

Istanbul Medipol University
School of Engineering and Natural Sciences
Graduation Project



PROJECT TITLE
Developing a Green Maturity Model for Technology-Based Start-Up Companies with Fuzzy AHP
PROJECT ADVISOR
Özgür EROL
TEAM MEMBERS
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Sponsor Company (if any):

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Project Title: Developing a Green Maturity Model for Technology-Based Start-Up Companies with Fuzzy AHP

Project Advisor: Özgür EROL YEŞİLSIRT

Team Members: Reyhan Selen Şen, İlayda Hanlı, Mehmet Safa Özoğlu, Ali Gökay Özdemir

Project Group Title:

PROJECT OVERVIEW/SUMMARY/ABSTRACT

In today's business world, adopting sustainable practices has emerged as a critical strategic goal for companies. While many organizations invest in sustainability strategies, changing from existing operations to greener approaches creates many challenges. However, if green and sustainable practices are adopted early in the start-up phase, those companies can achieve suitability in a better way. This paper presents the outcomes of a study focused on developing a Green Maturity Model for technology-based start-up companies using the Fuzzy Analytical Hierarchy Process (Fuzzy AHP). This maturity model offers a structured roadmap for technology-based start-ups to invest in sustainability in the early stages.

The research is aligned with both national and international sustainability goals, integrating insights from Türkiye's Twelfth Development Plan ('On İkinci Kalkınma Planı', 2024-2028) and the United Nations Sustainable Development Goals (SDGs) (THE 17 GOALS | Sustainable Development, 04.05.2025). The proposed Green Maturity Model has five levels: Initial, Repeatable, Defined, Managed, and Optimizing. Each level represents a phase in the adoption of green and sustainable practices. The Maturity Model also provides a roadmap for establishing a continuous improvement approach for creating sustainability for technology-based start-ups. These maturity levels are established based on a comprehensive set of criteria identified through a thorough review of existing literature. As a result, 15 sub-criteria were selected and organized into four main categories: environmental impact, sustainable product manufacturing, sustainability in the supply chain, and automation and digitalization. These criteria were ranked according to their weights using the Fuzzy AHP method and integrated into the Green Maturity Model.

Keywords: Sustainability, Green Manufacturing, Green Policies, Green Maturity Model, Continuous Improvement, Fuzzy AHP

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1. OBJECTIVE OF THE PROJECT

A technology-based start-up is a company that achieves profitability through research and development, new knowledge, and development of technology from a new perspective [3]. Bialetti defined technology-based startup-ups as "Technology entrepreneurship an investment in a project that assembles and deploys specialized individuals and heterogeneous assets that are intricately related to advances in scientific and technological knowledge to create and capture value for a firm [4].

According to TÜBİTAK BİGG data, it has been observed that the number of start-up companies that have started to receive significant investments between 2022 and 2024 has increased [5]. Along with this increase, there is also an increase in technology-based companies in the manufacturing sector. However, in order for technology-based enterprises to operate under sustainability standards in factory production processes, compliance with the rules and standards that must be followed, as in every company, must be ensured. These rules include measuring compliance with rules such as national and local legislation, industry-specific standards, sustainability criteria and ISO standards.

The main purpose of this article is to develop a Green Maturity Model that measures the suitability of technology-based start-ups for production activities and to test this model on start-ups.

Sub-objectives include:

- To establish the criteria that should be followed to reach the Green Maturity Model; these criteria and sub-criteria were determined by literature reviews.
- To use the Fuzzy AHP method under expert surveys to rank these criteria in order of importance.
- To ensure the integration of the Fuzzy AHP method into the Green Maturity Model.
- To ensure that the Green Maturity Model is a roadmap that directs companies to continuous improvement.
- Sustainability is the responsibility of the whole world, and this model should benefit the world and Türkiye.

2. LITERATURE REVIEW

The literature reviews conducted within the scope of the project include a comprehensive scan where Green Manufacturing, Green Agreement, Twelfth Development Plan, Product Life Cycle Management, Green Supply Chain, Green Production, Sustainability, Fuzzy AHP and so on are addressed as main topics below Table 1 provides a summary of reviewed materials.

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Table 1 : Literature Review

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Gartner's Handbook of Entrepreneurial Dynamics examines the entrepreneurial process together with environmental, social, psychological and institutional factors that affect the process, and emphasizes the interaction of multidimensional elements such as how a new business emerges, the entrepreneur's motivations, perception of opportunity, access to resources, social networks and institutional context. It also fills an important gap in the literature by providing a dynamic and systematic understanding of the entrepreneurial process with models supported by research based on extensive data. [3]	Handbook of Entrepreneurial Dynamics: The Process of Business Creation, Gartner W. [3]
This article defines the unique aspects that distinguish technology entrepreneurship from traditional entrepreneurship. The study defines technology entrepreneurship as a discipline based on the process of developing new products or services and also creating value and sharing this value among both individual entrepreneurs and stakeholders. Bailetti emphasizes that technology-based entrepreneurship differs in terms of factors such as innovation, growth, network effect and strategic partnership, while presenting a broad perspective by touching on the effects of technology entrepreneurship on the economy, universities, and industry. [4]	Technology Innovation Management Review Technology Entrepreneurship: Overview, Definition, and Distinctive Aspects, Bailetti T. [4]
This article examines the investments made in startups in Türkiye. While this article was being created, TURKSTAT and Startups Crunchbase have been used. These statistics mainly examine the rates of receiving investments and the sector-based rates of investments. In addition, it also mentions the types and ways of investing and mentions the importance of government incentives. Finally, by looking at all these things from the point of view of an entrepreneur, it also focuses on the problems that entrepreneurs may view. [5]	Türkiye’de Startup Yatırımları ve Finansmanı, B. İşletme, F. Dergisi, Ş. Sakarya, and S. İlkdoğan [5]
[6]This article discusses the directions for sustainable production for Industry 4.0. This article discusses the transformation of sectors such as digitalization, automation into production forces, contributing to sustainability. Industry 4.0 applications are strategies that enable companies to monitor their environmental impacts, reduce damage, and improve their sustainability performance. [7]	Sürdürülebilir Üretimde Endüstri 4.0’in Yeriözenir İ, Nakiboğlu G. [7]
This study focuses on sustainability in logistics. In the literature, these strategies are used to achieve the goals of reducing environmental impacts, resource efficiency, waste management and optimizing costs. It is concluded that these three strategies help to ensure sustainability in the logistics sector in economic and operational aspects. [8]	Sürdürülebilir Lojistik İçin Üç Öncelikli Strateji: Yeşil Lojistik, Tersine Lojistik Ve Yalın Lojistik, Süleyman M. et al. [8]

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<p>The 2024 State of the Energy Union and Governance of Climate Action Report is an assessment of the EU's progress towards achieving its energy security, sustainable energy production and climate goals. The literature focuses on the development of the Energy Union and the EU's efforts to manage energy more efficiently, cleanly, and securely. The Energy Union is particularly focused on three main objectives: energy security, strengthening the internal market and transitioning to a low-carbon economy. The literature focuses on energy transition policies, increasing investments in renewable energy sources and energy efficiency measures. In addition, it emphasizes the need for the unification of energy markets, the development of innovative energy technologies and greater harmonization of national energy planning. The literature emphasizes the need to accelerate the energy transition and develop policies through strong integration and cooperation. [9]</p>	<p>Energy Union and Climate Action Governance, European Commission. [9]</p>
<p>This article evaluates the integration of approaches such as eco-friendliness so greenness and agility for global software development providers. It is also being studied how these two methods can create a more sustainable structure together. In addition, this article has been published on the IEEE comprehensive platform. It has been shown as an example for those who want to measure the level of agility and environmental sustainability in software development processes. Finally, the article also reveals that by measuring these studies on about 30 companies, an energy saving of 15% has been achieved. [10]</p>	<p>Green-Agile Maturity Model: An Evaluation Framework for Global Software Development Vendors, Rashid N. et al. [10]</p>
<p>This article gives an overview of micro-enterprises in Turkey and deals with the relationship between green marketing strategies, carbon emission decoupling programs and the use of recyclable packaging and the financial performance of enterprises. The results of this article were put forward by conducting a survey for a total of 653 enterprises. [11]</p>	<p>Yeşil Pazarlama Stratejileri ve İşletmelerin Amaçlarına Etkisi, Gedik Y. et al. [11]</p>
<p>This article discusses the challenges that startups in developing countries may face when implementing sustainable business models. The effects of these difficulties on business model innovation, value creation, presentation and capture processes are examined. While examining these processes, a method mentioned in the article was used. Sustainable Value Exchange Matrix (SVEM) in line with the sustainability goals that initiatives should be subject to with this method, "How will they look for ways to improve their business development models?" it has been described. Last but not least, these studies conducted with 2 Brazilian startup companies were examined in a case analysis. [12]</p>	<p>Challenges of business models for sustainability in startups, Nunes A., Morioka S. et al. [12]</p>
<p>This article has developed a 4-level maturity model for companies. In addition, the model was tested by conducting a case study and trying to prove its applicability. The stages are as follows: Legal compliance and risk management, reducing costs by using environmentally friendly applications, to differentiate the brand through green products and processes, Corporate Social Responsibility (CSR) and Sustainable Competitive Advantage. The goal is to complete these stages and move on to the next stage. [13]</p>	<p>A Four-Stage Maturity Model of Green Manufacturing Orientation with an Illustrative Case Study, Shukla G., Adil G. [13]</p>

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<p>This study examines the effects of green technology R&D investments on corporate performance of energy companies and demonstrates the economic returns of environmentally friendly innovation. This case study, which covers energy companies in Beijing, analyzes the relationship between green R&D investments and corporate performance through both financial indicators and environmental sustainability criteria, and the findings show that green R&D investments increase the competitiveness of companies and their economic performance with environmental responsibility in the long term. In addition, external factors such as government policies, market pressures and corporate strategies seem to have affected R&D investments. This study contributes to the sustainable development literature by revealing the critical role of technology-oriented investments in the green transformation process. [14]</p>	<p>The Impact of Green Technology Research and Development (R&D) Investment on Performance: A Case Study of Listed Energy Companies in Beijing, China, Song P. et al. [14]</p>
<p>This study addresses the increasing importance of the concept of sustainability in sectors and the spread of environmentally friendly practices. In literature, sectors are undergoing transformation in many areas to protect natural resources and build a sustainable future, and the "Green Deal" is presented as an important example of these efforts. In this context, the emergence of the Green Deal, its sectoral effects and reflections in the logistics sector are analyzed in detail in the study, providing a broad perspective on global efforts for sustainability. [15]</p>	<p>Avrupa Yeşil Mutabakatı Ve Türkiye'deki Yeşil Lojistik Uygulamaları, Yolcu M. [15]</p>
<p>This study investigates the impact and importance Green Deal of European in Turkey by addressing the contradiction between global economic growth and ecological balance. In addition, this study addresses the development of new perspectives that Turkey may need in its fight against climate change while addressing the basis of the carbon footprint concept and the simplification of the complexities in calculation. In addition, it is seen that the Green Deal offers an opportunity in sustainable ecosystem management. [16]</p>	<p>Türkiye Perspektifinde Yeşil Mutabakat ve Karbon Ayak İzi: Tehdit Mi? Fırsat Mı? Ersoy M. et al. [16]</p>
<p>This article examines the economic model and its effects such as the green deal. Circular economy offers an innovative perspective for the continuation of sustainability. By looking at this, it contributes to the green deal by examining energy and climate policies for Turkey. [17]</p>	<p>Enerji Yönetimi ve Türkiye: Avrupa Yeşil Mutabakatı Çerçevesinde Bir Değerlendirme Yılmaz F. [17]</p>
<p>"This article has touched upon the formation of strategies for facility management by sustainability for the protection of energy. This article focuses on a model that aims to reduce environmental damage and keep costs at a minimum level through energy saving. Sustainability is targeted, and issues such as renewable energy sources are mentioned. This article mentions strategic planning for energy efficiency and decision-making processes by these strategies for facility managers to be suitable for green facilities. As a result, this article is an article that presents environmentally friendly approaches with innovative steps by showing guiding steps for managers who want to optimize for sustainability and energy use. [18]</p>	<p>Green Strategies During Lower of Occupancy: The Best Practices of Facilities Management for Energy Optimization in Commercial Office Buildings, Mirza Faizal M, Agus Salim N. [18]</p>

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<p>This article mentions what applications the European Union has made for the green economy and the realization of climate targets in 2050. The European Green Deal mentions energy scenarios for the future up to 2050 in its future plans. In this article, possible energy scenarios are examined by using 15 different energy reports. As a result of the research, it was mentioned that the 2050 targets can be achieved if the Paris Climate Agreement is acted in accordance with the plans envisaged by the EU Union the EU Green Deal. [19]</p>	<p>Avrupa Yeşil Mutabakatı ve Yeşil Ekonomiye Geçiş, Betül G. et al. [19]</p>
<p>This article discusses the applications made for the management area for sustainable facilities and the effects that these applications have on the facilities as a result of these applications. The article discusses the main issues for sustainable facilities, such as energy saving protection and the integration of applicable technologies that are environmentally friendly. As a result, this article provides important information for facility managers to achieve sustainable development goals as a guide in theory and practice. [20]</p>	<p>Journal of Turkish Operations Management Contents, Ecer B. Aktas A. et al. [20]</p>
<p>This article examines the combination of lean and green management approaches. It is an article that aims to increase efficiency by working on waste together with lean management, green management, the use of natural resources, and to show a way for environmental sustainability by reducing waste. [21]</p>	<p>Integrating lean and green management, Hallam C. et al. [21]</p>
<p>This article examines maturity model research, a widely used tool to assess and improve organizational processes, by determining the current status of organizations, and defining the steps required to reach targeted maturity levels. Wendler's systematic mapping study from 2024 addresses a comprehensive review of research on maturity models. The study classifies literature in this field, addresses the evolution of different maturity models, the methodologies used, and areas of application. It is a resource prepared to understand how the maturity model has evolved in the academic field and in which areas more in-depth research is needed. [22]</p>	<p>The Maturity of Maturity Model Research: A Systematic Mapping Study, Wendler R. [22]</p>
<p>This literature examines the supply chain management in terms of its application in the restaurant industry to promote environmental protection. It is stated that GSCM focuses more on the actual production processes and industries but less on services, especially in restaurants. Green supply chain management in the restaurant sector can be achieved by incorporating certain practices such as environmental sustainability, waste management, energy saving and green purchasing throughout the chain. This research sees that environmental issues, customer pressure and laws are among the issues that will help to establish green management policies. [23]</p>	<p>Developing Green Management Standards for Restaurants: An Application of Green Supply Chain Management, Wang Y. et al. [23]</p>

