EVALUATION FRAMEWORK FOR THE DIGITAL MATURITY MODEL WITH HESITANT FUZZY MULTI CRITERIA DECISION MAKING TECHNIQUES

(DİJİTAL OLGUNLUK MODELİ İÇİN KARARSIZ BULANIK ÇOK KRİTERLİ KARAR VERME TEKNİKLERİYLE DEĞERLENDİRME YAPISI)

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LIST OF SYMBOLS

AHP	**:** Analytic Hierarchy Process
AD	**:** Axiomatic Design
APIs	**:** Application Program Interfaces
DMs	**:** Decision Makers
DT	**:** Digital Transformation
DMM	**:** Digital Maturity Model
DSAP	**:** Digital Strategic Action Plan
HFL	**:** Hesitant Fuzzy Linguistic
HFLTS	**:** Hesitant Fuzzy Linguistic Term Sets
MCDM	**:** Multi Criteria Decision Making

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ABSTRACT

As organizations continually face pressures to gain and retain competitive advantage, identifying ways of cutting costs, improving quality, reducing time to market, meeting customer requirements, having flexible processes become increasingly important. In this context, Digital Transformation (DT) aim to create new customer experiences, improve operational efficiencies, generate new revenue streams and rapidly respond to changing conditions. Transformation impacts the whole business, not only questioning existing ways of managing and structuring it, but also challenging everyone in the organization to step out of their comfort zones, change their mind-sets and broaden their horizons. Therefore, DT leads to the emergence of new business models. New business models should be systematically shaped. Companies need to know where to start and how to follow a path in their DT journey. At this point, Digital Maturity Models (DMMs) help companies to analyze what levels they are in at DT journey and where to start.

In this thesis, it is aimed to provide a scientific method that guides organizations in their DT journey with 2 phases. In the first phase, an original DMM is constructed and a method for calculating the digital maturity score is proposed. To determine the criteria that affect company's digital maturity level, industry reports and academic papers are systematically reviewed and they are evaluated by experts. The original model consists of 9 dimensions with 36 factors. On the other hand, it is necessary to analyze the significance of these criteria. At this point, Hesitant Fuzzy Analytic Hierarchy Process (AHP) method is used to determine the importance degree of the criteria. Since decision makers (DMs) often have difficulties to express their thoughts and their hesitations during decision-making process, the hesitant fuzzy linguistic terms set (HFLTS) approach is preferred.

In the second phase, strategic action plans are offered according to digital maturity levels of the companies. Strategic action plans need to be designed with respect to organizations' shortcomings. Strategic action plans are determined based on academic papers, experts' review and industry reports. The insufficient parts of companies in terms of DT are determined by DMM evaluation and strategic action plans are proposed as improvement suggestions. At this point, Hesitant Fuzzy Axiomatic Design (AD) method best fits to select the best action plan. Because Hesitant Fuzzy AD method proposes a scientific approach for improving design activities and measures how well the system features respond to the requirements. The research methodology and the proposed evaluation framework are illustrated with a real case study and the results of the study are given.

RÉSUMÉ

Alors que les entreprises sont continuellement confrontées aux pressions pour obtenir et conserver un avantage concurrentiel, identifier les moyens de réduire les coûts, améliorer la qualité, réduire les délais de mise sur le marché, répondre aux exigences des clients, prendre de plus en plus d’importance. Dans ce contexte, Transformation Digitale (TD) vise à créer de nouvelles expériences client, à améliorer l'efficacité opérationnelle, à générer de nouvelles sources de revenus et à répondre rapidement aux conditions changeantes. La transformation a un impact sur l'ensemble de l'entreprise, non seulement en remettant en question les méthodes existantes de gestion et de structuration, mais aussi en incitant tous les membres de l'organisation à sortir de leur zone de confort, à changer d'état d'esprit et à élargir leurs horizons. Par conséquent, TD conduit à l'émergence de nouveaux modèles d'affaires. Les nouveaux modèles d'entreprise devraient être systématiquement façonnés. Les entreprises ont besoin de savoir par où commencer et comment suivre un chemin dans leur parcours TD. À ce stade, les Modèles de Maturité Digitale (MMD) aident les entreprises à analyser les niveaux auxquels elles se trouvent au cours du voyage TD et par où commencer.

Dans cette thèse, il est prévu de fournir une méthode scientifique en 2 phases qui guide les organisations dans leur parcours TD. Dans la première phase, un MMD original est construit et une méthode de calcul du score de MMD est proposée. Pour déterminer les critères qui influent sur le niveau de MMD de l'entreprise, les rapports sectoriels et les documents académiques sont systématiquement revus et évalués par des experts. Le modèle original se compose de 9 dimensions avec 36 facteurs. D'un autre côté, il est nécessaire d'analyser la signification de ces critères. À ce stade, la méthode de l’Analyse Hiérarchique des Procédés (AHP) dans l’environnement hésitant floue est utilisée pour déterminer le degré d'importance des critères. Comme les décideurs ont souvent du mal

à exprimer leurs pensées et leurs hésitations au cours du processus de prise de décision, l'approche Ensembles de Termes Linguistiques Hésitants Flous (ETLHF) est préférée.

Dans la deuxième phase, des plans d'actions stratégiques sont proposés en fonction des niveaux de maturité digitale des entreprises. Les plans d'action stratégiques doivent être conçus en fonction des lacunes des organisations. Les plans d'action stratégiques sont déterminés sur la base de documents académiques, de revues d'experts et de rapports sectoriels. Les parties insuffisantes des entreprises en termes de TD sont déterminées par l'évaluation MMD et des plans d'action stratégiques sont proposés comme suggestions d'amélioration. À ce stade, la méthode de Conception Axiomatique (CA) dans l'environnement hésitant floue convient le mieux pour sélectionner le meilleur plan d'action. Parce que la méthode CA propose une approche scientifique pour améliorer les activités de conception et mesure dans quelle mesure les caractéristiques du système répondent aux exigences. La méthodologie de recherche et le modèle d'évaluation sont illustrés par une étude de cas réelle et les résultats de l'étude sont donnés.

ÖZET

Kuruluşlar, rekabet avantajı kazanmak ve rekabetteki konumlarını korumak için sürekli baskılarla yüz yüze gelirken, maliyetleri düşürmenin, kaliteyi arttırmanın, pazara sunma sürelerini kısaltmanın, müşteri gereksinimlerini karşılamanın ve esnek süreçlere sahip olmanın önemi gün geçtikçe artmaktadır. Bu bağlamda, Dijital Dönüşüm (DD), yeni müşteri deneyimleri yaratmayı, operasyonel verimliliği artırmayı, yeni gelir akışları oluşturmayı ve değişen koşullara hızla cevap vermeyi amaçlamaktadır. Dönüşüm, yalnızca var olan yönetim ve yapılandırma yollarını sorgulamayı değil, aynı zamanda örgütteki herkesin kendi konfor bölgelerinden çıkmasını, zihniyet değiştirmesini ve ufuklarını genişletmesini zorunlu tutmaktadır. Bu nedenle DD, yeni iş modellerinin ortaya çıkmasına yol açmaktadır. Yeni iş modelleri sistematik biçimde şekillendirilmelidir. Şirketler, DD yolculuklarında yola nereden başlayacaklarını ve yolu nasıl takip edeceklerini bilmelidirler. Bu noktada, Dijital Olgunluk Modelleri (DOM), şirketlerin DD yolculuğunda hangi seviyelerde olduklarını ve yola nereden başlamaları gerektiğini analiz etmelerine yardımcı olmaktadır.

Bu tezde, DD yolculuklarında organizasyonlara rehberlik edecek 2 aşamalı bir bilimsel yöntem sunulması amaçlanmaktadır. İlk aşamada, özgün bir DOM oluşturularak dijital olgunluk skorunun hesaplanması için bir yöntem önerilmektedir. Şirketin dijital olgunluk seviyesini etkileyen kriterleri belirlemek için endüstri raporları ve akademik yayınlar sistematik olarak incelenmekte ve uzmanlar tarafından değerlendirilmektedir. Özgün model 9 boyut ve 36 faktörden oluşmaktadır. Öte yandan, bu kriterlerin önemini analiz etmek gerekmektedir. Bu noktada, kriterlerin önem derecesini belirlemek için Kararsız Bulanık Analitik Hiyerarşi Süreci (AHS) yöntemi kullanılmaktadır. Karar vericiler genellikle karar verme sürecinde düşüncelerini ve tereddütlerini ifade etmekte zorlandığından, kararsız bulanık dil terimleri yaklaşımı tercih edilmektedir.

İkinci aşamada firmaların dijital olgunluk seviyelerine göre stratejik aksiyon planları sunulmaktadır. Stratejik aksiyon planlarının, organizasyonların eksik yanlarına göre tasarlanması gerekmektedir. Stratejik aksiyon planları akademik yayınlara, uzman görüşlerine ve endüstri raporlarına göre belirlenmektedir. DOM ile değerlendirme yapıldığında şirketlerin DD açısından eksik yanları belirlenmektedir ve iyileştirme önerisi olarak da stratejik aksiyon planları sunulmaktadır. Bu noktada, Kararsız Bulanık Aksiyomatik Tasarım (AT) yöntemi en iyi stratejik aksiyon planını seçmek için en uygun yöntemdir. Çünkü Kararsız Bulanık AT yöntemi, tasarım faaliyetlerini iyileştirmek ve sistem özelliklerinin gereksinimlere ne kadar iyi yanıt verdiğini ölçmek için bilimsel bir yaklaşım önermektedir. Araştırma metodolojisi ve önerilen değerlendirme modeli gerçek bir vaka çalışması ile örneklendirilerek elde edilen sonuçlar verilmiştir.

1. INTRODUCTION

Investing in technology is not the same thing as the digital transformation. Every company is investing in new tools, platforms, and services and becoming tech-enabled. However, it does not mean that companies are really changing to compete in a digital economy. To gain competitive advantage in digital economy, technology should be driven by the purpose of reshaping the business. In this concept, Digital Transformation (DT) is the realignment of, or new investment in, technology, business models, and processes to more effectively compete in an ever-changing digital economy (Solis, 2017). According to IDC, DT is the approach by which enterprises drive changes in their business models and ecosystems by leveraging digital competencies (Turner, 2015). Building and executing a successful strategy for digital transformation is challenging and takes time. Transformation impacts the whole business, not only questioning existing ways of managing and structuring it, but also challenging everyone in the organization to step out of their comfort zones, change their mind-sets and broaden their horizons (Newman, 2017).

1.1. Background: Digital Transformation

In order to understand the meaning of DT, it is important to examine the nature of the relationship between technology and DT. Furthermore, the drivers of DT in the organizations should be clearly understood.

It is common knowledge that, digitalization is equal to DT. In the digital age, digitalization is necessary for many organizations to compete and survive. These changes are necessary and beneficial for organizations. Digitalization and technology adoption enables organizations to share documents with co-workers, collaborate on projects and make their products and services more convenient and accessible for their customers. In this context, technology helps to create valuable efficiencies. However, digitalization or adopting the latest technology does not lead to DT.

In organizations where the focus is on digitalization and technology adoption, marketing and IT departments takes the responsibility of DT. They redesign websites, improve social media profiles, buy new systems and sometimes create an application. Then, managers wait for these changes to grow their business. Generally, nothing really changes.

The missing link is the question "why" has not been explored and answered in detailed. Organizations need to know its own requirements, own weaknesses, own abilities and capabilities in terms of the competitive digital world. These questions should be asked:

- "Why our business needs technology?"
- "Why our customers might need or use our technology?"
- "If our technology is being implemented to create a competitive advantage, how do we know our technology is going to achieve that?" (Scott, 2017)

Technology is the tool that enables to answer the question "how" and it is a solution for DT. For creating a digital business, technology is one of the change blocks that must be addressed. These change blocks of DT can be listed as: strategy, culture, personnel, customer, process, innovation, technology, data and analytics.

Strategy determines the direction of the DT journey and the culture supports the digital strategy to realize the strategic decisions. Customer and personnel engagement shows the ability for providing digital products or services that are valued by the internal and external customers. Process and innovation is about creating innovation cycles that continuously evolving. Technology is the catalyzer of this cycle. Business and analytics helps to analyze the marketplace and to understand customer behaviors.

Therefore, companies should be aware of that DT requires far more profound changes than only investing in the new technologies. Their digital business models, digital operating models, digital talent and skills and digital traction metrics will be shaped by DT (WEF, 2016).

1.2. The Objective of the Study

Before starting their DT journey, companies have to know the starting point of their journey. Digital Maturity Model (DMM) offers a practical approach to DT. It has been crafted over the course of many months by industry thought-leaders (Newman, 2017). DMM lead companies to see what digital maturity level they have-where they are standing at their digitalization journey- and to give insights about their further developments. DMM provides a systematic approach to find this starting point by determining the digital maturity level of the companies.

The objective of the study is to guide companies on their DT journey by proposing a new evaluation framework combined with Hesitant Fuzzy Linguistic (HFL) Multi Criteria Decision Making (MCDM) techniques. Furthermore, the objective of this thesis is twofold. First, it is aimed to propose a DMM to guide companies on their DT journey, to propose an analytical tool to help companies to understand the importance of the factors affecting their digital maturity level and determine their digital maturity score. Secondly, it is aimed to propose new Digital Strategic Action Plans (DSAPs) and to select the most appropriate DSAP by using analytical techniques.

An integrated HFL MCDM methodology is implemented as analytical technique. Because, sometimes DMs can have difficulties to express their thoughts by numbers because these quantitative values are far from their realistic way of thinking in everyday life. The uncertainty and vagueness of information is reflected in this thesis by using fuzzy logic (Zadeh, 1965). Moreover, experts can hesitate while expressing their opinions. This is where the Hesitant Fuzzy Linguistic Term Sets (HFLTS) technique becomes helpful in solving this problem (Rodriguez et al. 2012). There are lots of advantages of using hesitancy to examine the thoughts of DMs by linguistic term sets. First of all, in this model of decision, the DMs have possibility to give their opinions by linguistic expressions, they do not have to convert their ideas into some numeric values. Furthermore, it creates a more convenient way by providing flexibility and capability of elicitation of linguistic expressions to DMs.

In this thesis, a multi-dimensional DMM is constructed by conducting a detailed literature survey. For proposing the new DMM, the criteria that affect company's digital maturity score, industry reports and academic papers are systematically reviewed and they are evaluated by experts. On the other hand, it is necessary to analyze the significance of these criteria. At this point, Hesitant Fuzzy Analytic Hierarchy Process (AHP) method is used to determine the importance degree of the criteria. A method for calculating the digital maturity score is proposed. Furthermore, this framework is used as a practical guide for determining the insufficient parts of the companies in terms of DT. After detecting the insufficient parts of the companies, DSAPs are proposed as improvement suggestions for DT. DSAP provides companies new directions in terms of DT by taking into consideration different focus areas. After determining the possible DSAPs, an analytical approach is needed to choose the right action plan at the DT journey. To meet the requirements of the design problem, Hesitant Fuzzy Axiomatic Design (AD) method is utilized. The reason behind choosing this methodology is its scientific approach for improving design activities and measuring how well the system features respond to the design requirements.

The rest of the thesis is organized as follows: Section 2 presents the basic concepts about DMM. Section 3 presents the proposed evaluation framework of the thesis. The research methodology is given in Section 4. In Section 5, a real case study is given to illustrate the robustness of the proposed approach. Conclusion and future directions are provided in Section 6.

2. DIGITAL MATURITY MODELS - LITERATURE REVIEW

2.1. Definition of the Digital Maturity Model

Digital Maturity Model (DMM) defines the level of maturity of an organization in addressing a business problem. It is originally developed in line with the Capability Maturity Model defined by Carnegie Mellon and often used to look at the maturity of software development processes (SSB Bart Group). Maturity models can be defined as multistage models that defines typical patterns for the development of organizational capabilities (Poeppelbuss et al., 2011). Maturity models are designed to evaluate the maturity (i.e. competency, capability, level of sophistication) of a selected area based on a set of criteria (De Bruin et al., 2005).

DMM measures the maturity of digital accessibility programs along a series of dimensions and aspects to assign them to particular levels (Avila and Smith, 2015). The DMM is a living dynamic model that continuously evolves. Digital maturity is an aspirational target. Because while companies are trying to reach digital maturity, it continues changing and improving (Newman, 2017). DMMs are designed to determine the stages within the digital transformation, using the affecting factors under different dimensions (Berghaus and Back, 2016).

DMM is effective for a variety of purposes (Newman, 2017):

- It forces organizations to analyze and properly structure the problem
- It illustrates the short and long term goals and plans
- It ensures a basis to help organizations for assessing realistically where they are in their digital transformation journey

Different types of DMM models exists in academia and industry. For example, International Association of Accessibility Professionals (IAAP) illustrates the maturity level content breakdown as in Figure 2.1 (Avila and Smith, 2015):

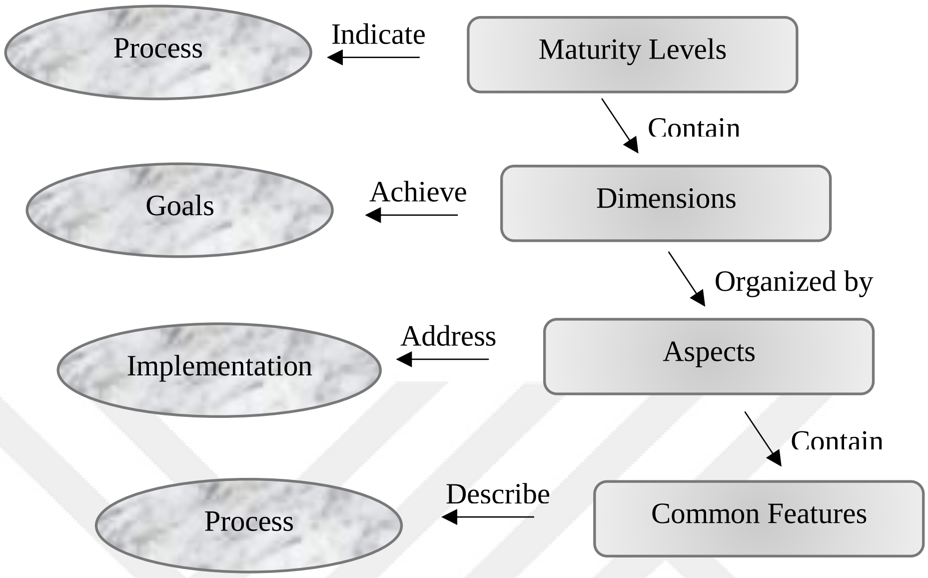

Figure 2.1: Maturity level content break down (Avila and Smith, 2015)

TM Forum determined 5 maturity dimensions as customer, technology, operations, organization and strategy with 5 levels as level 5: leading, level 4: advancing, level 3: performing, level 2: emerging, level 1: initiating. Figure 2.2 shows the model of TM Forum with its 5 maturity dimension (Newman, 2017):

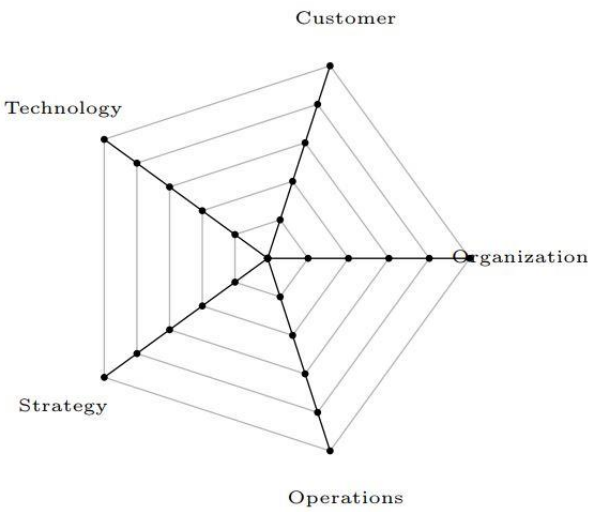

Figure 2.2: Maturity dimensions (Newman, 2017)

Deloitte admitted that, in order to overcome the complexity of digital business, enterprises should embrace the digital congruence. The definition of digital congruence is the alignment of the culture, people, and structure. Therefore, leaders can effectively address the challenges of the digital landscape. Figure 2.3 illustrates Deloitte's approach for digital maturity.

