STRATEGIC ANALYSIS OF DIGITAL TRANSFORMATION IN AVIATION INDUSTRY AND PROPOSITION OF A NEW DIGITAL SERVICE QUALITY MODEL

(HAVACILIK ENDÜSTRİSİNDE DİJİTAL DÖNÜŞÜMÜN STRATEJİK ANALİZİ VE YENİ BİR DİJİTAL HİZMET KALİTESİ MODEL ÖNERİMİ)

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LIST OF SYMBOLS

AD	Axiomatic Design
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
ARAS	Additive Ratio Assessment
BWM	Best Worst Method
CAM	Change and Adaptation Management
CCN	Customer Centricity
CM	Cognitive Map
COPRAS	Complex Proportional Assessment
CR	Consistency Ratio
CRITIC	Criteria Importance Through Intercriteria Correlation
CRM	Compromise Ratio Method
DANP	DEMATEL and ANP
DEA	Data Envelopment Analysis
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DIFWG	Dynamic Intuitionistic Fuzzy Weighted Geometric
DIN	Digital Interaction
DM	Decision Maker
DRSA	Dominance-Based Rough Set Approach
DSQ	Digital Service Quality
DT	Digital Transformation
DTCE	Digital Transformation Competency Evaluation
DTN	Digital Tangibles
DTR	Digital Trust
DTS	Digital Transformation Strategy
ELECTRE	Elimination Et Choix Traduisant la Realité

ESM	Even Swaps Method
FCM	Fuzzy Cognitive Map
FMEA	Failure Mode and Effect Analysis
FUCOM	Full Consistency Method
GRA	Grey Relational Analysis
IF	Intuitionistic Fuzzy
IFWA	Intuitionistic Fuzzy Weighted Averaging
IIFOWA	Interval Valued Intuitionistic Fuzzy Ordered Weighted Aggregation
IIFWA	Interval-Valued Intuitionistic Fuzzy Weighted Averaging
IoT	Internet of Things
IPIA	Importance-Performance-Impact Analysis
IVIF	Interval-Valued Intuitionistic Fuzzy Sets
IVIFPWA	Interval-Valued Intuitionistic Fuzzy Prioritized Weighted Average
IVIFWA	Interval-Valued Intuitionistic Fuzzy Weighted Averaging
MABAC	Multi-Attributive Border Approximation Area Comparison
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique
MAGP	Multi-Aspiration Goal Programming
MAIRCA	Multi-Attributive Ideal-Real Comparative Analysis
MARCOS	Measurement of Alternatives and Ranking according to the Compromise Solution
MCDM	Multi-Criteria Decision-Making
MCGP	Multi-Choice Goal Programming
MOORA	Multi-Objective on the basis of Ratio Analysis
MSGP	Multi-Segment Goal Programming
MULTIMOORA	MOORA plus Full Multiplicative Form
N/A	Not Applicable
NN	Neural Newtork
PIPREICA	Pivot Pairwise Relative Criteria Importance Assessment
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluations
QFD	Quality Function Deployment

RI	Randomness Index
RLB	Reliability
ROC	Rank Order Centroid
SAW	Simple Additive Weighting
SIFWA	Symmetric Intuitionistic Fuzzy Weighted Averaging
SO	Structure and Organization
SQ	Service Quality
SWARA	Stepwise Weight Assessment Ratio Analysis
SWOT	Strengths, Weaknesses, Opportunities, Threats
TE	Technology Enablers
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TTI	Technology Transformation and Implementation
VIKOR	VIšeKriterijumska Optimizacija i Kompromisno Rešenje
ZOGP	Zero-One Goal Programming

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ABSTRACT

In recent years, many industrial areas have started their digital transformation (DT) processes with the rapid acceleration in technology. The widespread use of digital technologies that have become easily accessible has changed people's behaviors, perceptions, and expectations. The use of digital technology that has become an indispensable part of daily life, has changed the way people and companies do business and make decisions. While the priorities of customers that are using digital channels have changed, companies have had to consider these priorities and meet changing customer expectations. This situation has moved the current competition to digital ecosystems where conditions are much tougher.

If the DT process is well managed and its requirements are met, it provides benefits such as profitability, flexibility, agility, customer satisfaction, and competitiveness to companies. However, a poorly managed DT process can also be destructive. At the same time, companies must consider the existence of companies that are born and continue to exist digitally. At this point, correct management, and implementation of DT, focusing on all the DT requirements, competing in the global competitive environment, and determining the critical points for the successful implementation of DT have become more important than ever.

When the literature on DT is examined, it is observed that there are various scientific studies carried out in different industrial areas based on DT, while the scientific studies based on DT applications in the aviation industry are relatively limited. These studies in the aviation industry focus on a single problem and present results regarding the use of a single technology. There are no integrated approaches that have a broader perspective or address more than one problem concerning the DT in the aviation industry to the best of our knowledge.

The results of conducted the literature review revealed that competence in DT, determination of the right DT strategies and a successful implementation of DT are vital

to benefit from the advantages that DT can provide. In addition, the findings revealed that the customer profile, customer experience and service quality perception have changed with the use of digital technologies. For this reason, in this thesis study, a roadmap based on an integrated approach is presented by focusing on DT, in which strategic points are determined so that companies in the aviation industry can achieve successful DT and benefit from this transformation process in the long term.

For this purpose, this proposed integrated approach consists of 4 main stages that contribute to both the literature and the aviation industry: proposition of a DT competency evaluation framework; Proposition of a DT strategy evaluation framework; Proposition of a DT success evaluation framework; Proposition of a digital service quality performance evaluation framework. The analytical dimension of the proposed approach is addressed by the Multi-Criteria Decision Making (MCDM) approach that is expanded to Interval-Valued Intuitionistic Fuzzy (IVIF) sets.

The first phase of the thesis study proposes a framework that consists of a new and generic DT competency evaluation model and an integrated IVIF AHP and IVIF VIKOR methodology. This stage is used as a tool for competency evaluation and identification of critical points to be considered for competence in DT. The second phase proposes a framework that relies on a SWOT-based integrated IVIF AHP and IVIF VIKOR methodology. This proposed framework is used for the determination of DT strategies and the selection of the most appropriate DT strategy. The third phase proposes a framework that consists of a new and generic DT success evaluation model and the IVIF ANP methodology. This stage is used as a tool to identify critical success factors that should be considered for the successful implementation of DT. The final phase proposes a framework that consists of a new and generic digital service quality model and an integrated IVIF AHP and IVIF VIKOR methodology. This stage is used to determine the criteria that are important for digital service quality, and to evaluate digital service quality performance.

All proposed approaches have been applied to real cases based on expert opinions. The obtained results are discussed, and final clarifications are made for DT in the aviation industry.

The contribution of this thesis study to the literature stems from the proposition of many generic models for DT in the aviation industry and the application of these models to real cases. Another contribution is the adaptation of IVIF MCDM methods to the aviation based on the proposed models for the first time.

ÖZET

Son yıllarda, pek çok endüstriyel alan teknolojideki hızlı ivmelenme ile dijital dönüşüm (DD) süreçlerini başlatmıştır. Kolaylıkla erişilebilir hale gelen dijital teknolojilerin yaygın kullanımı, insanların davranışlarını, algılarını ve beklentilerini değiştirmiştir. Günlük yaşamın vazgeçilmez parçası haline gelen dijital teknoloji kullanımı hem insanların hem de şirketlerin iş yapma ve karar verme şekillerini değiştirmeye başlamıştır. Dijital kanalları kullanan müşterilerin öncelikleri değişirken, şirketler bu öncelikleri göz önünde bulundurmak ve değişen müşteri beklentilerini karşılamak zorunda kalmıştır. Bu durum mevcut rekabeti, koşulları çok daha sert olan dijital ekosistemlere taşımıştır.

DD süreci iyi yönetildiğinde ve gereklilikleri yerine getirildiğinde şirketlere karlılık, esneklik, çeviklik, müşteri memnuniyeti, rekabet edebilme gücü gibi faydalar sağlamaktadır. Ancak, iyi yönetilemeyen bir DD süreci yıkıcı da olabilir. Aynı zamanda, şirketler, dijital olarak doğan ve dijital olarak varlıklarını sürdüren şirketlerin varlığını da göz önünde bulundurmak zorundadırlar. Bu noktada, DD'yi doğru bir şekilde yönetmek ve uygulamak, DD'nin tüm gerekliliklerine odaklanmak, küresel anlamda yarattığı rekabet ortamında yarışabilmek ve başarılı bir DD gerçekleştirmek için dikkat edilmesi gereken noktaları belirlemek hiç olmadığı kadar önemli hale gelmiştir.

DD'ye ilişkin literatür incelendiğinde, farklı endüstriyel alanlarda gerçekleştirilmiş ve DD'yi temel alan çeşitli bilimsel çalışmalar olduğu gözlemlenirken, havacılık endüstrisinde DD uygulamalarına dayalı bilimsel çalışmaların nispeten daha az olduğu görülmektedir. Havacılık endüstrisindeki bu çalışmalar tek bir soruna odaklanmakta ve tek bir teknolojinin kullanımına ilişkin sonuçlar sunmaktadır. Bildiğimiz kadarıyla daha geniş bir bakış açısına sahip ya da birden fazla sorunu ele alan bütünleşik yaklaşımlar mevcut değildir.

Gerçekleştirilen literatür araştırması sonuçları DD'de yetkinliğin önemli olduğunu, doğru DD stratejilerinin belirlenmesi ve başarılı bir DD uygulamasının DD'nin sağlayabileceği avantajlardan yararlanabilmek için kritik olduğunu ortaya koymuştur. Bunun yanı sıra, elde edilen bulgular, dijital teknolojilerin kullanımı ile müşteri profilinin, müşteri tecrübesi ve hizmet kalitesi algısının değiştiğini ortaya koymuştur. Bu nedenle bu tez çalışmasında, DD'ye odaklanılarak havacılık endüstrisindeki şirketlerin başarılı bir DD gerçekleştirmeleri ve uzun vadede bu dönüşüm sürecinden fayda sağlayabilmeleri için stratejik noktaların belirlendiği bütünleşik bir yaklaşıma dayalı bir yol haritası sunulmuştur.

Bu amaçla, önerilen bu bütünleşik yaklaşım hem literatüre hem de havacılık endüstrisine katkı sağlayan 4 temel aşamadan oluşmaktadır: DD yetkinlik değerlendirme yapısının önerilmesi; DD strateji değerlendirme yapısının önerilmesi; DD başarı değerlendirme yapısının önerilmesi; dijital hizmet kalitesi performans değerlendirme yapısının önerilmesi. Önerilen yaklaşımın analitik boyutu Aralık Değerli Sezgisel Bulanık Kümelere (IVIF) genişletilmiş Çok Kriterli Karar Verme (MCDM) yaklaşımı ile ele alınmıştır.

Tez çalışmasının ilk aşaması, yeni ve jenerik bir DD yetkinlik değerlendirme model önerimi ve bütünleşik bir IVIF AHP ve IVIF VIKOR metodolojisine dayalı bir yapı sunmaktadır. Bu aşama, DD'de yetkinlik için göz önünde bulundurulması gereken kritik noktaların tespiti ve yetkinlik değerlendirmesi için bir araç olarak kullanılmaktadır. İkinci aşama, SWOT temelli bütünleşik bir IVIF AHP ve IVIF VIKOR metodolojisine dayalı bir yapı önermektedir. Önerilen bu yapı, DD stratejilerinin belirlenmesi ve en uygun DD stratejisinin seçimi için kullanılmaktadır. Üçüncü aşama, yeni ve jenerik bir DD başarı değerlendirme model önerimi ve IVIF ANP metodolojisine dayalı bir yapı sunmaktadır. Bu aşama, başarılı bir DD uygulaması için göz önünde bulundurulması gereken kritik başarı faktörlerinin belirlenmesi için bir araç olarak kullanılmaktadır. Son aşama ise, yeni ve jenerik bir dijital hizmet kalitesi model önerimi ve bütünleşik bir IVIF AHP ve IVIF VIKOR metodolojisine dayalı bir yapı önermektedir. Bu aşama, dijital hizmet kalitesi için önemli olan kriterlerin belirlenmesi ve dijital hizmet kalitesi performans değerlendirmesi için kullanılmaktadır.

Önerilen tüm yaklaşımlar, uzmanların görüşlerine dayalı olarak gerçek vakalara uygulanmıştır. Elde edilen sonuçlar tartışılmış ve havacılık endüstrisinde DD için son açıklamalar yapılmıştır.

Bu tezin yazına katkısı, havacılık endüstrisinde DD ile ilgili jenerik birçok model önermesinden ve bu modelleri gerçek vakalara uygulamasından kaynaklanmaktadır. Bir diğer katkı ise, IVIF kümelere dayalı MCDM yöntemlerinin önerilen modeller üzerinden havacılık endüstrisine ilk kez uyarlanmasıdır.

1. INTRODUCTION

In recent years, rapid developments and accelerations in technological developments have caused the widespread use of digital technologies by both individuals and companies. With the rapid spread of digital technologies and the continuous introduction of new technologies, the Digital Transformation (DT) process has officially started. Digital technologies have transformed people's expectations and demands holistically. Today, people have the power for their demands concerning digital products and services. This fact is the main factor in managing the DT process. This situation has radically changed the way companies do business and make decisions, long-term investment methods and strategies, business models, products, and services they offer, infrastructure and management styles (Büyüközkan et al., 2020a; Büyüközkan et al., 2021a). Hence, it is critical to focus on DT process that causes such radical changes. Therefore, in this thesis study, the DT has been focused on. In this context, a detailed literature review process has been conducted as a first stage. Following the results of the conducted literature review, different evaluation frameworks that consist of model proposition and analytical approaches are proposed. The models proposed in the evaluation frameworks of the thesis study and the analysis process of these models are the parts of a decision-making process based on expert opinions and they include many criteria. Hence, Multi-Criteria Decision Making (MCDM) methods are adopted to the stages of the thesis by considering their wide range of usability. Analytic Hierarchy Process (AHP) (Saaty, 1980) method is used to prioritize the criteria of the proposed models and to calculate their weights. VIšeKriterijumska Optimizacija i Kompromisno Rešenje (in Serbian) (VIKOR) method (Opricovic, 1998) is utilized to select the most appropriate alternatives based on the criteria of the proposed models. Analytic Network Process (ANP) method (Saaty, 1996) is employed to deal with the interrelations between the criteria of the proposed models. However, proposed evaluation frameworks, all the performed studies, and analyses are applied on real cases based on the evaluations and opinions of the industrial experts.