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<p>This article addresses the concept of waste-free production to support the circular economy transition in the Singapore context. It emphasizes that waste-free production is a critical strategy to increase resource efficiency and reduce environmental impacts in industrial processes. The study examines current technologies as well as their gaps in research and application. Also, it stated that the main obstacles encountered in the transition to a circular economy are at the technical, economic, and political levels. In particular, the inadequacy of waste management infrastructure, limited applicability of innovative technologies and industrial scaling difficulties are noteworthy. It is also stated that waste-free production will provide not only environmental benefits but also economic sustainability. [24]</p>	<p>Zero Waste Manufacturing: A Framework and Review of Technology, Research, and Implementation Barriers for Enabling a Circular Economy Transition in Singapore, Kerdlap P. et al. [24]</p>
<p>This article is a study on how to integrate green manufacturing for green manufacturing. This research provides a purpose to make it suitable for sustainability goals such as minimizing energy consumption and waste, using resources more efficiently. Also, environmental impacts for production processes, modeling through simulation and minimizing its results are aimed. As a result, this study mentions the applicability of the principles for green manufacturing to the lowest level and the contributions it can make to this sector through simulations. [25]</p>	<p>A Simulation Based Approach to Realize Green Factory from Unit Green Manufacturing Processes, Singh A. et al. [25]</p>
<p>The discussion on the “Reduce, Reuse, Recycle and Refuse” framework expands the traditional 3Rs of sustainability by introducing the concept of “Refuse.” This addition questions the root cause of overconsumption by demonstrating proactive consumer choices to reject unnecessary products and services. This literature explores the importance of integrating rejection into environmental strategies, which is necessary to effectively reduce resource depletion. [26]</p>	<p>Reduce, Reuse, Recycle ... and Refuse, Benton R. [26]</p>
<p>This collective study describes 3R (Reduce, Reuse, Recycle) initiatives and waste management policy developments in various countries by conducting an international comparative analysis. The literature discusses the integration of 3R principles into national waste policies, the promotion of circular economy models and the importance of public-private partnerships and highlights the need for international collaboration and knowledge sharing to effectively address global waste management challenges. [27]</p>	<p>International Comparative Study of 3R and Waste Management Policy Developments, Sakai S. et al. [27]</p>
<p>The Twelfth Development Plan, published by the Strategy and Budget Presidency of the Republic of Turkey, presents Turkey's development goals, economic and social policies in a comprehensive framework and focuses on priority areas such as sustainable development, digital transformation, green economy, innovation, and social welfare. In addition, strategies such as economic growth goals, macroeconomic stability, increasing exports and implementing technology-focused industrial policies are emphasized. One of the innovative aspects of the plan is the integrated approach to green and digital transformation processes, and in this context, structural change strategies such as the dissemination of environmentally friendly practices in line with the Paris Climate Agreement goals, strengthening digital infrastructure, financial sustainability and development of institutional capacity are also mentioned. [1]</p>	<p>On İkinci Kalkınma Planı (2024-2028) Türkiye Cumhuriyeti Strateji ve Bütçe Başkanlığı. [1]</p>

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In this article, Product Life Cycle Management refers to the management of the entire life cycle of a product from the idea stage to the introduction, growth, maturity and decline stages. PLC, which enables the management of all product-related data and processes through a central system, offers advantages such as increasing innovation and production speed, reducing costs and improving quality to businesses. In addition, PLM systems have strategic importance in the implementation of sustainable production, environmental impact monitoring and circular economy approaches. [28]	“Product Life Cycle Management,” [28]
Yıldız's study examines the effects of green marketing strategies of companies on supply chain management, innovation processes and corporate performance. The research has shown that environmentally sensitive marketing practices, especially green supplier selection and green innovation activities, positively affect both environmental and financial performance. [29]	Yeşil Pazarlama Stratejilerinin Yeşil Tedarikçi Seçimi, Yeşil İnovasyon Ve Performans Üzerindeki Etkisi, Yıldız B. [29]
This article was developed in 1993 as an evolution of earlier software process maturity frameworks, and its main purpose is to help organizations improve their software development processes by structuring them based on five maturity levels. These levels describe the progression from initial processes to well-defined and optimized processes and speak to their impact. The model has become fundamental to the software engineering field, and its influence extends beyond the software industry to the fields of project management and organizational development, and beyond. [30]	Capability Maturity Model, Version 1.1, Weber C, Curtis B. et al. [30]
Focusing on the impact of the maturity level of the human factor in ensuring security in software development processes, the study by Al Hashimi et al. argues that improving software security is directly related not only to technical measures but also to the human competencies of the teams, such as knowledge, skills and security awareness, by using the Fuzzy-AHP (Fuzzy Analytical Hierarchy Process) method in the decision-making process. The model is supported by fuzzy logic in order to better manage uncertainties and subjectivity in expert opinions. [31]	Securing Software Development through People Maturity: A Fuzzy-AHP Decision Making Framework, Al Hashimi H. et al. [31]
Nasser et al.'s study used the Fuzzy-AHP (Fuzzy Analytic Hierarchy Process) method under uncertainty conditions to assess the information security maturity levels of businesses, where decision-making processes related to information security are often shaped by uncertainty and subjective judgments, and in this context, the fuzzy logic approach was used to model the differences in expert opinions more accurately. The model developed in the study analyzes the current status of businesses by classifying the factors affecting information security maturity in a hierarchical structure and determining their weights. [32]	Measuring the Information Security Maturity of Enterprises under Uncertainty Using Fuzzy AHP, Nasser A. et al. [32]
This article focuses on the solution of the problem of selecting personnel in a workplace. It focuses on the selection of the right personnel through analysis including some variables and fuzzy numbers. [33]	Bulanik Analitik Hiyerarşi Prosesi İle Personel Seçimi Ve Bir Uygulama Metin D. [33]

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<p>This study demonstrates that the definition of a successful student can be made more objective with the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) approach, which is one of the multi-criteria decision-making methods in the successful student selection process, and the criteria set developed based on the opinions of decision makers (academicians and administrators) in the evaluation of various criteria such as academic success, social activity participation, leadership abilities and communication skills by weighting them in the application conducted on Ege University Faculty of Economics and Administrative Sciences students. [34]</p>	<p>Bulanık Analitik Hiyerarşi Süreci İle Başarılı Öğrenci Seçimi: Ege Üniversitesi İktisadi Ve İdari Bilimler Fakültesi Örneği, Ayşe K. et al. [34]</p>
<p>Developed using a combination of Delphi and Fuzzy comprehensive assessment methods, the Occupational Health Maturity Model provides a structured approach to assessing and improving occupational health management systems. By combining expert consensus and quantitative techniques to assess maturity levels, the model provides a robust framework for identifying opportunities for improvement in workplace health and safety practices. [35]</p>	<p>Occupational Health Maturity Model by combined Delphi and Fuzzy comprehensive evaluation methods, Fertat L. et al. [35]</p>
<p>Maturity models commonly used to assess organizational capabilities, but their development process does not typically adopt a common approach. De Bruin et al. (2005) address this by outlining a six-stage model, Scope, Design, Populate, Test, Deploy, and Maintain, that encapsulates the systematic construction of maturity models. Their article emphasizes stakeholder participation and continuous validation, an area of the literature that offers more robust model construction. [36]</p>	<p>Maturity Assessment Model Understanding the Main Phases of Developing a Maturity Assessment Model, De Burin S. et al. [36]</p>
<p>In addition to adopting new technology, digital transformation involves creating value and significantly changing organizational structure (Gimpel & Röglinger, 2015; Davenport & Westerman, 2018). Maturity models are based on the Capability Maturity Model (CMM) and can be used by organizations to assess and improve their digital capabilities (De Bruin et al., 2005; Mettler, 2011). However, many of the current models lack sufficient validation, open design processes, and scientific rigor. To fill these gaps, Kırmızı (2022) conducted three thorough literature reviews and published a framework grounded in design science theory (Hevner et al., 2004; Peffers et al., 2007). The approach ensures the development of a strong, verified digital transformation maturity model with theoretical and practical implications. [37]</p>	<p>Digital Transformation Maturity Model: Robustly and Rigorously Validated Maturity Model Development Framework and A Case Study, Kırmızı M [37]</p>
<p>Fuzzy AHP, or Analytic Hierarchy Process, is a decision-making tool that is really making waves across different fields, especially in public sector procurement. This is where uncertainty and personal judgments can really come into play (Saaty, 1980; Chang, 1996). In the healthcare arena, procurement decisions often require a careful balance between cost, quality, and regulatory compliance, and that's where fuzzy AHP steps in to tackle these challenges. Mena and Van der Horst (2011) highlight how crucial procurement is in public hospitals for maintaining transparency. Meanwhile, Çebi and Bayraktar (2003) and Dogan and Bener (2010) show how it is used for selecting hospital locations and assessing hospital performance. Singh and Sahu (2016) delve into the intricacies of hospital procurement decisions, and Liu and Liang (2015) introduce a fuzzy decision-making model to evaluate procurement criteria. Together, these studies really highlight the significance of fuzzy AHP in healthcare procurement, especially in situations where decision-making is shaped by a mix of often unclear factors. [38]</p>	<p>Kamu Hastanelerinde Mal Alım Kararlarının Bulanık Ahp Yöntemiyle Değerlendirilmesi Ve Gediz Devlet Hastanesi Uygulaması Evaluation of Product Purchase Decisions with Fuzzy Ahp Method in State Hospitals: Gediz State Hospital Case, Kemal Vatansever [38]</p>

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<p>The study of Dağdeviren, Akay and Kurt, in job evaluation and performance appraisal processes, provided a hierarchical structure for the evaluation of employees' job positions with the Analytical Hierarchy Process (AHP) method and the comparative determination of the weights of these criteria by decision makers, while subjective evaluations were transformed into more rational and consistent ones thanks to the systematic structure provided by AHP. [39]</p>	<p>İş Değerlendirme Sürecinde Analitik Hiyerarşi Prosesi Ve Uygulaması, Metin Dağdeviren, Diyar Akay, Mustafa Kurt [39]</p>
<p>Industry 4.0 is all about transforming manufacturing through digital technologies like IoT and AI. However, for small and medium-sized enterprises (SMEs), jumping on board can be tough due to limited resources and a lack of clear paths for implementation. Maturity models, like the one created by Etkeser in 2019, help gauge how ready a business is for Industry 4.0 by looking at key areas such as technology, strategy, and processes. These models often employ techniques like the Analytic Hierarchy Process (AHP) to measure the significance of varied factors, including manufacturing software and organizational strategy, in assessing maturity. Other models, like the industry 4.0 Readiness Model from Li et al. in 2018, focus on the need for strategic alignment and organizational readiness. Etkeser's research, through real-world case studies, shows that a well-structured maturity model can effectively assist SMEs in embracing Industry 4.0 technologies by evaluating their current capabilities and offering a clear roadmap for their digital transformation journey. [39]</p>	<p>Endüstri 4.0'a Geçişte Olgunluk Modeli Oluşturulması Ve Yol Haritasının Belirlenmesi: Türkiye'de Kobi'ler Üzerine Bir Çalışma Sadi Etkeser [39]</p>
<p>The Fuzzy Analytic Hierarchy Process (FAHP) is a powerful tool for tackling multi-criteria decision-making (MCDM), particularly when it comes to dealing with subjective judgments and uncertainty. In their 2020 review, Liu, Eckert, and Earl dive into various FAHP techniques, emphasizing the role of fuzzy sets, group decision aggregation methods, defuzzification techniques, and consistency measurement to tackle the subjectivity that often clouds decision-making. They also shine a light on how FAHP applied in diverse areas like supplier selection, technology assessment, and machine selection, which really highlights its adaptability. Yet, there are still hurdles to overcome, particularly in boosting computational efficiency and fine-tuning aggregation and defuzzification methods. The authors call for more research to make FAHP even more applicable in complex and ever-changing decision-making scenarios. This work adds to our understanding of FAHP by examining its strengths, weaknesses, and potential future paths. [40]</p>	<p>A Review of Fuzzy AHP Methods For Decision-Making With Subjective Judgements Yan Liua, Claudia M. Eckertb, Christopher Earlb [40]</p>
<p>Idea of consistency within the Analytic Hierarchy Process (AHP) and its fuzzy counterpart, Fuzzy AHP. He tackles the tricky issue of maintaining consistent pairwise comparisons, particularly when judgments can be subjective or unclear. AHP is built on the principle of transitivity in comparisons, but inconsistencies can pop up, which can throw a wrench in decision-making. The paper takes a closer look at various methods for assessing consistency in both traditional AHP and fuzzy AHP, where fuzzy numbers help capture uncertainty. Liu also brings forth the notion of "fuzzy consistency" to better manage the vagueness that often comes with judgment evaluations, especially in group decision-making scenarios. This innovative approach enhances the reliability of AHP models, particularly when faced with conflicting or inconsistent judgments, leading to a more precise and nuanced decision-making process. [41]</p>	<p>On Consistency In AHP And Fuzzy AHP Liu, F.Et Al. [41]</p>

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Statement	Title & Author
In this article, three different models are proposed using multi-criteria decision making (MCDM) methods for the efficient selection of renewable energy sources. These are implemented by integrating DEMATEL, ANP and TOPSIS methods based on group decision making (GDM) with crisp, linguistic interval fuzzy and intuitionistic fuzzy (IF) data. These approaches are used to model the evaluations of decision makers under uncertainty, especially in energy investments. [42]	New Proposed Integrated MCDM Approaches For The Effective Renewable Energy Resources Selection Problem, Güteryüz S [42]
In this book, where Timothy J. Ross explains the basic concepts and practical uses of fuzzy logic theory in the context of engineering applications, classical set theory and fuzzy set theory are discussed comparatively, and topics such as membership functions, fuzzy relations, inference mechanisms, decision-making processes and fuzzy control systems are detailed. In this article, the advantages of fuzzy logic in decision-making and control systems are explained in detail. [43]	Fuzzy Logic With Engineering Applicationsross Tjohn Wiley, [43]
Among the multi-criteria decision-making techniques, the Analytical Hierarchy Process (AHP) was used in this study as a decision-making method used in solving such problems involving multiple criteria in the public transportation vehicle selection problem of municipalities. Chang's Rank Analysis Method, one of the Fuzzy Analytical Hierarchy Process techniques, was used in order to better express the verbal uncertainty in the binary comparison judgments discussed in the article. In order to rank the fuzzy numbers, the Square Mean and Kwong-Bai methods were used to rank the alternatives. [44]	Bulanik Ahp İle Belediyelerin Toplu Taşıma Araç Seçimi Miraç Erenşengül Ü, Eslamian Shiraz S [44]
Yong (2006) aimed to model uncertain situations for decision makers by applying classical TOPSIS to a fuzzy situation in order to evaluate them more realistically. In this study, the evaluation of the available alternatives and the criterion weights are shown by using triangular fuzzy numbers. [45]	Plant location selection based on fuzzy TOPSIS, Deng Yong, 2005 [45]
The AHP method is used in daily life to evaluate decision makers with quantitative values. However, in many cases there is a situation based on uncertain and subjective judgments. Fuzzy AHP was developed to solve this situation. In this method, surveys or linguistically spoken things are evaluated and modeled with triangular fuzzy numbers. [46]	Kuruluş Yeri Seçiminde Bulanık AHS-VIKOR Yaklaşımının Kullanımı: Otel Sektöründe Uygulama, İlker Murat AR Birdoğan BAKİ Fatih ÖZDEMİR [46]