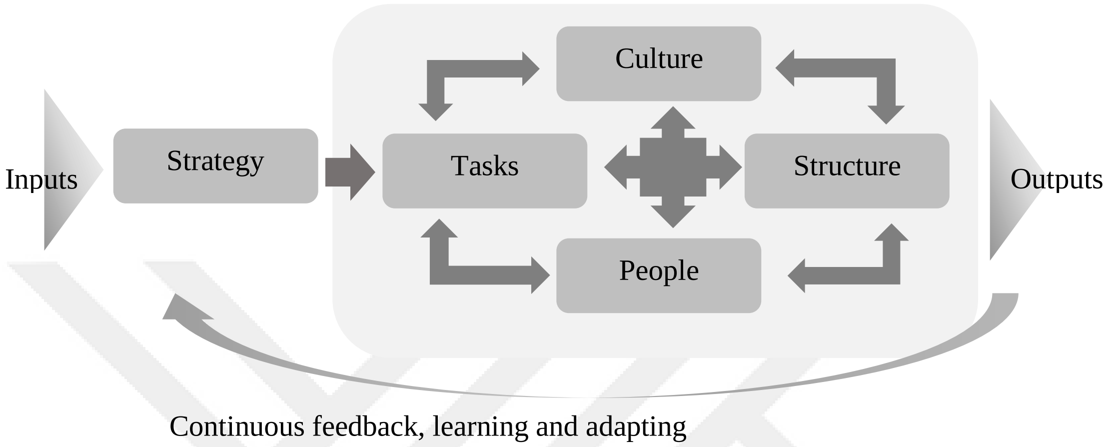

Figure 2.3: Digital congruence framework (Kane et al., 2016)

Forrester separated DMM into 4 categories and determined 7-8 requirements below these categories to measure organizations' digital maturity level. Figure 2.4 shows this model. To measure the maturity level, they asked: "How much do you agree with each of the following statements?" The organizations evaluated these requirements by using this scale: "0-Completely disagree, 1-Somewhat disagree, 2-Somewhat agree, 3-Completely agree".

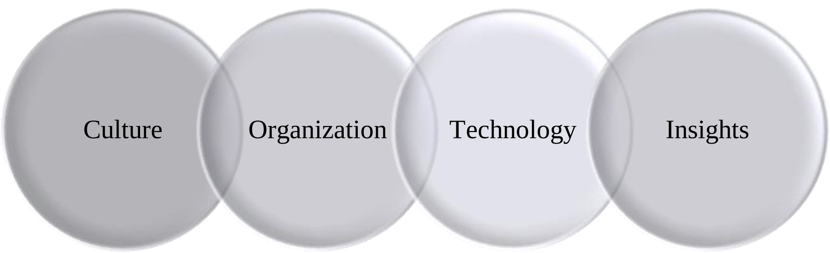

Figure 2.4: Digital maturity framework (Forrester, 2016)

To investigate the DMM subject comprehensively, the detailed literature survey is conducted and explained in following section. Furthermore, the different types of maturity models in industry reports and academic papers are examined in detail. Therefore, the various forms of DMMs are examined by listing different affecting dimension, factors and maturity levels. As a result, the original DMM of the study is constructed with the help of these analyses and experts' reviews.

2.2. Literature Survey for DMM

In recent years, several studies have been performed about maturity levels Table 2.1 shows the detailed survey of this subject. De Bruin et al. (2005) constructed a methodology for the main stages of capability model development. Wetering and Batenburg (2009) built a maturity model for hospital information systems. In the same year, Gottschalk (2009) introduced a maturity model for digital government concept. Poeppelbuss et al. (2011) reviewed the literature of maturity models in the area of information systems. In 2016, Berghaus and Back (2016) examined digital transformation strategies and contributed to the organizational transformation literature by presenting a maturity model.

Recently, the popularity of the maturity model has increased. Carolis et al. (2017) investigated manufacturing companies' digital maturity levels by constructing a methodology. Danjou et al. (2015) examined digitalization and provided a framework for defining maturity levels of companies. Grange and Ricoul (2017) provided a methodology of DMM which includes 4 stages of digitalization. Boström and Celik (2017) constructed a conceptual framework by determining the factors of digital business and developed a DMM. Hagg and Sandhu (2017) made a systematic literature review of the papers about DT. Tavakoli and Mohammadi (2017) examined the distribution process of the retail companies and defined the maturity levels of these companies. Gastaldi et al. (2018) developed a maturity model for measuring the maturity of BI tools in healthcare organizations.

Table 2.1a: Literature survey about DMMs

Year	Author(s)	Objective of the Study	Applied techniques	Field of application
2000	Luftman	Provide a tool for strategy alignment with strategic maturity assessment	Literature Analysis	Application of maturity model for IT strategic plans
2001	Holland and Light	Develop a stage maturity model for ERP systems	Competency Measurement	Adoption of the model to assess ERP maturity level in organizations
2004	Antonucci et al.	Present a maturity model to support enterprise systems education	Literature Analysis	Implementation of maturity model to ERP education
2004	Cottam et al.	Provide a CRM maturity model	Competency Measurement	Adoption of CRM maturity model for UK local councils
2004	Jiang et al.	Exploration of the connection between projects' performance and software development maturity	Regression Analysis	Implementation of the model for software projects
2005	De Bruin et al.	Construct a methodology and outline for the main phases of generic model development	Design Methodology	Adoption of maturity model in Knowledge Management and Business Process Management
2006	Luftman	Improve the IT business alignment with maturity perspective	Competency Measurement	Application of maturity model for business IT alignment
2009	Rohloff	Propose the Process Management Maturity Assessment (PMMA) model	Reference Modeling	Implementation of the PMMA model for Siemens
2009	Rudolph	Develop a maturity model to determine the quality of IT service catalogues	Benchmarking Study	Application of the model for IT service catalogues

Table 2.1b: Literature survey about DMMs

2009	Wetering and Batenburg	Develop a maturity model for picture archiving and communication systems (PACS)	Meta Analytic Review	Application of maturity model to hospitals for electronic patient record and other health information systems
2009	Gottschalk	Present a maturity model for digital government	Exploratory Research	Introduce a maturity model to public organizations to identify current maturity and future direction
2010	Dinter and Goul	Provide a new maturity model considering cross-cultural perspective	Hypothesis Testing	Implementation of proposed maturity model for BI subject
2010	Russell et al.	Provide an evaluation model for determining the connection between evolution and levels in CMM	Literature Analysis	Application of the framework for a large national organization
2011	Poeppelbuss et al.	Review the papers about maturity models in Information Systems (IS)	Literature Analysis, Meta-Analysis	Collection and analysis of maturity models in IS subject
2012	Friedel and Back	Develop a maturity model for Enterprise 2.0 development	Probabilistic Test Theory	Application of the maturity framework for enterprises
2016	Berghaus and Back	Give insight for understanding of digital transformation strategy and maturity models	Survey, Rasch-Algorithm, Cluster Analysis	Propose a study to contribute the organizational transformation literature
2016	Schumacher et al.	Develop a maturity model for Industry 4.0 concept by considering the organizational aspects	Literature Analysis	Implementation of the methodology to an Austrian manufacturing company

Table 2.1c: Literature survey about DMMs

2016	Valdez-de-Leon	Propose an evaluation model of digital transformation and maturity models	Three-stage development approach	Develop digital maturity framework for telecommunications sector
2017	Carolis et al.	Propose a framework to investigate companies' digital maturity	Scoring Method	Provide a methodology to manufacturing companies and researchers to figure out their digital readiness level
2017	Danjou et al.	Introduce a business model to highlight the digitalization and connectivity areas in companies	Review	Ensure a framework for determining maturity levels of companies in digital world
2017	Grange and Ricoul	Define the stages of maturity for digital enterprises	Review	Propose a maturity model that consist of 4 levels to provide a framework for companies
2017	Boström and Celik	Determine the factors of digital business and develop a maturity model for digitalization	Review	Provide practitioners a conceptual framework and give insight for researchers on digital business strategies
2017	Hagg and Sandhu	Research the articles about digital transformation and construct the digital maturity framework	Abductive Approach, Thematic Analysis	Guide managers to see their needs in order to improve their digital maturity level
2017	Tavakoli and Mohammadi	Define retail companies' digital maturity level and analyze the positive effects of digitalization on these companies	Qualitative Interviews, Questionnaire, Theoretical Research	Determine retail companies' digital maturity level for the distribution process

Table 2.1d: Literature survey about DMMs

2017	Wibowo and Taufik	Provide a self-assessment tool for companies to measure their maturity level	Delphi method, AHP method	Implementation of the maturity self-assessment tool for construction projects in Indonesia
2018	Gastaldi et al.	Develop a maturity model for measuring the maturity of BI tools in healthcare organizations	Benchmarking Study	Application of the two-phase model for ISMETT hospital

Existing studies concerning maturity models in the literature are investigated qualitatively (e.g. interviews, literature analysis) or quantitavely by using statistical methods (e.g. regression analysis). Wibowo and Taufik (2017) implemented AHP methodology for determining maturity factors' weights. Except this study, none of the studies in the Table implemented MCDM tools. The nature of maturity models is very appropriate for MCDM tool integration. Because, various factors may have different importance degrees according to companies' preferences and they should be reflected. For this reason, in this thesis, hesitant fuzzy AHP method is used for determining maturity factors' importance degrees.

In following sections, the existing maturity models are studied. The research area is divided in 2 sub-sections. The first one is industrial reports; the second one is academic researches (i.e. theses, articles, journals, proceedings). The maturity levels, maturity dimensions and maturity factors are illustrated differently at these studies.

2.3. The Types of DMMs in Industry Reports

To examine industry reports concerning DMMs, we conducted a detailed research on internet. This exploration gives an insight about maturity models in industry. The reports are investigated with respect to their maturity approach, maturity levels and maturity dimensions. Table 2.2 shows the research of DMMs in industry reports.

Table 2.2a: The DMMs in industry reports

Year	Institution/ Source	Maturity Approach	Levels	Dimensions
2015	SSB BART Group	Assessment in 6 dimensions, 5 levels.	Level 1-Informal Level 2-Defined Level 3-Repeatable Level 4-Managed Level 5-Optimized	1) Ownership and Governance 2) Policy and Standards 3) Training 4) Fiscal and Risk Management 5) Support and Documentation 6) Communications
2015	The International Association of Accessibility Professionals (IAAP)	Assessment in 10 dimensions, 5 levels.	Level 1-Initial Level 2-Managed Level 3-Defined Level 4-Quantatively Managed Level 5-Optimizing	1) Governance, Risk Management, and Compliance 2) Communications 3) Policy and Standards 4) Legal 5) Fiscal Management 6) Development Lifecycle 7) Testing and Validation 8) Support and Documentation 9) Procurement 10) Training
2015	The IDC	Assessment in 5 dimensions, 5 levels.	Level 1-Digital Resister Level 2-Digital Explorer Level 3-Digital Player Level 4- Digital Transformer Level 5- Digital Disrupter	1) Leadership 2) Omni-Experience 3) Information 4) Operating Model 5) Work Source
2015	VISA	Assessment in 3 dimensions, 4 levels.	Level 1-Limited Level 2-Basic Level 3-Mature Level 4-Leading	1) Strategy 2) Marketing 3) User Experience

Table 2.2b: The DMMs in industry reports

2015	Deloitte	Assessment in 6 dimensions, 3 levels	Level 1-Early Cluster Level 2-Developing Cluster Level 3- Maturing Cluster	1)Agility 2)Risk appetite 3)Decision making 4)Leader structure 5)Passion for work 6)Work style
2016	The Forrester Group	Assessment in 4 dimensions, 4 levels.	Level 1-Skeptics Level 2-Adopters Level 3-Collaborators Level 4-Differentiators	1) Culture 2) Organization 3) Technology 4) Insights
2016	PwC	Assessment in 6 dimensions, 4 levels.	Level 1-Digital Novice Level 2-Vertical Integrator Level 3-Horizontal Collaborator Level 4-Digital Champion	1)Business Models, Product & Service Portfolio 2)Market & Customer Access 3)Value Chains & Processes 4)IT Architecture 5)Compliance, Legal, Risk, Security & Tax 6)Organization & Culture
2017	TM Forum	Assessment in 5 dimensions, 5 levels.	Level 1-Initiating Level 2-Emerging Level 3-Performing Level 4-Advancing Level 5- Leading	1) Customer 2) Strategy 3) Technology 4) Operations 5) Organization
2017	Cognizant Group	Assessment 5 levels.	Level 1-Business as Usual Level 2-Test and Learn Level 3-Systemize and Strategize Level 4-Adapt or Die Level 5-Transformed and Transforming Level 6-Innovate or Die	-

Table 2.2c: The DMMs in industry reports

2018	SAP	Assessment in 6 dimensions.	-	1) Omni-Channel Marketing 2) Merchandising 3) Procurement and Private Label 4) Supply Chain 5) Omni-channel 6) Customer Experience 7) Smarter Enterprise
2018	Bain & Company's	Assessment in 7 dimensions, 5 levels	Level 1-Isolated Level 2-Clustered Level 3-Networked Level 4-Connected Level 5-Interconnected	1)Ambition 2)Customer 3)Operations 4)IT 5)Data 6)People 7)Orchestration

It is clearly seen that maturity levels are generally divided in five or six parts. Level 1 begins from the less digitalized degree and goes to Level 5-6 that has the most digitalized degree. Maturity dimensions highly varies according to the institutions. Generally, "Organization", "Technology" and "Culture" are preferred as maturity dimension. Some of the dimensions like "Orchestration" or "Agility" or "Training" are very interesting but rarely preferred. However, it is possible that they are reflected under other dimensions in other reports.

2.4. The Types of DMMs in Academic Papers

To gain an insight about maturity models in literature, academic papers concerning DMMs are investigated. The sources are found by writing "Digital Maturity", "Digital Transformation" and "Maturity Model" keywords. Researches are conducted in "web of science", "science direct" and "google scholar" web-sites. 24 studies are chosen for examining their DMMs and the papers are investigated with respect to their maturity approach, maturity levels and maturity dimensions. Since the number of the maturity factors could be very huge, they are not listed in the table. Table 2.3 shows the research of DMMs in academic papers (e.g. articles, proceedings, and thesis).

Table 2.3a: The DMMs in academic papers

Year	Source	Maturity Approach	Levels	Dimensions
2000	Luftman	Assessment in 6 dimensions, 5 levels.	1) Initial/Ad Hoc Process 2) Committed Process 3) Established Focused Process 4) Improved/Managed Process 5) Optimized Process	1) Communications Maturity 2) Competency/Value Measurements Maturity 3) Governance Maturity 4) Partnership Maturity 5) Scope & Architecture Maturity 6) Skills Maturity
2001	Holland and Light	Assessment in 5 dimensions, 3 levels.	1) Stage 1 2) Stage 2 3) Stage 3	1) Strategic use of IT 2) Organizational Sophistication 3) Penetration of the ERP System 4) Vision 5) Drivers and Lesson
2003	Luftman	Assessment in 6 dimensions, 38 items, 5 levels.	1) Without Process (no alignment) 2) Beginning Process 3) Establishing Process 4) Improved Process 5) Optimal Process (complete alignment)	1) Communications 2) Competency/Value Measurements 3) Governance 4) Partnership 5) Technology Scope 6) Skills
2004	Antonucci et al.	Assessment in 3 dimensions, 5 levels.	1) Initial/Siloed 2) Adaptive 3) Developing 4) Shared 5) Optimized	1) Functions 2) Process Integration 3) Level of Curriculum Development
2004	Cottam et al.	Assessment in 9 dimensions, 5 levels.	1) Aware 2) Developing 3) Practicing 4) Optimizing 5) Leading	1) Improving customer access 2) Using information in service delivery 3) Service processes 4) Joining up 5) Service choices 6) Business processes 7) Partnerships 8) Resources 9) Strategic procurement

Table 2.3b: The DMMs in academic papers

2004	Jiang et al.	Assessment in 5 dimensions, 38 items, 5 levels.	1) Initial 2) Managed 3) Defined 4) Repeatable 5) Optimizing	1) Organizational Learning 2) Process controls 3) Interpersonal communication quality 4) Operational efficiency 5) Software flexibility
2004	Kulkarni and Freeze		1) Difficult/Not Possible 2)Possible 3) Enabled/ Practiced 4) Managed 5)Continuously Improved	1) Culture 2) Expertise 3) Lessons Learned 4) Knowledge Documents 5) Data
2005	De Bruin et al.	Assessment in 6 dimensions, 30 items, 5 levels.	1) Not Possible 2) Possible 3) Enabled/Practiced 4) Managed 5) Continuous Improvement	1) Strategic Alignment 2) Governance 3) Methods 4) Information Technology 5) People 6) Culture
2008	Gottschalk et al.	Assessment in 9 constraints, 5 levels.	1) Computer Interoperability 2) Process Interoperability 3) Knowledge Interoperability 4) Value Interoperability 5) Goal Interoperability	1)Constitutional/legal constraints 2) Jurisdictional constraints 3) Collaborative constraints 4) Organizational constraints: 5) Informational constraints 6) Managerial constraints 7) Cost constraints 8) Technological constraints 9) Performance constraints

Table 2.3c: The DMMs in academic papers

2009	Rohloff	Assessment in 9 dimensions, 5 levels.	1) Initial 2) Managed 3) Defined 4) Quantatively Managed 5) Optimizing	1) Process Portfolio & Target Setting 2) Process Documentation 3) Process Performance Controlling 4) Process Optimization 5) Methods & Tools 6) Process Management Organization 7) Program Management, Qualification, Communication 8) Data Management 9) IT-Architecture
2009	Rudolph	Assessment in 6 dimensions, 5 levels.	1) Initial 2) Managed 3) Defined 4) Quantatively Managed 5) Optimizing	1) Perception of IT service catalogue by the customer 2) IT service orientation of the IT service catalogue 3) Transparency of the IT service portfolio 4) Quality of documentation of IT service portfolio and IT service delivery 5) Usage level of IT service catalogue 6) Planning the IT service budget
2010	Russell et al.	Assessment in 5 dimensions, 4 levels.	1) AD Hoc & Informal & Analysis Reporting 2) Centralization & Warehousing 3) Analytical Service Provisioning 4) Integration	1) Executive 2) Perception 3) Information Culture 4) Analytics Culture 5) Architecture
2010	Dinter and Goul	Assessment in 3 dimensions, 10 categories, 32 items, 6 levels.	1) Scope 2) Design 3) Populate 4) Test 5) Deploy 6) Maintain	1) Functionality 2) Technology 3) Organization

Table 2.3d: The DMMs in academic papers

2012	Friedel and Back	Assessment in 4 dimensions, 5 levels.	1) Level 1: 0-1 2) Level 2: 1-2 3) Level 3: 2-3 4) Level 4: 3-4 5) Level 5: 4-5	1) Information Technology 2) Processes 3) Strategy 4) People
2013	Bagheri et al.	Assessment in 3 dimensions, 5 levels.	1) Initial 2) Awareness 3) Defined 4)Managed/established 5)Optimization/sharing	1) People/organization 2) Processes 3) Technology
2016	Berghaus and Back	Assessment in 9 dimensions, 25 items, 5 levels.	1) Promote & Support 2) Create & Build 3) Commit to transform 4) User-centered & elaborated processes 5) Data-driven enterprise	1) Customer Experience 2) Product Innovation 3) Strategy 4) Organization 5) Process Digitization 6) Collaboration 7) Information Technology 8) Culture & Expertise 9) Transformation Management
2016	Schumacher et al.	Assessment in 9 dimensions, 62 items, 4 levels.	-	1) Strategy 2) Leadership 3) Customers 4) Products 5) Operations 6) Culture 7) People 8) Governance 9) Technology
2016	Valdez-de-Leon	Assessment in 7 dimensions, 30-35 items different for each level, 6 levels.	1) Not started 2) Initiating 3) Enabling 4) Integrating 5) Optimizing 6) Pioneering	1) Strategy 2) Organization 3) Customer 4) Technology 5) Operations 6) Ecosystem 7) Innovation
2017	Boström and Çelik	Assessment in 6 dimensions, 16 items, 5 levels.	1) IT Strategizing 2) Aligned Strategizing 3) Digital Strategizing	1) Communication 2) Value Measurement 3) Leadership 4) Ecosystem 5) Technology 6) Skills

Table 2.3e: The DMMs in academic papers

2017	Carolis et al.	DREAMY model: Assessment in 4 dimensions, 18 items, 5 levels.	1) Initial 2) Managed 3) Defined 4) Integrated and Interoperable 5) Digital-Oriented	1) Process 2) Monitoring and Control 3) Technology 4) Organization
2017	Danjou et al.	Assessment in 3 dimensions, 4 levels.	1) Monitoring 2) Control 3) Optimization 4) Autonomy	1) Technology 2) Deployment 3) Organization
2017	Hagg and Sandhu	Assessment in 6 dimensions, 15-20 items different for each level, 3 levels.	1) Awareness 2) Experience 3) Autonomy	1) Processes 2) Analytics 3) Strategy 4) Culture 5) Leadership 6) Information Technology
2017	Wibowo and Taufik	Assessment in 4 dimensions, 34 items, 4 levels.	1) Naïve: 0-24 2) Novice: 25-49 3) Normalized: 50-74 4) Managed: 75-100	1) Organizational Culture 2) RM Processes 3) RM Resources 4) RM Implementation
2018	Gastaldi et al.	Assessment in 4 dimensions, 23 items, 4 levels.	1) Initial 2)Managed 3)Systematic 4)Disrupted	1) Functional 2) Technological 3) Diffusional 4) Organizational

The research shows that maturity levels are grouped in five or six levels like in the industry reports. Some of these papers give original names to the maturity levels while some of them are just enumerating the levels. “Customer”, “Communication”, “Process”, “Organization” and “Technology” are frequently used as digital maturity dimensions. On the other hand, “Value Measurement”, “Partnership” and “Strategy” are interesting by less preferred dimensions.