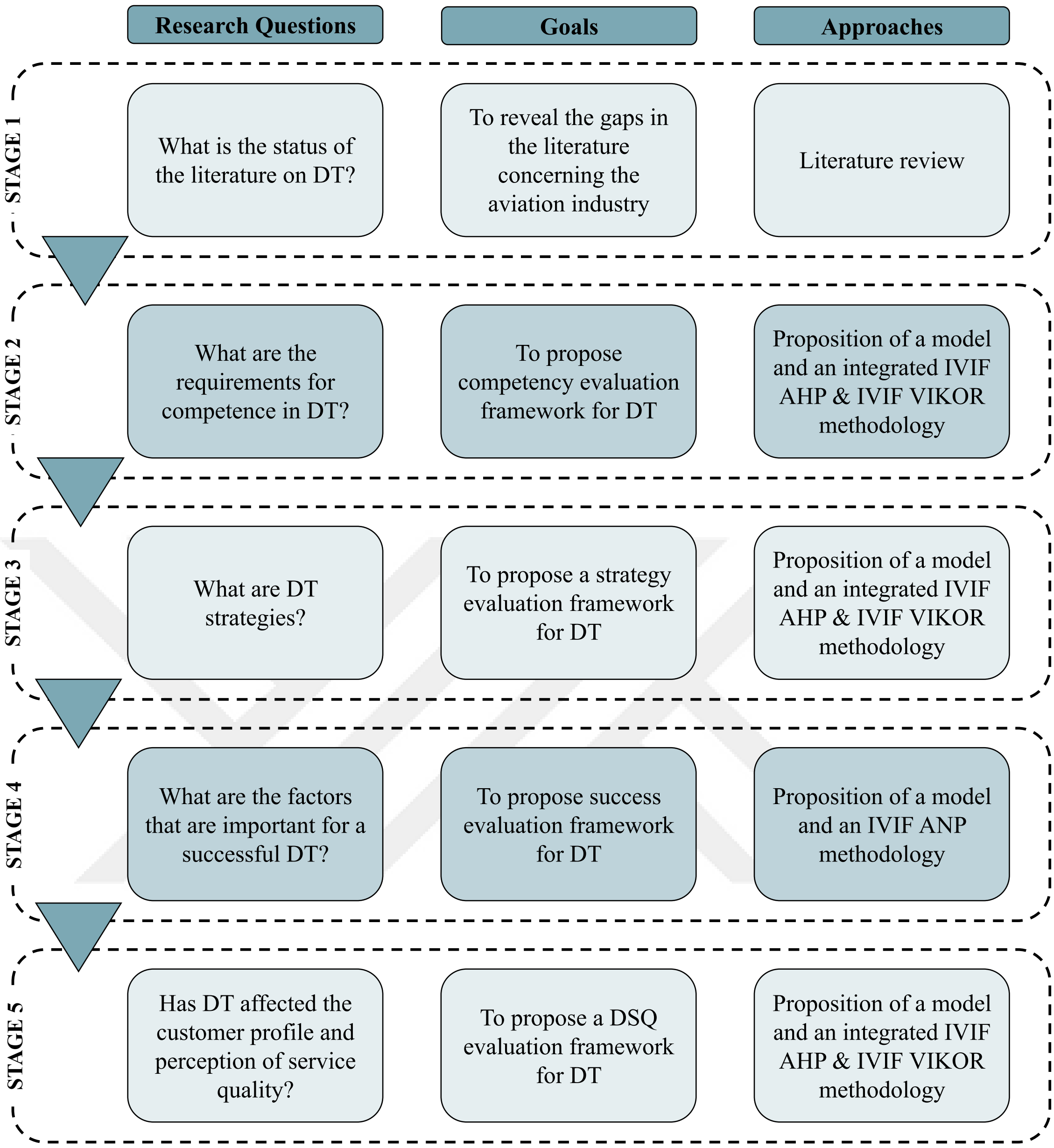


Figure 1.1: Main stages of the thesis study

Real-life problems and decision-making processes involve uncertainty and complexity. In such cases, crisp numbers may not be sufficient to model and solve decision-making problems. This may lead us to use fuzzy sets (Zadeh, 1965) to eliminate uncertainty. But the decisions and evaluations of decision-makers who play an active role in decision-making processes involve hesitation and intuition. So, employing the fuzzy sets may not deal with those human perception, hesitation, and intuition. Hence, utilization of the intuitionistic fuzzy (IF) sets (Atanassov, 1986) may eliminate the intuition in the decision-making processes in the thesis study. IF sets consist of membership and non-membership functions, and hesitation degree. On the other hand, interval-valued intuitionistic fuzzy

(IVIF) sets proposed by Atanassov & Gargov (1989) have the membership and non-membership functions in an interval. Therefore, all the MCDM methods used in this thesis study are expanded to IVIF environment and applied as IVIF MCDM methods for the analyses. The followed stages in the thesis study are shown in Figure 1.1. These stages are explained in the following paragraphs.

In the first stage of the thesis study, the definition of the DT is focused. The impact of DT on scientific literature has been investigated and the affected sectors by DT are revealed. When the scientific literature is examined, it is seen that especially in recent years, studies on digitalization have increased, but DT is still a new concept. It is seen that DT is significant for different sectors. On the other hand, the academic literature concerning the DT in aviation industry is relatively limited compared to other industries. Since the importance of the aviation industry for the world and the effects of DT on this sector, the field of this thesis study has been determined as the aviation industry. Following this, a detailed literature review is conducted for the aviation industry with DT perspective. Scientific studies, industrial reports, books, and thesis studies are determined as the resources for this purpose. Based on these resources, the gaps in the academic literature are revealed. The obtained results and gaps have initiated the second stage of the thesis.

In the second stage of the thesis, a competency evaluation framework for DT has been proposed. The evaluation framework contains a model proposition and an analytical approach to validate the proposed model. In this stage, significant criteria for DT competency are determined based on the opinions of the experts and results of a conducted literature survey. Following this, a new and generic DT competency evaluation model (DTCE) is proposed. The proposed model has been validated on a real case for the aviation industry in Turkey using an integrated IVIF AHP and IVIF VIKOR methodology. The importance degrees and weights of the criteria of the proposed model are obtained using the IVIF AHP method. The most digitally competent low-cost airline company in Turkey is determined by the IVIF VIKOR method. It is seen that the obtain results support the gaps obtained through the literature review. This is the first DTCE model proposed in the academic literature to the best of our knowledge. This is the first proposed evaluation framework applied to a real case in the aviation industry for DT competency to the best of our knowledge (Büyüközkan et al., 2021a).

In the third stage of the thesis study, the obtained results of the second stage have been considered. DT is not only a technology transformation but also management and strategy (Kane et al., 2015; Büyüközkan et al., 2021a,b). Hence the focus of this stage is determined as strategy analysis for DT in aviation industry. For this purpose, a SWOT analysis and integrated IVIF MCDM methodology-based evaluation framework is proposed. The internal and external factors are identified, and a SWOT model is constructed based on literature survey and opinions of the experts. Following that, possible DT strategies based on the constructed SWOT model are revealed with the help of experts' opinions. The proposed model has been validated on a real case for the aviation industry in Turkey using an integrated IVIF AHP and IVIF VIKOR methodology. The IVIF AHP method is utilized to calculate the criteria weights. Following that, the IVIF VIKOR method is used to evaluate proposed DT strategies and select the most appropriate one. It is seen that the obtain results support the gaps obtained through the literature review. This is the first proposed evaluation framework applied to a real case in the aviation industry for DT strategies to the best of our knowledge (Büyüközkan et al., 2021b).

In the fourth stage of the thesis study, a success evaluation framework based on a success evaluation model and the IVIF ANP methodology is proposed. For this purpose, a new and generic success evaluation model for DT has been introduced. The criteria of the proposed model are determined by the literature survey and opinions of the experts. The proposed model has been applied to a real case concerning the aviation industry in Turkey. The IVIF ANP method is used to analyze the criteria based on the assumption of interrelations between the criteria by considering the success concept. It is seen that the obtain results support the gaps obtained through the literature review. The proposed framework and model for success evaluation in DT are the first to the best of our knowledge. Furthermore, this is the first time that a success evaluation has been applied to a real case in aviation industry with DT perspective to the best of our knowledge.

Finally, in the fifth stage of the thesis study, it has been focused on differentiation of the customer profile and service quality perception by considering the obtained results of the literature review chapter and the stages of the thesis before this stage. The opportunities offered by digital technologies and channels in terms of products and services have changed people's expectations. The concept of a customer in the classical sense has left its place in the concept of digital customer. The classical service quality (SQ) perception has turned into a digital service quality (DSQ) perception. SQ has always been an important focus point for companies. But the digital market and ecosystem created by DT have become a much more intense competitive environment. Therefore, companies have had to look for ways to provide a DSQ performance level that meets the digital demands of digital customers to maintain their sustainability, market share, competitiveness, and profitability in today's competitive environment. Conducted literature survey on SQ has shown that there are many different SQ studies, and these studies are carried out in various fields for different purposes. In addition, it has been revealed that the classic SQ model that is SERVQUAL (Parasuraman et al., 1988), has been reorganized according to the field of applications and the purposes of the studies. Hence, there are various SQ models based on SERVQUAL in the academic literature. Especially in recent studies, it has been concluded that the SERVQUAL model has been adapted to comply with the developments in technology. From the past to the present, it has been observed that the perception of SQ has changed with technological developments and in parallel with this change, the models proposed in the literature have transformed (Büyüközkan et al., 2020a). It has been revealed that the number of studies based on electronic SQ and mobile SQ models is high. On the other hand, a DSQ model has not been proposed yet to the best of our knowledge (Büyüközkan et al., 2020a). Therefore, a new SQ model should be emerged. For this purpose, a DSQ evaluation framework has been introduced in this stage. The introduced framework consists of the proposition of a new and generic DSQ model and an integrated IVIF MCDM methodology. The criteria of the proposed model are determined through a literature survey and experts' opinions. The proposed model has been validated on a real case for the low-cost airline industry in Turkey using an integrated IVIF AHP and IVIF VIKOR methodology. The weights of the criteria are computed using the IVIF AHP method. The DSQ performance of different low-cost airline companies are evaluated and the most appropriate one with the highest performance is determined using the IVIF VIKOR method. This is the first study proposing a new and generic DSQ model and framework to the best of our knowledge. Furthermore, this is the first time that a DSQ performance evaluation has been applied to a real case in both low-cost airline industry and aviation industry with DT perspective to the best of our knowledge.

This thesis study consists of the following chapters: Chapter 2 gives the main issues, research gaps and future directions based on the literature review results. Chapter 3 illustrates the proposed methodology. Following this, proposition of the DTCE framework and its application in aviation industry are given in Chapter 4. Chapter 5 contains the proposition of the DT strategy evaluation framework and its application in aviation industry. Following this, proposition of the DT success evaluation framework and its application in aviation industry have been introduced in Chapter 6. Finally, proposition of the DSQ evaluation framework and its application in aviation industry are given in Chapter 7 before the thesis is concluded in Chapter 8.

2. LITERATURE REVIEW

This part of the thesis study provides a literature review to analyze and categorize the studies in aviation industry with DT perspective. This process is carried out based on three main stages: (1) data collection, (2) data analysis, (3) identification of the research gaps, main issues in the literature and determination of the research directions. The research methodology is illustrated in Figure. 2.1.

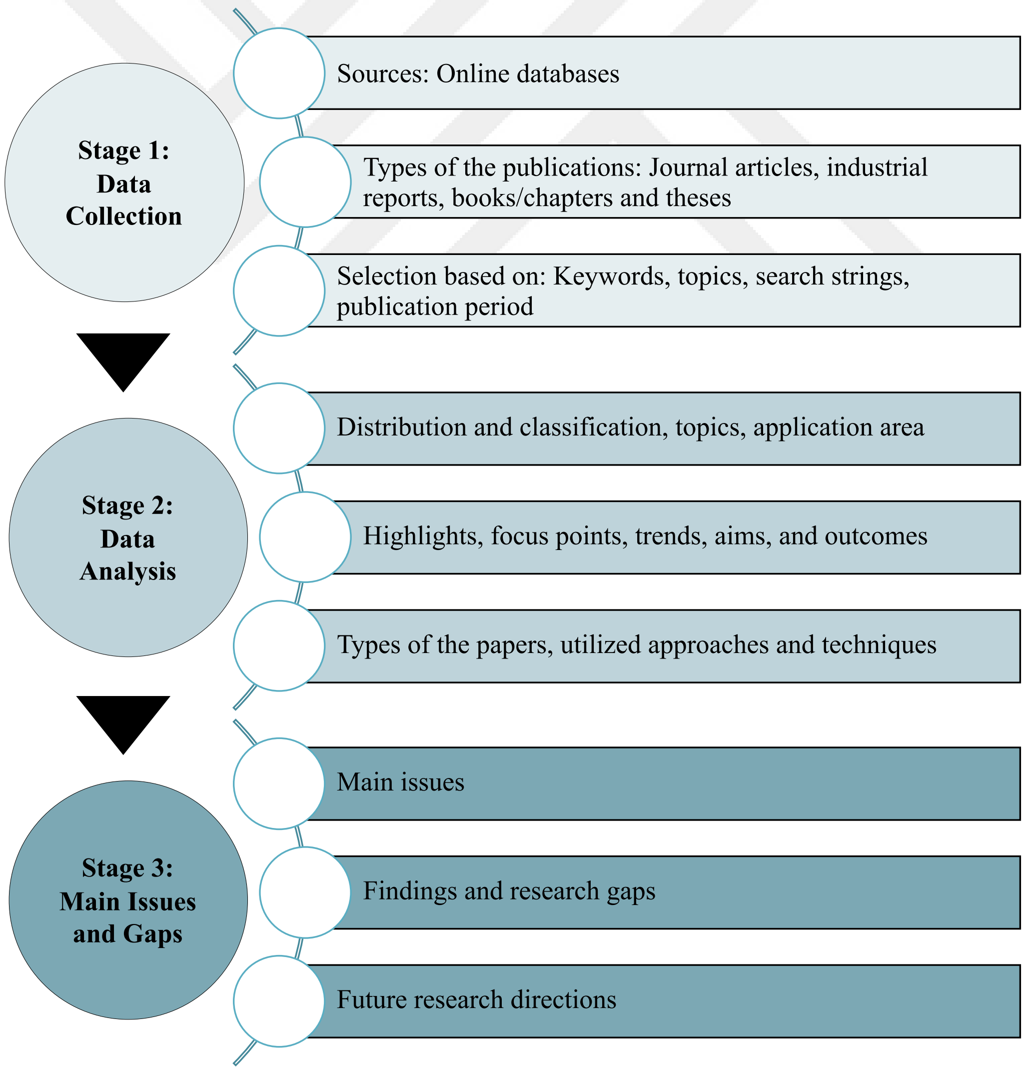


Figure.2.1: Research methodology of the literature review

2.1. Data Collection

In the data collection phase of the literature review process, online databases such as Web of Science (WoS) and Google are used to select, categorize, and analyze the publications. WoS database is used to research journal articles, book/chapters, and the industrial reports and thesis are searched by Google search engine.