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Statement	Title & Author
<p>Analytical Hierarchy Process (AHP) plays an important role in multi-criteria decision-making problems. However, it is quite difficult to evaluate decision makers in uncertain situations. Classical AHP is insufficient. For this reason, Fuzzy AHP method was developed by considering decision makers for uncertain judgments. [47]</p>	<p>Comparison of AHP and Fuzzy AHP for the Multicriteria Decision Making Processes with Linguistic Evaluations [47]</p>
<p>Buckley (1985) extended the traditional AHP method with fuzzy logic and included the uncertain judgments of decision makers in the model. In the study, triangular fuzzy numbers were used for comparisons and the criteria weights were calculated with the geometric mean method. This approach offers more flexible and realistic results in multi-criteria decision problems involving uncertainty. [48]</p>	<p>Fuzzy Hierarchical Analysis, J. J. BUCKLEY, 1984 [48]</p>
<p>It is a multi-criteria decision problem where quantitative and qualitative situations are taken into consideration and evaluated together with the supplier selection. In daily life, classical methods have difficulty in solving fuzzy situations. For this reason, fuzzy AHP has been developed and plays a very important role in modeling people's judgments in line with the decisions they make. [49]</p>	<p>A Fuzzy AHP Approach for Supplier Selection Problem: a case Study in a Gearmotor Company, Mustafa Batuhan AYHAN, 2013 [49]</p>
<p>The process of finding suitable suppliers is a very long process. It includes the evaluation process of criteria both verbally and numerically. Considering this, an uncertain situation is tried to be solved with Fuzzy AHP. It also shows important results for decision makers to model their judgments linguistically. This study has shown that Fuzzy AHP can be used in supplier selection through an example study. [50]</p>	<p>Fuzzy AHP approach for supplier selection in a washing machine company, Ozcan Kilincci, Suzan Asli Onal, 2011 [50]</p>
<p>It is a multi-criteria decision problem where quantitative and qualitative situations are taken into consideration and evaluated together with supplier selection. In daily life, classical methods have difficulty in solving fuzzy situations. In this case, Fuzzy AHP was used instead of classical and traditional methods and VIKOR method was also used. The weights of 4 main and 19 sub-criteria were found by using fuzzy AHP. [51]</p>	<p>Tedarikçi Seçiminde Bulanık-Ahp Ve Vikor Yönteminin Bağlantı Elemanları Firmasında Uygulanması, Saraçoğlu İ, 2017 [51]</p>

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Statement	Title & Author
<p>It has become very difficult to solve problems with traditional methods in multi-criteria decision-making problems. Due to uncertain situations, the fuzzy AHP method has been developed. Thanks to this method, more reliable results have been obtained in risk prioritization for uncertain situations by blending a fuzzy situation with AHP. This study shows the evaluation of situations that may be risky in the plastic industry and the applicability of fuzzy AHP in this situation. [52]</p>	<p>Fuzzy Analytical Hierarchy Process-based Risk Priority Number Approach in Failure Modes and Effects Analysis for Magnetic Resonance Imaging-guided High-dose-rate Brachytherapy for Gynecologic Cancer, Jina Chang et al. 2025 [52]</p>
<p>In this literature, fuzzy AHP has been used significantly in order to evaluate how the green model can be used and to develop a sustainability-based "blue curriculum" framework. In this study, some criteria were determined by using environmental and economic literature. They were weighted with triangular fuzzy numbers by using the opinions of experts. Fuzzy AHP was used to integrate the uncertain criteria into the existing model. As a result, the priority criteria were determined among the criteria. [53]</p>	<p>Fuzzy Ahp for Performance Analysis: Mapping Green Curriculum And Developing Blue Curriculum Framework, Widiaty I, 2024 [53]</p>
<p>Seesing, in his study called Project Maturity Model, developed a measurement tool to see every detail in order to evaluate project management processes by looking at SEI's five-level maturity structure. This model aims to systematically analyze the maturity level of companies by using the areas and applications of the project in the process based on PMI's information. With this structure, both very important and less important parts can be seen, processes can be scored and areas to be developed in this project can be noticed. [54]</p>	<p>Project maturity model: a detailed assessment instrument, Seesing, P. R. 2003 [54]</p>
<p>An evaluation table has been developed to determine the maturity level of corporate risk management. It aims to show the current status of businesses and the areas they are lacking in through the application by using the survey results obtained from 100 participants from the business world. Thanks to this model, it shows data on identifying weaknesses and increasing efficiency. [55]</p>	<p>Kurumsal Risk Yönetimi (Kry) Olgunluk Düzeyi, Görmen M, Korkmaz G, 2017 [55]</p>

3. ORIGINALITY:

In the literature reviews conducted for this project, it is distinguished from other studies in terms of adapting the sustainability and environmental policy standards that technology-based start-ups must comply with in their production to the Green Competence Model and analyzing the importance weights of the criteria with the Fuzzy AHP decision support method, while also measuring them with a case study. While existing studies are applied to large-scale enterprises or general industries, this study offers a comprehensive and original model with a unique green

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competence model for technology-based start-ups. This project will provide a holistic benefit to both manufacturing start-ups and Turkey and countries beyond the border, as well as a project that aims for continuous improvement, and will show its original effect of the project.

4. SCOPE OF THE PROJECT / METHODS

4.1.1 MATURITY MODEL

The concept of maturity model was first introduced by Gibson and Nolan in 1970 with the spread of the Capability Maturity Model in 1980, this term became well known. The meaning of the maturity model is known as "having reached a final or desired state" and "the quality or state of being mature" [30]. The results from a layered model provide a more comprehensive insight into an organization's strengths and weaknesses in that area. This insight helps develop targeted improvement strategies, which in turn facilitate more effective resource allocation and continuous improvement [36].

Maturity models allow companies to assess their current state and guide them to make improvements in their change processes. Since these processes can be complex, the maturity model helps companies to see where they are and understand where they need to be by isolating areas for improvement [37].

Maturity models have three purposes of use; Descriptive models, they can be used to analyze the current situations of companies, but it does not benefit in terms of improvement. The second is known as Propositional models, this model evaluates the current situation and draws suitable areas and a roadmap for companies to develop. The last one is used as Comparative models, this model is used to see how companies have progressed over time or to compare them with rival companies [37].

Each type of maturity model has design principles.

- In Basic Design Principles, maturity models include details of processes such as types, application areas, usage purposes, differences from existing models, usability conditions, and verification studies. Maturity model dimensions and levels must be precise. The maturity model should be detailed with theoretical information. The application area is expected to be understandable [36].
- In Descriptive Design Principles, descriptive maturity models are models that include evaluation criteria by knowing the necessary details and that allow companies to measure their maturity levels. This model allows a comparison of different evaluations. Evaluation criteria should be understandable and easily distinguishable. The procedures applied while using the model should be clearly stated, and suggestions for adapting the model for application should be presented [36].

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- In Suggestive Design Principles, suggestive maturity models are models that help determine areas that need to be improved and developed at each maturity level. Improvement areas should be prioritized according to the determined goals and relevant factors. Internal or external resources may also be used in improvement processes. People who use this model must analyze the situation correctly to choose areas for improvement [36].

Developing a maturity model has six phases: scope, design, populate, test, deploy and maintain [36].

i. Phase 1: Scope

Desired maturity model needs specific scope, and the most significant decision made in this phase. The focal point of the model focuses on its distinction from existing models, its originality, and its extensibility. Once the focal point of the model is determined, it becomes more obvious how it will be designed and developed [36].

ii. Phase 2: Design

The design of the model sheds light on the needs of the target audience, why the model is being implemented, how the model can be implemented in different structures, what is required in the implementation of the model, and what can be achieved with this model. In existing maturity models, maturity is seen as a cumulative stage where the levels of requirements for each stage increase, and maturity represents higher maturity. These maturity levels are named according to the reason for the stage and these names have changed according to the maturity models. Representing maturity as a series of one-dimensional linear stages is widely accepted as an approach [36].

As an example of these names, the Capability Maturity Model, Version 1.1 defines the levels as follows:

“Level 1 Initial: For an organization at the beginning level, planned situations do not continue stably. There is always a margin of deviation from procedures. In order to achieve success for Level 1, it depends on the competence and skills of the organizations [30].

Level 2 Repeatable: This level determines the management policies for the project and the procedures that implement these policies. The projects of the organization at this level constitute basic management controls. In order to reach this level, the people who advance the project must have policies that help to form the management process. This stage involves being more disciplined because project planning and monitoring should be more consistent, and previous successes can be repeated [30].

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Level 3 Defined: It is the integration of the processes formed in the project into an existing whole. This level involves being consistent because it is at a consistent and repeatable level for both engineering and management activities. The defined activities in this process, responsibilities, and a common understanding about the organization are considered in general [30].

Level 4 Managed: At this level, the organization has a good definition of products and processes, while also setting quantitative quality targets with consistent measurements. This level is predictable, and if its limits are exceeded, project managers take action to correct the situation [30].

Level 5 Optimizing: The entire organization is focused on process improvement in a continuous state. At this level, it is to identify weaknesses in the project and take precautions for possible defects. Therefore, it has the tools to proactively strengthen the process [30].

iii. Phase 3: Populate

After determining the scope and design of the model, the content of the model needs to be determined. Therefore, it is critical to define what needs to be measured in the maturity assessment. In this way, maturity is understood in more depth, otherwise, it becomes difficult to define specific improvement strategies. In this section, the definition of the field components is carried out through a comprehensive literature review. The layers obtained from the literature can also be supported by techniques such as the Delphi technique, the Nominal Group technique and case studies [36].

iv. Phase 4: Test

The durability and robustness of the model must be tested. The maturity model must be able to be used as a recorded scope and content and must be a correct model. Testing methods vary between models. Superficial permanence, Content maintenance and the distribution of the scope of important components in the literature are examined. Inter-rater Reliability, pilot testing and survey methods can be used to test the model [36].

v. Phase 5: Deploy

At this stage, to whom and with what method the model will be presented can be considered in two steps to ensure wider acceptance and increase the standardization of the model; in the first step, it should be implemented with the stakeholders involved in the development of the model, and in the second step, it should be implemented with independent applications in cases where there is more than one stakeholder. In other words, it is necessary for the standardization and acceptance of the model to be adopted and implemented by the organizations that will benefit [36].

vi. Phase 6: Maintain

Adequate resources must be provided to ensure the maturity model grows and continues to be used. At this stage, the evolution of the model must be monitored and developed [36].

4.1.2 GREEN MATURITY MODEL

The project developed a green maturity model was established with the scope of improving the production processes of technology-based start-ups. In this context, levels were defined through literature reviews. It is also visualized visually with Figure 1.

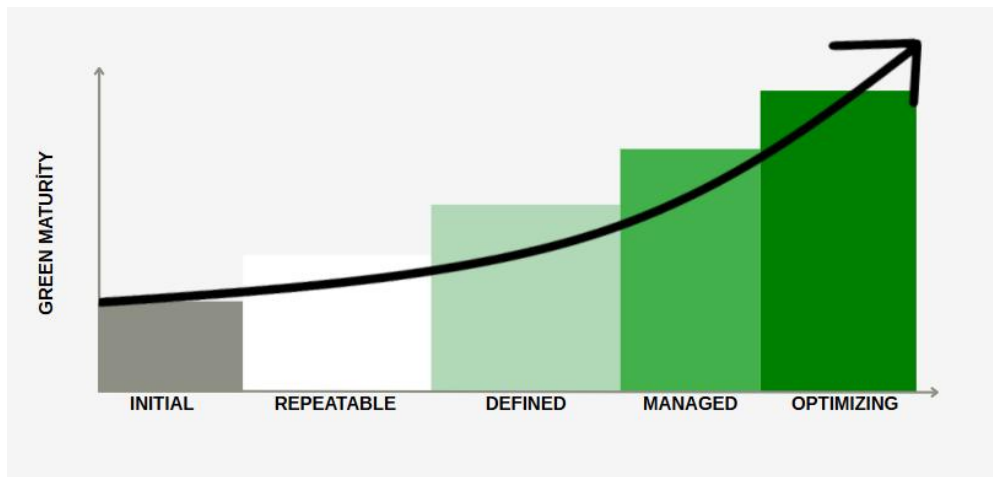


Figure 1 : Green Maturity Model

- **LEVEL 1: INITIAL**

At this level, start-ups have no green policy. They do not have any strategy or policy for the environment. They are not yet aware of the environmental impact levels of their initiatives. For this reason, they do not have awareness of the work they do and therefore do not implement it. Issues such as waste management and energy efficiency are ignored throughout the business processes. Sustainability is not even included in their work.

- **LEVEL 2: REPEATABLE**

Start-ups identify the challenges they may face to become sustainable. Green initiatives are in place but not fully embedded. They are beginning to recognize the importance of sustainability. They are aware of the environmental challenges they may face and are simply beginning to take basic steps to address this issue. Green practices do not provide complete stability, but they do follow a repeatable level.

- **LEVEL 3: DEFINED**

At this level, in the start-up green strategies are formalized and actively implemented. Some strategies known as environmentally friendly are known. Some targets on sustainability have been set and planned work has been started to achieve these targets. Environmental policies

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have been integrated into the initiatives. Employees have started to be told what they can do about sustainability. In addition, green strategies are now becoming a part of the strategic orientation for the company, considering environmental performance indicators.

- **LEVEL 4: MANAGED**

At this level, green practices are optimized and continuously improved. Identification, management, and continuous improvement of green practices. The company measures its sustainability performance at certain intervals and continues its green studies by making continuous improvements. According to the data obtained, arrangements and improvements are made in business processes to increase the efficiency of environmental factors. Green practices are optimized to the process by utilizing innovations and technology. Making decisions on sustainability throughout the entire process reaches a very important point.

- **LEVEL 5: OPTIMIZING**

At the most mature level, green strategies are ingrained into the culture and innovation. Green strategies, policies implemented, initiatives and companies have an important place in their mission. It is directed to environmental innovations. It reorganizes its work to minimize environmental impacts on products and services. It carries out the activities within the company in accordance with the green strategy. It includes each employee and business activities in these activities. In addition, it takes the lead by standing out from its other competitors as a green leader in the sector. It becomes a pioneering and important institution that is shown as an example for companies that reach this maturity model.