Majority of these studies determined different maturity factors under maturity dimensions. They are often listed in 25-30 interval. The assessments are generally made based on the competency of companies concerning these factors. Some of these studies preferred preparing questionnaires about maturity factors. According to these assessments, the maturity level of the companies is determined as maturity with respect to dimensions and the overall digital maturity.

3. PROPOSED EVALUATION FRAMEWORK

This thesis is composed of 3 main phases. In the first phase, the main problem is defined in detail. The requirements, the expectations, the barriers of DT are studied based on academic papers and industry reports. After the research phase, the problem is determined. First of all, the definition of problem according to MCDM logic is constructed. The problem is to evaluate the digital maturity score of the company and to select the most appropriate DSAP by using HFL MCDM techniques. The digital maturity criteria and digital action plan alternatives are identified. By taking into account the nature of the problem, the appropriate MCDM methods and the nature of the methodology are determined as AHP and AD methods in hesitant fuzzy environment.

In the second phase, to construct a new DMM, the research is focused on existing maturity models. After detailed research, the new maturity model is constructed with 9 dimensions and 36 factors. The weights of these factors are calculated by using HFL AHP technique. To evaluate companies' digital maturity, this factors are needed to be transformed into questions. For this reason, a digital maturity assessment questionnaire that consists of 108 questions is prepared (please refer to Appendix A. as an example of customer dimension).

In the third phase, the digital maturity score of companies are taken into consideration to determine the insufficient parts of the companies in terms of digitalization. To offer DSAPs to companies, the existing models are examined. The most appropriate DSAP is selected by using HFL AD technique. The overall evaluation framework of the study is illustrated in Figure 3.1.

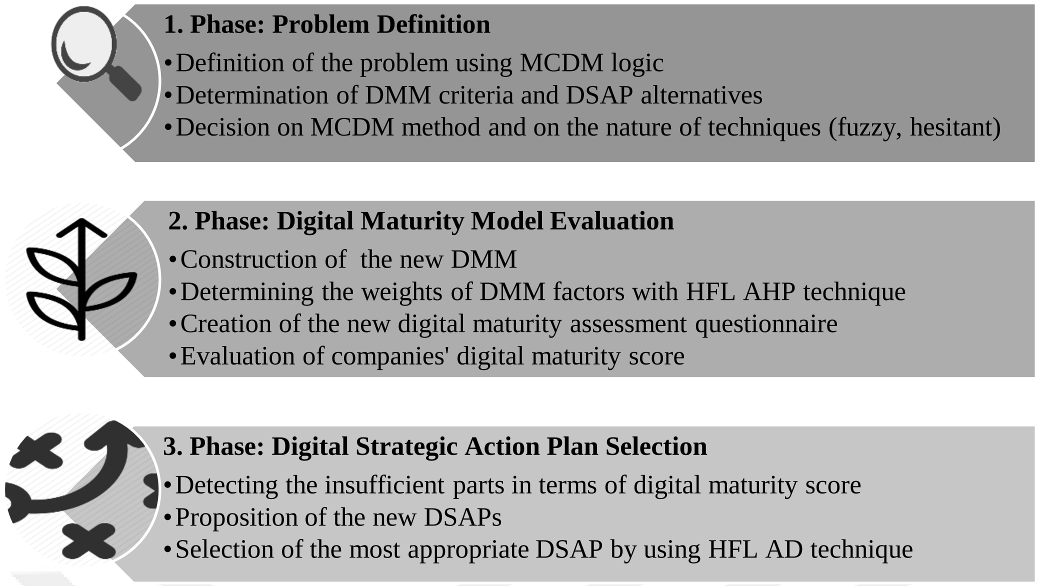

Figure 3.1: The general view of the proposed evaluation framework

3.1. Proposed DMM

The original DMM model is constructed with the help of experts' reviews, industry reports, internet research, panels about DT and academic papers. The model consists of 36 factors and 9 dimensions as: Customer, People, Communication, Culture, Technology, Processes, Business Model, Organization and Ecosystem.

The digital maturity factors below 9 dimensions are explained in detail in the following sections. Their order is constructed with a logic. For example, in customer dimension, first design for customer needs should be ensured, then online customer touch points, then BI utilization and as a result, customer experience via new technologies should be achieved.

3.1.1. Customer

This dimension focuses on customer participation and empowerment across all of the processes. On the other hand, new benefits created in customer experience through DT of the customer journeys are examined in detail. Figure 3.2 shows the factors of customer dimension

Figure 3.2: The factors of customer dimension

Design for Customer Needs: Customer experience design is a capability that organizations utilize to estimate customer requirements and meet their needs in real time (CGI Report, 2016). Design-thinking approach is being applied to design superior customer experiences across different industries. Transformation of businesses with right-skilled customer experience designers can be completed while driving disruptive innovative solutions to solve for customers' needs and complaints (Chandra, 2016). Technology design should consider customer experience assets, like personas and journey maps. For example, Accenture, Amazon, Disney, GE, Google, Facebook, IBM, Infosys, Netflix, and Starbucks leverage design thinking approach and digital trends to customer engagement in an effective way (Rao, 2018).

Online Customer Touch Points: A touch point is any instance when a client or potential client meets the company. Customers can recognize and remember the brand by the customer touch points since it is where customers and business engage to exchange information, provide service, or handle transactions (Gregory, 2010). Billboards, direct mails, web sites, in-store cashiers, call centers; social media, mobile applications can be used as online touch points. Customers can trust companies that deliver fast and transparent problem resolution service. For this reason, companies uses digital tools and offers self-service model to customers. In this way, companies save money while customers are saving time (Capgemini Report, 2011).

Utilization of Business Analytics (BI): BI is a framework that aims faster and better-informed business decisions by integrating technology, processes, and people (Saueressig et al., 2018). First objective of the analytics e.g. data analysis on social networks, is customer engagement. Businesses uses analytics for correctly analyzing customer trends, creating suitable products for customers, accelerating processes and eliminating problems

(Netaş, 2015). As a result, companies using analytics can improve their relationship with customers and enhance customer loyalty (IQUII, 2017).

Customer Experience via New Technologies: Recently advanced technologies are used for better understanding of customer needs and responding to these specific needs. The most frequently used technologies are; chatbots, big data analytics, artificial intelligence, virtual reality and internet of things. By using chatbots, businesses handle customer service functions. These virtual assistants can serve as an instant service support. By using big data analytics, it is possible to gather useful insights into consumer preferences and behaviors for providing personalized services. By using artificial intelligence-powered tools, businesses can pump up the business process automation. Virtua Reality (VR) can engage customers in a better way, as it provides a complete sensory experience that captures the attention, imagination, and senses unlike any other technology present in modern times. Internet of Things (IoT) solutions help businesses lower operational costs, and increase productivity, therefore, businesses are actively adopting such solutions to engage customers with delightful experiences (Ismail, 2017).

3.1.2. People

This dimension focuses on people and their talent. Moreover, digital capabilities and their enablement in DT and business processes are examined in detail. Figure 3.3 shows the maturity factors related to people dimension.

Figure 3.3: The factors of people dimension

C-Suites' Leading for Digitalization: Digital transformation is a priority for every forward-thinking organization. To have a successful digital transformation, c-suites must be onboard, working to implement new technologies and services, train employees, and communicate the value of digital tools (Tennyson, 2017). Transformation has to start at the top and leaders should create an innovation culture. They need to be open to change, prepared to take calculated risks and willing to fail fast, in summary, leaders need to lead differently (Manpower, 2018).

Digital Education and Training: Online corporation education is changing the rules of play of corporate learning (Roland Berger, 2015). There are many reasons to use digital learning in place of or in addition to traditional classroom learning. Generally, the main reason for using digital learning is indicated as its "reach". However, some organizations have different businesses on different continents, and traditional training could not match the global reach offered by digital learning (KPMG, 2016).

Personnel' Enablement in Digitalization: Nowadays, departmental silos and physical boundaries has to be changed within a digital workplace and working practices need to be designed around the employee. The main focus should be to deliver a personalized working environment that allows personnel to use their knowledge and experience to deliver business outcomes. They should not just simply complete specific tasks (CGI, 2017). It is important to focus on personnel' experience and enablement in digitalization by providing them with user experience they have outside the firewall. To sum up, organizations must provide choice, flexibility and personalization to employees (Deloitte, 2016).

Digitally Talented Personnel (Digital Skills, Know-How): Candidates are looking for progressive and innovative environments and organizations can win war on talent by offering these opportunities (Deloitte, 2016). To conduct a sustainable and successful digital transformation, a defined digital talent strategy that meets both business objectives and the preferences of digital talent is very important. Companies should focus on solving their digital talent challenges by focusing these three areas: attracting, developing, retaining digital talent (Capgemini, 2017).

3.1.3. Communication

This dimension focuses on communication across the company. Furthermore, communication capabilities that provide flexible and agile ways of working are investigated in detail. Figure 3.4 shows the maturity factors related to communication dimension.

Figure 3.4: The factors of communication dimension

Knowledge Sharing and Transparency: The digital workplace should encourage employees to do their job by collaborating, communicating and connecting with others. The main goal is to enable knowledge sharing across the organization and to create productive business relationships. Since solving the business problems and operating productively requires transparency and knowledge sharing across the company, organizations should leverage knowledge with online, seamless and integrated collaboration tools that enhance the employees' willingness to work together (Deloitte, 2016). To create a knowledge sharing culture, organizations should foster a transparent communication environment, organize scheduled meetings, engage people via conversations, tell success stories, create a knowledge base and implement open door policy (Boldt, 2017).

Spread of Digital Vision between Departments: The notations of "digital", "digital transformation", "digitalization" may differ within the company. To overcome the complexity of different meanings for different departments, and to constitute standardized notations, it became important to establish a common understanding–a uniform ground of what digital transformation exactly meant (Capgemini, 2013). This common understanding of digital transformation should line up with a clear digital vision. For projects to be successful, the digital vision need to be communicated between departments and recognized by all across the company (Fujitsu, 2016).

Inter/Intra Organizational Learning: Organizational learning can be defined as the process of change in organizational knowledge and behavior that contributes to organizational performance. Organizational learning may include the external partners too (Prats et al., 2015). In the inter-organizational context, learning mechanisms support learning from business partners (Prats et al., 2015). In the intra-organizational context, the focus is on embedding new knowledge into organizational norms and routines mechanisms to support feedback learning from the organization level to groups and individuals (Crossan, 1999).

Continuous Digital Improvement: Today, the most successful companies are the ones that constantly seek for improving their processes and customer journeys. Businesses cannot survive if they remain attached to the past (Newman, 2017). Developing the digital tools that are easy, intelligent, adaptable, and that enable deep connection are good enablers for continuous improvement. The tools themselves can evolve with the businesses, helping to continuously improve business operations and the customer experience. This is the ability of continuous improvement that creates the true digital transformation (Raut, 2017).

3.1.4. Culture

This dimension focuses on characterizing the creation of DT culture. Generally, culture should be open for change, conducive to DT and risk-aware. Figure 3.5 illustrates the factors below culture dimension.

Figure 3.5: The factors of culture dimension

Perception of Digitalization (digital→value): Over the past years, digital transformation's impact on the economy and society has increased significantly. Potential impacts of digitalization on business are about job content, profiles and professions. From an economic point of view, digitalization is expected to create new revenue streams. However, when we consider social impacts, there is a perception that digitalization will take place of existing jobs (European Commission, 2017). The acceptance of digitalization by the society is very important for adapting the concept of digitalization (Büyüközkan and Güler, 2018).

Company-wide Commitment: At the beginning of the transformation, C-level should be extremely clear and exact on the business outcomes that organization wants to achieve through digital transformation. Understanding company-wide intricacies and objectives provides C-level with an opportunity to approach transformation programs more efficiently (Hillebrecht, 2018). To ensure company-wide commitment, top management have to support digital transformation, company leadership should strongly emphasize the goal of transformation and the reasons behind it. Furthermore, C-level should be accountable for the success of digital transformation (Apigee, 2017).

Risk Awareness: The desired key digital leadership qualities are often a combination of a deep and intrinsic business understanding, together with a more visionary, risk seeking mindset that drives new ways of working and organizational change (Qwertz, 2017). An

appetite for risk and rapid experimentation is key to building an effective culture for digital transformation (Information Age, 2018).

Innovation Culture/Open Innovation: The need to enable open, collaborative, iterative change is where innovation management tools and practices come in. Innovation management can help your organization to engage your internal and external communities to adapt and accelerate the way you drive innovation, applying this to various aspects of your business model, its processes, products and services, to develop a more open, innovative organizational culture. By shifting from a traditional, top-down approach to innovation, business development and operational improvement to an inclusive approach where everyone is involved and shares responsibility for the definition and achievement of the business’s goals, your organization can become more agile, responsive and disruptive, embracing the changes that digital transformation brings and making them part and parcel of what defines your culture (MWD Advisors, 2017).

3.1.5. Technology

This dimension focuses on the capabilities that provide effective technology planning, deployment, and integration to support the DT. Figure 3.6 shows the factors of technology dimension.

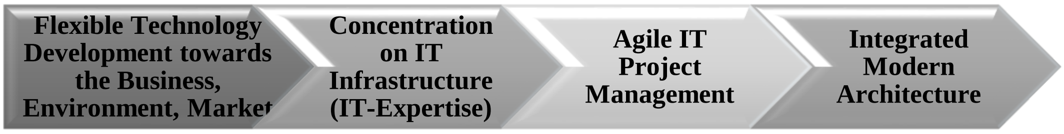

Figure 3.6: The factors of technology dimension

Flexible Technology Development towards the Business, Environment, Market: The secret weapon for embracing digital transformation in a right way is Application Program Interfaces (APIs). Because the API open doors for multiple platforms and ties them together. Therefore, it creates a fast and flexible ecosystem (Newman, 2016). "The trend is to decouple legacy backend systems and create flexible architectures." says Mehmet Olmez, Managing Director at Accenture, "This allows the digital frontend to connect to the backend using APIs, while creating new and light-weight products and services on

top." API orchestration enables using modern tools to work quickly in areas such as marketing, customer service, and sales. Furthermore, it is possible to leverage the data such as connecting back office process and forms to provide better self-service. As a result, APIs keep the digital experience consistent for both customers and employees and ensures flexible technology development (Brenninkmeijer, 2018).

Concentration on IT Infrastructure (IT-Expertise): Digital business requires reimagining the customer experience and planning an organization's strategic direction. IT infrastructure also needs precise planning. For this reason, concentration on IT infrastructure is very crucial in digital transformation journey. Five key impact areas are fundamental to designing an IT infrastructure strategy. They are end-user devices, enterprise storage, enterprise computing, networking and security (NTT data, 2016).

Agile IT Project Management: Agile companies use downtime to carefully consider what new technologies fit their customer needs the best, rather than adopting every new trend [v]. They investigate how they can use these new technologies for working in a smart way. On the other hand, organizations should modernize their infrastructure to deliver an agile and efficient foundation. Hardware abstraction including server, storage, and network virtualization or container technology are core elements to enable a level of infrastructure flexibility which digital future demands (Devnani, 2017).

Integrated Modern Architecture: Deploying modernized technology is one of the core parts of digital transformation. There are several ways for infrastructure modernization. They are generally named as ‘build’ vs ‘buy’ continuum. Organizations should prefer fully configured, tested, plug-and-play infrastructure solutions. The modern architectures offer the following benefits (Devnani, 2017):

- Faster-time-to-market: It eliminates the time and cost of design, test, and build.
- Plug-and-play: Thanks to its rapid deployment, benefits are achieved quickly.

3.1.6. Processes

This dimension focuses on the capabilities that support the service provision. It is possible to say that, DT of the processes requires more digitized, automated, and flexible operations. Figure 3.7 shows the factors of processes dimension.

Figure 3.7: The factors of processes dimension

Having Shared Digital Vision/Goals/Risks/Rewards and Penalties: The digital strategy should be aligned with business objectives that defined clearly and technology priorities. It is important to know what organizations want to accomplish with their digital workplace initiative. Both digital revolution and vision should work together. The strategy and both short- and long-term plans should be carefully constructed. Employees are facing enough change in today’s rapidly evolving business environment. It is crucial to ensure that the changes, the goals, the risks and the plans are being shared within the company (Newman, 2017).

Information in Digital Form: Transforming the organization into a digital competitor requires liberating neglected data, to improve and leverage company insights. Implementing the digital mobile forms solution for gathering and processing field service information empowers the whole organization. Because information in digital form allows the team to cultivate informed, compelling conclusions, based on a robust accumulation of field service data. Furthermore, it provides pinpointing even the subtlest trends, when organizations leverage the ability to digitally report across the entirety of the documents and forms (Chin, 2017).

Data-driven Business for Rapid/Automated Decision-Making: Recently speed is accepted as the new currency in business. Because companies face to make decisions in very short times in the highly volatile business environment. On the other hand, companies should be quick to deliver against customer and employee requirements or expectations in a competitive market. With data-driven business, the employee can see the necessary information at any time. A data-driven world facilitates to deliver an end-to-end, "on time and in full" customer experience (Samuel, 2017).

Defined, Repeatable or/and Automated Processes for Digital Program: Process automation can be applied in different sectors e.g. in finance, procurement, supply chain management, accounting, customer service and human resources. The defined, repeatable and automated processes bring a variety of benefits. Since the routine tasks are handled by automated processes, speed increases. Moreover, the labor costs reduce, employee experience enhances, quality improves and the scalability can be possible (Raut, 2017).

3.1.7. Business Model

This dimension focuses on digital business models that integrate capabilities across boundaries into innovative new solutions to create and capture value, as well as the new inter-organizational business architectures. Figure 3.8 illustrates the factors below the business model dimension.

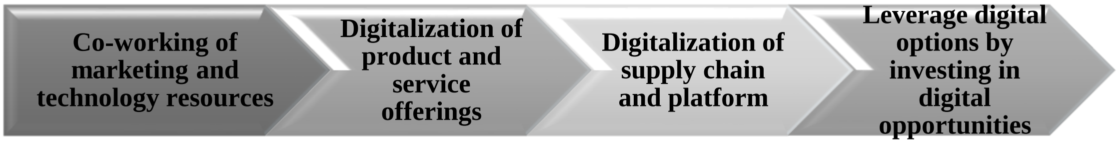

Figure 3.8: The factors of business model dimension

Co-working of marketing and technology resources: In businesses that focus on digital transformation, marketing and IT departments takes the responsibility for these changes. Marketing and IT departments then design websites with new tools, work on social media profiles, start Pay per Click (PPC) campaigns, and sometimes create an application or a new platform. These projects are lengthy, expensive and time-consuming projects. For this reason, marketing and technology departments should work together (Scott, 2017).

Digitalization of product and service offerings: Without any doubt, technology is a tool for driving business and it is the key for long-term success (Mindtree, 2017). Customer experience is reshaped by the new digital product and service offerings. Customers may be served in-store, at a bus stop, or anywhere. It is very important to manage these discontinuous moments. By using digital tools, companies can stage these moments over time, make them context-relevant, and customize the experience for every customer. Therefore, customer loyalty can be ensured easily (Nurun, 2017).

Digitalization of supply chain and platform: Digital Supply Networks bring together the organization's physical, financial, talent, and information supply chains. Furthermore, it leverages the information collected from the mobile, social media, analytics and cloud technologies. By digital technology, these streams empower companies and add value at multiple levels of the supply chain (Accenture, 2016). Digitalization of supply chain strengthens the brand value and company's image and augments top-line revenue and return (Kodiak Community, 2017).

Leverage digital options by investing in digital opportunities for the future: Forrester states in a recent digital report that: "You don't need a digital strategy; you need to digitize your business strategy." Just focusing on digital customer experience is not true. It is very important to focus on new sources of data emerging from social media, connected devices, or government departments. This information can be useful for improving the buying and managing capabilities of companies. For this reason, thinking about the ways of leveraging the data for unlocking new sources of customer value or building new revenue streams is very important for companies (Berdak et al., 2018).

