatively affects the performance metric of transportation cost between factories under the delivery performance dimension.

For the flexibility dimension, “rate of response to customer demands”, “sample repeat rate”, “rate of models adapted to production” sub-performance metrics are included. The adaptable product performance metric under the flexibility performance dimension can be identified as an area for improvement. The reason for the low score of this performance metric is determined as the volumetric size of the products. Only 2 of the 4 plants of the organization can produce large volume products. The reason for this is that while customer demands were for smaller volume products when the first 2 plants were being built, customer expectations have changed and the popularity of high-volume products has increased. Since this situation could not be foreseen during the installation stages of the plants, each plant of the organization does not have the flexibility to produce large volumes of products. The applied organization is trying to provide production flexibility in its facilities to meet the demands of its customers in order not to cause customer loss and to create an advantage over its competitors in the sector. In the adaptation process of this flexibility, it was determined that the waste rates of large volume products increased in the factory waste rate performance metric under the quality performance dimension. In addition, transportation between plants is carried out in order to make optimum use of the capacity in the four plants. Transportation between factories under the delivery performance dimension increases transportation costs. While transportation between factories is carried out in order to increase flexibility, unfavorable

situations during shipment may cause the products to be impacted and consequently cause wastage. Flexibility performance dimension negatively affects the factory waste performance metric under the quality performance dimension and the inter-factory transportation costs performance metric under the delivery performance dimension.

Under the people development dimension, “blue collar turnover rate”, “number of factory suggestions”, “number of factory kaizens”, “cumulative kaizen participation rate”, “cumulative suggestion participation rate”, “turnover rate of suggestions into kaizens”, “blue collar absenteeism rate” and “training participation rate” performance metrics are included.

The concept of continuous improvement is highly valued within the organization. In this context, the company attaches importance to the ideas of its employees and uses a suggestion and kaizen system. In this system, after identifying the points open to improvement, employees can log in to the system and express their ideas. These ideas are first characterized as suggestions. Then, ideas that can turn into projects can be turned into kaizen. In this process, there is a reward system to increase motivation. When the performance metrics of the number of suggestions and kaizens under the people development performance dimension are analyzed, it is seen that the number of suggestions and kaizens are below the best score but close. When the cumulative suggestion and kaizen participation rate performance metrics are analyzed, the distance to the best score is quite high. This is because not all employees in the organization are involved in the process. The main purpose of the continuous improvement philosophy is to disseminate the process to all employees and to ensure that they have this perspective. When the data are analyzed, the reason for the high number of suggestions and kaizens and low participation rates is due to the fact that not all employees participate in the process. Another performance metric that can negatively affect this process is the high turnover rate. As of the last month of 2022, based on the economic situation of the country, the organization has made a reduction in labor costs. It has decided to start working with subcontractors by laying off employees with strong technical knowledge but high age. The reduction in labor costs has an impact on the factory waste rate under the quality performance dimension and on the cost of poor quality under the cost dimension. The reason for this effect is the preference for employees who do not adopt the company culture and do not establish a career plan for themselves.

Under the delivery performance dimension, “finished product transportation cost”, “transportation cost between factories” and “late delivery rate” performance metrics are included. One of the reasons for the low score for the finished product transportation cost performance metric is due to the fact that the annual order forecasts are made in terms of transportation costs by sea and in some cases by road trucks. However, the dynamic nature of the automotive industry leads to rapid demand variability among customers. In order to adapt to this rapid variability, the organization has to adapt to short-term deadlines. Therefore, the organization is forced to make more frequent deliveries in small batches. However, this type of delivery is three times more costly than sea transportation. Although delivery charges are passed on to customers, profitability per unit can deviate from annual plans. In small batch transportation, shipment delays may occur due to long set up times or a high number of faulty products. This causes the vehicle to wait and thus increases the transportation cost.

The inter-factory transportation performance metric under the delivery performance dimension is characterized as an internal activity. In terms of lean philosophy, it is characterized as waste between factories. Inter-factory transportation activities are carried out in order to respond quickly to customer expectations and to use the capacity of 4 plants in an optimum way. During transportation between factories, quality problems may occur. If the product is hit, dropped or any area is scratched during transportation, it may cause the product to be wasted. In 2023, a total of 12,683 products were separated due to scratch and impact quality defects during transportation between factories. The cost of the separated products was € 253,660.

The inter-factory transportation activity under the delivery performance dimension, the factory wastage rate performance metric under the quality performance dimension and the cost of poor-quality performance metric under the cost performance dimension have a negative impact.