4.1.3. GREEN MATURITY MODEL CRITERIA DETERMINATION

While developing a green maturity model, it is important to detail the levels and determine the criteria related to the levels. The criteria table in Figure 2 touches on the importance of the literature required for the evaluation of start-ups in line with the Green Maturity Model:

- In the Turkey's Twelfth Development Plan, "Considering the current global trends, digitalization and green transformation-oriented policies aimed at creating more competitive and higher added value in production processes are important. Türkiye's adaptation to changing competitive conditions requires increasing qualified human resources, value-added production, and export capacity with a focus on digitalization and green transformation." With the article, it is important for start-ups to import and export in accordance with green factory strategies and policies, to receive investments, to access opportunities offered by the state and to contribute to the Turkish economy [1], [17].
- In the New Industrial Strategy, which is in line with the EU Green Deal, some articles have been created to reduce costs and move to new industrial processes and cleaner technologies. These articles are expected to create funds to help implement innovative projects, to ensure a safe and sufficient supply of low-carbon energy with energy efficiency, and to ensure a transition to low-carbon production technologies

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to reduce emissions in the industrial sector. It has also become valid for countries that are committed to this agreement to revitalize their industrial production bases, reduce costs for people and businesses, and to be in a first-class position to support other parts of the world in decarbonizing themselves [6], [9].

- Green supply chain management aims to achieve sustainable corporate development and improved environmental protection by integrating logistics and financial information to increase the competitiveness of the products or services of supply chain units. This concept describes the aspects of a company that can be improved through many operational activities, including green design, green production, green packaging, and green recycling. In this context, the strategies included, and the scope of green factory construction will be important. Requesting green products from suppliers and implementing green activities in distribution processes allow the process to be evaluated, as a whole [23], [29].
- Sustainable logistics and production can be achieved with strategies that include various principles such as energy and water efficiency, waste management, ecological design, sustainable material use, user perspective, ensuring indoor air quality, appropriate landscaping, improving quality of life, financial aspects, and strategic maintenance. Innovative applications such as selecting appropriate means of transportation to reduce carbon emissions and minimize fuel consumption, performing regular maintenance and repairs, shortening transportation distances, and reducing traffic around the warehouse or factory are suggestions that can be made for sustainable logistics [8], [15].
- One of the basic components of green factory construction is sustainable production and the use of resources in production, especially the choice of materials and energy, can cause ecological pollution in terms of greenhouse gas effects, toxic waste production, water use, the emergence of non-biodegradable materials such as plastic and the effects of the product on nature at the end of its life. When the economic aspect is also taken into account, in order to reduce the use of limited resources and waste of resources, green factories should be created and production should be carried out by integrating production environments with environmental sustainability and reducing their effects on the environment [18], [21], [25].
- Fabrication strategies are important within the scope of Industry 4.0. In a sustainable production system, it aims to ensure sustainability at all stages from raw material supply to product design and even product recycling, and in order for businesses to ensure sustainability, they need to optimize processes such as product design, raw material supply, logistics, production, sales distribution, usage, end-of-life processes and waste. The communication of these systems with each other becomes easier thanks to Industry 4.0. Industry 4.0 enables the establishment of smart factories that establish a complete communication network between various companies, factories, suppliers, logistics, resources, and customers. It is thought that smart factories provide customized and multi-party products in an efficient and

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profitable way. One of the advantages of Industry 4.0 is that these factories are an environment where people, machines and resources can naturally communicate with each other, therefore could manage complexity, are less prone to breakdown and can produce products more efficiently [7].

- The 3R concept is also important for sustainable factory production. It is generally accepted in the researched articles that reduction, reuse and recycling and waste management policies form the basis for developing a material cycle society and that waste management policies differ between countries due to the specific conditions or political strategies of each country [24], [27].
- ISO's green manufacturing standards were developed to promote environmentally responsible, energy-efficient, and sustainable manufacturing processes. These standards guide reducing energy consumption in industrial production, using natural resources more efficiently, optimizing waste management and minimizing environmental impacts. ISO 50001 Energy Management System aims to reduce carbon footprint by increasing energy efficiency, ISO 14001 Environmental Management System enables businesses to manage their environmental impacts systematically and ISO 14067 Carbon Footprint standard defines the processes for measuring and reducing carbon emissions of products [16], [17], [23], [25].
- The product life cycle is a cycle that refers to the time from the product's first introduction to the market to its final withdrawal from the market, and understanding a product's life cycle is one of the main factors that helps a company know when to introduce a product to the market and when to withdraw it from the market, as well as its position and success compared to its competitors [13], [25], [28].

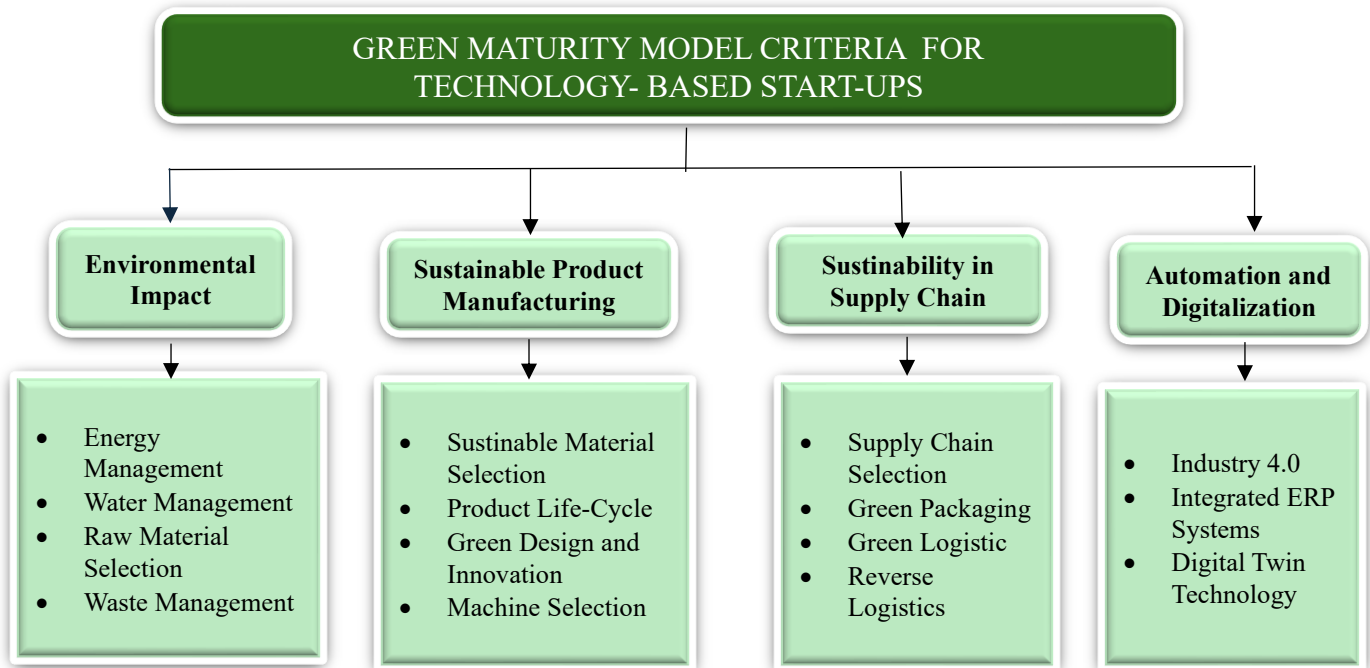


Table 2 : Green Maturity Model Criteria Table

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4.2 MULTI-CRITERIA DECISION MAKING

In multi-criteria decision-making processes, it has become hard to make decisions by looking at a single criterion in multi-criteria and multi-dimensional systems. It is now becoming a more complex and complicated system. In daily life, decision-making problems require the simultaneous evaluation of multiple criteria that conflict with each other, create problems or have different levels of importance. However, there may be more than one main or sub-criterion rather than a single alternative. These decision criteria must be analyzed systematically and in the most accurate way. Thanks to these difficulties, Multi-Criteria Decision-Making methods have emerged. Thanks to this method, it analyzes the comparison of various alternatives according to different criteria [42].

MCDM methods are used for a more effective solution for models in multi-criteria complex systems. This method solves by blending both quantitative and qualitative data into the same model. The most important task of this method is to help obtain more accurate and transparent results in decision-making processes for a large number of criteria and alternatives. This method allows the comparison of alternatives by showing their strengths and weaknesses together with only the optimal solution. In addition, attention is paid to the importance levels between the criteria. In addition, it helps multiple stakeholder views to come together in a common place during the decision-making process [42].

MCDM methods are divided into two groups: Ranking methods and Choice methods. Ranking methods make a ranking by including all alternatives. This ranking prioritizes the alternatives from best to worst. The selection method determines an alternative that is suitable for the created criteria set. Some methods can be classified according to the type of information used in the decision-making process. While some methods work with crisp and numerical data, some methods can be used intuitively with ambiguous expressions [42].

MCDM includes many types of techniques such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), TOPSIS, ELECTRE, VIKOR, PROMETHEE and DEMATEL. These techniques help in decision-making in areas such as engineering, supply chain management, sustainability, project selection, risk analysis and technology assessment [42].

In most of the classical methods, more clear and precise information is expected from the decision maker. When there is uncertainty or transparency, it causes some obstacles in terms of usability of the method. For this reason, methods based on uncertainty, such as fuzzy logic, are integrated into MCDM systems to achieve better results. Since Fuzzy Logic, data that does not contain definitive judgments but contains intuitive information is mathematically converted into numbers. In this way, more flexible decision structures can emerge [42]



4.3 ANALYTICAL HIERARCHY PROCESS

The Analytical Hierarchy Process is a tool that helps in multi-criteria decision-making processes, both quantitatively and qualitatively, and multi-dimensional evaluation processes. This method helps in making the right decision among problems with multiple criteria and alternatives in daily life. The Analytical Hierarchy Process contributes to making more realistic decisions within systematic evaluations for experts who make decisions with intuitive judgments. AHP was developed by Thomas L. Saaty in 1970. This method was first used in the fields of defense and public administration. Over time, AHP has been used in many sectors and has begun to be used for problems experienced in decision-making. This method, hierarchical ordering, allows for systematic evaluation by providing consistent and accurate decisions [31],[38],[56].

The basic structure of AHP is to analyze decision-making problems by separating them into their components. Decomposition is done to transform the problem into a hierarchical structure. With this decomposition, it will ensure that the decision to be taken is systematically analyzed at all levels. When this system is looked at, there must be a problem at the highest level of the hierarchy. Afterwards, there are main and sub-criteria under this problem. The decision alternatives that are effective in the decision-making process also follow these steps. Due to this structure that will be created, the criteria at each level will be compared with each other and will guide us in understanding how important they are and their level of importance. By looking at these steps, it can be seen more clearly which criteria are more important or less important in the decision-making process. The criteria that are formed are thus evaluated. Due to AHP, everything is seen more clearly and explicitly in the decision-making process, and it leads the way in systematic progress [31],[38],[56]. You can see an example of the main and sub criteria table in figure 2 below.

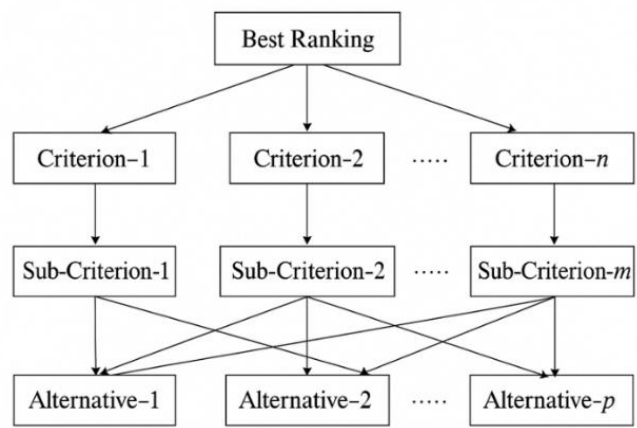


Figure 2 : AHP Hierarchy Model

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After adding criteria that are suitable for the main target and sub-criteria that have features that will affect the main target in the Analytical Hierarchy Process, the second step of AHP, which is paired comparisons, is passed. Paired comparisons are the process of comparing criteria with each other. In this process, the weights of criteria are determined to express the judgments of decision makers numerically [31],[38],[56]. The 1-9 scale used in these criteria is expressed as follows [57]:

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

Table 3: Saaty Scale

In the third stage, the synthesis and consistency calculation part apply. In this section, the values obtained as a result of the comparisons made between two criteria are placed in the comparison matrix by making the intersection in the rows and columns. This is done for each item, and as a result, a reciprocal matrix is obtained. The entire relationship between the criteria is revealed. Weights are calculated for each criterion from the pairwise compared matrices.

The consistency of the given data can be tested through pairwise comparisons made with AHP (Analytical Hierarchy Process). It is calculated so that the comparisons made support each other. If we give an example of this calculation, let's assume that one criterion is more important than the second criterion and the second criterion is more important than the third criterion. When the first and third criteria are compared, the first criterion is expected to be more important. If this does not happen, it means that an inconsistent result has been obtained. There is a numerical evaluation mechanism that measures consistency in the AHP method used to evaluate this situation [41].

Consistency is calculated from the largest eigenvalue of the comparison matrix (λ_{max}) and using this value, the Consistency Index (CI) is obtained with the following formula:
 $CI = (\lambda_{max} - n) / (n-1)$ [41].

Thanks to the CI value obtained, the matrix obtained as a result of the criteria comparisons should be compared with a fixed value depending on the size. As a result of this comparison, the Consistency Ratio (CR) is calculated. CR is obtained with the following formula:
 $CR = CI / RI$ [41].

In order to evaluate the CR values for the obtained results, they should be less than 0.10. Only then can a more accurate and acceptable result be obtained. If they are greater than 0.10, the values compared in the decision stage should be re-evaluated [41].

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4.4 FUZZY LOGIC

One of the most important problems in multi-criteria comparison questions is that the information remains uncertain or incomplete. Since classical logic systems consist only of "wrong" or "right", such information is insufficient. In response to this, Fuzzy Logic was developed. It was discovered by Lütüf Aliasker Zade in 1965. With this model, it was developed to model the uncertainties in people's thinking structures [43].

Fuzzy logic does not only focus on right or wrong for information. It also takes into account the degrees of accuracy at a certain level. This approach aims to surpass the definite results in the "crisp" structures used in classical set theory. In crisp sets, an element belongs only to 0 or 1. However, in fuzzy set theory, elements are shown with continuous values between 0-1. As a result, thanks to this structure, it can be transformed into a mathematical model for uncertain, inexpressible values experienced during the decision-making phase. Thus, quantitative, numerical values can be obtained from a qualitative situation [43].

In daily life, in engineering and management problems, fuzzy logic plays a very important role especially in decision-making processes with criteria that do not consist of numerical values. The fact that evaluations based on expert opinions are shown with more graduated expressions instead of numerical data provides realism in the decision process [43].