3.1.8. Organization

This dimension focuses on the organizational changes in culture, structure, training, and knowledge management that enable the organization to become a digital player and to gain competitive advantage. Figure 3.9 shows the factors related to organization dimension.

Figure 3.9: The factors of organization dimension

Governance: Traditionally, companies attempt to find the ways of ensuring stability and predictability. Generally, they employ a risk-averse mindset to set up for linear development trajectories. However, today, continuous and fast digital world requires companies to re-think their organizational models and classical governance structures and set up more adaptive governance models. The new governance models should embrace explorative approaches, allow for iterative processes, and tolerate failures. Therefore, current governance models need modification, however, many executives struggle for establishing the right organizational setup that supports the desired agility and speed (Qwertz, 2017).

Digital Leadership: Digital transformation has a strategic importance. When it comes to supporting the development of the digital transformation, the executive sponsorship and leadership gains a huge importance. For this reason, the digital leadership should contain the practical understanding of the opportunities and challenges related to digitalization on a concrete level (Qwertz, 2017).

Cross-Functional Team Set-up: Cross-functional teams aim to solve problems and not to just implement solutions. They are essential for wining the digital transformation war. These teams are self-directed and have their own responsibility to identify how to solve problems within the constraints defined by the leaders (Kundu et al., 2016). Technology is necessary, however, management disruptions such as breaking the departmental silos with cross-functional teams are most significant enablers of the digital transformation process (Rao, 2018).

Continuous Measurement of Digital Competence: Companies should continuously establish performance metrics aligned with business and technology strategies. To compete in today's highly volatile market, companies should regularly review the current status and continuously improve the digital workplace (Deloitte, 2016).

3.1.9. Ecosystem

This dimension focuses on the partner ecosystem development and the results of the digital relationships with external actors in the DT context. Figure 3.10 illustrates the factors below the ecosystem dimension.

Figure 3.10: The factors of ecosystem dimension

Digital Partnerships with External Actors: The co-creation ecosystem that accepted for developing digital projects grow up each day. Some organizations are proposing entirely new commercial models to strengthen their digital partnerships with external actors. They are implementing practices as sharing of benefits and co-ownership of intellectual property for elevating the value of their co-creation work (Fujitsu, 2016).

Managing Relationships via Online Channels: Digital transformation requires having fully digitized, integrated partner ecosystem with self-optimized, virtualized processes. Digitally mature companies focus on core competency and decentralized autonomy via online channels. In this way, they provide a real-time access to extended set of operative information and manages their relationships via online channels. (PwC, 2016).

Trust and Transparency in Relationships with Partners: In the digital world, companies generally collaborate with other stakeholders for delivering more comprehensive solutions. Naturally, these partnerships raise additional security concerns. Most companies don't build an ecosystem that sustains digital trust. To provide trust and transparency in relationships with partners, companies must establish common ethical standards, technical safeguards and holistic controls for all actors. The partners should also share the other partner's commitment to digital trust (Accenture, 2017).

Fast Reaction to Ecosystem Changes: In the digital age, one of the most important features is speed. In this context, agile design gives solutions that reacts fast and flexible to ecosystem changes. Moreover, it enables continuous feedback from all external actors throughout the project. Designers respond quickly to feedbacks and make changes as the project progresses rather than a pre-determined course of action (EY, 2016).

Figure 3.11 illustrates the aim of every digital maturity level with respect to 9 dimensions. After determination of the organization's maturity score for every dimension, its real situation can be illustrated with the sentences in the Figure 3.11. For example, if company's digital maturity level for customer dimension is at level 3, we can say that company has been implementing digital tools across the company. In the same way, if the communication maturity level of the company is at level 1, we can say that company use traditional approaches for communication. While proposing an action plan, these situations will be taken into consideration. For example, the gap analysis is accomplished and the shortcomings of the company in terms of DT are found as communication and technology. The action plan will be selected according to this result.

Figure 3.11: The goals for every level and maturity dimension

3.2.Proposed DSAPs

The strategic action models are identified with the help of experts' reviews and industry reports. 5 action plans are proposed to guide companies in their DT journey. They are taking into consideration different focus areas. The action plans are explained in detailed in following sections.

3.2.1. Customer and people centered action plan

Customer and people centered action plan focuses on customer and people as seen in Figure 3.12. Customer centricity is a strategy that is based on putting the customer first, and at the core of the business. For example, using customer data to understand buying behavior, and interests; determining opportunities for the best customers and using customer lifetime value to segment customers are the actions of the customer centricity. To create enhanced customer experience, organizations need to think about how they can stay in touch with customers all along their journey (Mac Donald, 2018).

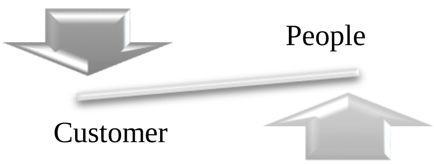

Figure 3.12: Main focus areas of the 1st action plan

On the people side, organizations should build trust and commitment to personnel for change, give the personnel in the organization more responsibilities and authorities in terms of DT, develop an open platform for continuous learning and track the personnel's behavior by using technology.

3.2.2. Value based action plan

Value based action plan focuses on organization and business models as seen in Figure 3.13. Organizations meet a variety of expectations with new value propositions that give people what they did not realize they wanted. Delivering new value propositions requires rethinking and reimagining the organizations' business conducting styles. For example, Walmart and Zara have digitally integrated supply chains for creating more effective and cheaper operations (Bughin et al., 2017).

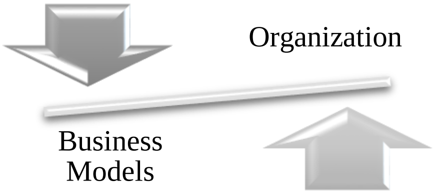

Figure 3.13: Main focus areas of the 2nd action plan

DT have enabled the new business models emergence. Peer-to-peer networks, freemium, crowdsourcing, as a service, personalization can be given as examples of the new business models. Organizations should develop strategic thinking to analyze how their networks, channels and customers can create value for their business and make profits with new revenue sources (WEF, 2016).

3.2.3. Integration and alignment action plan

Integration and alignment action plan focuses on communication and ecosystem as seen in Figure 3.14. Organizations today know that their companies should be aligned. Alignment means the arrangement of the strategies, capabilities, resources, and management systems of the company for supporting its purposes.

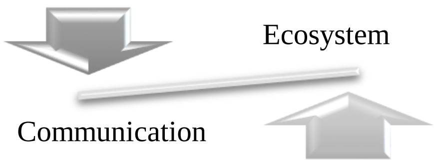

Figure 3.14: Main focus areas of the 3rd action plan

The responsibility belongs to multiple individuals and groups in the organizations. Generally, the responsible person for ensuring the company's strategically alignment is not known. For this reason, achieving and sustaining high strategic alignment is difficult, especially in a rapidly evolving environment. As a result, the importance of sharing knowledge, sharing knowledge and enhanced communication all across the company is obvious (Trevor and Barry, 2007).

Organizations become part of a larger ecosystem with the integrated value chains. Digital technology enables organizations to work more closely with external actors together (Cognizant, 2014).

3.2.4. Connected platforms action plan

Connected platforms action plan focuses on technology and processes as seen in Figure 3.15. Nowadays, organizations can improve business processes in several ways by advanced digital technology. For example, big data analytics can help in making decisions, the cloud can be used for create standard business processing platforms and mobile platforms can provide personnel to work anytime, anywhere and on any device.

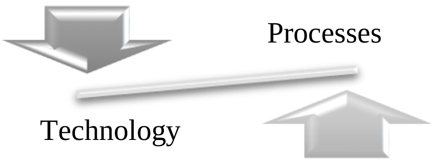

Figure 3.15: Main focus areas of the 4th action plan

When using standardized platforms, it is also easier to globally source processes, which leads to substantial cost reductions (WEF, 2016). By using connected platforms, organizations can become more agile, more responsive to changes in demand. Agility is very important, as competitiveness is increasingly dependent on responding and anticipating to fast-changing market conditions. Therefore, organizations must adopt an agile way of working. Organizations also need to enable employees the flexibility and freedom to work anytime, anywhere and on any device (Cognizant, 2014).

3.2.5. Collaboration and innovation action plan

Connected platforms action plan focuses on technology and culture as seen in Figure 3.16. Nick Perugini, GE Commercial CIO, states that: “We all cross the finish line together, or nobody wins.” Collaboration is indispensable for organizations (Gutowski, 2017).

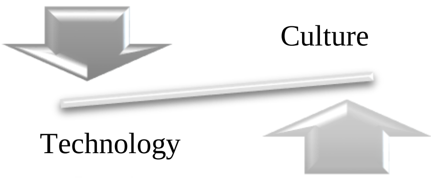

Figure 3.16: Main focus areas of the 5th action plan

Technology is not enough for DT; it needs to be balanced with a knowledge sharing culture. The technology teams and the domain experts should come together early. Personnel should work in cross-functional teams and open-learning mechanisms should be adopted across the company. Because, companies that have rapid, real-time collaboration have higher probability to innovate faster and win with customers (Gutowski, 2017).

4. PROPOSED RESEARCH METHODOLOGY

In the second and third phases, HFL MCDM techniques are preferred. Because, the combination of HFLTS technique and MCDM tools brings decision problems closer to real-life. HFLTS provides DMs with the flexibility in eliciting linguistic options. It also allows the utilization of comparative linguistic expressions (Rodríguez et al., 2013). HFLTS is a strong and helpful technique to overcome uncertainty and hesitancy. HFLTS is becoming more and more popular among scholars, as it provides a novel and powerful tool for DMs to express their assessments (Liao et al., 2014). By using HFLTS, DMs can voice their qualitative judgments under a set (Mousavi et al., 2014). Therefore, DMs have the option to offer their ideas about an alternative or compare two criteria by words. As a result, integrated HFL AHP and HFL AD methodology is an effective, flexible, adaptable and valid tool to achieve reliable results.

4.1. Computational Steps of the Proposed Methodology

The steps of the proposed research methodology are illustrated in Figure 4.1. The first phase is the preparation phase. First of all, the evaluation framework that consists of 3 phases is proposed. The DMM factors and digital action plan alternatives are identified based on the literature review, experts from industry and academy, and industry reports. The decision-making team is constructed. The linguistics and syntax of HFL AHP and HFL AD techniques are determined.

In the second phase, the main goal is to determine the DMMs' weights by using HFL AHP method. First, the pairwise comparison matrix with comparative linguistic term sets are collected from the DMs. These linguistic term sets are transformed into HFLTS and the fuzzy envelope for HFLTS is aggregated to convert the HFLTS into trapezoidal fuzzy numbers. By applying the steps of the HFL AHP method, the maturity criteria weights are computed.

To evaluate the company's digital maturity score, a questionnaire that consists of 108 questions is prepared. The questionnaire is based on the proposed DMM evaluation model. The responses are between 1 and 5 (1: the worst, 5: the best). If there is no relation with the question and the company, respondent can choose the NA (not available) choice. For example, a question is: "To which degree can your customers individualize the products they order?" (please refer to Appendix A as an example of customer dimension, question 2). The respondent can choose NA if individualization is not applied, or can choose 5 if it is "completely" applied in the company. According to the responses and considering the factors' weights, the scores under 36 maturity factors and under 9 maturity dimensions are calculated. Moreover, the overall maturity score of the company is calculated.

In the last phase, the aim is to select an appropriate DSAP according to company's maturity score. After the identification of the gaps between the goals of the maturity dimensions (Figure 3.11) and the results, alternative action plans are proposed. The most appropriate action plan is selected with HFL AD method. First, the evaluation of alternatives is collected from the DMs and the linguistic data is transformed into HFLTS. After the aggregation of the DMs' opinions, the FRs of the problem are determined. By applying the steps of the HFL AD method, the total information content of each alternative is calculated. At the end of the methodology, the most appropriate DSAP is selected and the possible suggestions for continuous digital improvement are made.

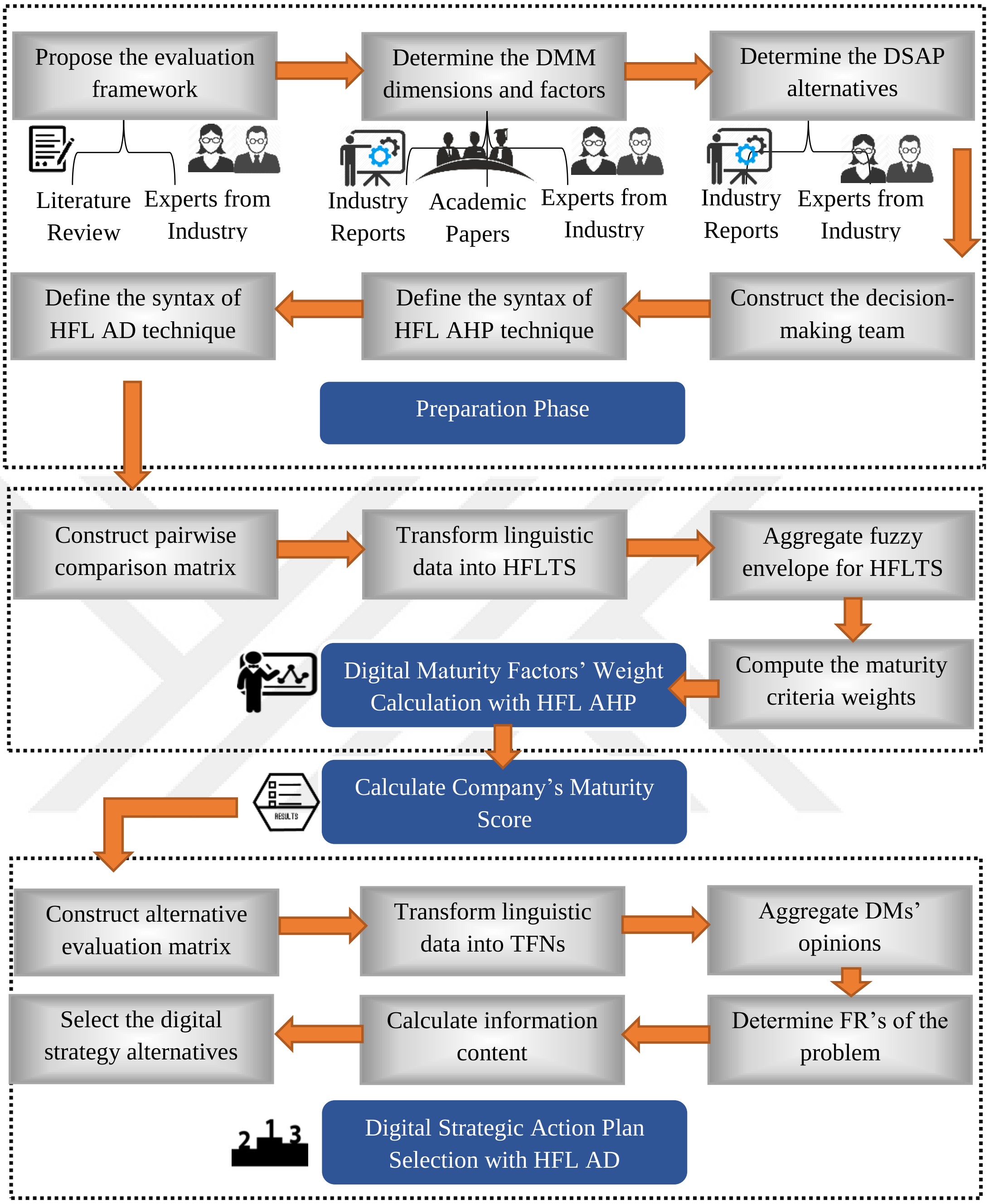

Figure 4.1: The steps of the research methodology

4.2. Hesitant Fuzzy Linguistic MCDM Methodology

In this section, the overview of MCDM methodology, the general concept of the HFLTS technique and the literature research of the HFL MCDM techniques are provided.

4.2.1. Multi Criteria Decision Making (MCDM) – An Overview

In today's world, people who have to make individual, or even larger, decisions, make their decisions based on more than one criterion. For example, while buying a car, people consider various criteria e.g. the price, the motor power, the safety. Therefore, selecting between different car alternatives depends on different factors and all of them need to be taken into account.

MCDM is an effective tool to solve complicated problems where different alternatives among different influencing factors exists. MCDM is a structure in which a multitude of disciplines such as mathematics, management, social sciences and economics come together to propose methods that enable DMs to evaluate and make decisions in multiple dimensions (Önder and Yıldırım, 2015). MCDM tools give their users scientific alternatives for how to illustrate real problems and aim to choose the most appropriate alternative among others or rank them.

MCDM problems can be examined in three main headings. They are choice, sorting and ranking problems (Vassilev et al., 2005).

Choice problems aim to determine the most suitable alternative. The objective here is to select the correct alternative for the existing problem from the set of alternatives. For example, a manager may choose the right-skilled personnel for a specific project (Önder and Yıldırım, 2015).

In sorting type of problems, alternatives are ranked according to certain preferences or criteria. The objective here is to bring together alternatives that show similar features and behaviors. For example, in a company, the classification of employees' performance as strong, average and weak, and then, accordingly the evaluation of employees is a classification problem (Önder and Yıldırım, 2015).

In sorting problems, alternatives are classified in a measurable or identifiable manner. This classification can be in various forms and multipart. The criteria taken into account in the ranking of universities around the world can be given as an example of this multi-part structure (Önder and Yıldırım, 2015).

During the stage of collecting ideas, DMs have to give opinions about factors and alternatives. In traditional approaches, DMs use numbers to express their ideas about influencing factors while evaluating alternatives. Zadeh (1965) introduced the fuzzy sets theory and provided different benefits to literature. Following sections summarizes the evolution of fuzzy approaches and their utilization with MCDM tools.

4.2.2. Hesitant Fuzzy Linguistic Term Sets (HFLTS)

The fuzzy approaches have played an important role in decision-making for years. Zadeh (1965) introduced the fuzzy sets theory and provided various benefits to literature. First, the uncertainty and vagueness can be considered in decision-making process. The evaluations of DMs are not just black and white; there is also a grey area. Second, fuzzy logic enables using linguistic terms at the evaluation of criteria and/or alternatives step. Furthermore, its fuzzy nature enables to consider and reflect the imprecise and vague information about the problem. Different kinds of sets have been proposed within the concept of fuzzy sets as type-2 fuzzy sets, interval-valued fuzzy sets, Atanassov’s intuitionistic fuzzy sets, Pythagorean fuzzy sets and hesitant fuzzy sets. In this thesis, the hesitant fuzzy linguistic sets are preferred.

In many cases, DMs have difficulties to correctly represent their thoughts and their hesitations about their information. At this point, Torra (2009) proposed the concept of hesitant fuzzy sets (HFSs). The HFS approach aimed to overcome these situations by defining a set of values that are membership of an element. Rodríguez et al. (2012) proposed HFLTS and integrated the concepts of linguistic fuzzy approach and HFSs. The

HFLTS approach allows the utilization of comparative linguistic term sets (Rodríguez et al., 2013).

The combination of HFLTS and MCDM methods makes the decision-making process closer to real-life. Since HFLTS brings flexibility by eliciting linguistic options, it facilitates the expression of DMs at the evaluation phases.

4.3. Literature Survey for Hesitant Fuzzy MCDM Methods

The integrated use of HFLTS and MCDM tools began in 2013 with the studies of Zhang and Beg. Zhang and Wei (2013) developed the HFL VIKOR technique, an effective MCDM technique to determine the best compromise solution by collecting linguistic expressions and compared this method with HFL TOPSIS method. Beg and Rashid (2013) represented Hesitant Fuzzy TOPSIS method and applied this approach to financial decisions.

In the literature, those techniques that integrate HFLTS and MCDM are used in different fields (e.g. logistics, insurance, finance, technology, management, health, transportation etc.) as shown in Table 4.1.