In this study, relevant studies are reviewed and classified to obtain insights into the DT areas. The literature is reviewed using different keywords and their combinations. Combinations of the keywords are used as search strings (Ghadge et al., 2019) during the review process. These keywords that are the basis of search strings, are not previously determined. The range of keywords has been expanded according to the course of the research. The review process is applied using the combinations of the keywords in search strings. This process is illustrated based on different examples as following: “Digital Transformation Aviation”, “Digital Transformation Airport”, “Digital Transformation Airline”, “Digital Aviation”, “Digital Airport”, “Digital Airline”, “Smart Aviation”, “Smart Airport”, “Smart Airline”, “Mobile Aviation”, “Mobile Airport”, “Mobile Airline”, “Aviation 4.0”, “Airport 4.0”, and “Airline 4.0”. English language-based publications from 2011 to end of 2021 are included in the literature review process. Only the articles, books and book chapters, early accesses and review articles are refined for the review process by using WoS database. Furthermore, the refined publications are refined one more time based on their WoS category. The utilized categories are “Business”, “Hospitality, Leisure, Sport, and Tourism”, “Industrial Engineering”, “Management”, and “Transportation”. Total number of the publications based on the utilized search strings and topics is 2516 between 2011 and 2021. These publications are refined for the above-mentioned document types and other types are excluded. Total number of the remaining publications are 1272. Additionally, those remaining publications are refined for the given WoS categories to eliminate the publications in unrelated categories. Following this, 265 publications are obtained. Finally, a full screening process is applied to those publications and in the end 23 articles are obtained. Furthermore, Google Search Engine is used to identify the eligible books, theses, and industrial reports. After conducting a full screening process for these sources, 15 industrial reports, 6 books and 5 thesis studies are obtained. The selection process of the publications is detailed in Figure 2.2. The review process given in Figure 2.2 is summarized in Figure 2.3 to provide overall perspective. For this step, 49 sources are used to illustrate the literature concerning the aviation industry with DT perspective.

Figure 2.2: Steps of the review process for articles

The following focus points are clarified during the review process:

- What is the current situation of DT concept in aviation industry?
- Is there any trend or tendency in the academic literature concerning DT in aviation industry?

- Is there any DT definition in the academic literature on the aviation industry?
- What kind of tools and techniques are used in the academic literature?
- Do the topics, highlights, scopes, and perspectives of the published articles comply with the content of the published industrial reports?
- What are the main issues and gaps?
- What kind of research questions should be determined for this thesis study?

Following sections of the literature review chapter illustrates the questions asked above.

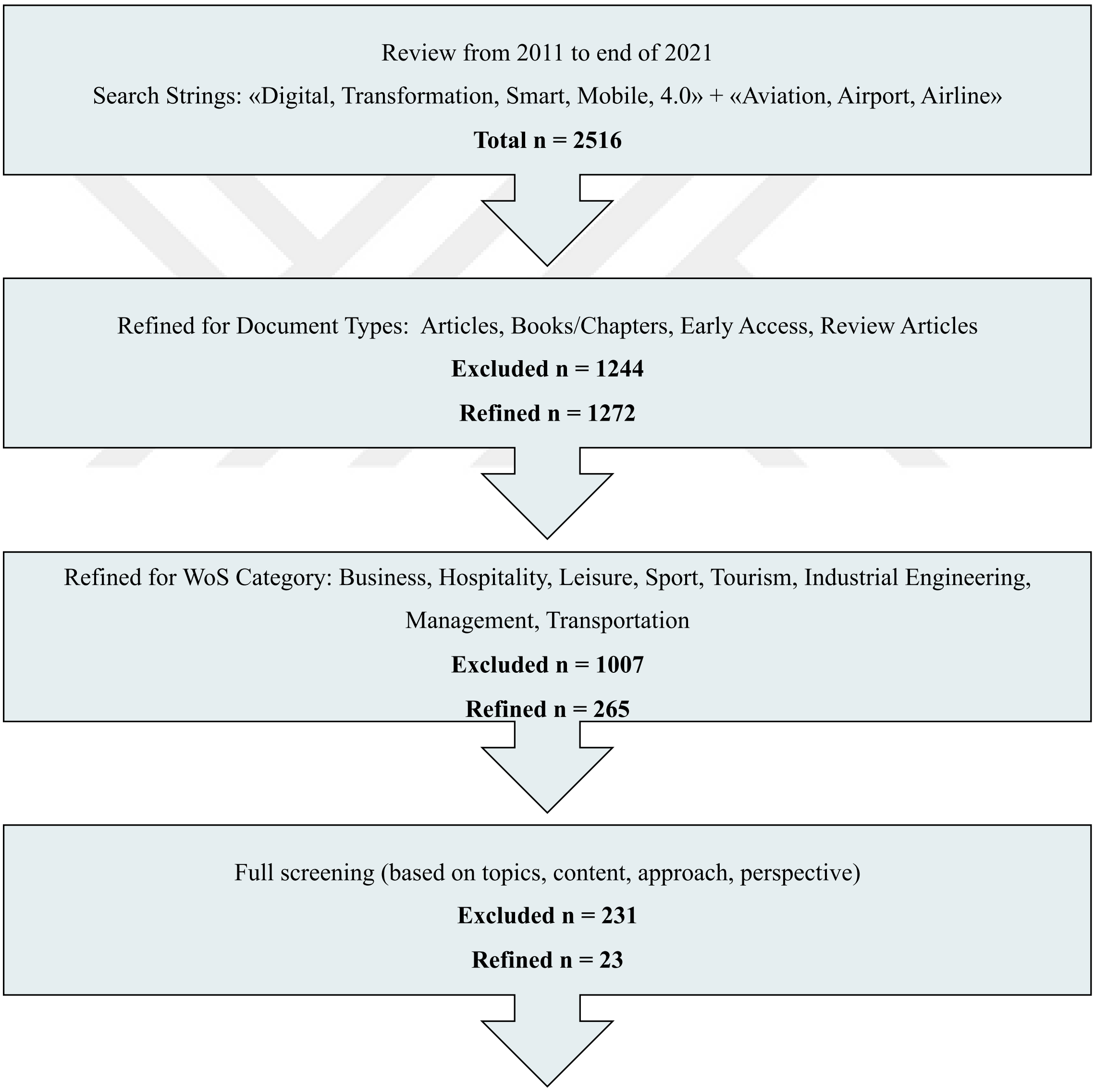


Figure 2.3: Summary of the review process*

* Common publications obtained with different search strings are excluded and used as single. Finally, 23 publications have been revealed after full screening process.

2.2. Data Analysis

This section briefly illustrates the DT and its effect. Following this, the DT definitions introduced by different authors are examined. Additionally, current situation of the academic literature on DT in different industries are revealed based on bibliometric analysis. The DT in aviation industry has been discussed. Finally, the resources obtained through the literature review process are examined and findings are presented.

2.2.1. Digital Transformation and Its Effects

Introduced advanced technologies to the market in recent years have become an indispensable part of people's lives. This situation has radically changed the way people and companies do business. The companies differentiated their decision-making mechanisms, business models, strategies, competition styles, product, and service types they offer. Finally, service perceptions have changed. Even the way we evaluate success and risks has undergone a holistic change (Büyüközkan et al., 2021a). The DT process, which is seen as the tsunami of the 21st century by today's senior executives, has begun to affect every sector in waves. Therefore, DT has become one of the most remarkable phenomena of the last decade. However, there is still no concrete definition of DT. Table 2.1 presents the different DT definitions.

The rapid introduction of emerging technologies has made these technologies easily accessible and usable for people. This has transformed people's behavior patterns, the way they buy products and services, and their expectations. Today, people spend more than 1/4 of the day on the internet. More than half of this time is spent on mobile devices. The world population is increasing. However, while the number of mobile device users increased by 124 million last year, the rate of internet usage worldwide increased by 7% and approached 70% (Hootsuite, 2020; Büyüközkan et al., 2021a). Moreover, in last year, the number of online people reached 300 million for the first time, while the number of active social media users increased by around 9%. The internet, digital technologies, and platforms increased human interaction with technology more than ever. The usage rate of mobile and smart devices has increased from 65% to 99% in North America, from 45% to 92% in Western Europe, from 14% to 80% in Latin America, from 15% to 92% in Central and Eastern Europe, from 10% to 71% in Africa and the Middle East and finally, from 17% to 81% in Asia and Pacific from 2013 to 2021 (Hootsuite, 2020).

Table 2.1: Some definitions of DT in literature

Sources	Definitions
Stolterman & Fors (2004)	"It refers to the process in which digital technologies affect the end-to-end transformation and change of human life."
Westerman et al. (2011)	"It represents the use of technology to radically improve performance or reach of enterprises."
Fitzgerald et al. (2014)	"It refers to transformation based on the use of digital technologies and digital platforms to improve customer experience or create new business models."
Mazzone (2014)	"It is the deliberate and continually digital evolution of a company, a process, a business model, or an idea, that can be both tactical and strategic."
Gimpel & Röglinger (2015)	"It refers to a managed adaptation process based on progressive and evolving digitalization for sustainable value creation."
Microsoft (2016)	"It refers to a process that includes the automation and improvement of processes in order to provide better services to customers and potential candidates who may be future customers."
Stief et al. (2016)	"It is the transformation of organizational structure, processes and products based on the emerging technologies. It is also expressed as an intervention in the company's DNA."
Wright et al. (2017)	"It refers to an organization-wide change, including the front, middle and back offices, to change both the business and operating models of an organization and the way its employees work."
Reis et al. (2018)	"It is a transformation process based on emerging technologies enabling significant business improvements and affecting all aspects of customers' lives."
Vial (2019)	"It is a process that aims to improve an asset by triggering significant changes in its properties through combinations of information, computing, communication and connectivity technologies."
Aronica et al. (2020)	"It is a process that enables new digital paradigms and enables new value creation with the direct use of data, review and redesign of existing work patterns and business models and improve existing opportunities."
Bican & Brem (2020)	"It is a transformation process based on improved data exchange covering all implications and radical changes with unconnected partners for all industrial areas."
Ziyadin et al. (2020)	"It is a concept that refers to the unification of personal and corporate IT environments and includes the impact of digital technologies and digital platforms."

Hence, fast technology diffusion is a worldwide reality. This provides to launch new business models, easiness about business, embracement of economic growth. New technology trends due to emerging technologies impact people's daily life and the way they do business (WEF & Accenture, 2016; Wright et al., 2017; Büyüközkan et al., 2020a; Büyüközkan et al., 2021a). Digitalization and transformation have changed the consumer sphere, and this has influenced all areas of the economy (Krys & Fuest, 2017).

Increased use of digital technologies such as smartphones, wearable smart devices, the internet, digital platforms such as social media, mobile applications, digital and intelligent assistants, artificial intelligence applications, virtual reality, augmented reality, internet of things have brought many issues such as customer experience, multi-channel, big data and analytics, customer touch-points and insights, satisfaction, remote operations, online services, customer centricity, cybersecurity and privacy, digital trust, digital competition, digital competency, success and risks digital strategies, digital maturity, readiness, meeting customer expectations and competition in the digital environment into focus.

Firms have started to see the transformation as a necessity based on the changing expectations and profiles of the customers. They have become direct influencers on companies' ability to compete in the digital ecosystem. Hence, companies in different sectors have made investments in digital technologies to increase their digital transformation abilities, digital readiness, maturity, and excellence. Digital technologies such as cybersecurity, big data analytics, the internet of things, multi-cloud strategies, and artificial intelligence/machine learning are the most invested digital technologies of 2019 (Synoptek, 2020).

Connecting the customer experience, digital customer experience, multi-cloud computing, co-creating value with the external stakeholders, data-driven business, APIs-based business performance measurement, highly personalized experience expectations, social media, and mobile device integrity, expectations about quickly launched digital products and services, IT efficiency, competing in the digital ecosystem, platformication (MuleSoft, 2019), cyber risks, core modernization, maintainability, scalability, reliability, cognitive technologies, digital reality, blockchain (Briggs et al., 2019), DSQ (Büyüközkan et al., 2020a) have become new focus areas for the companies. The growing impact of this wave has begun to be seen in almost all sectors such as agriculture (Lajoie-

O'Malley et al., 2020), education (Cantú-Ortiz et al., 2020), banking (Nguyen, 2020), healthcare (Syed et al., 2019) including airlines and airports (Di Vaio &Varriale, 2020; Büyüközkan et al., 2020a; Büyüközkan et al., 2020b; Büyüközkan et al., 2021a; Büyüközkan et al., 2021b).

A bibliometric mapping process is applied to illustrate the DT concept by considering the alternative keywords for it and the application areas of the DT by using the VOSviewer (Van Eck & Waltman, 2010) in WoS database. This process is applied for the most current studies. Here, the search key is directly “digital transformation”.

The results of the mapping process are obtained based on the “Co-occurrence” type of analysis and “Author keywords” analysis unit. The counting method is selected as full counting over 1486 keywords. Furthermore, the minimum number of occurrences of a keyword is selected as 1 and all keywords are considered. The results of the bibliometric analysis are detailed in Figure 2.4. and Figure 2.5. Figure 2.4 shows the used keywords in the academic literature. There are various utilized alternative keywords related to “digital transformation”.