Membership functions are defined with 3 parameters. These parameters are taken as l , m , u . The components of these membership functions as follows:

$$\mu_A(x; l, m, u) \begin{cases} \frac{x-l}{m-l} & \text{if } l \leq x \leq m \\ \frac{u-x}{u-m} & \text{if } m \leq x \leq u \\ 0 & \text{if } x > u \text{ or } x < l \end{cases} \quad (1)$$

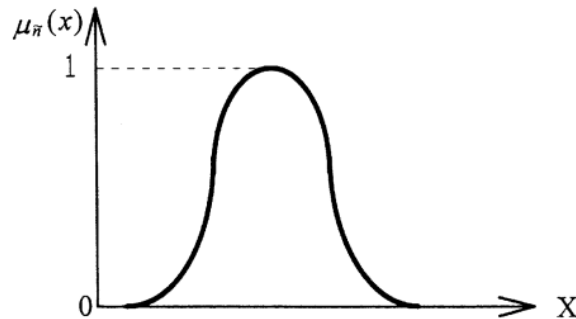


Figure 3: A fuzzy number membership function

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4.5 TRIANGULAR FUZZY NUMBERS

Fuzzy terms are a multivariate theory that uses comparisons that can be defined by dividing subjective values into degrees such as "medium", "high", "low". These definitions help to map objects to a scale between '0' and '1' with the fuzzy set. This concept is called the Triangular Fuzzy Number (TFN) set [35].

Fuzzy AHP is a method used in multi-criteria decision makers (MCDM). With this method, it adds a new dimension to analytical hierarchical processes. Only the one that is independent of answers such as yes or no. It is a method consisting of comparing each criterion with other criteria and as a result of this comparison, will obtain the importance weights of the criteria [32].

Triangular fuzzy numbers can be considered as triples in the ordered form for real numbers. The number consists of three components. It is shown as the smallest number, the middle number, and the largest number from beginning to end [46].

$\mu_A(x): R \rightarrow [0,1]$ including, triangular fuzzy numbers are expressed as follows: $A = (l_1, m_1, u_1)$

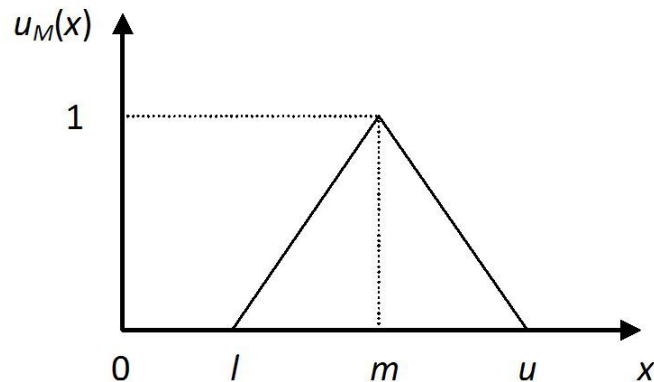


Figure 4 : A Membership Function Representation of Triangular Fuzzy

4.6 FUZZY ANALYTICAL HIERARCHY PROCESS

In the AHP method, decision makers are expected to obtain a crisp number evaluation, but the Fuzzy AHP method has emerged by integrating fuzzy logic into AHP with caring the human judgements effects on the criterion [43]. There are multiple approaches in the literature for calculating the criteria weights by applying the Fuzzy AHP method [46]. These are:

- Chang's Synthetic Extend Methods
- Buckley's Approach
- Van Laarhoven and Pedrycz Method
- Logarithmic Fuzzy Preference Programming (LFPP) and so on.

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The initial steps of the selected approaches are the same when applying the Fuzzy Fuzzy AHP method. For this reason, the common initial steps can be expressed as follows:

Step 1: Creating the target and decision hierarchy. In this step, the hierarchy structure shown in Table 3 is applied. The main criteria and sub-criteria are given in table 4 below by enumerating them. These enumerations will be quoted in the following tables [47].

Green Maturity Model (GMM) for Start-ups Criteria	Main Criteria	Sub-Criteria
	C1. Environmental Impact	C1.1 Energy Management
		C1.2 Water Management
		C1.3 Raw Material Selection
		C1.4 Waste Management
	C2. Sustainable Product Manufacturing	C2.1 Sustainable Material Selection
		C2.2 Product Life Cycle Analysis
		C2.3 Green Design and Innovation
		C2.4 Machine Selection
	C3. Sustainability in Supply Chain	C3.1 Supply Chain Selection
		C3.2 Green Packaging
		C3.3 Green Logistics
		C3.4 Reverse Logistics
	C4. Automation and Digitalization	C4.1 Industry 4.0
		C4.2 Integrated ERP Systems
C4.3 Digital Twin Technology		

Table 4: Criteria Notarization

Step 2: The linguistic scale is determined according to the fuzzy sets and the pairwise comparison surveys for the main criteria and sub-criteria created and presented to the experts. Triangular fuzzy sets are used in this article. The appropriate linguistic scale is shown in Table 5 [47], [57].

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Triangular Fuzzy Numbers Scale				
Saaty Scale	Definition	L	M	U
1	Equally Important	1	1	1
3	Weakly Important	2	3	4
5	Fairly Important	4	5	6
7	Strongly Important	6	7	8
9	Absolutely Important	9	9	9
2	Intermittent Values Between Two Adjacent Scales	1	2	3
4		3	4	5
6		5	6	7
8		7	8	9
1	Equally Less Important	1	1	1
3	Weakly Less Important	1/4	1/3	1/2
5	Fairly Less Important	1/6	1/5	1/4
7	Strongly Less Important	1/8	1/7	1/6
9	Absolutely Less Important	1/9	1/9	1/8
2	Intermittent Values Between Two Adjacent Scales	1/3	1/2	1
4		1/5	1/4	1/3
6		1/7	1/6	1/5

Table 5 : Triangular Fuzzy Numbers Scale

Step 3: Obtaining matrix views of the created pairwise comparisons.

For a given criterion, a vector can be used for a significant ranking. The A matrix shown below in figure 5 can be used for pairwise comparisons planned to be performed at a certain level. i with element j into the position a_{ji} as below [43], [58], [59].

Where

n = criteria number to be evaluated

C_i = i . criteria,

a_{ij} = importance of i . criteria according to j th criteria

$$A = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & \cdot & C_n \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ \cdot \\ C_n \end{matrix} & \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & \cdot & a_{1n} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & \cdot & a_{2n} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & \cdot & a_{3n} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & \cdot & a_{4n} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & \cdot & a_{5n} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & \cdot & a_{6n} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 1 & \cdot \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & \cdot & 1 \end{bmatrix} \end{matrix}$$

Figure 5: Matrix



Step 4: If there is more than one expert, aggregation of pairwise comparison matrices is performed. At this point, there are different aggregation methods [44].

After this step, the steps of Chang's Synthetic Extend Methods and Buckley approaches to find the criterion weights to be used in the article will be explained.

4.6.1 Chang's Synthetic Extend Methods

Based on Chang's Extent Analysis in fuzzy AHP, each criterion is dependent on the degree of probability. Based on the answers to the questions in the questionnaire, triangular fuzzy values corresponding to the variables are placed for the variables linguistically. In the continuation of this process, comparison matrices are created for paired situations at a certain level. Subtotals are calculated for each row in the matrix and the newly formed (l, m, u) set is obtained according to the calculated result. Then, general triangular fuzzy values must be found to evaluate each criterion. In the next step, $M_i(l_i, m_i, u_i)$ is used as the last set for the M_i criterion. In the next stage, membership functions are created for each criterion. Intersections are determined by the compared criteria. Considering the fuzzy logic, the intersection process for each criterion is performed for all of them. Then, the membership values of the point correspond to the weight of the determined point. The membership value obtained is also known as the probability degree. In cases where the value found for certain criteria has a greater value than others, it is the smallest probability degree and also the weight before normalization for this criterion. After obtaining the weight for each criterion one by one, normalization is done. This is called the final importance degrees or weights for the hierarchy level [32], [47].

To perform the processes considering this hierarchy, each criterion is taken into account according to the scope analysis method by considering Chang's (1992) scope analysis and the analysis values are obtained as follows [47]. Therefore, m extent analysis values for each criterion can be obtained by using the following notation:

Step 1: Fuzzy Synthetic Extent Value Calculation

Triangular fuzzy numbers expressed in pairwise comparisons of each criterion M_{gi}^j is expressed with. With this formula, ith object for m goals is defined as [32], [47], [52]:

$$s_i = \sum_{j=1}^M M_{gi}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} \quad (2)$$

Step 2 : The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as below, according to each taking the minimum degree of possibility [32], [47], [52].

$$V(M_1 \geq M_2) = \sup_{x \geq y} [(\min (\mu_{M_1}(x), (\mu_{M_2}(y))) \quad (3)$$



$$V(M_1 \geq M_2) = hgt(M_1 \cap M_2) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \frac{l_2 - u_2}{(m_2 - u_2) - (m_1 - u_1)} & \text{otherwise} \end{cases} \quad (4)$$

Step 3: The degree of possibility for a triangular fuzzy number to be greater than k triangular fuzzy numbers M_i ($i = 1, 2, \dots, k$) can be defined by using below [32][47], [52] :

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_i) \quad i = 1, 2, \dots, k. \quad (5)$$

$$d(A_i) = \min V(S_i \geq S_k), \quad k = 1, 2, \dots, n; k \neq i. \quad (6)$$

S_i is the synthetic degree value.

Step 4: The weight vector is defined by [47], [52].:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T, \quad A_i (i = 1, 2, \dots, n) \text{ are } n \text{ elements of the vector.} \quad (7)$$

Step 5: The normalized weight vectors is calculated as [32], [47], [52]:

$$NW_i = \frac{W_i}{\sum W_i} \quad (6)$$

4.6.2 Buckley's Approach

Buckley's method contributed to the subject by determining the fuzzy priorities of comparison ratios having triangular membership functions [48].

Step 1: In the Buckley method, matrix aggregation is calculated with geometric mean and continues on the aggregated matrix. This calculation [60]:

$M_{ij} = (l_{ij}, m_{ij}, u_{ij})$ with K number of experts

$$l_{ij} = \left(\prod_{k=1}^K l_{ij}^{(k)} \right)^{1/K}, \quad m_{ij} = \left(\prod_{k=1}^K m_{ij}^{(k)} \right)^{1/K}, \quad u_{ij} = \left(\prod_{k=1}^K u_{ij}^{(k)} \right)^{1/K} \quad (7)$$

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Step 2: For each criterion, a fuzzy pairwise comparison matrix combined with the geometric mean is created [60], [61].

$$\begin{matrix} & C1 & \dots & Cn \\ C1 & \left[\begin{matrix} d_{11}^{\sim} (l_{11}, m_{11}, u_{11}) & \dots & \\ \vdots & \ddots & \vdots \\ \dots & \dots & d_{ij}^{\sim} (l_{nn}, m_{nn}, u_{nn}) \end{matrix} \right] & &
 \end{matrix}$$

Step 3: For each criterion, the geometric mean of the fuzzy values in the relevant row corresponding to the l,m,u values of the combined fuzzy pairwise comparison matrix is calculated and a vector showing the relative fuzzy importance is obtained [53], [60], [61].

$$r_i^{\sim} = \left(\prod_{j=1}^n d_{ij}^{\sim} \right) i = 1, 2, \dots, n \quad (8)$$

Step 4: The inverse of the fuzzy weights for each criterion is calculated with the following equation [60], [61]:

Expression of the inverses of the sums of the total column weights found:

$$lw_i^{-1} = \frac{1}{uw_i}, \quad mw_i^{-1} = \frac{1}{mw_i}, \quad uw_i^{-1} = \frac{1}{lw_i} \text{ is found with the formulas [53], [60], [61].}$$

$$\text{In conclusion } r_i^{\sim} = (lr_i, mr_i, ur_i). \quad (9)$$

Step 5: In this step, which provides the normalization of the weights of the fuzzy weights for each criterion for the calculation of fuzzy weights, the following equation is used. The fuzzy multiplication operation with each inverse vector is calculated by multiplying it with the value in the sum of each column. And thus, the fuzzy weights are calculated [53], [60], [61].

$$W_i^{\sim} = r_i^{\sim} \otimes (r_1^{\sim} \oplus r_2^{\sim} \oplus \dots \oplus r_n^{\sim})^{-1} = (lw_i, mw_i, uw_i) \quad (10)$$

Step 6: The W_i^{\sim} values found with the defuzzification method are converted to crisp numbers. The defuzzification method used at this stage is calculated with this formula developed by Chou and Chang, which is the center of area method [53], [60], [61]:

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (11)$$

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Step 7: The M_i values are normalized and expected to reach the value of 1. The formula for this is [53], [60], [61]:

$$N_i = \frac{M_i}{\sum_{j=1}^n M_j} \quad (12)$$

4.7 FUZZY AHP TO MATURITY MODEL ADOPTION

The fuzzy AHP weights assigned to each criterion can be used in the maturity level proposed methodology. Maturity leveling consists of ranking the criteria that should be placed in each Maturity Level starting from Maturity Level 1 according to the definitions of the levels and the criteria weights from highest to lowest [31].

In the process of evaluating the maturity levels of the Maturity Model, which is designed to reveal how sustainable companies are, to evaluate their performance and to see what maturity level they are at, the model is created using methods such as cumulative maturity model, mean maturity score, score intervals, assessment scales. The steps followed and the values used in this section are explained first with the Mean Maturity Score and Cumulative Maturity Scoring (Threshold-Based Maturity Scoring) methods as follows:

4.7.1 Mean Maturity Score

Step 1: Calculating Total Weights

After the criteria weights are calculated as main and sub-criteria, the total weights of the sub-criteria are found by multiplying the weight of each sub-criteria with the weight of the main criterion to which it belongs [37], [56], [62].

Step 2: Calculating Level-Based Scores

In order for the total weights of the criteria found to be scored on a company basis, the appropriate score levels that can be obtained are determined, numbered as the number of levels [62].

Step 3: Maturity Level Scoring

After each criterion is made comparable with the appropriate score, the maximum score that can be obtained from the determined criteria is calculated by multiplying each criterion by the highest score degree [62].

Step 4: Maturity Level Intervals

The score range for each level is calculated by dividing the highest total score found by the specified number of levels [62].

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Step 5: Company Scoring

With the survey prepared for the companies, a company needs to score its status according to the determined criteria with the determined scoring degrees. The scores that the companies receive from each criterion are multiplied by the total weights of the criteria. The company is accepted at the level that the score obtained by the sum of the multiplications falls into in the Maturity Level interval [62].

4.7.2 Cumulative Maturity Scoring (Threshold-Based Maturity Scoring)

The basis of leveling with this scoring method is to show that the company cannot reach other levels without reaching a certain percentage in the scores corresponding to the determined levels. At the same time, the Cumulative Maturity Model progresses by including the criteria in each level in the other levels [62], [63].

Steps 1-2 and 3 of the Mean Maturity Score are the same for Cumulative Maturity Model.

Step 4: Levels Scoring

After placing the criteria into levels according to the levels of the maturity model, the scores for each level are obtained by adding the total weighted scores, which are the multiplication of the criteria at each level by the highest possible score, starting from level 1 and including the total scores of the criteria at each level [54], [55], [63].

Step 5: Threshold Score

In order to check whether companies have passed their current levels, the score the company receives at the current level must be 80% higher than the current level, which is the most appropriate value to use in this method. These scores can also be calculated with 70-90%. Below 70% reduces the distinguishing feature of the model, while above 90% can make the model difficult and dysfunctional. This value is calculated with the following formula [54], [55], [63]:

$$\text{Threshold Score}_{(k)} = 0.80 \times \text{Maximum Level Score}_{(k)} \quad (13)$$

Step 6: Determining the Level of the Company

As a result of comparing the scores received by the company at each level with the threshold scores, it is seen that the company is at the level at which it cannot exceed 80 percent [54], [55], [63].