Table 4.1a: Hesitant Fuzzy MCDM methods in the literature

Year	Author(s)	Aim of the Study	Hesitant MCDM methods	Type
2013	Zhang and Wei	Select the best project alternative	VIKOR and TOPSIS	Case Study
2013	Beg and Rashid	Find the best investment option	TOPSIS	Case Study
2013	Xu and Zhang	Select the energy policy	Maximizing Deviation and TOPSIS	Case Study
2013	Yu et al.	Evaluate the personnel	Generalized hesitant fuzzy aggregation operator	Illustrative Example

Table 4.1b: Hesitant Fuzzy MCDM methods in the literature

2013	Zeng et al.	Propose HFS-MULTIMOORA method and make an application for telecommunication sector	OWA operator, MULTIMOORA	Case Study
2014	Wang et al.	Solve the problems in which the criteria are in different priority levels	Prioritized aggregation operator	Illustrative Example
2014	Wei et al.	Define operations on HFLTSs and give possibility degree formulas for comparing HFLTSs.	OWA, LOWA, Possibility degree formula.	Illustrative Example
2014	Wei and Zhang	Develop an extended VIKOR method and compare with TOPSIS method	VIKOR, TOPSIS, Shapley value	Case Study
2014	Liao et al.	Propose some novel methods to determine the weights of hesitant fuzzy variables in different stages	Improved maximum entropy method, minimum average deviation method	Case Study
2014	Onar et al.	Select the best company for making strategic decision	TOPSIS and Interval Type 2-Fuzzy AHP	Case Study
2014	Rodriguez and Liu	Select a material supplier	HFLTS, OWA operator and Fuzzy TOPSIS	Case Study
2014	Mousavi et al.	Propose HFS for AHP method and apply for bridge construction problem	AHP	Case Study
2014	Zhang and Xu	Rank the service quality among domestic airlines	TODIM	Case Study
2014	Zhu and Xu	Develop hesitant multiplicative programming method (HMPM) as a new method of classification	AHP and HMPM	Case Study

Table 4.1c: Hesitant Fuzzy MCDM methods in the literature

2015	Liao and Xu	Demonstrate the advantages and practicality of HFL VIKOR and comparison analysis	VIKOR and TOPSIS	Illustrative Example
2015	Zhou et al.	Make comparison analysis for two methods	TOPSIS and TODIM	Illustrative Example
2015	Chen and Zhu	Select the a suitable third-party reverse logistics provider for reverse logistics in battery industry	ELECTRE II	Case Study
2015	Peng et al.	Present a method for comparing multi-hesitant fuzzy numbers	ELECTRE	Illustrative Example
2015	Wang et al.	Propose the directional Hausdorff distance and outranking approach	Outranking approach	Illustrative Example
2015	Liao et al.	Propose HFL VIKOR method	VIKOR	Illustrative Example
2015	Wei et al.	Extend TODIM method in hesitant fuzzy environment	TODIM	Case Study
2015	Yu et al.	Propose four linguistic hesitant fuzzy Heronian mean operators	Heronian mean operator	Illustrative Example
2015	Chunqiao et al.	Present an extended Choquet-based TODIM method	TODIM, Choquet Integral	Illustrative Example
2015	Chen et al.	Develop a hesitant fuzzy ELECTRE I method	ELECTRE I	Case Study
2015	Zhang et al.	Select the best supplier	TOPSIS and Linear Programming	Case Study
2015	Wei et al.	Integrate HFLTS and TODIM method	TODIM and Score Function	Case Study
2016	Adem and Dağdeviren	Select life insurance policy	Preference relation matrix	Case Study

Table 4.1d: Hesitant Fuzzy MCDM methods in the literature

2016	Senvar et al.	Select the optimum site for a new hospital in Istanbul	TOPSIS	Case Study
2016	Wang et al.	Propose the Hausdorff distance for HFLNs	TOPSIS, TODIM	Illustrative Example
2016	Zhang et al.	Evaluate green supply chain initiatives	QUALIFLEX	Case Study
2016	Serdarasan	Propose DEMATEL method in hesitant fuzzy environment with group decision making approach	DEMATEL	Illustrative Example
2016	Wu et al.	Incorporate the HF-DEMATEL and the HF-VIKOR into the process of QFD	VIKOR, DEMATEL, and QFD	Case Study
2016	Zhu et al.	Develop new prioritization method to derive priorities	AHP	Case Study
2016	Onar et al.	Propose new QFD approach based on HFLTS	AHP, TOPSIS, and QFD	Case Study
2016	Zhou and Xu	Develop hesitant fuzzy sigmoid preference relation (AHSPR) and utilize in AHP	Sigmoid Preference Relation and AHP	Illustrative Example
2016	Jin et al.	Develop a GDM approach for MCDM with interval valued HFS	Interval valued HFS, entropy and similarity measure	Illustrative Example
2016	Joshi and Kumar	Recruit a project manager	TOPSIS and Choquet Integral	Illustrative Example
2017	Dong et al.	Evaluate an intelligent transportation system (ITS)	VIKOR	Case Study
2017	Gou et al.	Select the best alternative for hospital management	Alternative queuing method (AQM)	Case Study
2017	Liang and Xu	Select the most appropriate energy project	TOPSIS, Pythagorean fuzzy sets	Case Study
2017	Li and Wang	Propose a novel possibility degree and then, employ it for extending the QUALIFLEX and PROMETHEE II methods	QUALIFLEX, PROMETHEE II	Illustrative Example

Table 4.1e: Hesitant Fuzzy MCDM methods in the literature

2017	Liu and Zhang	Introduce Hamming distance measure of neutrosophic HFS extend VIKOR method	Multiple neutrosophic hesitant fuzzy set, VIKOR	Illustrative Example
2017	Peng et al.	Evaluate watershed ecological risk	COWA operator, relative ratio method	Case Study
2017	Faizi et al.	Propose an outranking method for group decision-making (GDM) using intuitionistic HFLTSs	Outranking approach	Case Study
2017	Faizi et al.	Extend Characteristic Objects Method (COMET) method in hesitant fuzzy environment	COMET	Illustrative Example
2017	Zhang	Select the best green supplier alternative	QUALIFLEX	Case Study
2017	Zhang	Introduce the concept of possibility-based comparison indices	TOPSIS	Case Study
2017	Wang et al.	Select the best company for investing	Covariance, correlation coefficient, northwest corner rule	Case Study
2017	Wei et al.	Propose the linear assignment method	Linear assignment method	Illustrative Example
2017	Xiao et al.	Select the best renewable energy alternative	Choquet Integral	Case Study
2017	Sellak et al.	Integrate outranking approaches MCDM context based on HFLTS	Knowledge –based comparison method	Illustrative Example
2017	Ren et al.	Represent an extended VIKOR method	Dual Set, VIKOR, and TOPSIS	Case Study
2017	Xue et al.	Represent an integrated model based on hesitant 2-tuple LTS and an extended QUALIFLEX approach	2-tuple Linguistic Term Sets and QUALIFLEX	Case Study

Table 4.1f: Hesitant Fuzzy MCDM methods in the literature

2017	Wei et al.	Develop an MCDM approach under HFE	Linear Assignment Method	Case Study
2017	Yu et al.	Introduce a new method to MCDM literature by using unbalanced HFLTS	TODIM	Case Study
2018	Wu et al.	Develop a projection model with HFLTS	Error analysis method	Case Study
2018	Yuan et al.	Select the best renewable energy alternative	Choquet Integral	Case Study
2018	Li et al.	Evaluate mineral resources alternatives	TODIM	Case Study
2018	Zhao et al.	Evaluate movie quality	Qualitative judgments, distance measure	Case Study
2018	Büyüközkan et al.	Rank the renewable energy sources by using HFL MCDM methods	SAW, TOPSIS	Case Study
2018	Galo et al.	Supplier categorization based on HFL MCDM	ELECTRE	Case Study
2018	Sun et al.	Develop an innovative TOPSIS method on hesitant fuzzy environment	TOPSIS	Illustrative Example
2018	Yıldız and Tüysüz	Select strategic retail location	AHP, GRA	Case Study

In Hesitant Fuzzy MCDM literature, different MCDM methodologies are implemented for different application areas. AHP, TOPSIS, VIKOR, TODIM, ELECTRE, DEMATEL, QUALIFLEX and PROMETHEE methods are preferred in many of these studies. Table 4.2 analyses utilization of these methods in the related literature. HFL MCDM techniques are implemented in a variety of areas as energy evaluation, management, supplier selection, green supply chain, intelligent transport system etc.

Some of these studies applied integrated methodologies as AHP, QFD, TOPSIS (Onar et al., 2016) or VIKOR, DEMATEL, QFD (Wu et al., 2016) while some of them used aggregation operators e.g. OWA (Zeng et al., 2013; Wei et al., 2014).

Table 4.2a: The utilization of Hesitant Fuzzy MCDM methods

Year	Author	MCDM methods							
		AHP	TOP-SIS	VIKOR	TODIM	ELEC-TRE	DEMA-TEL	QUALIF-LEX	PROMET-HEE
2013	Beg and Rashid		X						
2013	Wei and Zhang		X	X					
2013	Xu and Zhang		X						
2013	Zhang and Wei		X	X					
2014	Mousavi et al.	X							
2014	Onar et al.		X						
2014	Rodriguez and Liu		X						
2014	Zhang and Xu				X				
2014	Zhu and Xu	X							
2015	Chen and Xu					X			
2015	Chen et al.					X			
2015	Chunqiao et al.				X				
2015	Liao and Xu		X	X					
2015	Liao et al.			X					
2015	Peng et al.					X			
2015	Rodriguez et al.				X				
2015	Wei et al.				X				
2015	Zhang et al.		X						
2015	Zhou et al.		X		X				
2016	Joshi and Kumar		X						
2016	Onar et al.	X	X						
2016	Senvar et al.		X						

Table 4.2b: The utilization of Hesitant Fuzzy MCDM methods

2016	Serdarasan						X		
2016	Wang et al.		X		X				
2016	Wu et al.			X			X		
2016	Zhang et al.							X	
2016	Zhu et al.	X							
2016	Zhou and Xu	X							
2017	Dong et al.			X					
2017	Li and Wang							X	X
2017	Liang and Xu		X						
2017	Liu and Xhang			X					
2017	Ren et al.		X	X					
2017	Xue et al.							X	
2017	Yu et al.				X				
2017	Zhang							X	
2017	Zhang		X						
2018	Li et al.				X				
2018	Büyüközkan et al.		X						
2018	Galo et al.					X			
2018	Sun et al.		X						
2018	Yıldız and Tüysüz	X							

In the related literature, there is a gap on the AD method's extension in hesitant fuzzy environment. Therefore, this is the first study that proposes HFL AD methodology. Moreover, the integrated use of HFL AHP-HFL AD methodology does not exist in the related literature. The second contribution of the thesis is the proposition of integrated AHP and AD method in hesitant fuzzy environment.

4.4. Preliminaries of Hesitant Fuzzy Linguistic Term Sets

Torra and Y. Narukawa (2009) presented Hesitant Fuzzy Sets (HFS) first. HFS describes the membership level of a component to be one of the possible values between 0-1. The preliminaries of HFS are summarized as:

Definition 1: Assume that X is a set. The function of HFS, where HFS is membership functions' union over X is provided as (Torra, 2010):

$$E = \{\langle x, h_E(x) \rangle \, x \in X\} \tag{4.1}$$

Here, $h_E(x)$ is named as hesitant fuzzy element (HFE) and H is the set of all HFE.

Definition 2: h is a function that renders values between [0, 1]:

$$h: X \rightarrow \{[0, 1]\} \tag{4.2}$$

Definition 3: $M = \{\mu_1, \mu_2, .., \mu_n\}$ is defined as a series of functions n. h_M is denoted as:

$$h_M : M \rightarrow \{[0, 1]\} \tag{4.3}$$

$$h_M(x) = \cup_{\mu \in M}\{\mu(x)\} \tag{4.4}$$

Definition 4: The bounds of h are denoted as as (Torra, 2010):

$$h^-(x) = \min h(x) \tag{4.5}$$

$$h^+(x) = \max h(x) \tag{4.6}$$

Definition 5: The envelope of h ($A_{env}(h)$) is defined as:

$$A_{env(h)} = \{x, \mu_A(x), v_A(x)\} \tag{4.7}$$

Then, μ and v are formulated as:

$$\mu_A(x) = h^-(x) \tag{4.8}$$

$$v_A(x) = 1 - h^+(x) \tag{4.9}$$

Rodriguez et al. (2012) present a model where experts voice their opinions with comparative linguistic term sets. This model represents the linguistic expressions by a set of HFLTS.

Definition 6: $S = \{s_0, \ldots, s_g\}$ is a set with linguistic terms. HFLTS, H_s, is a subset of the elements of S. Sometimes, S is expressed by subscript-symmetric term sets $S=\{si \mid i=-\tau,\ldots,-1,0,1,\ldots,\tau\}$.

Definition 7: The boundaries of HFLTS H_s, H_{s+} and H_{s-} are defined as:

$$H_{s+} = \max(s_i)=s_j \text{ , } s_i \in H_s \text{ and } s_i \leq s_j \quad \forall i; \tag{4.10}$$

$$H_{s-} = \min(s_i)=s_j \text{ , } s_i \in H_s \text{ and } s_i \leq s_j \quad \forall i; \tag{4.11}$$

Definition 8: Let E_{GH} is a function which converts phrases into HFLTS, H_S. Let G_H be a grammar which uses the term set in S. S_{ll} is the domain of expression created by G_H. This relationship is given as:

$$E_{GH}: S_{II} \rightarrow H_s \tag{4.12}$$

Comparative expressions are transformed into HFLTS with these functions:

$$E_{GH}(s_i)= \{s_i|s_i \in S\} \tag{4.13}$$

$$E_{GH}(at\ most\ s_i)= \{s_j|s_j \in S \text{ and } s_j \leq s_i\} \tag{4.14}$$

$$E_{GH}(lower\ than\ s_i)= \{s_j|s_j \in S \text{ and } s_j < s_i\} \tag{4.15}$$

$$E_{GH}(at\ least\ s_i)= \{s_j|s_j \in S \text{ and } s_j \geq s_i\} \tag{4.16}$$

$$E_{GH}(greater\ than\ \ s_i)= \{s_j|s_j \in S\ and\ s_j > s_i\} \tag{4.17}$$

$$E_{GH}(between\ s_i\ and\ s_j)= \{s_k|s_k \in S\ and\ s_i \leq s_k \leq s_j\} \tag{4.18}$$

Definition 9: Liu and Rodriguez (2014) built a fuzzy envelope for HFLTS. Assume that DMs hesitate about linguistic expressions, however, they are confident with the worst assessment and use the expression *"at least s_i"*, for which the factors of the trapezoidal fuzzy membership function, denoted by $A = (\alpha,\beta,\gamma,\delta)$, will be calculated with the following steps:

$$\alpha = \min \{a_L^i, a_M^i, a_M^{i+1}, \ldots, a_M^g, a_R^g\} = a_L^i \tag{4.19}$$

$$\delta = \max \{a_L^i, a_M^i, a_M^{i+1}, \ldots, a_M^g, a_R^g\} = a_R^g \tag{4.20}$$

$$\beta = OWA_{w^2}\left(a_M^i, a_M^{i+1} \ldots, a_M^g\right) \tag{4.21}$$

$$\gamma = a_M^g \tag{4.22}$$

Here, OWA operation requires a weight vector that consists of the 2nd types of weights between [0,1]. The 2nd type of weights $W^2= (w_1^2, w_2^2,..., w_{g-i+1}^2,)^T$ is defined as:

$$w_1^2 = \alpha_1{}^{g-i}, w_2^2 = (1- \alpha)\ \alpha^{g-i-1},\ldots, w_{g-i+1}^2 = 1- \alpha \tag{4.23}$$

where $\alpha =g/i$, g is the number of elements in the evaluation scale, and i is the rank of the lowest evaluation value within its defined interval.

Definition 10: Assume that DMs hesitate about linguistic expressions. However, they are confident with the best assessment and use the expression *"at most s_i"*, for which the factors of the trapezoidal fuzzy membership function, denoted by $A = (\alpha,\beta,\gamma,\delta)$, will be calculated with the following steps (Liu and Rodriguez, 2014):

$$\alpha = \min \{a_L^0, a_M^0, a_M^1, \ldots, a_M^i, a_R^i\} = a_L^0 \tag{4.24}$$

$$\delta = \max \{a_L^0, a_M^0, a_M^1, \ldots, a_M^i, a_R^i\} = a_R^i \tag{4.25}$$

$$\beta = a_M^0 \quad (4.26)$$

$$\gamma = OWA_{w^1}\left(a_M^0, a_M^1 \ldots, a_M^i\right) \quad (4.27)$$

Here again, the OWA operation requires a weight vector that consists of 1st types of weights between [0,1]. The 1st type of weights $W^1 = (w_1^1, w_2^1, \ldots, w_{i+1}^1,)^T$ is defined as:

$$w_1^1 = \alpha,\ w_2^1 = (1-\alpha)\,\alpha, \ldots,\ w_{i+1}^1 = (1-\alpha)^i \quad (4.28)$$

where $\alpha = i/g$, g is the number of elements in the evaluation scale, and i is the rank of the highest evaluation value within its defined interval.

Definition 11: Assume that the DMs' evaluations change between two terms i.e. s_i and s_j. Then they use the expression *"between s_i and s_j"*. The factors of the trapezoidal fuzzy membership function, denoted by A = (α,β,γ,δ), will be calculated with the following steps (Liu and Rodriguez, 2014):

$$\alpha = \min\{a_L^i, a_M^i, a_M^{i+1}, \ldots, a_M^j, a_R^j\} = a_L^i \quad (4.29)$$

$$\delta = \max\{a_L^i, a_M^i, a_M^{i+1}, \ldots, a_M^j, a_R^j\} = a_R^i \quad (4.30)$$

$$\beta = \begin{cases} a_M^i & \text{if } i+1=j \\ OWA_{w^2}\left(a_M^i, \ldots, a_M^{\frac{i+j}{2}}\right) & \text{if } i+j \text{ is even} \\ OWA_{w^2}\left(a_M^i, \ldots, a_M^{\frac{i+j-1}{2}}\right) & \text{if } i+j \text{ is odd} \end{cases} \quad (4.31)$$

$$\gamma = \begin{cases} a_M^{i+1} & \text{if } i+1=j \\ OWA_{w^1}\left(a_M^{j}, a_M^{j-1}, \ldots, a_M^{\frac{i+j}{2}}\right) & \text{if } i+j \text{ is even} \\ OWA_{w^1}\left(a_M^{j}, a_M^{j-1}, \ldots, a_M^{\frac{i+j+1}{2}}\right) & \text{if } i+j \text{ is odd} \end{cases} \quad (4.32)$$

In this case, the OWA operation requires two types of the weight vector. For this reason, the 1st and 2nd types of weights between [0,1] must be described.

i. If $i+j$ is odd, then the 1st type of weights $W^1 = (w_1^1, w_2^1, \ldots, w_{(j-i+1)/2)}^1)^T$ is defined as:

$$w_1^1 = \alpha_2,\ w_2^1 = \alpha_2\,(1-\alpha_2),\ \ldots,\ w_{(j-i+1)/2}^1 = \alpha_2\,(1-\alpha_2)^{(j-i-1)/2} \quad (4.33)$$

The 2nd type of weights $W^2 = (w_1^2, w_2^2, \ldots, w_{(j-i+1)/2}^2)^T$ is defined as:

$$w_1^2 = \alpha_1^{(j-i-1)/2},\ w_2^2 = (1-\alpha_1)\,\alpha_1^{(j-i-3)/2},\ \ldots,\ w_{(j-i-1)/2}^2 = 1-\alpha_1 \quad (4.34)$$

ii. If $i+j$ is even, then the 1st type of weights $W^1 = (w_1^1, w_2^1, \ldots, w_{(j-i+2)/2)}^1)^T$ is defined as:

$$w_1^1 = \alpha_2,\ w_2^1 = \alpha_2\,(1-\alpha_2),\ \ldots,\ w_{(j-i+2)/2}^1 = \alpha_2\,(1-\alpha_2)^{j-i/2} \quad (4.35)$$

The 2nd type of weights $W^2 = (w_1^2, w_2^2, \ldots, w_{(j-i+2)/2}^2)^T$ is defined as:

$$w_1^2 = \alpha_1^{j-i/2},\ w_2^2 = (1-\alpha_1)\,\alpha_1^{(j-i-2)/2},\ \ldots,\ w_{(j-i+2)/2}^2 = 1-\alpha_1 \quad (4.36)$$

where $\alpha_1 = \frac{g-(j-i)}{g-1}$, $\alpha_2 = \frac{(j-i)-1}{g-1}$, g is the number of elements in the evaluation scale, j is the rank of the highest evaluation and i is the rank of the lowest evaluation value within its defined interval.

4.5. HFL AHP Method

The AHP method, introduced by Saaty (1980), is a popular technique for calculating the weights of different criteria (Marchais-Roubelat and Roubelat, 2011). The decision making methodology is decomposed into the following steps to make a decision in a systematic way (Zhu et al., 2016):

Hesitancy is commonly observed in decision making processes. Many possible values are used in hesitant AHP to describe the hesitancy of the assessment of the DMs. The judgment that is found by various possible values is called a hesitant judgment (Onar et al., 2016).