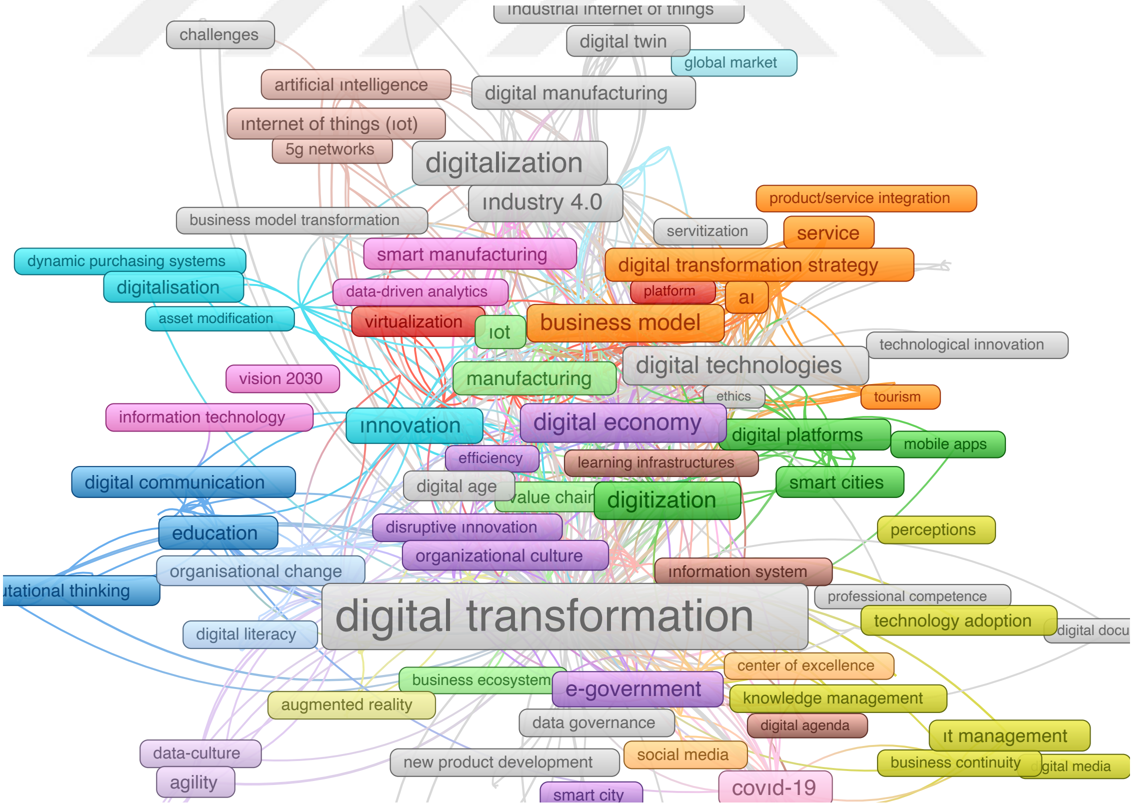


Figure 2.4: Keyword-based bibliometric analysis

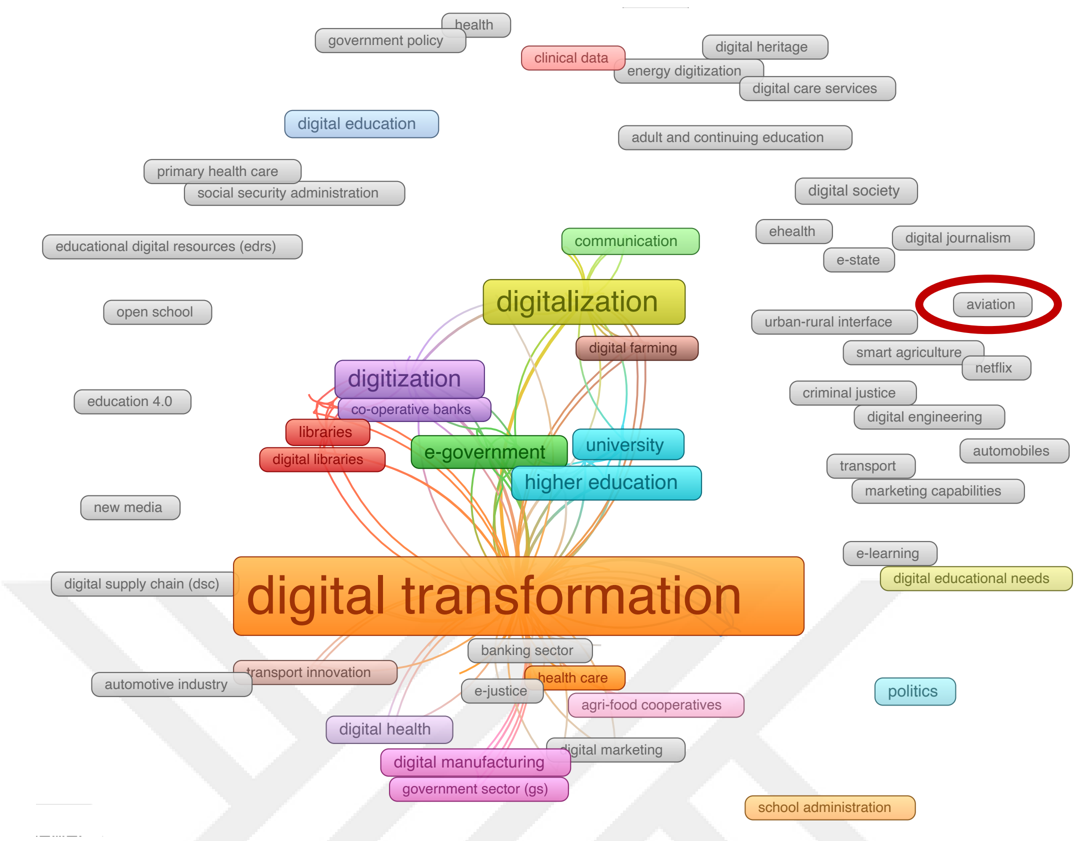


Figure 2.5: Sector-based bibliometric analysis

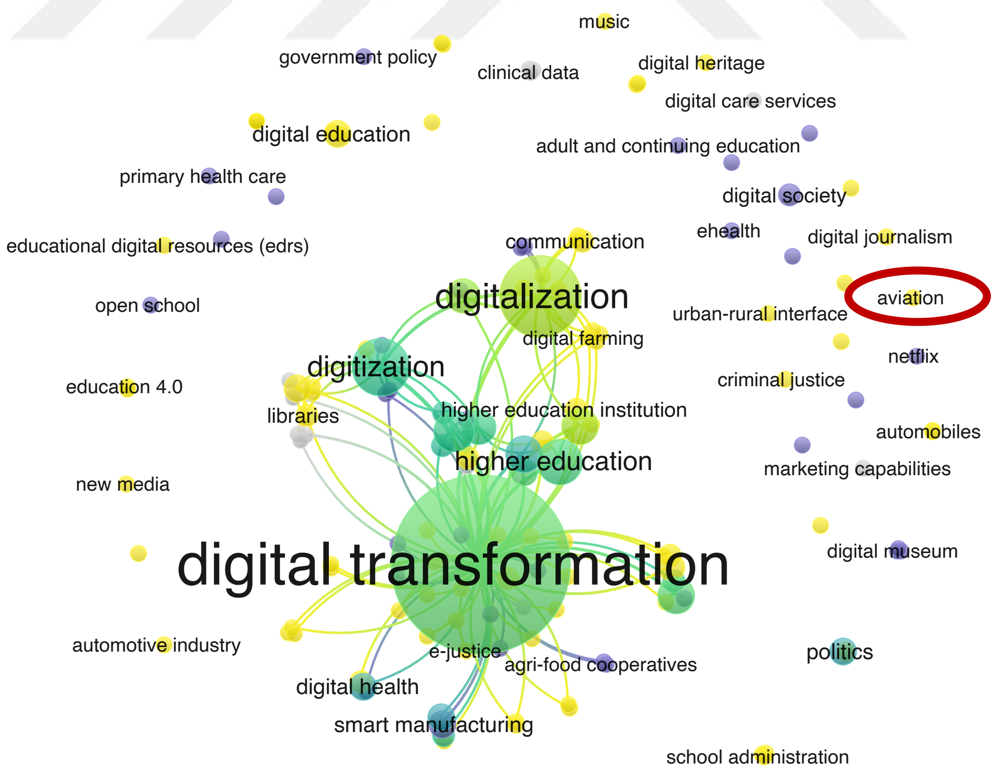


Figure 2.6: Trend-based bibliometric analysis

The used keywords related to "digital transformation" reveals that there is no common and accepted DT concept in the literature yet. Furthermore, sectors are analyzed based on "digital transformation" keyword. Figure 2.5 shows that DT is still a new concept for most of the industries and one of those areas is the aviation industry. Additionally, trend in DT based publications in the last year is analyzed with bibliometric analysis using "digital transformation" keyword. Yellow labeled areas in Figure 2.6 show the sectors where there is increased trend for DT-based publications. From this figure, aviation industry is one of those areas.

Hence, the results of conducted bibliometric analysis support the focus area of the thesis study. It has been observed that DT concept and perspective in aviation industry is new. There is a gap in the academic literature regarding this topic. Therefore, this thesis study focuses on DT in the aviation industry.

2.2.2. Digital Transformation in Aviation Industry

In today's conditions, the perception of travel has changed, and almost all processes are integrated with mobile devices. The use of mobile devices positioned the passengers to the center by including them in all processes. The airline industry, which already has a highly competitive ecosystem, has turned into a much more competitive ecosystem with the involved passengers using digital technologies in the processes. Airline companies have made efforts to maintain their profitability and sustainability while keeping their competitive power by increasing passengers' satisfaction. As the developments in technology gain speed and the speed of passengers to adapt to these technologies increases, it has become a necessity for airline companies to keep up with this transformation. Airline companies have begun to look for the ways to provide digital experiences with enriched digital products and services. Especially with the spread of personal mobile devices, the number of "always connected" passengers has started to increase. Hence, airlines must develop innovative experiences and proactive solutions that help passengers manage their travel on the go (Cognizant, 2011). Now, the passengers are in focus. Many digital initiatives and applications have been carried out for this. Blockchain and cloud technologies have been used for the storage of information related to users. The digital trust of the passengers has been provided in this way. Almost all processes such as online ticketing, purchasing, check-in, selection of in-flight entertainment, baggage tracking, self-baggage delivering with kiosk machines, flight information tracking, announcements, gate information, before and post-travel experiences have been moved to cyber-physical systems. Passengers use mobile devices and applications, social media platforms, and smart devices. Furthermore, smart airports relate to airline companies through digital channels. All processes are connected for the passengers right now.

Airline companies are already doing a good job and trying to keep up with both this transformation and passengers' expectations by implementing digitized processes. However, most projects are currently small-scale trials to reveal what is possible. Digitalization in general should become a corporate culture, and innovation and optimization should be encouraged in all areas of the companies. First, it is vital to realize the potential for digitalization for customers and flight operations. Digitalization and DT will offer new ways for customer relationships. However, it is an undeniable fact that the days when what is offered to passengers today will not be enough will come (Mattig & Hausweiler, 2017). Furthermore, smart airports are designed, airports, airlines and the passengers have become integrated.

2.2.3. Journal Articles

This section illustrates the academic literature based on the articles obtained through the review process showed in Figure 2.2 and Figure 2.3. Obtained results of the conducted review process is detailed in Table 2.2 and Table 2.3.

Misopoulos et al. (2014) aim to reveal the critical elements of customer service for the airline industry and customer service experiences based on social media. They determine the customer satisfaction areas. Following that, flight experiences, mobile and online check-in services, and favorable prices are determined as positive sentiments. Negative sentiments are identified lost luggage, flight delays and usability of the websites of the companies.

Wattanacharoensil & Schuckert (2015) aim to investigate the engagement of the global airports with social media users. Facebook usage by the airports in different areas for different aspects of communication with users is investigated. Importance of strategic marketing, Facebook pages for effective communication, characteristics and functions of the pages, innovative, interesting, and well-designed social media content and accessibility of the content is emphasized.

The aim of Straker & Wrigley (2016) is to determine and understand the passengers' emotions concerning their airport experiences based on digital channel engagement. The importance of values, consequences, and attributes of the emotions to propose strategic future digital channel engagements and digital channel content is highlighted.

Martin-Domingo & Martín (2016) introduce a framework and identified the innovative airports. The effect of mobile internet adoption, and importance of easy access, quality of information, and dining and shopping are revealed.

Lee & Park (2016) analyze the effect of sustainable brand on relationship between performance of airport business and sustainable brand. Important impact of social media, social responsibility, and transparency on performance of airport business and brand management in digital environment are discussed.

Suki & Suki (2017) examine the determinants of individual intention for using mobile device app in flight ticket booking. They emphasize the importance perceived trust, using advances in ICT for marketing strategies and using interactive and attractive feature of online channels. Furthermore, the significance of perceived usefulness impact on engagement of individuals with apps and mobile devices is highlighted.

Inversini (2017) argues the impact of mobile technology on passenger experience at airports. Mobile touchpoints, information sources, understanding of customer journey, main activities of the passengers, mobile devices as personalization tools, passenger end-to-end journey and interactive communication are the main highlights of the study.

Bogicevic et al. (2017) investigate the impact of airport technology that is traveler-focused on the satisfaction of traveler. A positive relationship between confidence benefits and self-service technology is determined. Positive impact of enjoyment and confidence benefits on satisfaction is highlighted. Positive relationship between enjoyment of the travelers and supporting technology has been revealed.

Straker & Wrigley (2018) illustrate the role of digital channel utilization at airports based on integration of digital channel usage and company strategy. They show the impact of airport technology usage on overall service ranking, and a digital channel platform-based performance evaluation of the airports is discussed.

Punel & Ermagun (2018) investigate the market segments in the airline industry using social media networks. Importance of the detection of the segments for marketing customer strategy has been revealed.

Mantouka et al. (2019) identify the factors influencing the acceptance of smartphone gamified applications concerning the airports. Importance of indoor navigation and information concerning the airport services for the application and willingness to pay is emphasized.

Keskin & Salman (2020) propose a building information management framework for smart airport lifecycle management. They focus on connectivity, improvement of end-user experience via new connected technologies, enhancement of operational efficiencies, and strategizing digital initiatives.

Büyüközkan et al. (2020a) propose a DSQ evaluation framework and identified the most critical criteria for better DSQ performance in aviation industry. They reveal the importance of customer insight, proactive customer service, digital trust for digital aviation industry.

Ahmed et al. (2020) examine the perception of passengers for app-based ridesharing services. Influence of perceived quality and value for money on passenger satisfaction, direct relationship between perceived quality and value for money, increased communication with passengers through apps are discussed and highlighted.

Rengarajan et al. (2021) investigate the effect of decision model innovation for competitive productivity, customers, and customer satisfaction at airports. Improvement of corporate culture, talent, and resource management for competitive productivity of the firms is emphasized. Incorporation of customer-focused digitally enabled solutions is discussed.

Mwesiumo et al. (2021) measure the privacy concerns in airport digital context. Importance of interaction management for willingness to provide personal data has been focused on.

Mrňa et al. (2021) aim to cover IoT implementation aspects into airport operations. IoT applications in airport operations, intersection between airport infrastructure components and IoT elements are discussed. Importance of the readiness of airports for DT and digital tool availability for DT is emphasized.

Katsoni & Poulaki (2021) focus on revenue management based on digitalized air services and new customized products for airlines. Airline digitalization process, adoption of a digital evolution marketing plan, DT maturity, technology acceptance, and customer-centric strategy concepts and their importance are highlighted.

Hernandez Bueno (2021) develop a framework based on passenger experience for airport design. Passenger-centered design solutions, frictionless and seamless travel, autonomy and personalized experience, relationship between passenger, airport design, process, experience, and optimal operation factors are discussed based on the developed framework.

Halpern et al. (2021a) examine the impact of organizational readiness and innovation, and airport size and ownership on digital change at airports. Direct effect of airport size on digital change has been determined. Positive impact of successful development of organizational readiness on innovation has been revealed.

Halpern et al. (2021b) determine passenger preferences, identify the segments of the passengers, and reveal how the passengers' segments change through the digital technologies. Wants of passengers to have increased control for their journey using automated and personalized options have been focused on. Change of passenger preferences based on digital technology adoption and differences between the passenger profiles in different passenger segments are discussed. It is stated that automated and personalization segments are dominated by the passengers using digital technologies.

Büyüközkan et al. (2021a) propose a DT competency evaluation framework and evaluated the competency of low-cost airline companies. Importance of the transformation and adaptation management, value proposition, DT strategy, digital customer experience, digital business model, DSQ, digital skillset, mindset and leadership is highlighted.

Büyüközkan et al. (2021b) aim to propose a DT strategy evaluation framework and identify the DT strategies for airline industry. They reveal that the DT is more than technology and technology implementation. Importance of focusing differentiated service quality and customer experience with business model adaptation is highlighted.