Under the inventory management performance dimension, “inventory turnover ratio” and “average order delivery time” performance metrics are defined. Value stream mapping studies are carried out at certain periods in the organization. Value stream mapping is a tool that draws a business process from start to finish in detail and makes it easy to understand. Thanks to value stream mapping, wastes and unnecessary activities in the process can be identified. In this way, the factors that cause unnecessary inventory

to increase can be revealed. Inventory turnover rate is an important indicator of how fast stocks turn over and the inventory management performance of the business. The automotive supplier industry is often characterized by rapidly changing demands, innovation and technological developments. Therefore, it is important that the inventory turnover rate is in line with the dynamics in the sector. In the organization, the inventory turnover rate is 15,16 days. Order variability from the customer increases both finished product stock and inter-process stocks, leading to cost, performance and productivity losses. Inventory management performance dimension negatively affects the performance metric of finished product inventory cost under the cost performance dimension.

Under the customer service performance dimension, “solution rate at first contact”, “customer loss rate” and “delivery reliability score” are determined as the performance metrics. The performance metric with the lowest score among these 3 performance metrics is the delivery reliability score. In order to ensure delivery reliability, the organization checks its products at the quality gate before shipping the products to the customer in its warehouses located outside the country. This is designed to eliminate negative situations during shipment before they are sent to the customer. If a faulty product is detected, it is reinforced from the model-based confidence stocks kept in the warehouses and a complete product is delivered to the customer. In order to ensure delivery reliability, the organization has to incur warehouse costs and inventory costs for keeping the trust stock. However, after the detection of faulty products during shipment, the finished products are sent back to the production centers. These products are separated as waste at the production centers. The customer service performance dimension is negatively related to the factory waste rate performance metric under the quality performance dimension, the finished product inventory cost performance metric under the cost performance dimension, and the finished product transportation cost performance metric under the delivery performance dimension.

Under the adaptability performance dimension, “white-collar problem-solving success rate” and “change management success rate” are determined as the performance metrics. Major automotive industry customers are well-established companies that have adopted the world class manufacturer (WCM) philosophy and have established their methods within this framework. The supplier development departments of customers in

the automotive sector who have adopted this philosophy expect their suppliers to adopt the WCM philosophy and to carry out their work using the tools under WCM. In order to meet customer expectations, most of the companies operating in the automotive supplier industry are trying to establish and disseminate the WCM culture in their own companies. With this perspective, the organization started to build its own production management system in 2022 in line with its own needs. The production management system consists of 11 pillars. These pillars are occupational health and safety and environment, autonomous maintenance, professional maintenance, demand-driven production, energy, new product commissioning and termination, cost deployment, focused improvement, quality and workplace organization. Under these roofs, it aims to ensure that 4 plants use the same methods by approaching the processes methodically. Since 2022, change management success has been monitored every year. In addition, a mentoring program was initiated to improve the problem solving skills of employees in the organization. It aims to ensure that everyone working in the organization can carry out kaizen, problem solving forms, 8D, 6 sigma projects with the right methods and tools.

Under the cooperation performance dimension, "R&D collaboration success rate" and "new product launch rate" performance metrics are included. With a team of 110 people and various R&D projects, the organization achieves success in increasing energy efficiency, designing new production methods and developing competitive products in order to provide a competitive advantage in the automotive industry. Since 2010, the company has achieved significant successes such as 10 TÜBİTAK projects, 5 university-industry cooperation projects, 1 manufacturing network project, 17 patents and 29 design registrations. They are also actively involved in supplier development. The organization carries out the commissioning of new products in accordance with customer specifications under the leadership of new product commissioning teams within the scope of production management systems. In addition to its own design capability, the organization has the ability to offer customer-specific designs and the ability to collaborate with customers to create joint designs.

The effects of the performance metrics under the adaptability and cooperation performance dimensions are abstract. Even though the metrics under these performance dimensions are close to 100, it is difficult to analyze their effects mathematically. The significance given to adaptation and collaboration activities means responding effectively

to customer demands. The better this process is coordinated, the higher the level of collaboration.

Under the quickness performance dimension, there are “production lead time per unit” and “processing time” performance metrics. Production lead time represents the time from the moment the raw material arrives at the factory until it becomes a finished product. Production lead time performance metric enables effective management of processes, rapid response to customers and accurate resource management. Value stream mapping was used to measure the production lead time performance metric. In value stream mapping, bottleneck processes can be identified and processes that increase production lead times can be identified. When annual customer production demand forecasts and bottleneck analyses are brought together, although there are no major variations in our production quantities, customer takt time decreases year by year. According to the results of the bottleneck analysis, while the customer takt time for 1 product was 10.55 in 2023, the customer takt time will decrease to 10.19 in 2024. In order to meet this demand, the bottleneck processes should be analyzed in detail and aligned to the customer lead time. If no action is taken against the results of the bottleneck analysis, the prolongation of the production lead time will negatively affect performance by increasing the late delivery rate under the delivery performance metric.

CONCLUSION

It is important for organizations to design and manage performance assessment systems to gain and sustain competitive advantage. By combining agile and lean principles in a balanced way, the leagile performance assessment system offers the opportunity to successfully optimize lean principles such as efficiency and waste reduction along with agile principles such as customer orientation and flexibility. Although metrics specific to lean and agile approaches are defined in the literature, this study targeted to address the question of whether the leagile performance assessment system can be tailored to the field or industry in which it is used to improve understanding and applicability of the performance metrics. In this thesis specifically, lean, agile and leagile performance dimensions and metrics were determined in the automotive supplier industry sector and the applicability of the performance assessment model was demonstrated.