4.5.1. Literature Survey for AHP Method and its Fuzzy Extensions

Emrouznejad and Marra (2017) reviewed utilization of AHP method in the literature between 1979-2017. The evolution of AHP method can be examined within 3 periods. In the first period (1979-1990), AHP is used in banking sector (Javalgi, Armacost, and Hosseini 1989), bond ratings (Johnson, Srinivasan, and Bolster 1990; Srinivasan and Bolster 1990), medical and healthcare decisions.

In the second period (1991-2001), the method became more popular between academicians. During these years, AHP method began to be applied in research areas as mathematical methods (Arbel and Vargas 1993), followed by computer science (Hanratty and Joseph 1992; Hanratty, Joseph, and Dudukovic 1992), business, management, health sector (Carter et al. 1999; Castro et al. 1996), and new research areas as environmental science and technology (Ramanathan 2001), supply chain management and logistics (Korpela and Lehmusvaara 1999; Korpela, Lehmusvaara, and Tuominen 2001), energy sector (Ramanathan and Ganesh 1994a), mechanical engineering, ecology (Kangas and Kuusipalo 1993; Kurttila et al. 2000), social studies and materials science.

The AHP method is used most frequently in the third period (2002-2017). The method is integrated with other MCDM methods e.g. TOPSIS, DEA, SWOT, QFD. AHP-TOPSIS methodology is applied for evaluating e-logistics-based strategic alliance partners (Büyüközkan, Feyzioğlu, and Nebol 2008), facility location selection (Ertuğrul and Karakaşoğlu 2007), assessment of intelligent buildings (Kaya and Kahraman 2014). AHP-DEA methodology is applied for solving practical design problems (Yang and Kuo 2003), evaluate the economic performance of local governments (Lin, Lee, and Ho 2011). AHP and SWOT analysis is integrated to determine management strategies in construction enterprises (Zavadskas, Turskis, and Tamosaitiene 2011) and in reverse logistics (Tavana et al. 2016). AHP-QFD methodology is used for ranking and selecting suppliers (Bhattacharya, Geraghty, and Young 2010).

Additionally, AHP was extended in fuzzy environment. One of the most influential authors in this area is Kahraman. He published many studies proposing fuzzy AHP and its applications. Fuzzy AHP has been applied in areas as supplier selection (Kahraman et al., 2003), hair dryer design (integrated with QFD method) (Kwong and Bai, 2003), catering service company evaluation (Kahraman et al., 2004), material selection in automotive industry (Ayağ, 2005), energy alternative selection (Kahraman and Kaya 2010), supply chain performance evaluation (Jakhar and Barua, 2013), risk assessment in occupational health and safety (Ilbahar et al., 2018), risk assessment for steel industry (Fattahi and Khalilzadeh, 2018), global supplier selection (integrated with VIKOR method) (Awasthi et al., 2018) reverse logistics (Sirisawat and Kiatcharoenpol, 2018). Fuzzy AHP method is frequently preferred since the practical nature of the methodology. Furthermore, its fuzzy nature enables to consider and reflect the imprecise and vague information about the problem. Different types of sets have been developed within the concept of fuzzy sets as type-2 fuzzy sets, interval-valued fuzzy sets, intuitionistic fuzzy sets etc. In this thesis, the hesitant fuzzy AHP method is preferred.

Mousavi et al. (2004) first proposed Hesitant Fuzzy AHP method. He combined AHP method with the concept of HFLTS. To demonstrate the usability of the method, he illustrated HF-AHP for the bridge construction problem. Zhu and Xu (2014) considered GDM approach under hesitant fuzzy environment and introduced AHP-hesitant group decision-making (AHP-HGDM) approach. Table 4.3 illustrates the studies that use AHP method in hesitant fuzzy environment between 2014-2018.

Table 4.3: Literature survey for studies using Hesitant Fuzzy AHP method

Year	Author(s)	Application Area	Integrated Methods	Type
2014	Mousavi et al.	Bridge construction	-	Illustrative Example
2014	Zhu and Xu	Water conservancy in China	-	Illustrative Example
2016	Başar	Software cost estimation problem in Turkey	-	Case Study
2016	Onar	Computer work station design	QFD, TOPSIS	Case Study
2016	Zhou and Xu	Selection of the most livable city	-	Illustrative Example
2016	Zhu et al.	Assessment of the strategic positions of islands and reefs	-	Case Study
2017	Tüysüz and Şimşek	Analysis of the factors affecting the performance of a cargo company in Turkey	-	Case Study
2017	Çolak and Kaya	Prioritization of renewable energy alternatives	TOPSIS	Case Study
2018	Yıldız and Tüysüz	Retail location selection	GRA	Case Study

As seen in Table 4.3, Hesitant Fuzzy AHP method is used in different application areas as bridge construction, water conservancy, software cost estimation, design of computer, evaluation of cities, choosing strategic positions of islands and reefs, performance evaluation of companies and prioritization of renewable energy alternatives. Therefore, hesitant fuzzy AHP method can be adapted to different types of problems. In the literature, the methodology is new and integrated with just QFD and TOPSIS methods. For this reason, there is a gap in its combination with other MCDM methods.

In this thesis, we combined hesitant AHP method with hesitant AD methodology for the first time. Because, AHP method and AD method are complementary and compatible. In the literature, the use of integrated Fuzzy AHP-Fuzzy AD methodology exists (Alp et al., 2012; Bilişik et al.2014; Chakraborty et al., 2017). Alp et al. (2012) used the methodology for determining the public transportation system in Istanbul, Bilişik et al. (2014) used the methodology for determining the precedencies of the alternative garage location and Chakraborty et al. (2017) used the methodology for determining the most suitable design alternative for remanufacturing.

4.5.2. Preliminaries of HFL AHP Method

Definition 12: $A = \{a_1, a_2, ..., a_n\}$ is defined as a set of elements, which will be aggregated. Here, F, the OWA operator, can be defined as**:**

$$F(a_1, a_2, ..., a_n) = wb^T = \sum_{i=1}^{n} w_i b_i, \tag{4.37}$$

where $w = (w_1, w_2, ..., w_n)^T$ is a weighting vector. Here, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$ and b is the associated ordered value vector, where $b_i \in b$ is the i^{th} largest value in A.

Table 4.4: Linguistic scale for HFL AHP (Onar et al., 2016)

Linguistic term	s_i	Abb.	Triangular fuzzy number
Absolutely High Importance	s10	(AHI)	(7,9,9)
Very High Importance	s9	(VHI)	(5,7,9)
Essentially High Importance	s8	(ESHI)	(3,5,7)
Weakly High Importance	s7	(WHI)	(1,3,5)
Equally High Importance	s6	(EHI)	(1,1,3)
Exactly Low Importance	s5	(EE)	(1,1,1)
Equally Low Importance	s4	(ELI)	(0.33,1,1)
Weakly Low Importance	s3	(WLI)	(0.2,0.33,1)
Essentially Low Importance	s2	(ESLI)	(0.14,0.2,0.33)
Very Low Importance	s1	(VLI)	(0.11,0.14,0.2)
Absolutely Low Importance	s0	(ALI)	(0.11,0.11,0.14)

Steps 1–5 are repeated for both the main and their sub-criteria. Overall sub-criteria weights are found by using steps 6-7. The steps of hesitant fuzzy AHP are (Onar et al., 2016):

Step 1. First, pairwise comparison matrices are constructed and the compromise evaluations from the DMs are obtained with HFLTS, which are found by using the linguistic terms listed in Table 4.4.

Step 2. The fuzzy envelope for HFLTS is aggregated and built with the OWA operator (Liu and Rodriguez, 2014). This aggregation procedure described in the *Definition 9, Definition 10 and Definition 11* gives a trapezoidal fuzzy number as a result. The scale used for HFL AHP is given in Table 2.

Step 3. The pairwise comparison matrix $(\widetilde{C})$, which consists of the aggregated fuzzy numbers generated in *Step 2* with $\widetilde{c_{ij}} = (c_{ijl}, c_{ijm1}, c_{ijm2}, c_{iju})$, is obtained. The reciprocal values are obtained as shown next:

$$\widetilde{c_{ij}} = \left(\frac{1}{c_{iju}}, \frac{1}{c_{ijm2}}, \frac{1}{c_{ijm1}}, \frac{1}{c_{ijl}}\right) \tag{4.38}$$

Step 4. For each row, the fuzzy geometric mean $(\tilde{r}_i)$ of the matrix $\tilde{C}$ is calculated with (4.38).

$$\tilde{r}_i = (\tilde{c}_{i1} \otimes \tilde{c}_{i2} \ldots \otimes \tilde{c}_{in})^{1/n} \tag{4.39}$$

Step 5. The fuzzy weight $(\widetilde{w}_i^{CR})$ of each main criteria is computed with $(\tilde{r}_i)$ values, as shown below:

$$\widetilde{w}_i^{CR} = \tilde{r}_i \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \ldots \otimes \tilde{r}_n)^{-1} \tag{4.40}$$

Step 6. The fuzzy global weights of sub-criteria are computed.

$$\widetilde{w}_{ij}^{G} = \widetilde{w}_i^{CR} \times \widetilde{w}_j^{CR} \tag{4.41}$$

where $\widetilde{w}_{ij}^{G}$ is the global weight of sub-criteria.

Step 7. Trapezoidal fuzzy numbers $\tilde{w}_{ij}{}^{G}$ using (42) are defuzzified and the defuzzified values are normalized using (4.43).

$$w_{ij}{}^{G} = \frac{\alpha+2\beta+2\gamma+\delta}{6} \tag{4.42}$$

$$w_{ij}{}^{N} = \frac{w_{ij}^{G}}{\sum_i \sum_j w_{ij}^{G}} \tag{4.43}$$

4.6. HFL AD Method

The principles of AD were proposed by Suh (1990). In engineering, the utilization of this technique is very widespread. The method aims to establish a scientific basis for improving design activities and to measure how well the system features respond to requirements (Arsenyan and Büyüközkan, 2013). To do so, the methodology provides a theoretical background by using logical and rational thought process and tools for the designer (Suh, 2001). The method is separated from other MCDM methods by the following property. AD method allows for the selection of not only the best alternative by considering different criteria, but also the method proposes the most appropriate alternative. The Functional Requirements (FRs) are the minimum set of independent requirements that characterize the design goals. The main concept of the AD is the “design axioms”. The first axiom is named as “Independence Axiom”. The second axiom is named as “Information Axiom”. They are basically summarized as:

1. The Independence Axiom: Maintain the independence of FRs
2. The Information Axiom: Minimize the information content

The first axiom indicates that the FRs should be independent to characterize the design goals. The best design is the design with the lowest information content. The information is described by using information content I_k (Kannan et al., 2015).

4.6.1. Literature Survey for AD Method and its Fuzzy Extensions

Rauch et al. (2016) investigated the utilization of AD method in the literature over the past 20 years. After the introduction of the AD method that aims to develop a scientific, generalized, codified, and systematic procedure for design, by Suh (1990), its utilization area has mainly focused on manufacturing system design. However, the method has also been used in different application areas as (Kulak et al., 2010):

- Product Design
- Decision Making
- Software Design
- System Design
- Manufacturing System Design
- Others.

In the years 1999-2001, the utilization of AD method was preferred for lean and flexible manufacturing systems, in the years 2005-2007 studies focused on reconfigurable manufacturing systems. For example, Coelho et al. (2007) utilized AD for supporting decision making in manufacturing. Franzellin et al. (2010) determined stakeholders' and customers' benefits and requirements by AD method. Kandjani and Bernus (2011) focused on process and people capability maturity models. After 2012, agile and changeable manufacturing systems and modern topics as sustainability, life cycle management or cloud manufacturing preferred frequently in the application area of AD methodology.

Kulak and Kahraman (2005) first proposed the extension of AD method in fuzzy environment. Yücel and Aktaş (2007) used FAD for the design of electronic consumer products. Kahraman and Çebi (2009) proposed hierarchical fuzzy axiomatic design (FAD) that has made the most important contribution to classical FAD by selecting problems through a hierarchical structure. Çelik et al. (2009) used FAD methodology for decision-making in the maritime industry. In another study, Çelik et al. (2009) combined FAD with fuzzy TOPSIS and SWOT analysis for developing strategies in the maritime industry. Cebi and Kahraman (2010) debated the current FAD principles. Büyüközkan

(2011) utilized FAD methodology integrated with fuzzy AHP approach for evaluating green suppliers and in her another study, she used FAD approach to select personal digital assistant and compared the results of FAD method with fuzzy TOPSIS method (Büyüközkan et al., 2012). Maldonado et al. (2013) implemented FAD for assessing the ergonomic compatibility of the advanced manufacturing technology. Arsenyan and Büyüközkan (2013) integrated FAD method with fuzzy QFD and fuzzy rule based systems. Kannan et al. (2014) used FAD for green supplier selection and illustrated the method by a case study from Singapore. Kır and Yazgan (2016) considered the single machine problem with earliness and tardiness penalty costs and implemented FAD methodology for scheduling of a cheese production process in the food industry. The integrated fuzzy AHP and FAD methodology was extended with GDM approach by Büyüközkan et al. (2017) and used for RFID service provider selection problem. Ighravwe and Oke (2017) selected the proper maintenance strategy in manufacturing systems by using FAD and fuzzy TOPSIS approaches. Karataş (2017) proposed multi-period probabilistic weighted FAD approach and illustrated this methodology by a case study of industry selection in Turkey.

The intuitionistic fuzzy extension of AD approach exists in the related literature. Büyüközkan and Göçer (2017) proposed a new combined intuitionistic fuzzy AHP-AD approach for supplier selection. Öztayşi et al. (2017) used hierarchical intuitionistic fuzzy AD methodology for assessing the performance of call centers. Kahraman et al. (2018) proposed a novel approach considering trapezoidal intuitionistic fuzzy information axiom and demonstrated its applicability by a case study of landfill site selection. In the related literature, the studies that combines intuitionistic fuzzy sets approach and AD method exists. However, none of these studies considered the hesitancy concept. Therefore, there is a lack of study implementing AD methodology with hesitant fuzzy concept. For this reason, in this thesis, the hesitant fuzzy AD method is proposed for the first time.

4.6.2. Preliminaries of HFL AD Method

The steps of hesitant fuzzy AD are:

Step 1. First, alternatives' evaluation matrices are constructed by collecting DMs' opinions with comparative linguistic expressions like "*At most* s_i"; which is indicated as

"*At_m* s_i"; "*Lower than* s_i" which is indicated as; "*Lw than* s_i" "*At least* s_i"; which is indicated as "*At_l* s_i"; "*Greater than* s_i" which is indicated as "*Grt than* s_i"; "*Between* s_i *and* s_j" which is indicated as "*Btw* s_i *and* s_j".

Table 4.5: Linguistic scale for HFL AD (Zeng et al., 2007)

Linguistic term	s_i	Abb.	Triangular fuzzy number
Very High	s5	(VH)	(7.5,10,10)
High	s4	(H)	(5,7.5,10)
Medium	s3	(M)	(2.5,5,7.5)
Low	s2	(L)	(0,2.5,5)
Very Low	s1	(VL)	(0,0,2.5)

Step 2. The evaluation matrix is transformed to the HFLTS matrix by using the E_{GH} as shown in *Definition 8*. The linguistic terms used in this thesis are listed in Table 4.5 with their abbreviations and triangular fuzzy numbers (TFNs).

Step 3. The DMs evaluations with TFNs are aggregated by using an aggregation operator named as the fuzzy weighed trapezoidal averaging operator. The aggregation equation is:

$$\tilde{S}_{ij} = \frac{1}{K}\left(\tilde{s}_{ij}^{1} + \tilde{s}_{ij}^{2} + \ldots \tilde{s}_{ij}^{1t} + \ldots \tilde{s}_{ij}^{K}\right), \tilde{s}_{ij}^{1t} = (a_{ij}. b_{ij}. c_{ij}) \quad (4.44)$$

Where K is the number of the DMs; $\tilde{S}_{ij}$ is the ratings of alternatives with i representing the alternative and j representing the criterion.

Step 4. For each criterion, the FRs that identifies the minimum sets of independent requirements are determined. The TFNs are utilized for describing the FRs and it is given in Table 4.6.

Table 4.6: Minimum set of requirements for HFL AD (Kannan et al., 2014)

FRs	Abb.	Triangular fuzzy number
At least Very Good	(AVG)	(7.5,10,10)
At least Good	(AG)	(5,10,10)
At least Fair	(AF)	(4,10,10)
At least Very Fair	(AVF)	(3,10,10)
At least Very Very Fair	(AVVF)	(0.5,10,10)

From the experts' evaluations, and according to the maturity score, the threshold values for each criterion are determined. The general logic is; the FRs of the weakest maturity factors (their scores are between 2 and 2.67) are accepted as AVG. Because, the implemented action plan should improve these weak sides of the company in a very efficient way. The FRs of the average maturity factors (their scores are between 2.68 and 3) are accepted as AG. Because these factors can be upgraded with the new action plan. Since their scores are acceptable, (between 3.1 and 5), the strongest maturity factors are not considered in the alternative evaluation phase except the most important 5 factors. If their scores are acceptable but they are very important, the FRs are determined as AF. Since they are important, their value can not be under AF.

Step 5. The information content (I) for each alternative is calculated. To calculate I for each alternative, the common range and the system range is necessary. The main concept of AD is to find the intersection area between design range and system range. Figure 4.2 illustrates the design range, which indicates the expectation level, the system range, which indicates the real level and the common area, which indicates their intersection.

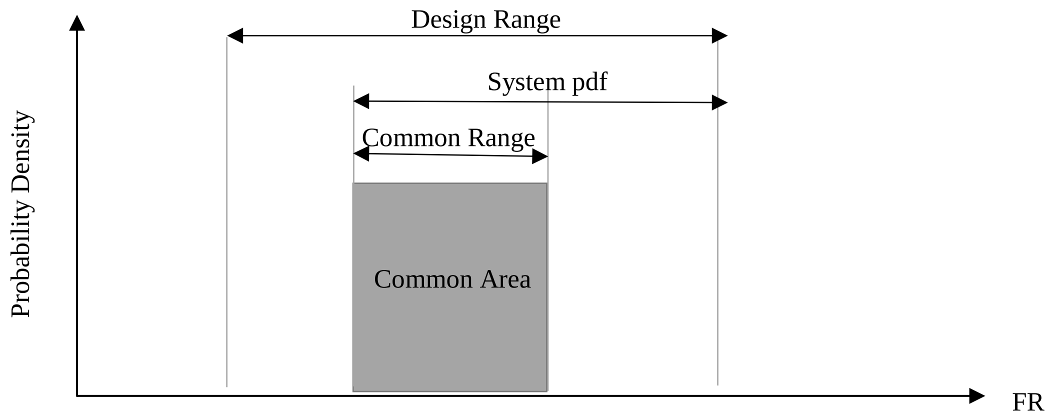

Figure 4.2: Design range, system range, common range (Kulak and Kahraman, 2005)

In fuzzy case, the incomplete information can be preferred by using TFNs or trapezoidal fuzzy numbers. The membership functions are used in fuzzy case in lieu of probability density function in crisp case. The system range and design range are defined by using TFNs. Figure 4.3 shows the illustration of these ranges in fuzzy case.

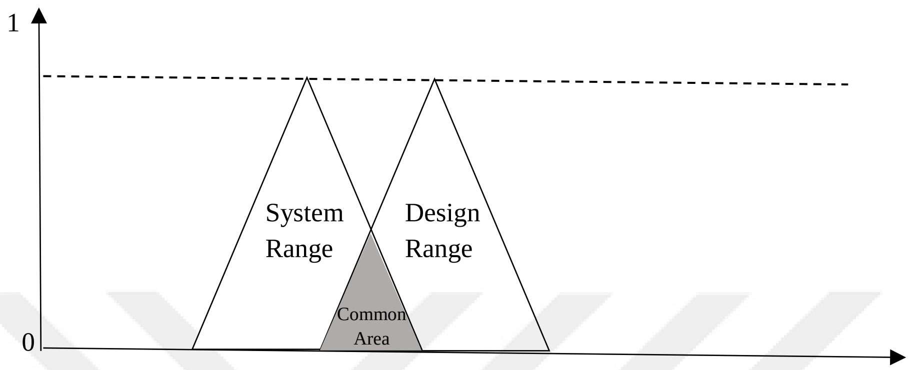

Figure 4.3: The common area of the design range and system range (Kannan et al., 2015)

The information content is calculated by using this formula:

$$\boldsymbol{I} = \log_2 \left(\frac{TFN\ of\ System\ Design}{Common\ Area} \right) \tag{4.45}$$

Step 6. The best alternative which has the minimum information content is identified. The selection of the best alternative is completed by following equations (Kannan et al., 2015):

$$I_i^t = \sum_{j=1}^{n} I_{ij} \tag{4.46}$$

$$I^* = \min \begin{Bmatrix} I_1^t \\ I_2^t \\ \vdots \\ I_m^t \end{Bmatrix} \tag{4.47}$$

where *i* indicates the alternatives and *j* indicates the criteria.