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4.8 WORK PACKAGES

The work package descriptions required for the completion of this project and their impact on the project are described as follows:

Work Package 1: Research of the Start-up Types:

In this work package, it is planned to conduct an analysis for startups working in the technology sector with a survey to be conducted via internet browsers. With the data to be obtained, the best two startups will be selected for this situation and a detailed examination is planned. This selection process is an important step to examine and evaluate processes for sustainability.

Work Package 2: Research about Regulations and Sustainability Processes:

In this work package, it is planned to examine the policies suitable for start-ups. This study evaluates the applicability of sustainability policies for small and micro enterprises. In addition, in this work package, sustainability processes in Turkey and Europe, national and international standards (ISO, EU Green Deal, etc.) will be examined and how start-ups can be integrated into this situation will be analyzed.)

Work Package 3: Criteria Table Creation Based on Literature Review:

At this stage, the investment opportunities offered for the growth and development of start-ups in Türkiye and the incentives provided by the state will be examined. With this application, it is to determine whether entrepreneurs can receive financial support. In addition, the main criteria will be determined by using multi-criteria decision-making methods by considering the needs and situations of the start-ups.

Work Package 4: Ranking with Fuzzy AHP

It is the work package required for weighting the determined criteria using the Fuzzy AHP method. Calculations must be made, and surveys must be conducted with experts for the process to progress.

Work Package 5: Transforming the Maturity Model

It includes leveling criteria with determined weights according to the maturity model.

Work Package 6: A Case Study on Determined Start-Ups:

It is expected to be tested with the data obtained at this stage. The accuracy of the model created will be measured by conducting a case study on the two selected start-ups. As a result of the analysis, the start-ups' compliance levels with green production standards will be evaluated. As a result, it is aimed at increasing their environmental performance.

5. PROJECT TARGETS AND SUCCESS CRITERIA

The table 6 below shows each work plan and their possible effects on the project, measurable outcomes, and targets. Each measurement is measurable and effective on the project. Work packages have been completed according to the determined targets.

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Table 6 Work package targets, their assessment, and the contribution of each work package to the overall project success.

Work package	Target	Measurable outcome	Contribution to overall success (%)
WP1: Research of the Start-up Types	Conducting research for start-ups and their types in the technology sector.	Determining the two most suitable start-ups and starting the investigations.	A project of 5% has a successful contribution
WP2: Research about Regulations and Sustainability Processes	Determining sustainability policies for start-ups.	Researching Turkish and European standards.	A project of 10% has a successful contribution.
WP3: Criteria Table Creation Based on Literature Review	Determining financial support and investment opportunities for start-ups.	Determining a criteria table suitable for multi-criteria decision-making methods	A project of 10% has a successful contribution.
WP4: Ranking with Fuzzy AHP	Developing a suitable maturity level and applying ranking method	Ranking with the Fuzzy AHP method needs surveys with experts	A project of 30% has a successful contribution.
WP5: Transforming Maturity Model	Acceptable transformation of the criteria weights	Leveling of criteria with determined weights according to the maturity model.	A project of 25% has a successful contribution.
WP6: Case Study on Determined Start-Ups	Testing the accuracy by trying the created model on selected start-ups.	Measuring environmental performance by conducting case studies on selected start-ups.	A project of 20% has a successful contribution.

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6. PROJECT MANAGEMENT RISKS AND B PLANS:

Project work packages risk and b-plans shown in Table 7. Since no risks arose in the project, no plans were implemented.

Work Package	Risk	B-Plan
WP 2	Renewing or amending the sustainability consensus and development goals sought for 2025 and beyond.	<p>The studies to be conducted will be ranked from general to specific. The effect of this on the stated risk is that we foresee that the studies ranked from specific to specific can be changed more, so pivoting our study will be quick in this sense.</p> <p>Therefore, we foresee that possible changes will have a positive effect on the change and applicability of our output without affecting their general context.</p>
WP 4-5	The stated strategies and roadmap are not compatible with the entrepreneur's resources and wishes.	<p>In such cases, we foresee directing the entrepreneur to government incentives and subsidies for possible resource difficulties.</p> <p>In case of problems that may arise in terms of request and application, we foresee proving that the entrepreneur or business should not be considered as an expense while increasing its business volume by mentioning the standards it should be subject to, and that these strategies it will do or plans to do can have high returns in terms of both sales and investment in the long term in terms of green facilities and sustainability.</p>
WP 6	Research-specific outputs do not appeal to enterprises or SMEs outside the target audience (those producing and developing new technological products).	<p>As mentioned above, the research starts with general research and addresses the targeted audience, which is the enterprises that produce and develop new technological products.</p> <p>Since we proceed from general to specific, the article we plan to publish actually addresses all small-scale businesses and business owners in general.</p> <p>Therefore, it is anticipated that all the output we will prepare and publish will not be limited to our target audience, but will also cause many entrepreneurs to achieve positive outputs.</p>

Table 7: Work Packages Risks and B-plans.

No risks were encountered in this project. Therefore, no B plans were implemented.

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7. WORK TIME PLAN OF THE PROJECT

Work time plan of the project and distribution of the work package table 8 -9 and reached %100 success of work packages.

Table 8 Detailed Definition of Work and Activity

WP No	Detailed Definition of Work and Activity
1	Research of the Start-up Types
2	Research about Regulations and Sustainability Processes
3	Criteria Table Creation Based on Literature Review
4	Ranking with Fuzzy AHP
5	Transforming Maturity Model
6	Case Study on Determined Start-Ups

Table 9

WORK PACKAGE DISTRIBUTION						
Project Member	WP1	WP2	WP3	WP4	WP5	WP6
Reyhan Selen ŞEN	%20	%30	%30	%30	%30	%30
İlayda HANLI	%20	%30	%30	%30	%30	%30
Mehmet Safa ÖZOĞLU	%20	%20	%30	%30	%30	%30
Ali Gökay ÖZDEMİR	%20	%20	%10	%10	%10	%10
Total	100%	100%	100%	100%	100%	100%

8. DEMO PLAN

Demo Plan of the Project details explained and shown in Figure 6.

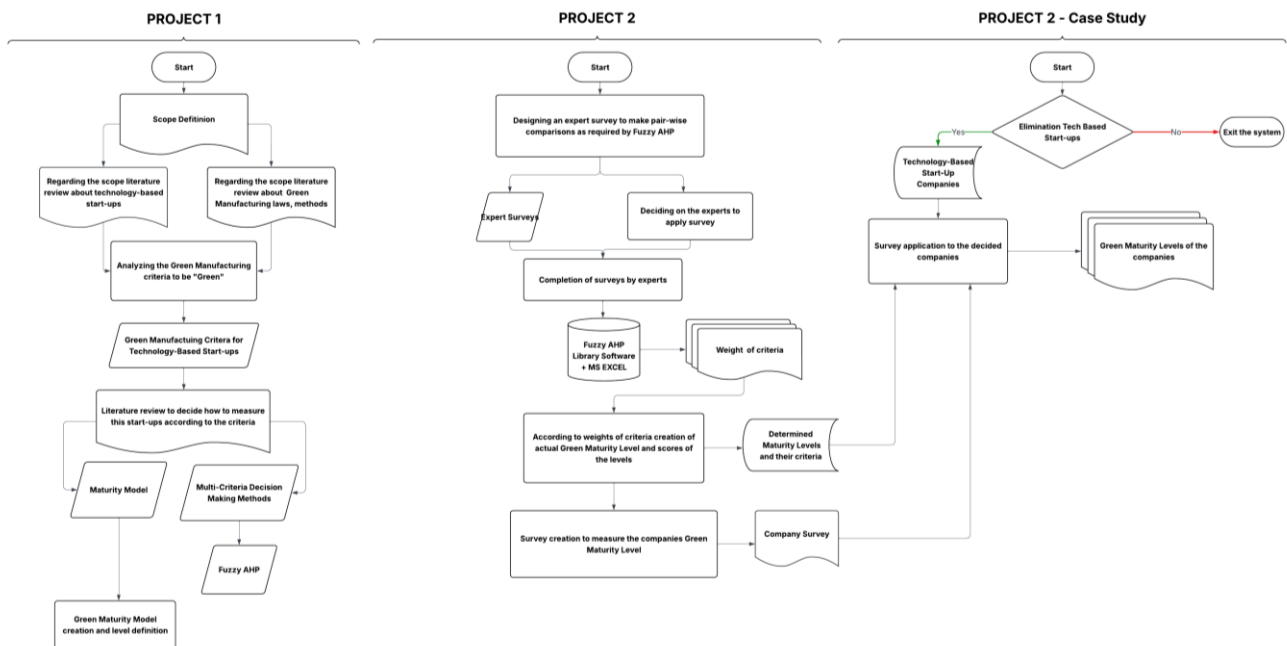


Figure 6: Demo Plan Framework

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As a result of the literature review conducted to measure the production processes of technology-based businesses, criteria should be determined and the necessary methods for calculating the criteria should be determined and the methods should be put into practice. The first of the methods, the Green Maturity Model, should be created and leveled. In order to apply the Fuzzy AHP method, the weights of the criteria should be measured against each other, the surveys to be applied should be created and the surveys to be applied to the selected experts should be created and applied to the necessary experts. The surveys, the determined criteria weights should be added to the Fuzzy-AHP library application and MS EXCEL and the criteria weights should be determined. The determined criteria should form the Green Maturity Model levels. In order for the created Green Maturity Model to be applied to technology-based businesses, an evaluation survey should be created throughout the company. Surveys should be completed for the technology-based businesses selected for the application. The obtained results should be scored and show the maturity level of the companies. For demo, only MS EXCEL is used for calculations.

Fuzzy AHP Results with Buckley’s Method:

In this step, firstly, pairwise comparison surveys were created for each main and sub-criteria of the survey to be applied to the experts. The empty survey of sub-criteria of Environmental Impact main criteria pairwise comparison below figure 7. The main question is “how important against each criteria?”.

Q7. How importance is *energy management (C1.1)* when it is compared with *water management (C1.2)* ?

Q8. How importance is *energy management (C1.1)* when it is compared with *raw material selection (C1.3)*?

Q9. How importance is *energy management (C1.1)* when it is compared with *waste management (C1.4)*?

Q10. How importance is *water management (C1.2)* when it is compared with *raw material selection (C1.3)*?

Q11. How importance is *water management (C1.2)* when it is compared with *waste management (C1.4)*?

Q12. How importance is *raw material selection (C1.3)* when it is compared with *waste management (C1.4)*?

Sub-Criteria of Environmental Impact Pair-wise Comparison

Question	Sub-Criteria	Absolutely Important	Between These	Strongly Important	Between These	Fairly Important	Between These	Weakly Important	Between These	Equally Important	Between These	Weakly Less Important	Between These	Fairly Less Important	Between These	Strongly Less Important	Between These	Absolutely Less Important	Against Sub-Criteria
Q7	C1.1: Energy Management																		C1.2: Water Management
Q8	C1.1: Energy Management																		C1.3: Raw Material Selection
Q9	C1.1: Energy Management																		C1.4: Waste Management
Q10	C1.2: Water Management																		C1.3: Raw Material Selection
Q11	C1.2: Water Management																		C1.4: Waste Management
Q12	C1.3: Raw Material Selection																		C1.4: Waste Management

Figure 7: Empty Survey

The metric filled in in Figure 7 goes through a number of numerical operations. The formulation of these numerical operations is made according to each other and the sums of the numbers in the expressions numbered (l,m,u) that using in triangles.

The entire survey filled from 11 experts was tested for in Excel using the Buckley method to be applied to the survey results for the main and sub-criteria.

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Main criteria surveys matrices aggregated with formula 7 and obtained result below figure 8.

	Environmental Impact			Sustainable Product Manufacturing			Sustainability in Supply Chain			Automation and Digitalization		
	l	m	u	l	m	u	l	m	u	l	m	u
Environmental Impact	1	1	1	2,5097348	3,06604479	3,65877381	1,655507	2,126355	2,629032	0,777203	0,925865	1,093262
Sustainable Product Manufacturing	0,256066	0,326153	0,398448	1	1	1	0,501656	0,586013	0,685175	2,210063	2,636996	3,094118
Sustainability in Supply Chain	0,355092	0,470288	0,604045	1,4594801	1,70644773	1,99339862	1	1	1	4,608346	5,654863	6,683737
Automation and Digitalization	1,095873	1,113619	1,334977	0,3231938	0,37921939	0,45247579	0,205939	0,245851	0,30062	1	1	1

Figure 8: Matrix of aggregation of main criteria

With using formula 8 the geometric mean of the l, m, u values of each row and the sum of these values were calculated as table 10.

	l	m	u
	1,340520078	1,567438394	1,80079375
	0,729945639	0,842576798	0,958688964
	1,243143059	1,459552759	1,684304667
	0,51968536	0,567642306	0,652787605
SUM	3,833294135	4,437210256	5,096574985

Table 10 : Geometric mean of aggregated l,m,u values

Using formula 9 and formula 10 the fuzzy weights of the criteria calculated as table 11.

Inverse Sum GM L	Inverse Sum M	Inverse Sum U
0,196210201	0,225366828	0,260872233

Fuzzy Weight L	Fuzzy Weight M	Fuzzy Weight U
0,263023713	0,353248619	0,469777086
0,14322278	0,18988886	0,250095331
0,243917349	0,328934775	0,439388319
0,101967569	0,127927746	0,17029416

Table 11: Fuzzy weight calculation results

Using formula 11 and 12 the actual weights of the main criteria obtained as follows in Table 12:

	Defuzzification	Normalized
	0,362016473	0,352420496
	0,194402324	0,189249298
	0,337413481	0,328469657
	0,133396491	0,129860549
SUM	1,027228769	1

Table 12: The normalized weights of main criteria

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After calculating the main criterion weights with Buckley, the same steps were applied for the sub-criteria of the Environmental Impact main criterion. These steps are shown below.