Table 2.2: Analytical publications in the academic literature (2011-2021)

Source	Approach	Technique	Perspective
Büyüközkan et al. (2021a)	Model Proposition & Framework	IVIF MCDM	DT Competency
Büyüközkan et al. (2021b)	Model Proposition & Framework	Fuzzy MCDM	DT Strategy
Halpern et al. (2021a)	Model Proposition	Statistics	Organizational Readiness
Halpern et al. (2021b)	Discussion	Statistics	Digital Technology Based Passenger Segmentation
Mwesiumo et al. (2021)	Framework	Statistics	Privacy
Ahmed et al. (2020)	Model proposition	Statistics	Perceived Quality and Passenger Satisfaction
Büyüközkan et al. (2020a)	Model Proposition & Framework	IVIF MCDM	DSQ
Keskin & Salman (2020)	Framework	Statistics	End User Experience and Lifecycle Management
Mantouka (2019)	Discussion	Statistics	Technology Acceptance and Gamification
Punel & Ermagun (2018)	Discussion	Statistics	Market Segments and Social Media
Bogicevic et al. (2017)	Model Proposition	Statistics	Technology and Traveler Satisfaction
Suki & Suki (2017)	Framework	Statistics	Mobile Devices and App Usage Determinants
Lee & Park (2016)	Conceptual Model Proposition & Discussion	Statistics	Performance, Sustainability, and Social Media
Martin-Domingo & Martín (2016)	Framework	Statistics	Innovation and Mobile Internet Adoption
Misopoulos et al. (2014)	Discussion	Statistics & Sentiment Analysis	Customer Service, Customer Experience and Social Media

Table 2.3: Conceptual publications in the academic literature (2011-2021)

Source	Approach	Technique	Perspective
Hernandez Bueno (2021)	Discussion	NA	Passenger Experience
Katsoni & Poulaki (2021)	Model Combination	NA	Customization and Digitalization Based Revenue Management
Mrňa et al. (2021)	Concept and Design Suggestion & Discussion	NA	DT Readiness and IoT Implementation
Rengarajan et al. (2021)	Model Proposition	NA	Customer Satisfaction
Straker & Wrigley (2018)	Discussion	NA	Digital Channel Platform and Strategy
Inversini (2017)	Discussion	Survey & Interview	Mobile Technology and Passenger Experience
Straker & Wrigley (2016)	Taxonomy & Discussion	Survey	Passenger Emotions and Digital Channel Engagement
Wattanacharoensil & Schuckert (2015)	Discussion	NA	Social Media Engagement

The results of the conducted literature review show that the academic literature concerning the aviation industry with DT perspective is limited. Table 2.2 and Table 2.3 indicate that most of the studies in the academic literature adopted statistical approach. Obtained results are summarized and illustrated with the graphs given in Figures 2.7, 2.8 and 2.9, respectively.

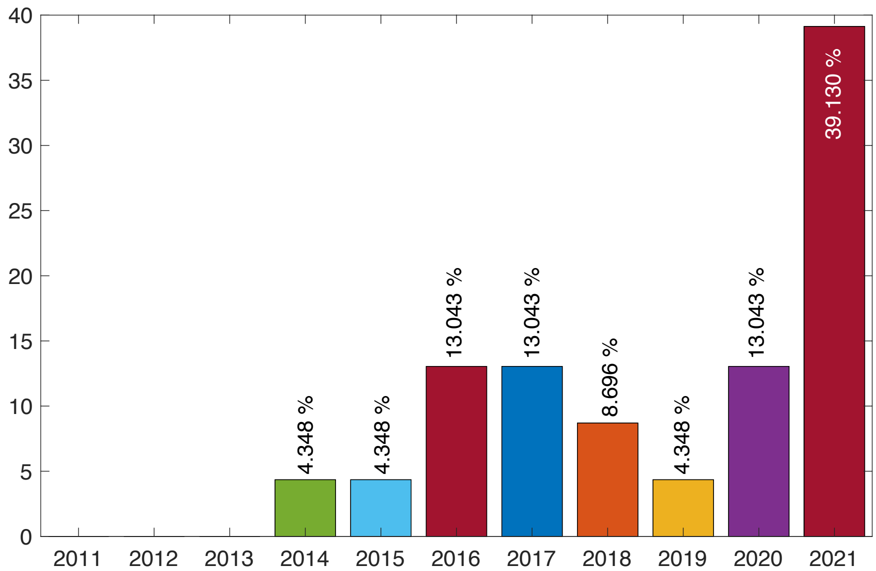


Figure 2.7: Distribution of the articles between 2011-2021

Figure 2.7 shows that the number of studies conducted with the DT perspective in the aviation industry between 2011-2021 is quite limited. In addition, an obvious acceleration was observed in the number of these studies, especially in 2021.

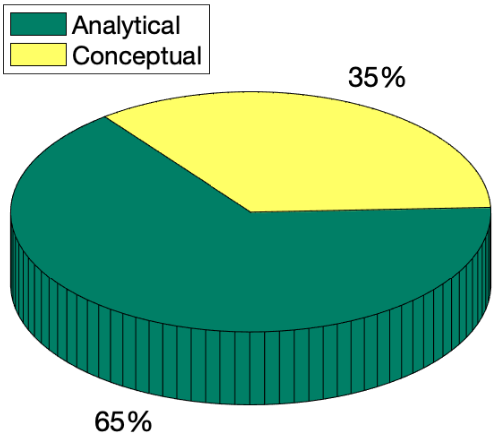


Figure 2.8: Distribution of the types of the articles between 2011-2021

Figure 2.8 indicates that most of the studies conducted between 2011-2021 period used an analytical approach. On the other hand, the number of the conceptual articles is relatively less. Additionally, no review article is found, to the best of our knowledge.

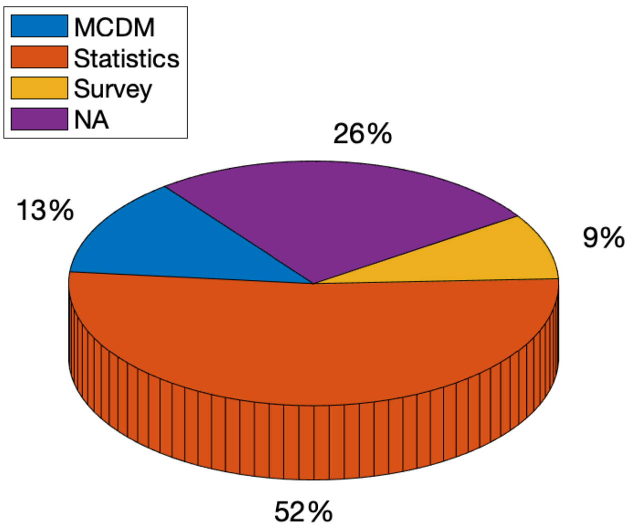


Figure 2.9: Distribution of the utilized techniques in the articles between 2011-2021

Figure 2.9 illustrates the rates of the utilized techniques and methods in the articles published between 2011-2021. It is seen that more than half of the studies used statistics as a technique. Using survey, interviews or questionaries is limited. Additionally, a considerable part of these articles used no techniques. On the other hand, when the rate of use of MCDM is examined, it is seen that it was used limited with 13%.

The articles introduced in Tables 2.2 and 2.3 adopted different approaches as follows: Discussion, framework, model proposition, model and framework proposition, model combination, concept and design suggestion, and taxonomy. Yet, the number of studies including both model proposition and framework is also limited.

2.2.4. Expanded Review

When Tables 2.2 and 2.3 are examined, another significant finding has been obtained. Each paper adopted different perspectives. Even if they have some common perspectives such as service quality, strategy, perceived quality, passenger experience, passenger satisfaction, customer satisfaction and digital channel, in most of the studies the adopted perspective is directly related to the utilized digital technologies. To see whether this is really the case and to see the place of studies based on the use of digital technology rather than DT in the academic literature, the literature survey section has been expanded, and research is conducted with Google Scholar in addition to WoS by considering other databases. At this point, use of digital technologies such as automation, big data, blockchain technology, cloud technology, digital channels and platforms, data analytics, mobile applications, mobile devices, radio frequency identification, internet of things, self-service technology, social media, wearable smart devices, and websites in the articles concerning aviation industry is considered. This additional review process has also been conducted for 2011-2021 period.

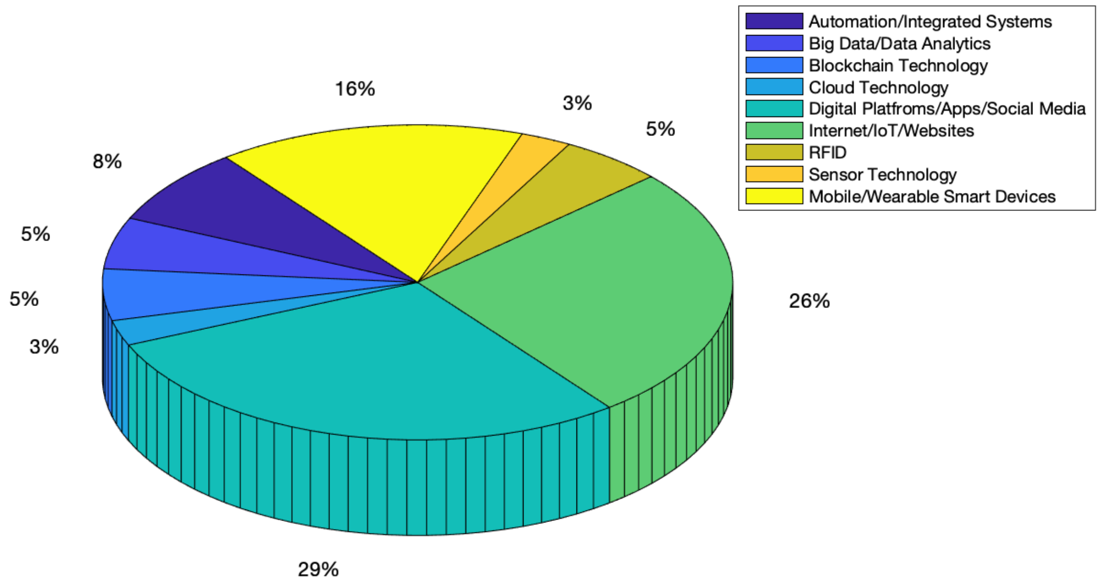


Figure 2.10: Distribution of the implemented technologies in the literature

Table 2.4: Technology implementation in aviation-based studies (2011-2021)

Implemented Technology	Sources
Automation	Bouyakoub et al. (2017); Rodoplu Şahin et al. (2019).
Big Data	Kovynyov & Mikut (2019); Di Vaio & Varriale (2020).
Blockchain Technology	Ying et al. (2018).
Cloud Technology	AlMashari et al. (2018).
Data Analytics	Keskin & Salman (2020).
Digital Channels and Platforms	Straker & Wrigley (2016); Keskin & Salman (2020).
Information Technology Platforms	Tsai et al. (2011).
Integrated Systems	Bouyakoub et al. (2017).
Internet	Tsai et al. (2011); Galang (2012); Budd & Vorley (2013); Elkhani et al. (2014); Moreno-Izquierdo et al. (2015); Karaağaoğlu & Çiçek (2019).
Internet of Things	Bouyakoub et al. (2017); AlMashari et al. (2018).
Mobile Applications	Budd & Vorley (2013); Ghazal et al. (2016); AlMashari et al. (2018); Karaağaoğlu & Çiçek (2019); Rajapaksha & Jayasuriya (2020).
Mobile Devices	Budd & Vorley (2013); Rajapaksha & Jayasuriya (2020).
Radio Frequency Identification	Rajapaksha & Jayasuriya (2020).
Self-Service Technology	Rajapaksha & Jayasuriya (2020).
Sensor Technology	AlMashari et al. (2018).
Social Media	Grančay (2014); Knoblich et al. (2017); Seo & Park (2018); Karaağaoğlu & Çiçek (2019).
Wearable Smart Devices	Ghazal et al. (2016); Kovynyov & Mikut (2019); Rajapaksha & Jayasuriya (2020).
Website	Tsai et al. (2011); Elkhani et al. (2014).

Figure 2.10 and Table 2.4 summarizes the results of the conducted literature review concerning the utilized digital technologies in the aviation industry.

Table 2.5: Perspectives of some of the technology-based studies (2011-2021)

Source	Aim of the Study	Perspective
Tsai et al. (2011)	To propose a model for the evaluation of effectiveness of web-based marketing.	Website Quality and Service Quality
Galang (2012)	To investigate the influencing factors for the timing of electronic ticketing adoption by airlines based on hazard models.	E-ticketing, Technology Insights and Strategy
Budd & Vorley (2013)	To determine and classify the functionality of the iOS apps to support business travel and to evaluate user experience.	Mobile Customer Relationship Management and Passenger Services
Elkhani et al. (2014)	To evaluate the effectiveness of airline websites based on customers' point of view.	Website Quality
Grančay (2014)	To investigate how the airlines use social media platforms.	Interaction with Customers
Moreno-Izquierdo et al. (2015)	To investigate low-cost prices.	Price Strategy
Straker & Wrigley (2016)	To introduce a unique method for understanding of passengers' emotions.	Passenger Experience, Digital Channel and Strategy
Ghazal et al. (2016)	To introduce a smart airport system.	Real Time Tracking
Knoblich et al. (2017)	To examine social media practices in marketing for airlines.	Social Media Marketing, Content and Success Factors
Bouyakoub et al. (2017)	To propose an airport management system.	Passenger Journey
Ying et al. (2018)	To reveal how the blockchain technology is used in airline industry.	Technology Implementation

Table 2.5: Perspectives of some technology-based studies (2011-2021) (*continue*)

Source	Aim of the Study	Perspective
Seo & Park (2018)	To illustrate the influence of marketing activities on customer response and brand equity for airlines.	Social Media Marketing Impact and Brand Image
AlMashari et al. (2018)	To propose a smart airport solution.	Technology Integration
Rodoplu Şahin et al. (2019)	To review the effects of Industry 4.0 in airport and airline management practices.	Trends and Strategic Business Model Components
Kovynyov & Mikut (2019)	To reveal that the focus for researching how airport ground operations have changed with digital transformation.	Customer Centricity, Digital Services for Passengers and Digital Maturity
Karaağaoğlu & Çiçek (2019)	To evaluate digital marketing applications.	Differentiation of Customer Demands and Expectations and Digital Marketing Strategies
Rajapaksha & Jayasuriya (2020)	To illustrate future of airport operations.	Technology Adaptation and Strategic Challenges
Keskin & Salman (2020)	To propose a framework of building information modeling and implementation for life cycle management of smart airports	Connectivity and Digital Technology Implementation
Halpern et al. (2021a)	To focus on the effect of digital transformation readiness and innovation on digital airports.	Organizational Readiness Determinants, Digital Change, Strategy and Leadership
Di Vaio & Varriale (2020)	To investigate the blockchain technology implications for sustainable performance in airport industry.	Collaborative Decision-Making Platform and Cooperation
Halpern et al. (2021b)	To determine the segment-based passenger preferences using digital technologies	Passenger Segmentation

Kondori & Yousefi (2011) suggest a new system providing baggage tracking and not to lose them in airports. Koo et al. (2011) focus on a decision about the adoption of a single or multi-channel approach for the online distribution of online tickets. Tsai et al. (2011) propose an effective evaluation model for web-based marketing in the airline industry, and the proposed model was applied to analyze the websites of air transportation companies. Different MCDM methods are utilized for the analysis process. Budd & Vorley (2013) study on the utilization of mobile technologies and applications by airlines for business travel.