5. CASE STUDY

The aim of this chapter is to introduce a real case study. The company is chosen from the banking sector. Because DT affects the banking sector day after day and the sector is highly competitive. Moreover, the banks in Turkey has taken significant steps in terms of DT.

The case study is about a bank on DT journey in Turkey. For privacy concerns, the name of the bank will be denoted as the “ABC” bank. First, the weights of the proposed DMM factors are calculated with HFL AHP method. To find the current position of the ABC in digitalization, maturity score of the company is calculated and results are illustrated for every maturity dimension. Finally, according to maturity scores, the weak digital maturity factors are determined as evaluation criteria. The proposed DSAPs are evaluated with HFL AD method and the most appropriate DSAP for the ABC is selected.

5.1. Phase 1: Preparation Phase

This section presents the application steps of the research methodology. In the evaluation phases of the methods, the data is collected from 3 DMs. DMs are working in a consulting firm and they have knowledge about DT. DM1 is the technology manager, DM2 is the technology expert and the DM3 is the finance general manager. The ABC and the consulting firm have had a project about DT, and DMs have advised to ABC for a while. For this reason, the questionnaire about measuring the ABC’s digital maturity score is directed to the same DMs. Table 5.1 summarizes the digital maturity factors with their abbreviations.

Table 5.1: The digital maturity factors

Dimensions	Digital Maturity Factors
C1. Customer	C11. Design for Customer Needs
	C12. Online Customer Touch Points
	C13. Utilization of Business Analytics (BI)
	C14. Customer Experience via New Technologies
C2. People	C21. C-Suite’s Leading for Digitalization
	C22. Digital Education and Training
	C23. Personnel’ Enablement in Digitalization
	C24. Digitally Talented Personnel (Digital Skills, Know-How)
C3. Communication	C31. Knowledge Sharing and Transparency
	C32. Spread of Digital Vision between Departments
	C33. Inter/Intra Organizational Learning
	C34. Continuous Digital Improvement
C4. Culture	C41. Perception of Digitalization (digital as value)
	C42. Company-wide Commitment
	C43. Risk Awareness
	C44. Innovation Culture/Open Innovation
C5. Technology	C51. Flexible Technology Development towards the Business, Environment, Market
	C52. Concentration on IT Infrastructure (IT-Expertise)
	C53. Agile IT Project Management
	C54. Integrated Modern Architecture
C6. Processes	C61. Having Shared Digital Vision/Goals/Risks/Rewards and Penalties
	C62. Information in Digital Form
	C63. Data-driven Business for Rapid/Automated Decision-Making
	C64. Defined, Repeatable or/and Automated Processes for Digital Program
C7. Business Model	C71. Co-working of marketing and technology resources
	C72. Digitalization of product and service offerings
	C73. Digitalization of supply chain and platform
	C74. Leverage digital options by investing in digital opportunities for the future
C8. Organization	C81. Governance
	C82. Digital Leadership
	C83. Cross-Functional Team Set-up
	C84. Continuous Measurement of Digital Competence
C9. Ecosystem	C91. Digital Partnerships with External Actors (e.g. consulting firms)
	C92. Managing Relationships via Online Channels
	C93. Trust and Transparency in Relationships with Partners
	C94. Fast Reaction to Ecosystem Changes

5.2. Phase 2: Calculation of the DMM Factors' Weights with HFL AHP Method

First, the DMs are asked to evaluate the 9 maturity factors' weight. Since 9 is too many for applying HFL AHP technique, DMs directly indicated the dimensions' weights. Table 5.2 shows the maturity dimensions' weight.

Table 5.2: The maturity dimensions' weights

Dimensions	DM1	DM2	DM3	Average Weights
Customer (C1)	0.1	0.1	0.2	0.133
People (C2)	0.1	0.15	0.15	0.133
Communication (C3)	0.05	0.1	0.05	0.067
Culture (C4)	0.1	0.05	0.05	0.067
Technology (C5)	0.1	0.1	0.1	0.100
Processes (C6)	0.15	0.1	0.1	0.117
Business Model (C7)	0.2	0.1	0.15	0.150
Organization (C8)	0.1	0.15	0.1	0.117
Ecosystem (C9)	0.1	0.15	0.1	0.117

The DMs evaluated each 4 factor under 9 dimensions by using comparative linguistic term sets. For the customer (C1) dimension the Table 5.3, Table 5.4 and Table 5.5 shows the evaluations. Other dimensions' evaluations are made with the same way.

Table 5.3: The DM1's evaluation about customer dimensions' factors

	C11	C12	C13	C14
C11	EE	Between ELI and EE	Between ELI and EE	Between EE and EHI
C12		EE	Between EE and EHI	At least WHI
C13			EE	At least WHI
C14				EE

Table 5.4: The DM2's evaluation about customer dimensions' factors

	C11	C12	C13	C14
C11	EE	Between ELI and EE	Between ESLI and ELI	Between EE and EHI
C12		EE	Between ELI and EE	Between EHI and WHI
C13			EE	Between WHI and ESHI
C14				EE

Table 5.5: The DM3's evaluation about customer dimensions' factors

	C11	C12	C13	C14
C11	EE	Between ESHI and VHI	At least ESHI	At least VHI
C12		EE	Between ELI and EE	Between EHI and WHI
C13			EE	Between WHI and ESHI
C14				EE

The fuzzy envelope for HFLTS described in *Definition 9, Definition 10 and Definition 11* is aggregated. Table 5.6 shows the fuzzy enveloped numbers of DM1's evaluations.

Table 5.6: The fuzzy values of the DM1's evaluation about customer dimension

	C11	C12	C13	C14
C11	(1,1,1,1)	(0.33,1,1,1)	(0.33,1,1,1)	(1,1,1,3)
C12		(1,1,1,1)	(1,1,1,3)	(1,5.88,7,9)
C13			(1,1,1,1)	(1,5.88,7,9)
C14				(1,1,1,1)

The 3 DMs' evaluations are aggregated by the following equation:

$$v_k^* = v_k / \sum_{i=1}^{n} v_i \tag{5.1}$$

Since the importance of DMs can not be equal, the v_k (the weight of the DMs) is taken into consideration. (Çifçi and Büyüközkan, 2012). The aggregated pairwise comparison matrix is calculated, Table 5.7 provides this matrix for the customer dimension.

Table 5.7a: The aggregated comparison matrix for customer dimensions' factors

	C11	C12
C11	(1,1,1,1)	(1.13,2.200,2.800,3.400)
C12	(0.29,0.36,0.45,0.88)	(1,1,1,1)
C13	(0.29,0.31,0.35,0.93)	(0.56,1,1,1.67)
C14	(0.21,0.29,0.30,0.45)	(0.21,0.29,0.30,0.45)

Table 5.7b: The aggregated comparison matrix for customer dimensions' factors

	C13	C14
C11	(1.07,2.86,3.20,3.400)	(2.20,3.34,3.40,4.80)
C12	(0.60,1.00,1,1.80)	(1,2.95,4.60,6.60)
C13	(1,1,1,1)	(1,4.15,5.80,7.80)
C14	(0.13,0.17,0.24,1)	(1,1,1,1)

The results of the HFL AHP method is given in Table 5.8. According to the table, it is possible to say that the most important factor is "C74. Leverage digital options by investing in digital opportunities for the future" with the "0.122" normalized weight. The second important factor is "C21. C-Suite's Leading for Digitalization" with the "0.090" normalized weight. The third important factor is "C72. Digitalization of product and service offerings" with the "0.085" normalized weight that is very close to the second important factor's weight. The fourth important factor is "C11. Design for Customer Needs" with "0.063" weight. The fifth important factor is "C91. Digital Partnerships with External Actors" with "0.049" weight.

The results show that the factors under "C7. Business model", "C2. People", "C1. Customer" and "C9. Ecosystem" dimensions have significant importance on company's digital maturity.

Table 5.8: The weights of the digital maturity factors

Factors	Relative Scores				Global Scores				Deffuzz. Weights	Normalized Weights	Rank
C11	0.18	0.42	0.51	0.96	0.18	0.42	1.54	4.81	1.486	0.063	4
C12	0.09	0.20	0.26	0.64	0.09	0.20	0.79	3.18	0.873	0.037	9
C13	0.09	0.21	0.26	0.66	0.09	0.21	0.78	3.29	0.894	0.038	7
C14	0.04	0.07	0.08	0.24	0.04	0.07	0.25	1.19	0.311	0.013	25
C21	0.13	0.47	0.68	1.53	0.13	0.47	2.04	7.63	2.130	0.090	2
C22	0.04	0.10	0.13	0.44	0.04	0.10	0.38	2.20	0.531	0.022	15
C23	0.06	0.15	0.19	0.50	0.06	0.15	0.57	2.49	0.665	0.028	13
C24	0.07	0.14	0.17	0.90	0.07	0.14	0.52	4.51	0.981	0.041	6
C31	0,14	0.29	0.42	1.08	0.02	0.09	0.15	1.08	0.263	0.011	29
C32	0,11	0.25	0.39	0.79	0.01	0.08	0.13	0.79	0.204	0.009	32
C33	0.07	0.14	0.23	0.51	0.01	0.05	0.08	0.51	0.127	0.005	34
C34	0.05	0.13	0.20	0.38	0.01	0.04	0.07	0.38	0.102	0.004	35
C41	0.10	0.31	0.50	0.99	0.01	0.10	0.17	0.99	0.257	0.011	30
C42	0.06	0.13	0.24	0.59	0.01	0.04	0.08	0.59	0.140	0.006	33
C43	0.03	0.08	0.14	0.41	0.00	0.03	0.05	0.41	0.094	0.004	36
C44	0.13	0.28	0.36	1.18	0.02	0.09	0.12	1.18	0.271	0.011	28
C51	0.12	0.19	0.35	0.90	0.04	0.19	0.35	0.90	0.338	0.014	22
C52	0.07	0.14	0.23	0.53	0.02	0.14	0.23	0.53	0.216	0.009	31
C53	0.08	0.20	0.35	0.61	0.03	0.20	0.35	0.61	0.288	0.012	27
C54	0.10	0.24	0.36	0.77	0.03	0.24	0.36	0.77	0.334	0.014	24
C61	0.07	0.17	0.24	0.60	0.07	0.17	0.24	1.79	0.446	0.019	19
C62	0.09	0.24	0.31	0.66	0.09	0.24	0.31	1.97	0.529	0.022	16
C63	0.13	0.32	0.41	1.23	0.13	0.32	0.41	3.69	0.881	0.037	8
C64	0.05	0.12	0.21	0.46	0.05	0.12	0.21	1.38	0.348	0.015	21
C71	0.04	0.11	0.12	0.45	0.04	0.33	0.62	3.15	0.851	0.036	10
C72	0.11	0.30	0.38	0.90	0.11	0.91	1.91	6.30	2.007	0.085	3
C73	0.04	0.12	0.14	0.39	0.04	0.35	0.69	2.70	0.801	0.034	11
C74	0.11	0.39	0.45	1.49	0.11	1.17	2.23	10.5	2.894	0.122	1
C81	0.09	0.22	0.32	0.59	0.09	0.22	0.32	1.76	0.490	0.021	17
C82	0.14	0.21	0.36	0.95	0.14	0.21	0.36	2.85	0.689	0.029	12
C83	0.08	0.18	0.31	0.54	0.08	0.18	0.31	1.63	0.448	0.019	18
C84	0.07	0.16	0.30	0.55	0.07	0.16	0.30	1.66	0.443	0.019	20
C91	0.14	0.44	0.73	1.51	0.14	0.44	0.73	4.52	1.169	0.049	5
C92	0.04	0.10	0.13	0.43	0.04	0.10	0.13	1.30	0.300	0.013	26
C93	0.05	0.12	0.18	0.45	0.05	0.12	0.18	1.35	0.335	0.014	23
C94	0.07	0.14	0.19	0.89	0.07	0.14	0.19	2.67	0.570	0.024	14

5.3. Phase 3: Calculation of the Digital Maturity Score

First, a questionnaire about the digital maturity factors of the proposed DMM evaluation framework is responded by DMs. The questionnaire about DMM factors is sent by e-mail to DMs.

After getting the responds of the questionnaire, the digital maturity score of the company is calculated with this equation (Schumacher et al., 2016):

$$M_D = \frac{\sum_{i=1}^{n} M_{DIi} * g_{DIi}}{\sum_{i=1}^{n} g_{DIi}} \quad (5.2)$$

where the *M* denotes the maturity, *D* denotes the dimension, *I* denote the item (factor), *g* denotes the weighting factor and *n* is the number of the maturity factors.

The overall maturity score of the company is provided in Table 5.9. To better understand the current situation, the maturity scores are visualized by the radar chart in Figure 5.1.

Table 5.9: The overall maturity score of the ABC

Dimensions	Score
Customer (C1)	9.811
People (C2)	7.019
Communication (C3)	8.097
Culture (C4)	10.442
Technology (C5)	9.664
Processes (C6)	11.251
Business Model (C7)	11.133
Organization (C8)	10.260
Ecosystem (C9)	10.477
	Total: 88.154

The maturity score of the customer dimension is calculated as:

M_{11} (design for customer needs) =7; g_{11}=0.063

M_{12} (online customer touch points) =15; g_{12}=0.037

M_{13} (utilization of BI) =9; g_{13}=0.038

M_{14} (customer experience via new technologies) =11; g_{14}=0.013

$$M_1 = \frac{\sum_{i=1}^{n} M_{1Ii} * g_{1Ii}}{\sum_{i=1}^{n} g_{1Ii}} = \frac{7 * 0.063 + 15 * 0.037 + 9 * 0.038 + 11 * 0.013}{0.063 + 0.037 + 0.038 + 0.013} = 9.811$$

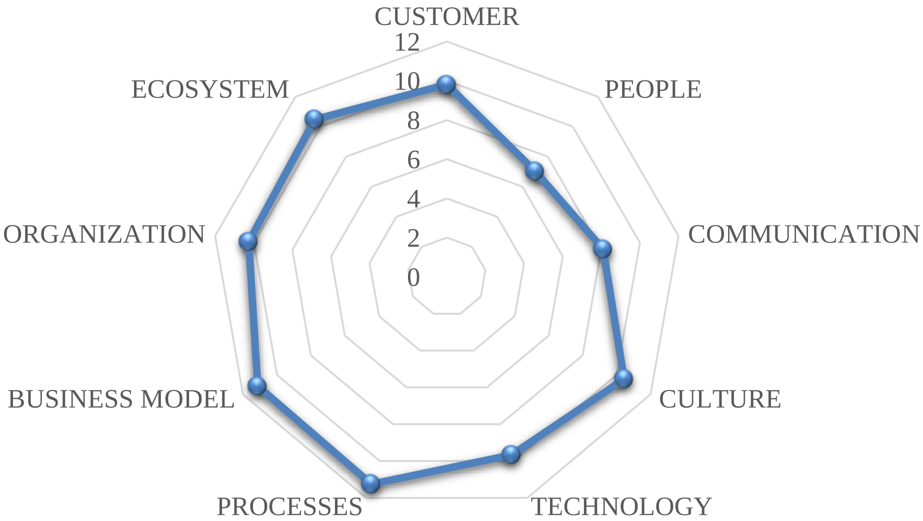

Figure 5.1: Radar chart visualizing digital maturity dimensions

The high maturity score in "Processes" and "Business Model" is justifiable in the banking sector. The "People" and "Communication" dimensions are the weak sides of the ABC. Therefore, they need to implement a strategy that focuses on these dimensions.

To better examine the ABC, the maturity score for each factor is calculated. Their radar charts are provided in Appendix B.

5.4. Phase 4: Selection of DSAP with HFL AD Method

The criteria and alternatives are determined with respect to the digital maturity score of the ABC. Furthermore, the threshold values for each criterion are determined. The FRs of the weakest maturity factors are accepted as AVG. The FRs of the average maturity factors are accepted as AG. The strongest maturity factors are not considered in the alternative evaluation phase except the most important 5 factors. The criteria with their FRs are provided in Table 5.10.

Table 5.10: Evaluation criteria and the FRs

Evaluation Criteria	FRs
C11. Design for Customer Needs	AVG (7.5,10,10)
C12.Utilization of Business Analytics (BI)	AG (5,10,10)
C21.C-Suite’s Leading for Digitalization	AVG (7.5,10,10)
C22.Digital Education and Training	AG (5,10,10)
C23.Personnel’ Enablement in Digitalization	AG (5,10,10)
C24.Digitally Talented Personnel (Digital Skills, Know-How)	AVG (7.5,10,10)
C31.Spread of Digital Vision between Departments	AVG (7.5,10,10)
C32.Inter/Intra Organizational Learning	AG (5,10,10)
C41. Risk Awareness	AVG (7.5,10,10)
C42. Innovation Culture/Open Innovation	AG (5,10,10)
C51. Agile IT Project Management	AG (5,10,10)
C52. Integrated Modern Architecture	AG (5,10,10)
C61. Defined, Repeatable or/and Automated Processes for Digital Program	AVG (7.5,10,10)
C71. Co-working of marketing and technology resources	AG (5,10,10)
C72. Digitalization of product and service offerings	AG (5,10,10)
C73. Leverage digital options by investing in digital opportunities for the future	AF (4,10,10)
C81. Continuous Measurement of Digital Competence	AG (5,10,10)
C91. Digital Partnerships with External Actors (e.g. consulting firms)	AF (4,10,10)
C92. Managing Relationships via Online Channels	AG (5,10,10)
C93. Trust and Transparency in Relationships with Partners	AG (5,10,10)
C94. Fast Reaction to Ecosystem Changes	AG (5,10,10)

The evaluation alternatives (DSAPs) with their possible solutions are provided in Table 5.11.

Table 5.11a: Evaluation alternatives with solutions

Alternatives	Definition (Offered Solutions)
A1.Customer and people centered action plan	Use customer data to understand buying behavior, interests and engagement
	Analyzing customer behavior on social media, it is possible to predict their usage of a business's products and their level of satisfaction
	Use customer lifetime value to segment customers
	Stay in touch with customers all along their journey
	Build trust and commitment to workforce for change
	Give the individual in the organization more responsibilities and authorities
	Using tracking technologies to analyze personnel's behavior
	Develop an open platform for learning
A2. Value based action plan	Digital products are the core of the business
	Heighten expectations with new value propositions that give people what they didn't realize they wanted- Extreme marketing
	Rethinking, or reimagining the business systems
	Networks, channels and customer engagement can create value for the business
A3.Integration and alignment action plan	The strategy and strategies, organizational capabilities, resources, and management systems are arranged to support the enterprise's purpose and use of different channels to communicate
	Shape and orchestrate an ecosystem and introduce their standards into the transparent industry value chain
	Implement agile supply chain (ASC) strategy aiming quick and effective response of the supply chain to changing environmental needs.
	Establish an academy where workers from different units and external actors share knowledge and develop new competencies
A4. Connected platforms action plan	Communicate and implement digital strategy for all processes
	Use of big data technologies to make decisions about marketing
	Digital integration of data with the customer to improve decision-making
	Use robots and bionic enhancement for automation

Table 5.11b: Evaluation alternatives with solutions

A5.Collaboration and innovation action plan	Let people work in cross-functional projects and adapt open-learning mechanism in order to be more open for learning and change
	Get the tech teams and the "talk" teams (domain experts) together early
	Break down the silos within your organization, and get your functions working together to solve for the customer
	Minimize the complexity of digital ecosystems and learn to create value within such ecosystems

3 DMs evaluated the 5 alternatives with respect to 21 criteria. Table 5.12 shows the evaluations of the DM1. The procedures of *Step 2* of the HFL AD method is applied to transform the evaluations with comparative linguistic expressions into HFLTS. To aggregate 3 DMs' evaluations, the calculations in the *Step 3* is applied.

To calculate the information content (I), the equations given in *Step 5* of the HFL AD method are applied. Since the area calculations requires high effort, the results are achieved by using Python programming language. The results are provided in Table 5.13. To illustrate this calculation, a sample calculation for A1 and C11 is provided. The FRs of the C11 was (7.5, 10, 10) and the aggregated TFN value is (6.667, 9.167, 10).

Common Area: 0.938; System Area: 1.667

$$I = \log_2\left(\frac{1.667}{0.938}\right) = 0.830$$

Therefore, the information content for A1 and C11 is found as 0.830.