	Energy Management			Water Management			Raw Material Selection			Waste Management		
	l	m	u	l	m	u	l	m	u	l	m	u
Energy Management	1	1	1	3,957804	4,558155	5,139297	0,15912	0,19135	0,242097	0,436101	0,536022	0,653346
Water Management	0,391785	0,499779	0,579374	1	1	1	0,170518	0,206063	0,260913	0,168461	0,203195	0,256624
Raw Material Selection	4,261107	5,226031	6,284558	3,832689	4,852888	5,864473	1	1	1	3,796154	4,843983	5,872875
Waste Management	1,715133	1,865595	2,293047	3,896744	4,921373	5,936097	0,170274	0,206442	0,263424	1	1	1

Figure 9 : Aggregated matrix of sub criteria

	l	m	u
	0,723921793	0,826894125	0,949530837
	0,325708754	0,38034069	0,443800994
	2,806031035	3,329229303	3,83564712
	1,03285002	1,173343793	1,376076343
SUM	4,888511602	5,709807911	6,605055294

Inverse Sum GM L	Inverse Sum M	Inverse Sum U
0,151399187	0,17513724	0,204561241

Fuzzy Weight L	Fuzzy Weight M	Fuzzy Weight U
0,109601171	0,144819955	0,194237206
0,049312041	0,066611819	0,090784482
0,424830817	0,583072032	0,784624735
0,156372653	0,205496194	0,281491884

Defuzzification	Normalized
0,149552777	0,145137924
0,06890278	0,066868745
0,597509195	0,579870503
0,214453577	0,208122828
SUM	1,03041833

Table 13: All calculation results of sub criteria weights

The transactions were calculated with the same formulas and order for all sub-criteria and the following result was reached:

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Main Criteria	Main-Weights	Sub-Criteria	Sub-Weights
C1. Environmental Impact	0,3524	C1.3 Raw Material Selection	0,5799
		C1.4 Waste Management	0,2081
		C1.1 Energy Management	0,1451
		C1.2 Water Management	0,0669
C3. Sustainability in Supply Chain	0,3285	C3.1 Supply Chain Selection	0,5963
		C3.3 Green Logistics	0,2254
		C3.4 Reverse Logistics	0,0969
		C3.2 Green Packaging	0,0814
C2. Sustainable Product Manufacturing	0,1892	C2.1 Sustainable Material Selection	0,4689
		C2.2 Product Life Cycle Analysis	0,2457
		C2.3 Green Design and Innovation	0,1907
		C2.4 Machine Selection	0,0947
C4. Automation and Digitalization	0,1299	C4.2 Integrated ERP Systems	0,4627
		C4.1 Industry 4.0	0,4447
		C4.3 Digital Twin Technology	0,0927

Tablo 14 : The combining of all weights of the criteria

After finding the criteria weights, an estimated Green Maturity Model leveling was made by placing the highest weight to the lowest weight in the first level. It is an estimate below.

				C1.3 Raw Material Selection
				C1.4 Waste Management
				C1.1 Energy Management
				C1.2 Water Management
			C1.3 Raw Material Selection	C3.1 Supply Chain Selection
			C1.4 Waste Management	C3.3 Green Logistics
			C1.1 Energy Management	C3.4 Reverse Logistics
		C1.3 Raw Material Selection	C1.2 Water Management	C3.2 Green Packaging
		C1.4 Waste Management	C3.1 Supply Chain Selection	C2.1 Sustainable Material Selection
		C1.1 Energy Management	C3.3 Green Logistics	C2.2 Product Life Cycle Analysis
	C1.3 Raw Material Selection	C1.2 Water Management	C3.4 Reverse Logistics	C2.3 Green Design and Innovation
	C1.4 Waste Management	C3.1 Supply Chain Selection	C3.2 Green Packaging	C2.4 Machine Selection
C1.3 Raw Material Selection	C1.1 Energy Management	C3.3 Green Logistics	C2.1 Sustainable Material Selection	C4.2 Integrated ERP Systems
C1.4 Waste Management	C1.2 Water Management	C3.4 Reverse Logistics	C2.2 Product Life Cycle Analysis	C4.1 Industry 4.0
C1.1 Energy Management	C3.1 Supply Chain Selection	C3.2 Green Packaging	C2.3 Green Design and Innovation	C4.3 Digital Twin Technology
Level 1	Level 2	Level 3	Level 4	Level 5

Figure 10 : Example Demo for Maturity Level Adaptation of the Criteria

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9. FINANCIAL EVALUATION

Proposed and actual budget shown in Table 15.

Table 15 Proposed and actual Budget in ₺

		ITEMS				
		PEOPLE	MACHINE- INSTRUMENT	MATERIALS	SERVICE	TRAVEL
IMU FUND		-	0	0	0	0
SPONSOR COMPANY FUND		-	0	0	0	0
TOTAL		-	0	0	0	0
			0	0	0	0

10. RESULTS

10.1 Fuzzy AHP Results

In result section the Fuzzy AHP Library Software used to obtained criteria weights. The profiles of the experts included in the expert surveys required for the Fuzzy AHP method, their IDs and years of expertise are shown in table 16.

ID	Profile	Years of Experiments
ME17	Mechanical Engineer-Project Manager	17
IE15	Industrial Engineer- SAP Expert	15
QCE 12	Quality Control Engineer	12
IE10	Industrial Engineer	10
IE14	Industrial Engineer - Senior Project Manager	14
EE12	Environmental Engineer	12
ME15	Mechanical Engineer - Project Director	15
ME14	Mechanical Engineer - Production Manager	14
IE12	Industrial Engineer - Assistant director	12
IE14/2	Industrial Engineer - Business Analyst	14
ESS9	Entrepreneurship and Sustainability Specialist	9

Table 16: Expert's Profiles

Verbal reciprocal data from the surveys were displayed as triangular fuzzy numbers. The tables added below are the expressions of the evaluations on the main criteria as triangular fuzzy numbers in table 17 to 27.

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ME17	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	4	5	6	4	5	6	1/8	1/7	1/6
SPM	1/6	1/5	1/4	1	1	1	1/6	1/5	1/4	4	5	6
SSC	1/6	1/5	1/4	4	5	6	1	1	1	4	5	6
AD	6	7	8	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1

IE15	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	4	5	6	2	3	4	2	3	4
SPM	1/6	1/5	1/4	1	1	1	1	1	1	1	1	1
SSC	1/4	1/3	1/2	1	1	1	1	1	1	2	3	4
AD	1/4	1/3	1/2	1	1	1	1/4	1/3	1/2	1	1	1

QCE 12	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	1/8	1/7	1/6	1/8	1/7	1/6	1/6	1/5	1/4
SPM	6	7	8	1	1	1	1/8	1/7	1/6	1/6	1/5	1/4
SSC	6	7	8	6	7	8	1	1	1	6	7	8
AD	4	5	6	4	5	6	1/8	1/7	1/6	1	1	1

IE10	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	6	7	8	1/4	1/3	1/2	1/6	1/5	1/4
SPM	1/8	1/7	1/6	1	1	1	1/8	1/7	1/6	4	5	6
SSC	2	3	4	6	7	8	1	1	1	4	5	6
AD	4	5	6	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1

IE14	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	6	7	8	2	3	4	1	1	1
SPM	1/8	1/7	1/6	1	1	1	2	3	4	4	5	6
SSC	1/4	1/3	1/2	1/4	1/3	1/2	1	1	1	4	5	6
AD	1	1	1	1/6	1/5	1/4	1/5	1/4		1	1	1

EE12	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	6	7	8	4	5	6	6	7	8
SPM	1/8	1/7	1/6	1	1	1	4	5	6	4	5	6
SSC	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	4	5	6
AD	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1

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ME15	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	6	7	8	4	5	6	1/8	1/7	1/6
SPM	1/8	1/7	1/6	1	1	1	1/6	1/5	1/4	6	7	8
SSC	1/6	1/5	1/4	4	5	6	1	1	1	6	7	8
AD	6	7	8	1/8	1/7	1/6	1/8	1/7	1/6	1	1	1

ME14	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	2	3	4	4	5	6	4	5	6
SPM	1/4	1/3	1/2	1	1	1	1/8	1/7	1/6	1/6	1/5	1/4
SSC	1/6	1/5	1/4	6	7	8	1	1	1	6	7	8
AD	1/6	1/5	1/4	4	5	6	4	5	6	1	1	1

IE12	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	6	7	8	4	5	6	1/8	1/7	1/6
SPM	1/8	1/7	1/6	1	1	1	1/6	1/5	1/4	6	7	8
SSC	1/6	1/5	1/4	4	5	6	1	1	1	6	7	8
AD	6	7	8	1/8	1/7	1/6	1/8	1/7	1/6	1	1	1

IE14/2	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	4	5	6	2	3	4	4	5	6
SPM	1/6	1/5	1/4	1	1	1	1	1	1	4	5	6
SSC	1/4	1/3	1/2	1	1	1	1	1	1	6	7	8
AD	1/6	1/5	1/4	1/6	1/5	1/4	1/8	1/7	1/6	1	1	1

ESS9	EI			SPM			SSC			AD		
	l	m	u	l	m	u	l	m	u	l	m	u
EI	1	1	1	1/5	1/4	1/3	1	1	1	6	7	8
SPM	3	4	5	1	1	1	7	8	9	6	7	8
SSC	1	1	1	1/9	1/8	1/7	1	1	1	5	6	7
AD	1/8	1/7	1/6	1/8	1/7	1/6	1/8	1/7	1/6	1	1	1

Table 17 to 27 : Pairwise Comparison Matrices

All data obtained from expert surveys in table 17 to 27 were entered into Fuzzy AHP Library Software and criterion weights were automatically calculated from Fuzzy AHP Library Software, which applies Chang's Synthetic Extend Methods. Tables below show that results in table 28-32.

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Weight of Main Criteria		
Table 1. Weights of Main Criteria		
Rank	Name	Weight
2	C1 Environmental Impact	0,256
3	C2 Sustainable Product Manufacturing	0,249
1	C3 Sustainable Supply Chain	0,263
4	C4 Automation and Digitalization	0,232
Rank by decreased order	Name	Weight
1	C3 Sustainable Supply Chain	0,263
2	C1 Environmental Impact	0,256
3	C2 Sustainable Product Manufacturing	0,249
4	C4 Automation and Digitalization	0,232

Table 28: Weights of main criteria

Weight of Environmental Impact (C1) Sub-Criteria		
Table 1. Weights of Main Criteria		
Rank	Name	Weight
3	C1.1 Energy Management	0,27
4	C1.2 Water Management	0,063
1	C1.3 Raw Material Selection	0,367
2	C1.4 Waste Management	0,3
Rank by decreased order	Name	Weight
1	C1.3 Raw Material Selection	0,367
2	C1.4 Waste Management	0,3
3	C1.1 Energy Management	0,27
4	C1.2 Water Management	0,063

Table 29: Weights of Environmental Impact C1

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Weights of Sustainable Product Manufacturing (C2) Sub-Criteria		
Table 1. Weights of Main Criteria		
Rank	Name	Weight
1	C2.1 Sustainable Material Selection	0,27
2	C2.2 Product Life Cycle Analysis	0,251
3	C2.3 Green Design and Innovation	0,245
4	C2.4 Machine Selection	0,234
Rank by decreased order	Name	Weight
1	C2.1 Sustainable Material Selection	0,27
2	C2.2 Product Life Cycle Analysis	0,251
3	C2.3 Green Design and Innovation	0,245
4	C2.4 Machine Selection	0,234

Table 30: Weights of Sustainable Product Manufacturing C2

Weights of Sustainable Supply Chain (C3) Sub-Criteria		
Table 1. Weights of Main Criteria		
Rank	Name	Weight
1	C3.1 Supply Chain Selection	0,307
4	C3.2 Green Packaging	0,213
2	C3.3 Green Logistics	0,256
3	C3.4 Reverse Logistics	0,224
Rank by decreased order	Name	Weight
1	C3.1 Supply Chain Selection	0,307
2	C3.3 Green Logistics	0,256
3	C3.4 Reverse Logistics	0,224
4	C3.2 Green Packaging	0,213

Table 31: Weights of Sustainability in Supply Chain C3

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Weights of Automation and Digitalization (C4) Sub-Criteria		
Table 1. Weights of Main Criteria		
Rank	Name	Weight
2	C4.1 Industry 4.0	0,387
1	C4.2 Integrated ERP Systems	0,391
3	C4.3 Digital Twin Technology	0,222
Rank by decreased order	Name	Weight
1	C4.2 Integrated ERP Systems	0,391
2	C4.1 Industry 4.0	0,387
3	C4.3 Digital Twin Technology	0,222

Table 32: Weights of Automation and Digitalization

After reaching the weights of all criteria, all the steps required to transition to the maturity model were implemented as follows. For the transition to maturity model, the criteria weights are ranked in decreasing order as shown in table 28-32, the main criteria are ranked first and the rankings of each sub-criteria are ranked within their main criteria in decreasing order.

10.2 Fuzzy Ahp To Maturity Model Adoption With Mean Maturity Score

Step 1: Total weights calculation according to Maturity Score gives the results in table 33.

	Main Criteria	M- Weights	Sub-Criteria	S- Weights	Total Weights
	Green Maturity Model (GMM) for Start-up Criteria	C3 Sustainability in Supply Chain	0,263	C3.1 Supply Chain Selection	0,307
C3.3 Green Logistics				0,256	0,067328
C3.4 Reverse Logistics				0,224	0,058912
C3.2 Green Packaging				0,213	0,056019
C1 Environmental Impact		0,256	C1.3 Raw Material Selection	0,367	0,093952
			C1.4 Waste Management	0,3	0,0768
			C1.1 Energy Management	0,27	0,06912
			C1.2 Water Management	0,063	0,016128
C2 Sustainability in Product Manufacturing		0,249	C2.1 Sustainable Material Selection	0,27	0,06723
			C2.2 Product Life Cycle Analysis	0,251	0,062499
			C2.3 Green Design and Innovation	0,245	0,061005
			C2.4 Machine Selection	0,234	0,058266
C4 Automation and Digitalization	0,232	C4.2 Integrated ERP Systems	0,391	0,090712	
		C4.1 Industry 4.0	0,387	0,089784	
		C4.3 Digital Twin Technology	0,222	0,051504	

Table 33: Total weights

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Step 2 : The Start-up Survey created and the rating scale of the survey that will use according to these data is expressed as follows:

The explanation of the 0-4 scoring is as follows:

- 0: The start-up has no knowledge or application on this subject.
- 1: The start-up has limited knowledge on this subject.
- 2: The start-up has basic knowledge and limited application on this subject.
- 3: The start-up has sufficient knowledge and application on this subject.
- 4: The start-up has advanced knowledge and systematic continuous application on this subject.

Start-up survey was conducted with Montek Teknoloji (Start-up 1) and Uyu Sleep Capsule (Start-up 2).

Step 3 : The results obtained by multiplying the total weights with the highest score to calculate the highest score that can be obtained from each criterion are as follows in table 34.

Sub-Criteria	Total Weights	Max Score
C3.1 Supply Chain Selection	0,080741	0,322964
C3.3 Green Logistics	0,067328	0,269312
C3.4 Reverse Logistics	0,058912	0,235648
C3.2 Green Packaging	0,056019	0,224076
C1.3 Raw Material Selection	0,093952	0,375808
C1.4 Waste Management	0,0768	0,3072
C1.1 Energy Management	0,06912	0,27648
C1.2 Water Management	0,016128	0,064512
C2.1 Sustainable Material Selection	0,06723	0,26892
C2.2 Product Life Cycle Analysis	0,062499	0,249996
C2.3 Green Design and Innovation	0,061005	0,24402
C2.4 Machine Selection	0,058266	0,233064
C4.2 Integrated ERP Systems	0,090712	0,362848
C4.1 Industry 4.0	0,089784	0,359136
C4.3 Digital Twin Technology	0,051504	0,206016
<i>SUM =</i>		4

Table 34: Max Scores

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Step 4 : Inverval of the maturity levels defines as total of max score is total 4 divided by 5 level of the maturity in table 35.