Grančay (2014) focuses on how airlines use social media platforms to diversify sales channels, communicate with customers, and manage public relations because the way airline companies interact with the public has changed with the change of new media. The focus is on how airlines use social media platforms. Moreno-Izquierdo et al. (2015) investigate low-cost airline price determination and the impact of the internet on this pricing strategy. Wattanacharoensil & Schuckert (2015) focus on how global airports interact with social media users. López-Bonilla & López-Bonilla (2015) focus on the adoption of self-services and e-ticketing by the consumers in the airline industry. At the same time self-consciousness and profiles are taken into consideration.

Alghadeir & Al-Sakran (2016) focus on an IoT-based smart airport architecture. Martin-Domingo & Martín (2016) use a new theoretical model to test the adoption of mobile internet by airports by considering the maturity level and time of adoption. Straker & Wrigley (2016) introduce a unique method for understanding passengers' emotions based on their airport experiences to design digital channels and improve them to focus on the latent needs of passengers. Ghazal et al. (2016) introduce a smart system to apply a real-time track for the luggage in airports based on mobile applications and smartwatches.

Avram (2017) investigate the way of the usage of ancillaries to add value, to offer flexibility, interaction, and satisfaction to the passengers to obtained commercial opportunities and differentiated brand. Bouyakoub et al. (2017) propose an airport management system integrated with IoT to automate the passenger processes, to offer safe and pleasant journeys and to improve offered services in a smart airport environment.

The impact of offline influences and social media on consumer behavior is investigated in the airline industry by Bigne et al. (2018). Yau & Tang (2018) analyze the influencing factors of customer satisfaction by considering the self-service technology adoption in airports. Seo & Park (2018) illustrate the influence of marketing activities on customer response and brand equity based on social media in the airline industry. Social media-based marketing activities affect brand awareness and image. Furthermore, the study shows that brand image influences online word-of-mouth and commitment. Maigha & Crow (2018) focus on airport parking lots in smart airports based on a transactive operating model. Mohamed et al. (2018) explore the utilized digital technologies for international smart airports by considering passenger experience and self-service solutions. Kovynyov & Mikut (2018) reveal the key areas of DT in airport ground operations, and they focused on digital technologies used in airport operations, digital services, big data, network efficiency improvement through technologies, and finally, how DT changed the airport ground operations. AlMashari et al. (2018) propose a smart airport solution based on IoT. Furthermore, this IoT-based solution contains mobile application and sensor network systems that are integrated with the cloud. Ying et al. (2018) investigate the digital enablement of blockchain technology in the airline industry and the study is supported with a case study.

Karaağaoğlu & Çiçek (2019) investigate the digital marketing strategies such as mobile applications, social media marketing, web marketing, and e-mail marketing for both national and international airline companies. While the study reveals that airline companies use digital tools effectively, considering the changing customer demands and expectations, it is argued that it is important to determine the right strategy in the digital management process to create opportunities and compete. Somsen et al. (2019) illustrate the reasons and the way of evolvement of the success factors in the DT process over different cases in the airline industry. Purwitasari et al. (2019) focus on a concept based on new digital experience in the digital era by considering the challenges of airline companies in communication marketing. Lykou et al. (2019) research the cybersecurity of smart airports and their cyber resilience to promote operational efficiency and to facilitate robust cybersecurity governance in smart airports. Rodoplu Şahin et al. (2019) investigate the airline and airport management practices, challenges, and opportunities with Industry 4.0 perspective based on strategic business model components such as value proposition, customer segments, channel strategies, customer relationship, revenue streams, etc., and innovative trends such as intelligent automation, liquid workforce, platform economy, predictable disruption, and digital trust are revealed for airlines and airports as a strategy. Baghirov et al. (2019) focus on the management of social media platforms for global airlines. Kovynyov & Mikut (2019) reveal that the focus is data-driven and customer-centric innovation while researching how airport ground operations have changed with DT. Furthermore, different business scenarios are discussed through wearable airport ground operations, big data, and new digital services for passengers and associated digital technologies. Finally, the digital maturity levels of the technologies discussed are evaluated. Tian et al. (2019) develop a new analytical approach based on social media analytics to measure the service quality in the airline industry. Martin-Domingo et al. (2019) use social media as a resource to analyze airport service quality through sentiment analysis. Koenig et al. (2019) focus on baggage handling in an airport with Industry 4.0 perspective. Taufik & Hanafiah (2019) focus on the examination of factors influencing the adoption of self-service technologies and behaviors of airport passengers. Kim & Park (2019) examine the impact of characteristics for airport self-service on behavioral intention, satisfaction, and perceived value of passengers. Menon et al. (2019) propose a conceptual model on a brand's post-engagement through social media. The key determinant is revealed as entertaining. The study addresses the distinction between consumer brand post engagement on two social media platforms. Ashdown (2019) focus on a rising cyber threat in the international aviation industry and focuses on cybersecurity, vulnerabilities, and aviation law.

Rajapaksha & Jayasuriya (2020) illustrate the future of airport operations based on the smart airport concept. They cover technology adaptation levels of airports, and airport 4.0 is highlighted. The advantages of smart airports are revealed as aviation security, passenger convenience, operational efficiency, and optimization of limited resources. Smart check-in, self-boarding, indoor navigation, biometric services, smart wearable devices, RFID baggage tags, self-baggage tagging, kiosks for lost luggage, border control, mobile devices, and airport apps are focused on smart airport operations and applications. Furthermore, strategic challenges are highlighted. IoT-based solutions for smart airport operations are focused on by Zhang (2020). Keskin & Salman (2020) propose a framework of building information modeling and implementation of this for life cycle management of smart airports by considering the importance of connectivity, utilization of connected digital technologies in smart airports to improve the experiences of end-users. Büyüközkan et al. (2020a) introduce a new DSQ model by considering changing behavior of passengers based on the technology usage levels of the passengers for their travel journey and to meet the expectations of digital passengers by the airline companies. The proposed model is validated with a case study conducted in airline industry. Büyüközkan et al. (2020b) propose an aviation 4.0 success model to evaluate the successes of the airline companies and to select the most successful airline companies among the alternatives using a combined intuitionistic fuzzy MCDM methodology. Di Vaio & Varriale (2020) investigate the blockchain technology implications for sustainable performance in the airport industry. It is revealed that the Collaborative Decision-Making platform which is one of the blockchain technology applications promotes cooperation between the main players in the aviation industry. Oliveira (2020) focus on the digital twin in airport management. Information technologies and innovative navigation are focused on by Khadonova et al. (2020) for digital smart airport systems.

Halpern et al. (2021a) focus on the effect of digital transformation readiness and innovation on digital airports. Indicators for digital change and organizational readiness are revealed and relationships are obtained. It is revealed that organizational readiness has a direct effect on both digital change and innovation. Airport size is also found as an influential factor by the readiness.

The keywords “digitalization”, “digital”, “digital technology”, and “digital transformation” were used during the expanded literature review process. Above-mentioned issues and the results of the expanded literature review proved that the trend in the published articles is based on technology implementation. Even if this is the case, they have common features when their perspectives are examined. Strategy, passenger, service quality, success factors, challenges, readiness may be seen as the main domains.

2.2.5. Industrial Reports

There are a considerable number of industrial reports on DT in the aviation industry in terms of airlines, airports, utilized technologies, new trends, and strategies. The analysis related to industrial reports is provided in this section.

Cognizant (2011) focus on the development of a digital strategy for global airlines based on increased customer-centricity. It is declared that the usage of personalized mobile devices has increased, and this influences passenger demands. Furthermore, complying with these changed passenger demands through innovative experiences has become a priority for airline companies to offer journey management for their customers. A specific example based on an airline company that serves more than 160 million passengers per year is given. It is emphasized that digital experiences such as social media, kiosks, websites, tablets can be improved to offer a better customer experience. Having own digital technologies and channels costs less. Hence, Company-owned digital experiences can be encouraged. The importance of personalized experiences, next-level customer experiences, adoption of new technologies as an owner, and digital strategy is highlighted.

Blondel et al. (2015) focus on the DT of airports and provide a viewpoint to illustrate airport 4.0. Hyper-competition, fast-changing business ecosystems, sophistication, and new customer power, disruptive technological advances are evaluated as business trends. Improvement of airport models from Airport 1.0 to Airport 4.0 is highlighted. Finally, key success factors for airport DT are introduced.

Borgogna et al. (2016) focus on retail travel changes and emphasized that increased online channel usage and multiple devices for booking and search processes, widespread social media and experience sharing, loyalty programs are the themes in the global airline ecosystem. It is indicated that airline companies should focus on understanding the change in customer behavior. The rate of online adoption of some regions are presented as follows: 95% in Australia, 88% in China, 75% Western Europe and 70% in U.S. Personalized solutions for booking and travel search through multiple touchpoints are seen as opportunities for airlines to facilitate trust and increase the relationship with customers. Emerging technologies are the strategic opportunity providers for airlines. The need for a holistic travel distribution strategy, which consists of the transformation of the business model, partnership with technology, content and channel players, and internal capability enhancement is highlighted. Technology environment, digital channel capability, knowledge related to customers, providing loyalty, and commercial capability are evaluated as the internal capabilities that should be enhanced. Furthermore, the success factors are a customer-centric organization, service culture based on customer orientation, and coherent customer strategy. Finally, the need for the identification of opportunities, challenges, internal capabilities, and the points that can be strengthened is underlined.

Harteveldt (2016) emphasize that the behaviors of airline passengers are constantly changing. It is found that delivering smart retailing experiences to passengers is quite critical. Effective airline retailing can influence the passengers and connect with the emotions of the passengers for better experiences. It was declared that the mobile will not be “a” channel, it will be “the” channel that is providing the travel agents and passengers can contact airline companies in 2021. The distribution of airlines will be influenced by the lately launched technologies such as artificial intelligence, mobile technologies, augmented reality, and virtual reality. It is highlighted that the new trend in digital technologies will make it possible for connected travelers and airlines to interact with each other.

Lymbersky & Barre (2016) illustrate the increased passenger handling efficiency through the self-service initiatives. It is stated that the airports realize the opportunities based on digital customer experiences. Furthermore, drivers such as competition, corporate strategy, stakeholders and partners, technology, and innovation, and at the same time, constraints such as people readiness, regulation, budget, and resources are emphasized for the digital strategies of the airports. Digital trends such as e-commerce, biometrics, big data, IoT, information services, mobility, and extended self-services are revealed. Finally, a “top-down & bottom-up methodology” named “Tailor-Made Digital Strategy” is proposed. The “Top-down” part of the proposed methodology consists of benchmarks, targets, objectives of leadership, strong building to avoid weaknesses. Process analyses, management view, capabilities of the organization, the profiles of customers, and the landscape of current technology are the components of the “bottom-up” part of the proposed strategy methodology.

ACI (2017) explains the importance of DT and declared that the airports have been expanded to enhance customer experiences and innovations. Furthermore, the leaders of airports state that the reason behind their success is not the technology deployment. It is the business transformation, adapting to cultures, staff, customers, and the emerging new technologies to meet the objectives. It is expressed as the DT of airports is related to the evolvement of processes and services to provide improved experiences to passengers and customers via implementation, adoption, and integration of new technologies to the existing ones. Personalized experiences and seamless flow are seen as the basics of a better experience. It is emphasized that derivation of some strategic goals and benefits from DT is important. DT is a business transformation not only about technology. Opportunities, challenges, internal readiness, and its requirements, strategic plan and objectives for airports, and potential application areas are illustrated.

Dykins (2017) look for the answers to the questions about how passengers evaluate an airline, how they choose the airline they will fly to, and how airline companies maintain loyalty to their brands. Service, convenience, and products are taken into consideration. 56% of the potential air travelers declared that the total package is important for them. Airline customers are expecting products offered by the airline company such as loyalty points, seat comfort, extra experience, free baggage allowances. On the other hand, they create value for services such as fast-track passport control, mobile boarding pass, self-check-in options, speedy boarding, and unique touches. Accessibility from the airport, ease of booking, and seat reservation are the convenience keys. Managing Director of e-Commerce, Loyalty Programs, and Ancillary Revenue, Air Canada declared that customers demand interaction through various digital channels at different times, but at the same time, they desire consistent experience. DT is seen as an opportunity for airline companies that do not offer a physical product. The availability of multiple booking channels creates new challenges for airline companies. Hence, they focus on a different point rather than offered prices and scheduling to attract new customers. Marketing strategies for customer segments, strategy for omnichannel digital marketing, data to understand the travelers, and communicating with customers have become new key points.

Nau & Benoit (2017) focus on future challenges such as raised capacity, passenger experience and changing needs of the passengers, security and cybersecurity, process optimization, and cost reduction for airports. Digital maturity is a characteristic of an airport. During the development of the airport model from Airport 1.0 to Airport 4.0, the business type also evolved from B2B to B2C. Airport passenger experience is the major challenge. Furthermore, omnichannel experience, mobility solutions, personal digital assistants, cloud, connectivity, network, IoT, and cybersecurity are crucial.

SAP (2018) states that digital technologies are used by leading airlines to provide customers with unique and personalized experiences based on data and data analytics, engage with customers, achieve efficiency in asset transactions, create customer-driven business models and smart businesses. The report focuses on new business value, smart technologies, challenges and opportunities, and strategic priorities.

Allen & Bolivar (2019) highlight the importance of digital engagement and passenger journeys in airport operations. Mariani et al. (2019) express that the airports have become more digitally connected. IoT can offer new opportunities, and it can transform the travel experience by providing new revenue. Strategic differentiation, new revenue, and operational efficiency are the potential benefits of IoT applications. Traveler experience and airport operations experience are the areas that IoT applications are utilized. Finally, barriers such as talent, security, privacy, safety, technology, and infrastructure to IoT implementations are introduced. Dey (2019) focuses on blockchain technology implementation in the airline industry.