Table 5.12: The evaluations of DM1 about alternatives

	A1	A2	A3	A4	A5
C11	At least VH	Between L and VL	Between M and H	Greater than M	Between M and H
C12	At least VH	Between L and VL	At most L	At least H	At most L
C21	Between H and VH	Between L and VL	At least H	Lower than L	Between M and H
C22	Greater than H	Between L and VL	At least VH	Lower than L	Greater than H
C23	At least VH	At most L	At most L	Lower than L	Between L and M
C24	At least H	At most L	At least H	Between M and H	Between M and H
C31	Between H and VH	At most L	Greater than H	Greater than H	At least H
C32	Between H and VH	Greater than M	Greater than H	At least H	Greater than M
C41	Between M and H	At most L	Between M and H	At most L	At least VH
C42	At least H	Greater than M	Between M and H	At most L	Greater than H
C51	Greater than M	At most L	Between H and VH	At least H	Greater than H
C52	At most L	At most L	Greater than M	Greater than H	At most L
C61	At most L	Between M and H	At most L	Greater than H	Greater than H
C71	Lower than L	Greater than H	Between M and H	At least H	Greater than H
C72	Between L and VL	At least VH	Between M and H	At least H	Greater than M
C73	Greater than M	At least VH	Between L and VL	At least H	Lower than L
C81	Between L and VL	Greater than H	Between M and H	At most L	At most L
C91	Lower than L	Lower than L	At least VH	At most L	Between M and H
C92	Greater than M	Lower than L	At least VH	Between L and VL	Between H and VH
C93	Lower than L	Lower than L	Greater than H	Between L and VL	Between H and VH
C94	Between L and VL	Lower than L	Greater than H	Between L and VL	At most L

Table 5.13: The information content for each alternative

	FRs			A1	A2	A3	A4	A5
				I	I	I	I	I
C11	7.50	10.00	10.00	0.830	inf	5.171	2.000	5.171
C12	5.00	10.00	10.00	0.000	inf	2.152	0.263	2.585
C21	7.50	10.00	10.00	1.474	inf	1.474	inf	5.171
C22	5.00	10.00	10.00	0.070	inf	0.807	inf	1.830
C23	5.00	10.00	10.00	0.305	inf	3.754	inf	3.754
C24	7.50	10.00	10.00	1.474	inf	1.474	inf	2.644
C31	7.50	10.00	10.00	2.000	inf	1.474	0.830	2.644
C32	5.00	10.00	10.00	0.070	5.493	0.263	0.263	0.070
C41	7.50	10.00	10.00	5.171	inf	3.169	inf	1.474
C42	5.00	10.00	10.00	0.678	1.755	2.585	inf	1.322
C51	5.00	10.00	10.00	1.111	inf	0.263	0.263	0.263
C52	5.00	10.00	10.00	5.756	inf	1.755	0.000	1.755
C61	7.50	10.00	10.00	5.171	inf	4.001	0.000	1.474
C71	5.00	10.00	10.00	3.491	0.263	2.585	0.585	0.263
C72	5.00	10.00	10.00	3.491	0.070	3.491	0.585	2.322
C73	4.00	10.00	10.00	4.824	0.042	3.398	0.340	4.824
C81	5.00	10.00	10.00	3.491	0.263	1.755	inf	5.493
C91	4.00	10.00	10.00	4.824	inf	0.000	inf	1.179
C92	5.00	10.00	10.00	2.585	inf	0.070	inf	2.322
C93	5.00	10.00	10.00	5.493	inf	0.070	inf	2.322
C94	5.00	10.00	10.00	3.491	inf	0.000	inf	3.754
			Total:	**55.803**	**inf**	**39.714**	**inf**	**52.637**

The results show that the most appropriate DSAP for the ABC bank is the "A3. Integration and Alignment Action Plan" with the minimum I=39.714. This method not only selected the best alternative, also the DSAPs which did not satisfy the case company's requirements are used. For example, "A2. Value Based Action Plan" and "A4. Connected Platforms Action Plan" does not satisfy the required criteria. Their information content is infinity (inf), that indicates that they are under the threshold values. However, they were best in some criteria. For example, A2 satisfies the C73 and C72 very well. A4 satisfies C12, C52, C61 very well.

As a result, ABC bank should implement the Integration and Alignment action plan focusing on ecosystem and communication dimensions. With this strategy, it is expected ABC to reach higher level of digital maturity in a short time.

6. CONCLUSION AND PERSPECTIVES

Nowadays, organizations search new ways of gaining competitive advantage in a rapidly and continuously changing environment. DT is accepted as a solution for businesses to improve quality, reduce costs, meet the customer requirements, have flexible processes and rapidly respond the changing conditions. Transformation is not just about the technology implementation; it changes the ways that organization conduct their businesses. Therefore, before this radical changes, organizations should identify the right digital strategy and the following path according to their requirements. Before starting the DT journey, organizations need to assess their current digital positions to determine where to start to the DT journey. Here, DMM helps organizations to determine their digital maturity score.

In this thesis, it is aimed to provide a scientific method that guides organizations in their DT journey with 2 phases. In the first phase, a new DMM framework that consists of 9 dimension and 36 factors is constructed with the help of academic papers, industry reports, panels, experts' reviews. The maturity factors' weights are calculated with HFL AHP method. For each factor, 3 comprehensive questions (total:108 questions) are replied by the experts who wants to learn its company's digital maturity score and a scientific method for calculating the digital maturity score is proposed.

In the second phase, 5 DSAPs are proposed according to digital maturity score of the organizations. The appropriate action plan is selected with HFL AD method. The originality of the thesis comes from proposing a new DMM framework, evaluating the maturity weights with scientific methods and combining DMM framework with DSAPs.

The integrated HFL AHP and HFL AD techniques provides a flexible and practical approach. In the related literature, integrated AHP and AD techniques exists and implemented for different application areas. However, the integrated AHP and AD technique in hesitant fuzzy environment is a missing link. This is the first study that proposes an integrated HFL AHP and HFL AD techniques. Moreover, AD method has not been extended in hesitant fuzzy environment. For this reason, other scientific contribution of the thesis is to propose HFL AD technique.

In this thesis, digital maturity factors and action plans were determined by researching industry reports, academic papers and by using experts' reviews. After the construction of the DMM framework, a questionnaire is prepared. To illustrate the evaluation framework and the research methodology, it is implemented for a real case study on the banking sector. First, the evaluation criteria matrices, the evaluation alternative matrices and the DMM questionnaire are sent to 3 DMs who are expert in technology advisory domain. After getting the responds, the maturity factors' weights and the maturity scores are calculated. Since the calculation of the information content of the action plans requires high effort, they are calculated on Python. At the end of the case study, the integration and alignment action plan is selected as the most appropriate action plan.

This thesis contributes to the literature by being the first study which evaluate digital maturity of the companies with an integrated HFL MCDM method. Moreover, this thesis guides organizations for following their DT journey by proposing an original DMM framework.

In the future research, the correlation between digital maturity factors can be considered and their weights can be evaluated by other MCDM approaches. To compare the organizations in the same sector, the case study can be implemented for 2 or more organizations.

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APPENDICES

Appendix A.

1	CUSTOMER — 1:THE WORST, 5:THE BEST, NA:NOT AVAILABLE	SCORE
Design for Customer Needs	How much does your organization advantage enriched consumer insights to track context and interests and adapt them into your digital strategy? **(1: Not at all; 2: Few; 3: Medium; 4: Much; 5: Too much)**	NA 1 2 3 4 5
	To which degree can your customers individualize the products they order? **(1: Not at all; 2: Somewhat; 3: Intermediate; 4: Quite; 5: Completely)**	NA 1 2 3 4 5
	How dynamic and customer-tailored is your pricing system (consideration of customer's "willingness to pay “)? **(1: Not at all; 2: Somewhat; 3: Intermediate; 4: Quite; 5: Completely)**	NA 1 2 3 4 5
Online Customer Touch Points	What percentage of your customer-facing processes are digitized and available online? **(1: %0-%20; 2: %21-%40; 3: %41-%60; 4: %61-%80; 5: %81-%100)**	NA 1 2 3 4 5
	How much does your customers can engage with the organization via any channel throughout their journey from awareness, to selection, transaction, service and advocacy? **(1: Not at all; 2: Few; 3: Medium; 4: Much; 5: Too much)**	NA 1 2 3 4 5
	How far does your organization integrate multiple channels (website, blogs, forums, social media platforms etc.) into your customer interactions for communicating news, receiving feedback, managing claims etc.? **(1: Not at all; 2: Somewhat; 3: Intermediate; 4: Quite; 5: Completely)**	NA 1 2 3 4 5
Utilization of Business Analytics (BI)	How important is the usage and analysis of data (customer data, product or machine generated data) for your business model? **(1: Not at all; 2: Less important; 3: Important; 4: Very important; 5: Absolutely important)**	NA 1 2 3 4 5
	To which extent does your organization analyze customer data to increase customer insight (e.g. personalized offers to customers based on their personal situation, preferences, location, credit score; consideration of usage data for design etc.)? **(1: Not at all; 2: Somewhat; 3: Intermediate; 4: Quite; 5: Completely)**	NA 1 2 3 4 5
	To which extent does your organization advantage machine learning and predictive algorithms to develop context-relevant, personalized recommendations based on customers' sentiment, history and preferences? **(1: Not at all; 2: Somewhat; 3: Intermediate; 4: Quite; 5: Completely)**	NA 1 2 3 4 5
Customer Experience via New Technologies	How much does your organization delivers a relevant, value-adding, convenient, and personalized experience throughout the customer's journey that is consistent across channels? **(1: Not at all; 2: Few; 3: Medium; 4: Much; 5: Too much)**	NA 1 2 3 4 5
	How much does your organization use the latest technology - in-store and otherwise - to tailor customer experiences at an individual level and gain competitive advantage? **(1: Not at all; 2: Few; 3: Medium; 4: Much; 5: Too much)**	NA 1 2 3 4 5

Figure A: Maturity questions under customer dimension

Appendix B.

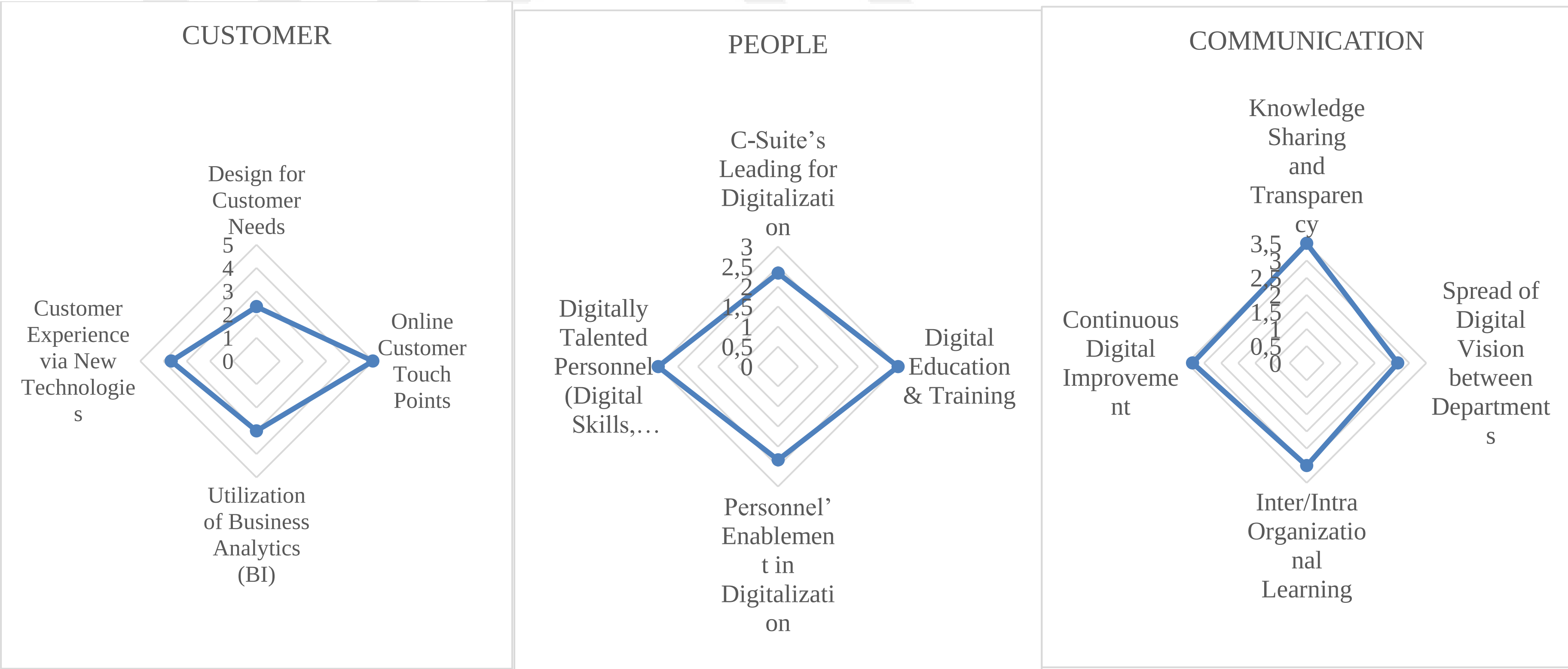

Figure B.1: Radar chart visualizing digital maturity factors under dimension

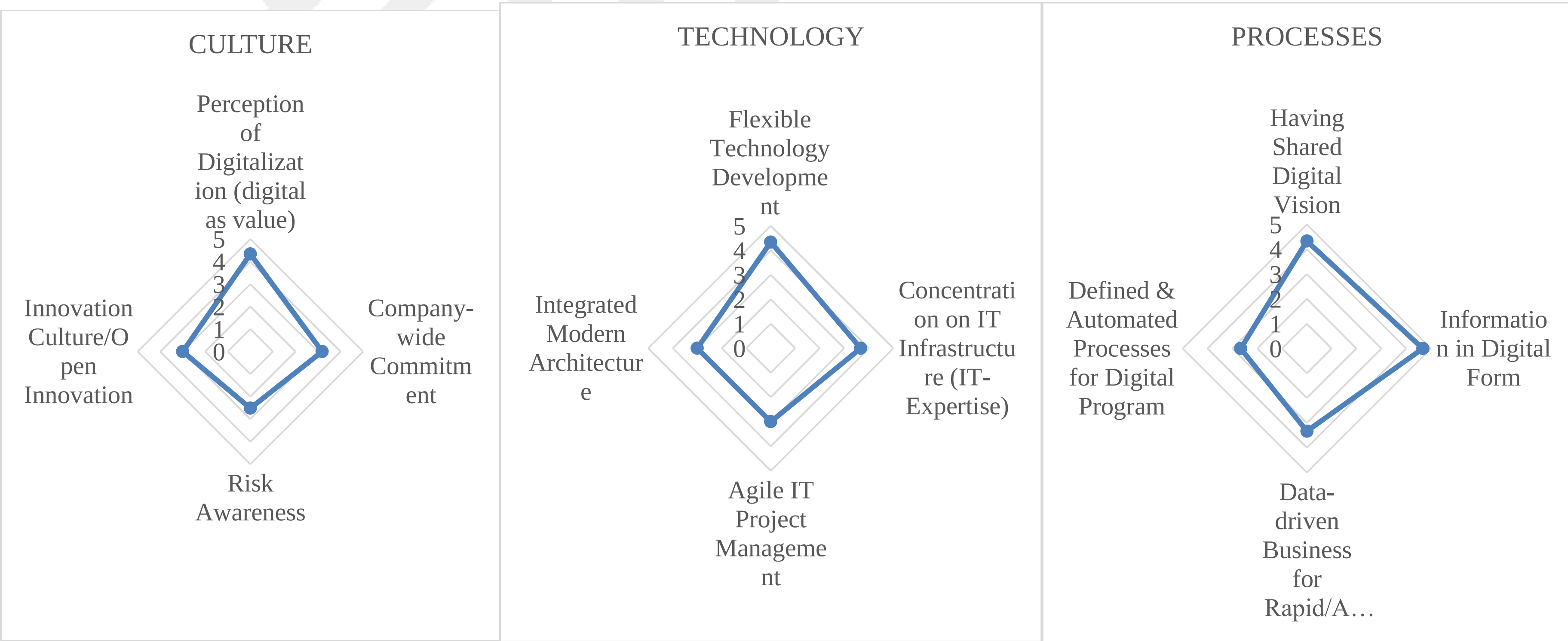

Figure B.2: Radar chart visualizing digital maturity factors under dimensions

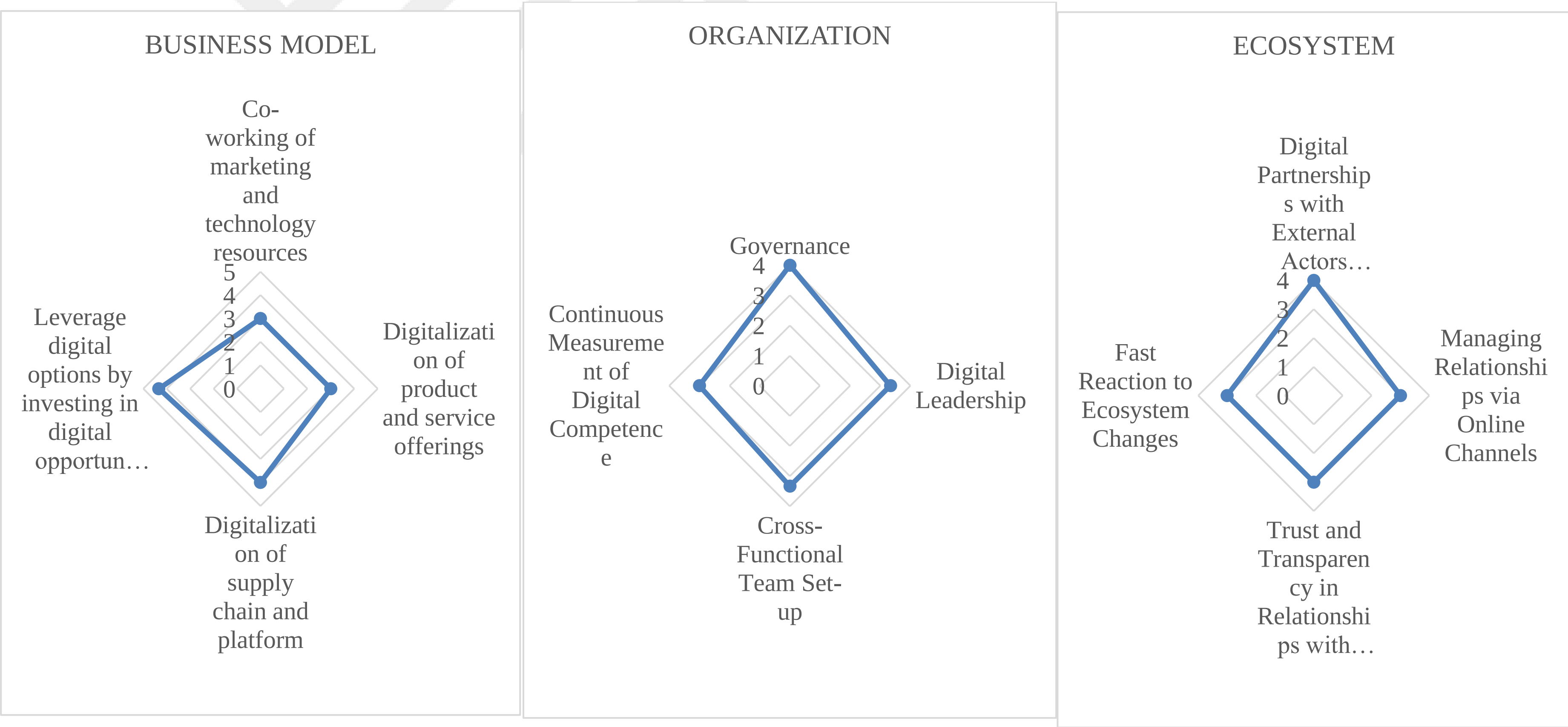

Figure B.3: Radar chart visualizing digital maturity factors under dimensions

BIOGRAPHICAL SKETCH

Merve Güler was born on May 3, 1993 in Istanbul. She received her high school education in Florya Tevfik Ercan anatolian high school and graduated as the first ranking graduate in 2011. In 2016, she obtained the B.S. degree in Industrial Engineering Department of Galatasaray University as the first ranking graduate. She started her graduate studies in Industrial Engineering at the Institute of Science of Galatasaray University in 2017. Since February 2017, she has been working as research assistant in Industrial Engineering Department of Galatasaray University. Currently she is working towards master's degree under the supervision of Prof. Dr. Gülçin Büyüközkan Feyzioğlu. Her areas of interest include: Multi-criteria decision making, digital transformation, technology selection.

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