0 – 0,79	Level 1
0,80 – 1,59	Level 2
1,60 – 2,39	Level 3
2,40 – 3,19	Level 4
3,20 – 4,00	Level 5

Table 35 : Intervals

Step 5 : The results obtained in table 32 multiplied by the result of start-up survey of Start-up 1 and 2 for determining which maturity level they are in and which of the ranges calculated in step 4.

Sub-Criteria	Total Weight	Start-up 1 Score	Criteria Score
C1.1 Energy Management	0,06912	3	0,20736
C1.2 Water Management	0,016128	3	0,048384
C1.3 Raw Material Selection	0,093952	4	0,375808
C1.4 Waste Management	0,0768	3	0,2304
C2.1 Sustainable Material Selection	0,06723	4	0,26892
C2.2 Product Life Cycle Analysis	0,062499	4	0,249996
C2.3 Green Design and Innovation	0,061005	3	0,183015
C2.4 Machine Selection	0,058266	3	0,174798
C3.1 Supply Chain Selection	0,080741	2	0,161482
C3.2 Green Packaging	0,056019	2	0,112038
C3.3 Green Logistics	0,067328	2	0,134656
C3.4 Reverse Logistics	0,058912	2	0,117824
C4.1 Industry 4.0	0,089784	2	0,179568
C4.2 Integrated ERP Systems	0,090712	2	0,181424
C4.3 Digital Twin Technology	0,051504	2	0,103008
SUM=			2,728681

Table 36 : Start-Up 1 Results

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Sub-Criteria	Total Weight	Start-up 2 Score	Criteria Score
C1.1 Energy Management	0,06912	1	0,06912
C1.2 Water Management	0,016128	1	0,016128
C1.3 Raw Material Selection	0,093952	3	0,281856
C1.4 Waste Management	0,0768	2	0,1536
C2.1 Sustainable Material Selection	0,06723	1	0,06723
C2.2 Product Life Cycle Analysis	0,062499	1	0,062499
C2.3 Green Design and Innovation	0,061005	4	0,24402
C2.4 Machine Selection	0,058266	1	0,058266
C3.1 Supply Chain Selection	0,080741	1	0,080741
C3.2 Green Packaging	0,056019	1	0,056019
C3.3 Green Logistics	0,067328	1	0,067328
C3.4 Reverse Logistics	0,058912	1	0,058912
C4.1 Industry 4.0	0,089784	2	0,179568
C4.2 Integrated ERP Systems	0,090712	1	0,090712
C4.3 Digital Twin Technology	0,051504	3	0,154512
SUM=			1,640511

Table 37 : Start-Up 2 Results

According to the results in table 36 and 37, Start-up 1 located at Green Maturity Level 4 – Managed and Start-up 2 located at Green Maturity Level 3 - Defined.

10.3 Fuzzy Ahp To Maturity Model Adoption With Cumulative Maturity Scoring (Threshold-Based Maturity Scoring)

In Cumulative Maturity Scoring step 1-2-3 are the same as Mean Maturity Scoring results.

Step 4: According to the Green Maturity Model level definition, criteria of the model levelled as their definition.

Step 5-6: Procedure of step 5 and 6 shown in table 38-40. These steps initially involve placing criteria under previously defined levels of the Green Maturity Model and calculating the maximum score for each criterion at these levels. Then, each start-up was multiplied by the total weight of the requirements according to the score it scored in each of the criteria appropriate to these levels, and these multiplications were collected under each level. The totals shown in the tables include the totals of all the criteria above it for each level, and are presented in this way for ease of presentation. Since exceeding 80% of the maximum score that can be obtained from each level is the critical point, it was checked whether they reached this result at each level.

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				C3.1 Supply Chain Selection	C3.1 Supply Chain Selection
				C3.3 Green Logistics	C3.3 Green Logistics
			C3.1 Supply Chain Selection	C3.4 Reverse Logistics	C3.4 Reverse Logistics
			C3.3 Green Logistics	C3.2 Green Packaging	C3.2 Green Packaging
			C3.4 Reverse Logistics	C1.3 Raw Material Selection	C1.3 Raw Material Selection
			C3.2 Green Packaging	C1.4 Waste Management	C1.4 Waste Management
			C1.3 Raw Material Selection	C1.1 Energy Management	C1.1 Energy Management
			C1.4 Waste Management	C1.2 Water Management	C1.2 Water Management
		C3.1 Supply Chain Selection	C1.1 Energy Management	C2.1 Sustainable Material Selection	C2.1 Sustainable Material Selection
		C3.3 Green Logistics	C1.2 Water Management	C2.2 Product Life Cycle Analysis	C2.2 Product Life Cycle Analysis
		C3.4 Reverse Logistics	C2.1 Sustainable Material Selection	C2.3 Green Design and Innovation	C2.3 Green Design and Innovation
		C3.2 Green Packaging	C2.2 Product Life Cycle Analysis	C2.4 Machine Selection	C2.4 Machine Selection
		C1.3 Raw Material Selection	C2.3 Green Design and Innovation	C4.2 Integrated ERP Systems	C4.2 Integrated ERP Systems
	C3.1 Supply Chain Selection	C1.4 Waste Management	C2.4 Machine Selection	C4.1 Industry 4.0	C4.1 Industry 4.0
-	C3.3 Green Logistics	C1.1 Energy Management	C4.2 Integrated ERP Systems	C4.3 Digital Twin Technology	C4.3 Digital Twin Technology
Initial	Repeatable	Defined	Managed	Optimizing	

Table 38 : Green Maturity Model Levels with Criterion

		Total Weights	Start-up 1 Scores According To Every Criteria	Start-up 1 Scores of Each Level	Summation of Scores of Each Level	%80 of Each Level' Max Score	Threshold Score Compliance
Initial	-	-	-	-	-	0	✓
Repeatable	C3.1 Supply Chain Selection	0,080741	3	0,242223	0,847912	0,592276	✓
	C3.3 Green Logistics	0,067328	3	0,201984			
	C3.4 Reverse Logistics	0,058912	4	0,235648			
	C3.2 Green Packaging	0,056019	3	0,168057			
Defined	C1.3 Raw Material Selection	0,093952	4	0,375808	1,73828	2,011488	x
	C1.4 Waste Management	0,0768	4	0,3072			
	C1.1 Energy Management	0,06912	3	0,20736			
Managed	C1.2 Water Management	0,016128	3	0,048384	2,466088	3,434848	x
	C2.1 Sustainable Material Selection	0,06723	2	0,13446			
	C2.2 Product Life Cycle Analysis	0,062499	2	0,124998			
	C2.3 Green Design and Innovation	0,061005	2	0,12201			
	C2.4 Machine Selection	0,058266	2	0,116532			
C4.2 Integrated ERP Systems	0,090712	2	0,181424				
Optimizing	C4.1 Industry 4.0	0,089784	2	0,179568	2,748664	4	x
	C4.3 Digital Twin Technology	0,051504	2	0,103008			

Table 39 : Start-up 1 Levelling Procedure

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		Total Weights	Start-up 1 Scores According To Every Criteria	Start-up 1 Scores of Each Level	Summation of Scores of Each Level	%80 of Each Level' Max Score	Threshold Score Compliance
Initial	-	-	-	-	-	0	✓
Repeatable	C3.1 Supply Chain Selection	0,080741	1	0,080741	0,436843	0,592276	x
	C3.3 Green Logistics	0,067328	1	0,067328			
	C3.4 Reverse Logistics	0,058912	3	0,176736			
	C3.2 Green Packaging	0,056019	2	0,112038			
Defined	C1.3 Raw Material Selection	0,093952	1	0,093952	0,884075	2,011488	x
	C1.4 Waste Management	0,0768	1	0,0768			
	C1.1 Energy Management	0,06912	4	0,27648			
Managed	C1.2 Water Management	0,016128	1	0,016128	1,330627	3,434848	x
	C2.1 Sustainable Material Selection	0,06723	1	0,06723			
	C2.2 Product Life Cycle Analysis	0,062499	1	0,062499			
	C2.3 Green Design and Innovation	0,061005	1	0,061005			
	C2.4 Machine Selection	0,058266	1	0,058266			
	C4.2 Integrated ERP Systems	0,090712	2	0,181424			
Optimizing	C4.1 Industry 4.0	0,089784	1	0,089784	1,574923	4	x
	C4.3 Digital Twin Technology	0,051504	3	0,154512			

Table 40: Start-up 2 Levelling Procedure

When levelling was done with this method, Start-up 1 remained at Level 3 – Defined, and Start-up 2 remained at Level 2 – Repeatable.

11. DISCUSSION

While applying Buckley Fuzzy AHP shown in the demo plan, the calculation was made without considering consistency and the obtained criteria weights were calculated accordingly. In the following steps, the criteria weights found using Fuzzy AHP Library Software were obtained with Chang Extended Analysis, and the criteria weight data found differed from the Buckley Fuzzy AHP method. It was seen that this difference was due to the Chang Extended Analysis Method calculating the consistency rate within itself and giving the criteria weights accordingly. Therefore, the clearest weights used in the results section come from the data obtained from the used application.

In addition, average scoring and cumulative scoring were used while levelling the Green Maturity Model scores. When the average sum was used, when the company received low scores in the first levels and high scores for the criteria in the other levels, the final result obtained resulted in the company being shown at a higher level. However, this project aims to ensure that each level has its weight and that the company does not move on to the next level without completing 80% of the weight at this level. For this reason, it has been determined that the most appropriate level of scoring for this project, which plans to present a roadmap to start-ups, is cumulative scoring.

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12. ASSESSMENT OF ENGINEERING STANDARDS

This project aims to ensure the implementation of various engineering standards to comply with global or local criteria recognized in sustainability, production, and technological development. Thanks to these standards, it can contribute to sustainability and efficiency goals, while at the same time making operations scalable and environmentally responsible for green production. The standards in this scope are as follows:

- ISO 14001: It is used in management systems for the environment, aiming to minimize environmental factors as much as possible during production.
- ISO 50001: It is a standard that includes energy management for studies aiming to increase energy efficiency.
- Sustainability Standards: The European Green Deal [6] methods used to include and integrate sustainability into projects on their own and to help guide them. It also refers to strategies aimed at reducing waste.
- It integrates with Turkey's Twelfth Development Plan [1] and shows compliance with national standards for green transformation and digitalization.
- Automation and technologies are used for efficient use of resources since Industry 4.0 standards [7].

13. UNIVERSAL AND SOCIAL EVALUATION OF THE PROJECT/ LIMITATIONS

- As for the general scope of the project, it is mostly prepared for technology-based startups and has no direct production constraints. However, since the project has created a roadmap for start-ups, the trustee has been subject to a restriction on what it should do as a priority in the guidelines we have given at the request of start-ups.
- A detailed literature review was conducted especially during the initial stages of the project while conducting research and before revealing the criteria created. Some political issues that are also frequently mentioned in the literature influenced us when choosing the criteria for our report. Sustainability is the most important of these, a number of global and regional studies are being conducted for future civilizations both in the world and in our country, and these studies have been guiding when choosing our criteria.
- In our project, it is aimed to provide an environmental and sustainable contribution rather than environmental problems. In other words, it does not pose any environmental problems.

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- The project is a project built on sustainability.
- Economically, there are no restrictions and people who want to can learn the green maturity level of their company for free in accordance with this model created.

14. CONCLUSION

In this project, the Green Maturity Model was developed by blending sustainability policies and international standards in order to ensure the transition of businesses to green production processes. This project aimed to strategically show a roadmap for technology-based start-ups to achieve sustainability goals, such as environmental and social, and proved how this could be done with the results it presented. Considering this, the theoretical foundations of this project were laid, and the groundwork was prepared for future studies.

In the first stage of this project, a detailed literature review was conducted in terms of the applicability of sustainability policies and green production strategies to businesses. In particular, national, and international standards such as the European Green Deal (European Commission, 2024) and ISO 14001 were examined, and theoretical information was obtained on how they could be applied to micro-scale companies and businesses. In this process, it was decided to use the fuzzy AHP method for uncertainties that may occur in decision-making processes. In the second part of the project, methodological preparations were made for the applicability of the selected method and Fuzzy AHP was presented as an important component of the project, especially to prevent uncertainties that arise in multi-criteria decision-making processes. The criteria were determined, and processes such as a survey and data collection were completed. The obtained survey and data results were synthesized, and the "Green Maturity Model" was created and defined. In the last part, the Green Maturity Model was levelled according to the weights and definitions of the criteria and the maximum score that could be obtained from this model was determined. After the survey on the degree to which the criteria applied to the start-ups were applied in their start-ups was completed, the start-ups were assessed on the Green Maturity Model.

The survey was completed for the initiatives that were among the success outputs of our project, and initiatives that were in line with sustainability goals were determined, and the green maturity levels of these initiatives were analyzed. The compliance of the selected initiatives with policies such as energy efficiency, carbon footprint reduction and sustainability were determined quantitatively. As a result of these processes, it is aimed to increase the environmental performance of the companies.

The Green Maturity Model results calculated with Cumulative Scoring are effective in presenting a roadmap for technology-based enterprises on which criteria they can give more importance to in order to be sustainable and produce green, and how they can reach the highest maturity in this regard. Enterprises can achieve continuous improvement in their companies by developing them according to the existing criteria at every level.

Finally, the theoretical studies and methodological preparations carried out in the project have created a strong foundation for achieving the project goals. The project represents an innovative

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approach for entrepreneurs that will help them achieve their sustainability goals by bringing environmental benefits together.

15. PLAN FOR FUTURE STUDIES

In this project, it may be possible to develop an application that automatically assigns maturity levels. It may also be possible to proceed by comparing existing criteria with different MCDM methods and other fuzzy sets.

16. ASSESSMENT OF ENGINEERING COURSES

In general, all the courses taken at Medipol University Faculty of Engineering and Natural Sciences have an impact on this project. What has been learned in these courses, countless projects and assignments throughout the semesters, and all kinds of topics that may be needed, from basic subjects such as project development and project management to the creation of specific details of the project and completion of the project, have been learned up to this point. The courses that the group members have taken and will take up to this period have been used since the first stages of this project and will continue to be used. First of all, the subjects in other courses such as Quality Engineering and Supply Chain have been helpful for the criteria examined within the scope of Green Maturity Model, Quality Standards and Sustainability. Probability, Linear Algebra and Statistics courses will be used extensively in ratios, error rates and weight calculations, determining weights and matrices in Fuzzy AHP methods and other calculations required in this project. In addition, the Decision Analysis, Strategic Management and Fuzzy Logic and Modeling courses are directly and indirectly connected in various ways in the selection and implementation stages of Decision-Making Methods. Lastly, in the Innovation and Entrepreneurship course, detailed information was gained about startups and their structures.

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