SITA (2019) focuses on how technology changes the way passengers interact with the world, creating new expectations for the air travel experience, and this will shape how we travel by 2025. It is indicated that there is a changing passenger profile. The effect of generation differences and the technology acceptance levels of the generations to the changing profiles and expectations are underlined. It is stated that 68% of total passengers are assessed as post-digital passengers, and 32% of them are seen as pre-digital passengers. However, it has been stated that most of the passengers are already using technologies such as mobile applications, websites, and kiosks and that the travelers adopt the technology. While the satisfaction rate of the passengers who use technology for booking, check-in, bag tag, self-bag drops, passport, dwell time, boarding, onboard, and bag collection operations vary between 8.27 and 8.49 over 10 points, this satisfaction rate for those who do not use technology for the same operations is between 7.69 and 8.34. It is highlighted that 85% of the airlines are using artificial intelligence for chatbots and virtual agents. It is emphasized that passenger expectations will start with the airline company, continue with the expectations about the airport and continue the plane. Biometric journeys and one ID for all journeys were underlined for airports. Faster in-flight connectivity, 5G in the air, and cheaper in-flight connectivity are focused on for personalized and frictionless experience is expected by the passenger through the aircraft.

Changing passenger profile, digital technologies, collaboration, airport experience, passenger experience, and strategy are the critical parts in the overall reflection of the report. WNS (2020) focuses on disruptive trends such as connectivity, the era of robots, airline distribution evolvement, digital twin, AI that influence the airline industry.

2.2.6. Books and Theses

In this section, first, the published books in the literature are focused on. Some of the books that could be reached are reviewed. The obtained results are presented as follows:

Taneja (2011) declares that the passengers have become digital and mobile. Strategies related to technology, business, and information have been focused. The IT-based initiatives such as the loyalty of the passengers, flowless experience for passengers, passenger segmentation, internet, social media, and mobile applications, and future passengers are some of the important issues in the published book.

IT in the airline operations, developments, and capabilities, concerning the computer-based reservation systems, IT challenges, e-ticketing, the evolvement of distribution channels, internet distribution channels, and innovations concerning passenger processing are explained and discussed in a specific chapter by Belobaba et al. (2015).

Taneja (2016) focuses on the future of the airline business by considering different aspects in the published book. Some of these aspects can be given as follows: The transformation of the business models and innovation-based values, requirements for the passenger value, the organization structure, technology, management of transformative technology, and leadership. Enerstvedt (2017) illustrates and discusses human rights, data protection, privacy, and aviation security issues by considering the legal principles and technologies.

The e-book published by Tata (2019) focuses on 4 main issues related to DT, provided by IoT. These are presented as follows: The business growth which is sustainable cross-border. Here, geo-political boundaries are not taken into consideration. Recognition of the gains concerning the improved business efficiency and productivity. Usage of IoT and DT for improving the partner and customer engagement. Change of aviation industry is discussed based on these four issues. The global mobility challenge and the way of dealing with mobile networks are emphasized to maintain service continuity. Connected transport ecosystem, continuous collaboration, and ubiquitous data access, big data, IoT, the engagement of the customers and customer experience, omnichannel experience, the importance of reliability and security, and success in aviation management during DT are focused on by Tata (2019). Megatrends, artificial intelligence, blockchain, privacy, cybersecurity, legal aspects and law, and digital age are discussed by Abeyratne (2020).

Besides the published books in the literature, the theses are focused. Some of the theses that could be reached are reviewed. The obtained results can be summarized as follows:

The strategies concerning digital customer experience and digital flight performance are proposed based on a theory introduced by Ross et al. (2017) in the conclusions of the thesis. Kuisma (2018) aims to examine both the digitalization concept and its effect on the commercial aviation industry. Kuisma (2018) discusses the importance of investments in digital technologies for the satisfaction of the customers and operational efficiency. It is declared that digital technologies and trends such as big data, IoT, AR, and automation increase customer satisfaction. Digitalized customer experience is focused on. The capabilities of the firms, the need for a digital strategy, and the successful implementation of digital technologies are some important results of the thesis. Patel (2018) focuses on the travel journey of the passengers in the airports. The currently implemented technologies for passenger processing are analyzed in different airports in the world and challenges are revealed. Following that, a new technology is presented for a better travel experience, improved operational efficiency, security, and safety.

The influence of the emerging technologies and IoT in the smart airport concept are studied in a final graduation project by Yaqoobi (2019). It is indicated that the power of a smart airport is not just about the technology but also it is related to the transformation of the business. The greater experience for passengers is emphasized. Furthermore, the digital maturity of the airports is mentioned in the thesis.

Nair (2020) focuses on digitized airports and ground handling operations in the thesis. The advantages and solutions concerning digitization are discussed by considering the effectiveness in cost and easiness of the operations. The importance of simulation-based improvements for planning accuracy, real-time monitoring is highlighted. The most preferred technology is determined as cloud technology.

2.3. Main Issues and Gaps

There are gaps, insufficiencies, and points that are needed to be improved in digital aviation literature. These are summarized as follows:

- **Unclear DT Concept in Aviation Industry:** Based on the definitions given above, DT refers to an end-to-end holistic change process that enables companies to achieve much better than the version they are in. DT in the aviation industry, on the other hand, can be defined as an “end-to-end transformation philosophy in which all components of the aviation ecosystem are tactically and strategically redesigned and integrated through digital technologies to create value for passengers and customers”.
- **Lack of DT Concept in Academic Literature for Aviation Industry:** When the literature is examined, it is seen that there are many scientific studies based on DT, especially in the recent period. The number of studies carried out by focusing on different industrial areas is quite high. The number of studies focusing on other industrial fields is higher than those carried out in the aviation industry. In addition, while the number of industrial reports focusing on DT in the aviation industry is quite high, the academic literature is insufficient in this regard. Therefore, there is a gap in the literature on this subject.

- **Technology Implementation Based Focus:** Especially when academic literature is examined, there are various successful studies on the use and application of digital technologies. These studies focus on the application of a certain technology such as social media or blockchain, their advantages, results, or related strategies. Given the fact that DT is a holistic transformation philosophy, focusing solely on digital technology applications creates certain gaps. DT is not just about the adoption and application of technologies (Kane et al., 2015; Kane et al., 2017) such as mobile device applications and social media. A framework should be emerged. There are gaps in this regard in the literature.

- **Utilized Methods:** There are studies in different categories such as journal articles, and book chapters. These studies are analytical and conceptual studies. On the other hand, review studies concerning the aviation industry with DT perspective is limited. Most of the analytical studies have adopted a statistical approach. However, real-life problems require considering multiple conflicting criteria at the same time. Therefore, it may be useful to use multi-criteria decision-making (MCDM) methods. The literature is insufficient regarding the applications of DT based MCDM methods in the aviation industry. Also, real-life problems are complex and contain uncertainty. Fuzzy sets should be considered to eliminate this complexity and uncertainty. More complex typologies and fuzzy extensions such as IFSs and interval-valued IFs (IVIFs) can be utilized combined with MCDM methods.

- **Comparison of Academic Literature and Industrial Reports:** Both academic literature and industrial reports emphasize a better passenger experience, putting the passenger at the center. Industrial reports provide a more general management framework. These reports focus on digital strategy, personalized and improved passenger experience, changing passenger expectations and desires, and changing passenger profile. There are some different points in academic literature. Some studies focus on these concepts through a certain channel, as well as studies that draw a general perspective. In addition, studies are focusing on SQ depending on the passenger profile that changes depending on the use of digital technologies. However, neither in academic literature nor in industrial reports there is an emphasis on the perception of SQ that has also been digitized and evolved into DSQ (Büyüközkan et al., 2020a). Industrial reports emphasize that DT strategy is very important. There is also an emphasis on academic literature (Kuisma, 2018). However, there is a lack of work proposing a framework for DT strategies in the aviation industry in general or DT strategies concerning airlines/airports. In addition, both academic literature and industrial reports highlighted the importance of focusing on success and risk factors for DT in the aviation industry. However, there is insufficiency about conceptual models or frameworks for success or competency in DT. There is a need for such a framework in the literature.

2.4. Research Directions of the Thesis

This thesis study focuses on DT in the aviation industry. First, studies related to DT or digital technologies concerning different industrial areas were examined with a detailed literature survey. Due to the limited number of studies with a DT perspective in the aviation industry, the focus has been on the aviation industry. A literature survey has been conducted in the aviation industry considering the DT concept. The studies in the literature are examined in terms of their approaches, the digital technologies they focus on, their purposes, the techniques they use, categories, types, and keywords. Following this, the applications, needs, gaps, and trends in the literature are revealed. The general perspective obtained from the literature survey can be summarized as follows:

- The academic literature on the aviation industry with DT perspective is limited and the number of review articles concerning the DT in the aviation industry is insufficient. A review study should be emerged.

- Most of the studies in the academic literature are focusing on technology implementation. DT is an end-to-end transformation process. Industrial reports have this type of perspective. However, there is no general framework for this in the academic literature. Additionally, this idea is supported by industrial experts. They emphasized that the DT competency of the companies in the aviation industry is crucial. A new DT competency evaluation framework consisting of a new and generic model, and a methodology should be proposed.

- There is no strategy analysis and model concerning DT in aviation industry in the literature. Hence, a DT strategy evaluation framework consisting of a new model, and a methodology should be emerged.

- Limited usage of the MCDM methods in this scope may be focused on.

- The importance of success in DT has been highlighted but the academic literature is limited in terms of a model or framework concerning the successful DT process. A DT success evaluation framework consisting of a new and generic model, and a methodology should be proposed.

- The importance of the customer experience and changed behavior of the customers have been emphasized but there is no concern for the digital service quality. A new DSQ evaluation framework consisting of a new and generic model, and a methodology should be introduced.

The above-mentioned highlights identified the overall scope of the thesis study. Figure 2.11 gives proposed evaluation frameworks in this thesis study.

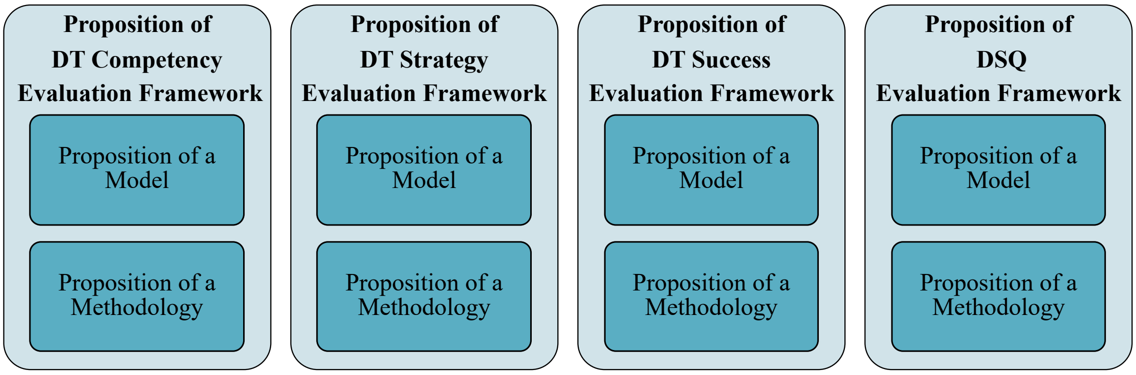


Figure 2.11: Proposed evaluation frameworks in the thesis study

3. THEORETICAL BACKGROUND FOR UTILIZED METHODS

Throughout this thesis, MCDM techniques are used for the analysis of the proposed models and the case studies carried out. This section contains detailed information about these techniques.

3.1. Scope of Utilized Methods

The decision-making processes based on the selection of the most appropriate alternative especially the decisions taken at the same time in the work-life include several criteria and sheds light on the solution of many complex problems (Lertprapai, 2013, Büyüközkan et al., 2019). To manage these decision-making processes, various MCDM techniques such as Analytic Hierarchy Process (AHP) (Saaty, 1980), Analytical Network Process (ANP) (Saaty, 1996), VIšeKriterijumska Optimizacija i Kompromisno Rešenje (in Serbian) (VIKOR) (Opricovic, 1998), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang & Yoon, 1981), Operational Competitiveness Rating Analysis (OCRA) (Wang, 2006), Measurement of Alternatives and Ranking according to the Compromise Solution (MARCOS) method (Stević et al., 2020), have been proposed. Although these techniques have been successfully applied in many different decision-making problems (Toloie-Eshlaghy & Homayonfar, 2011; Mahtani & Garg, 2018) and an integrated way (Nassereddine & Eskandari, 2017; Awasthi et al., 2018a) these approaches are expressed as classical MCDM techniques.

In this thesis study, it has been seen that DT concept is a relatively new phenomenon and concept. To deal with this new concept, model and solve decision-making problems concerning the DT concept, different frameworks and models have been proposed. In this context, these models contain multiple criteria that may conflict with each other. Hence, MCDM methods are quite suitable for modeling and solving the focused problems. Therefore, MCDM approach and techniques have been adopted in this thesis study.

Several authors reviewed the MCDM methods in the academic literature concerning MCDM utilization. The studies conducted by these authors have been searched. Xidonas & Psarras (2009) illustrate the usability of the MCDM methods in the equity portfolio management area. Abu-Taha (2011) reveals the multi-criteria applications in renewable energy analysis. Pérez et al. (2015) identify the place of multi-criteria approaches for urban passenger transport systems.

Shafiee (2015) presents the usage of MCDM methods in maintenance strategy selection. Si et al. (2016) search the place of the MCDM techniques in building-integrated green technologies area. de Almeida et al. (2017) review the MCDM applications in risk management. Kumar et al. (2017) show the usage of the MCDM methods in sustainable renewable energy development. Danesh et al. (2018) illustrate the MCDM applications in project portfolio management. Kaya et al. (2018) introduce the use of MCDM techniques for energy policies. Kazimieras Zavadskas et al. (2019) review the MCDM applications in business process information management. Glaize et al. (2019) review the multi-criteria decision analysis based decision-making applications in healthcare. Dožić (2019) shows the MCDM applications in aviation industry. Stojčić et al. (2019) show the usage of the MCDM methods in sustainability engineering. Chowdhury & Paul (2020) fulfilled the research gap on MCDM applications in corporate sustainability. Malemnganbi & Shimray (2020) introduce the applicability of the MCDM approaches in solar power plant site selection. Schramm et al. (2020) examine the usage of MCDM methods in sustainable supplier selection.

It is possible to say that use of the MCDM methods/techniques in the academic literature has remained popular from past to present when the review studies are examined. It is mentioned that there are more than 70 MCDM methods in the literature to simplify the decision-making process (Sun et al., 2014; Mousavi-Nasab & Sotoudeh-Anvari, 2017). But a literature review process has been conducted to see the use of MCDM methods in the academic literature concerning the aviation industry. The review process relies on WoS and Google Scholar Search Engine. Books, book chapters and conference proceedings are excluded, and the articles are refined for 2011-2021 period. The results of the conducted literature review are detailed in Table 3.1.

Table 3.1 shows that there are different MCDM methods applied to various decision-making problems for different purposes in the searched articles concerning the aviation industry. However, most of those studies utilized similar MCDM methods in the aviation industry. The most used MCDM method is the AHP method based on the review results. This was also supported by Mardani et al. (2015). Besides, use of the ANP and VIKOR methods in the articles is quite common. Hence, the MCDM approach has been adapted in this thesis study. The AHP, ANP and VIKOR methods have been used based on this approach during the case studies of the thesis study.