Initially, a literature review was conducted to determine the performance dimensions and metrics for constructing the lean, agile, and leagile performance assessment system. Decisions were made regarding the scope of the literature review and how the filtering process should be conducted. The literature review was conducted using keywords such as "leagile performance criteria," "leagile performance metrics," "leagile performance indicator," "leagile performance measures," "leagile performance requirements," "leagile performance guidelines," "leagile performance assessment," and "leagile performance evaluation." According to the results of the literature review, it was determined that there were 123 studies on determining leagile performance metrics. Among 123 studies, 50 repetitive studies were eliminated, and literature review was conducted on the remaining 73 studies. To create the leagile performance assessment system specific to the automotive supplier industry, performance dimensions “time effectiveness”, “quality”, “cost”, “process”, “flexibility”, “people development”, “delivery”, “inventory management”, “customer service”, “adaptability”, “cooperation”, “quickness” and their corresponding metrics were determined. Fuzzy methodology was used to convert the determined metrics into scores and to make comparisons between the metrics. According to the fuzzy methodology, positive and negative comments can be made about the performance

dimensions according to the proximity of each performance dimension to 100. The closer each dimension is to 100, the better it performs.

The case study was conducted in a company operating in the automotive supplier industry. The company specializes in producing aluminum alloy wheels for both passenger and commercial vehicles in the automotive industry. When examining the results of the leagile performance assessment system implemented in this company, the total leagile performance assessment score is found to be 41.11. The distance of the total leagile performance assessment score from 100 can be stated as 58.89 units. The individual performance dimensions that contributed to the formation of the total leagile performance score were analyzed separately. It was determined that the metrics under each performance dimension positively or negatively influenced each other. The interaction graph is depicted in Table 3. According to Table 3, the influencing performance dimension is the performance dimension that affects different dimensions positively or negatively. The affected performance dimension refers to the performance dimension that is positively or negatively affected by different dimensions. The most effective performance dimensions are time efficiency and customer service performance dimensions. Among the performance dimensions, the most affected performance dimensions are observed as quality, cost and delivery performance dimensions.

According to the performance assessment system applied in the automotive supplier industry, efforts are made to shape production processes to meet customer expectations and respond quickly to changing demands. The shift of customer expectations towards high-volume products has led to a reduction in capacity for 2 out of 4 facilities. Efforts to expand the model range increase the waste rates under the quality performance dimension in the facilities. The increase in waste rate increases the cost of poor quality metric under the cost dimension. While lean and agile are defined as different concepts in the literature, it has been proven that in organizations where both are used together, lean and agile performance metrics are interrelated, creating a domino effect of these relationships. Approaching the organization with an agile perspective will provide an advantage in the automotive supplier industry compared to competitors. However, it is essential to accurately analyze the potential losses that could occur in production processes with the adoption of agile philosophy.

Under the time effectiveness dimension in the leagile performance assessment system, "average set-up time per unit", "average lead time per unit", "average cycle time per unit", "average takt time", “value-added time ratio” and “the ratio of value-added activities to non-value-added activities” performance metrics, “waste rate” metric under the quality dimension, "capacity utilization rate" and "OEE" metrics under the process dimension are used in the automotive supplier industry. The specified performance metrics can also be used in different sectors other than the automotive supplier industry.

For organizations that integrate both agile and lean philosophies, leagile performance assessment systems provide significant advantages in assessing lean and agile performance metrics together, following their interactions, and identifying focal points for improvement. As observed while implementing the leagile performance assessment system in the automotive supplier company, lean and agile performance dimensions negatively influence each other. For this company, while agile performance dimensions such as cooperation, adaptability, and customer service have high scores, lean performance dimensions such as time effectiveness, delivery, and process have lower scores. This situation indicates that, while the company strives to increase customer satisfaction by quickly adapting to changing customer needs and demands, it incurs waste in its processes, thereby reducing profitability per unit. In the similar way, the design of leagile performance assessment can help organizations in determining where losses occur and identifying influencing or affected performance dimensions, providing significant advantages for organizations embracing both philosophies.

The leagile performance assessment system, designed in a company operating in the automotive supplier industry, has different potential areas for future researchers. In this study, the leagile performance assessment system was evaluated specifically for a company operating in the automotive supplier industry and the importance levels of the performance dimensions defined in the leagile performance assessment system are assumed as equal in this study. Future studies can compare organizations operating in two different sectors and also may adjust the system based on the importance of each dimension. Besides, the leagile performance assessment system can be also examined in terms of green deal and sustainability. These studies can evaluate the

effectiveness of the leagile approach in measuring, monitoring and reducing the environmental impacts of organizations. Additional leagile performance metrics specifically can be designed to evaluate green deal and sustainability performance.

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