The complexity of the real-life problems, human perception and the intuition or hesitation during the decision-making process conducted by the Decision Makers (DMs) should be considered. Hence, MCDM methods can be used with fuzzy extensions. However, the review results presented in Table 3.1 show that most of the utilized MCDM methods in the articles concerning the aviation industry were expanded to classical fuzzy environment and use of other complex fuzzy extensions is limited in the academic literature of the aviation industry.

There is a limited academic literature concerning the use of fuzzy extensions with MCDM method. Hence, this thesis study employs the use of complex fuzzy extensions with MCDM method to fill this gap. The obtained results based on the conducted literature survey concerning the usage of MCDM methods between 2011-2021 also show that most of the studies in the academic literature used the AHP method to calculate the criteria weight.

Additionally, the AHP method is combined with different selection methods. In this thesis study, the AHP method is used to calculate the weights of the criteria concerning the proposed models. The selection of the most appropriate alternative is conducted through the VIKOR method. The ANP method is utilized for the analysis of the DT success factors based on the assumption of the dependence and relationship between the criteria. The reasons of selection these MCDM methods and utilization of the integrated MCDM methodology to proceed the thesis study are explained in the following section.

Table 3.1: MCDM methods in the aviation industry literature (2011-2021)

Source	Aim of the Study	Utilized Technique	Sets
Aydogan (2011)	Performance measurement.	AHP, TOPSIS	Rough, Fuzzy
Kuo (2011)	Airline service quality improvement.	GRA, VIKOR	Interval-Valued Fuzzy
Kuo & Liang (2011)	Airport service quality evaluation.	GRA, VIKOR	Fuzzy
Liou et al. (2011)	Domestic airline service quality improvement.	Modified VIKOR	x
Torlak et al. (2011)	Business competition analysis.	TOPSIS	Fuzzy
Tsai et al. (2011)	Web-based marketing effectiveness evaluation.	ANP, DEMATEL, VIKOR	x
Sevkli (2012)	Strategy analysis.	ANP	Fuzzy
Hsu & Liou (2013)	Outsourcing provider selection.	ANP, DEMATEL	x
Liao (2013)	Business travel airline selection.	AHP, MSGP, TOPSIS	x
Wu et al. (2013)	Airline competitiveness evaluation.	AHP	Fuzzy
Baltazar et al. (2014)	Predictive model development	DEA, MACBETH	x
Kilic et al. (2014)	ERP system selection.	AHP, TOPSIS	Fuzzy
Oghojafor & Adekoya (2014)	Customer satisfaction determinants identification.	AHP	x
Rezaei et al. (2014)	Airline supplier selection.	AHP	Fuzzy
Bruno et al. (2015)	Aircraft evaluation.	AHP	Fuzzy
Dožić & Kalić (2015)	Aircraft type selection.	AHP, ESM	x

Table 3.1: MCDM methods in the aviation industry literature (2011-2021) (*Continue*)

Source	Aim of the Study	Utilized Technique	Sets
Lupo (2015)	Airport service quality evaluation.	ELECTRE III	x
Saket et al. (2015)	Customer performance index evaluation	VIKOR	Fuzzy
Chen (2016)	Service quality improvement criteria selection.	ANP, DEMATEL	x
Delbari et al. (2016)	Full-service airline key competitiveness indicators and drivers' investigation.	AHP, Delphi	x
Garg (2016)	Strategic alliance partner evaluation.	AHP, TOPSIS	x, Fuzzy
Kazemi et al. (2016)	Airport service quality evaluation.	TOPSIS, VIKOR	Fuzzy
Ozdemir & Basligil (2016)	Aircraft selection.	ANP, Choquet Integral	Fuzzy
Prakash & Barua (2016)	Airport service quality enablers evaluation.	AHP, TOPSIS	x, Fuzzy
Zeng et al. (2016)	Method development.	TOPSIS	Pythagorean Fuzzy
Çelik & Gök Kısa (2017)	E-service quality evaluation.	AHP, PROMETHEE	Fuzzy
Deveci et al. (2017)	Airline new route selection.	TOPSIS	Interval Type-2 Fuzzy
Dinçer et al. (2017)	Airline performance evaluation.	ANP, DEMATEL, MOORA	Fuzzy, x
Görener et al. (2017)	Supplier performance evaluation.	AHP, TOPSIS	Interval Type-2 Fuzzy
Haghighat (2017)	Airline service quality evaluation.	ANP, DEMATEL	x, Fuzzy

Table 3.1: MCDM methods in the aviation industry literature (2011-2021) (*Continue*)

Source	Aim of the Study	Utilized Technique	Sets
Li et al. (2017)	In-flight service quality evaluation.	AHP	Fuzzy, 2-Tuple Fuzzy Linguistic
Lee et al. (2018)	Green aviation fleet program management strategy selection.	ANP, DEMATEL, ZOGP	x
Lu et al. (2018)	Sustainable performance evaluation.	ANP, DEMATEL, Modified VIKOR	x
Barak & Dahooei (2018)	Safety evaluation.	ARAS, COPRAS, DEA, MULTIMOORA, SAW, TOPSIS, VIKOR	Fuzzy
Chen & Ren (2018)	Alternative aviation fuel evaluation.	ANP, GRA	Fuzzy
Eshtaiwi et al. (2018)	Performance evaluation.	AHP	x
Gupta (2018)	Airline service quality evaluation.	BWM, VIKOR	x
Lin & Vlachos (2018)	Customer satisfaction improvement.	ANP, DEMATEL, IPIA, NN	x
Mahtani & Garg (2018)	Financial distress key factor analysis.	AHP	Fuzzy
Perçin (2018)	Airline service quality evaluation.	ANP, DEMATEL, VIKOR	Fuzzy
Pineda et al. (2018)	Airline operational and financial performance improvement.	ANP, DEMATEL, DRSA, VIKOR	x
Sennaroglu & Celebi (2018)	Military airport location selection.	AHP, PROMETHEE, VIKOR	x

Table 3.1: MCDM methods in the aviation industry literature (2011-2021) (*Continue*)

Source	Aim of the Study	Utilized Technique	Sets
Shojaei et al. (2018)	Airport evaluation.	BWM, VIKOR	x
Badi & Abdulshahed (2019)	Airline performance measurement and evaluation.	AHP, FUCOM	x
Fu (2019)	Catering supplier selection.	AHP, ARAS, MCGP	x
Kucukaltan & Topcu (2019)	Key airline selection indicator assessment.	AHP	x
Shen et al. (2019)	Vendor selection.	MCGP, MAGP, TOPSIS	x, Fuzzy
Vatankhah et al. (2019)	Airline business model structure evaluation.	AHP	Fuzzy
Alkhatib & Migdadi (2020)	Green airline evaluation.	AHP, DEMATEL, TOPSIS	x
Bakır et al. (2020)	Airline operational performance evaluation.	MAIRCA, PIPREICA	x
Büyüközkan et al. (2020a)	Digital service quality model proposition.	AHP	Interval-Valued Intuitionistic Fuzzy
Chakraborty et al. (2020)	Airport performance evaluation.	BWM, MABAC	x
Erkan & Elsharida (2020)	Airport site selection.	AHP, ROC	x
Kaya & Erginel (2020)	Sustainable airport design.	SWARA, QFD	Hesitant Fuzzy
Kumar et al. (2020)	Airport green performance evaluation.	BWM, VIKOR	x
Van Asch et al. (2020)	Strategic success factor analysis.	AHP	x

Table 3.1: MCDM methods in the aviation industry literature (2011-2021) (*Continue*)

Source	Aim of the Study	Utilized Technique	Sets
Bakır & Atalık (2021)	Airline e-service quality evaluation.	AHP, MARCOS	Fuzzy
Bakır et al. (2021)	Regional aircraft selection	PIPREICA, MARCOS	Fuzzy
Borjalilu et al. (2021)	Supplier selection.	Entropy, VIKOR	x
Büyüközkan et al. (2021a)	Digital competency evaluation.	AHP, VIKOR	Interval-Valued Intuitionistic Fuzzy
Büyüközkan et al. (2021b)	Digital transformation strategy analysis.	AHP, MARCOS	Fuzzy
Fu et al. (2021)	Duty-free product suppliers' selection	AHP, ARAS, MSGP	Fuzzy, x
Göçmen (2021)	Performance standards and technology evaluation.	AHP	Fuzzy
Huang et al. (2021)	Airport resilience measurement model development.	Bayesian BWM, Modified PROMETHEE	x

3.2. Utilized MCDM Methods

In this thesis study, the AHP and VIKOR methods are used as an integrated methodology. Following that IVIF ANP method is applied. There are different applications of these MCDM methods in the literature. The usability of these methods in the academic literature is shown in Table 3.1. Further explanations are given to support the idea of integrated AHP and VIKOR methodology and the usage of the IVIF ANP method.

The AHP method was proposed by Saaty in 1980 (Saaty, 1980). The AHP method is one of the MCDM methods and it is used to model and solve complex decision-making problems. The wide range of usability of this technique makes the usage rational. Furthermore, it can be clearly said that it is the most used MCDM method, and it is used in different areas for different purposes in the academic literature (Toloie-Eshlaghy & Homayonfar, 2011). Furthermore, the AHP method is quite common in studies concerning the aviation industry (Mardani et al. 2015). There are different advantages of the AHP method. These can be summarized as follows (Narasimhan, 1983, Büyüközkan et al., 2020a):

- The decision-making processes can be converted into formal and systemic structures,
- It provides to convert the complex decision-making problems into a hierarchical structure,
- It is easy to implement and repeat,
- Sensitivity analyses can be conducted over the obtained results,
- It makes it possible to perform sensitivity analysis on the results,
- The method supports the group decision-making,
- It allows conducting consistency checks,
- The AHP method can simplify complex problems,
- DMs in the decision-making processes can assign their goal-oriented preferences accurately,
- Importance degree of the criteria can be assigned based on pairwise comparisons.
- There are many AHP applications in a fuzzy environment (Kahraman et al., 2015).

The problems concerning real-life may be complex. Furthermore, they may include several criteria which are contradictory and non-commensurable. Hence, a solution meeting all the criteria at the same time may not be obtained. In this case, a compromise solution that leads to a final decision can be helpful for the DMs to solve the problem. (Opricovic & Tzeng, 2004). For this, appropriate selection methods should be considered.

VIKOR method is used to obtain the ranked order of the alternatives and to select the most appropriate one among them (Opricovic, 1998). Not only the VIKOR method but also different MCDM techniques such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang & Yoon, 1981) can be utilized to rank the alternatives and to choose one of them. Although it is used for the same purpose, the TOPSIS method finds distance-based solutions. Distance from positive and negative solutions are considered in the method. On the other hand, it does not consider the relationship between the alternatives and the relative distances of these alternatives. VIKOR method provides a feasible solution based on a compromise solution at this point. The obtained feasible solution is a mutual concessions-based solution, and it is the closest to the ideal solution (Opricovic & Tzeng, 2004). The above-mentioned advantages of the AHP and VIKOR methods approve the usability of these methods. Furthermore, the linear structure of the AHP method can be supported with the VIKOR method. The VIKOR method considers the evaluations and assessments of the DMs at the initial level. Hence, integration of these techniques can be taken into consideration to deal with complex decision-making problems efficiently and effortlessly.

The ANP method was proposed by Saaty (1996), and it is seen as the AHP method. The AHP establishes a one-way hierarchical relationship between decision levels. The ANP provides the relationships between decision levels and attributes in a more general form. The ANP-based system offers a network-based system that replaces one-way relationships with dependency and feedback, rather than hierarchy (Saaty, 1996; Büyüközkan & Çifçi, 2012). The basis of the ANP is the pairwise comparisons like in the classical AHP method. The ANP refers to systems in which a level can both directly or indirectly dominate and or be dominated by other decision attributes and levels (Büyüközkan & Çifçi, 2012).

In some cases, there may be a multidirectional relationship among the criteria and a hierarchical structure may not be obtained. In such cases, it may be advantageous to use the ANP. On the other hand, the hierarchical network structure of the ANP method is like the structure of the AHP Method (Ayağ & Özdemir, 2009; Theißen & Spinler, 2014; Büyüközkan et al., 2017). The influence of the networks with dependence and feedback is considered in the ANP method. The elements may be related to each other directly or indirectly. The ability of the ANP method to deal with interdependence among the elements through the computation of the composite weights based on a "supermatrix" which is like the Markov Chain process is an attractive feature of the ANP method (Büyüközkan & Çifçi, 2012).

The main purpose of the ANP method is to go beyond linear relationships and allow interrelationships between items and determine the overall impact of all items (Tuzkaya et al., 2008; Büyüközkan & Öztürkcan, 2010). Furthermore, the ANP method has been widely used in the academic literature in different decision-making problems for various purposes (Büyüközkan & Öztürkcan, 2010).

It is not just about the selection of MCDM techniques suitable for the problem. A real-life problem may contain uncertainty. It can be too complex to model it. In such a case, using classical MCDM methods may not be sufficient. Table 3.1 shows the wide range of usability of the classical fuzzy MCDM methods. However, the decision-making process contains human perception and the decisions of the experts. The opinions and the judgments of the experts or DMs may contain intuition and hesitancy. Dealing with such cases needs more complex typologies and fuzzy extensions to eliminate that intuition and hesitancy. When Table 3.1 is examined, it is seen that the popularity of the usage of these fuzzy extensions with MCDM methods is still limited. From this point of view, the classical AHP, ANP, and VIKOR methods are expanded to the IVIF environment during the analyses of the thesis study.

The following section illustrates the IVIF sets and the integrated IVIF AHP and IVIF VIKOR methodology and IVIF ANP methodology, respectively.

3.3. IVIF MCDM Methods

This section illustrates the IVIF sets, firstly. Following that, the results of the conducted literature review concerning the IVIF MCDM method are presented. Finally, the proposed methodology based on the IVIF AHP, IVIF VIKOR and IVIF ANP methods is explained by giving their computational steps.

3.3.1. Overview of IVIF Sets

This section briefly describes intuitionistic fuzzy (IF) sets, interval-valued intuitionistic fuzzy (IVIF) sets and arithmetic operations concerning them. Real-life problems contain various contradictory criteria, and they are decision-making problems. However, real-life problems are complex. They contain uncertainty and ambiguity. Furthermore, modeling and solving these complex decision-making problems contain human perception. Hence, crisp (ordinary) numbers may be insufficient for these problems. To eliminate the uncertainty Fuzzy Sets are proposed by Zadeh (1965). But human perception, decision-making processes, and uncertainty may contain intuition and hesitations. Hence, there may be a need for more complex typologies. For this purpose, the IF sets developed by Atanassov (1986) are based on the fuzzy set theory developed by Zadeh (1965) and expanded from it. A membership degree is constituted to each element by IFSs. A crisp (fixed) set E is presented by Atanassov where $A \subset E$ and A^* denotes an IFS. Then A^* can be defined in E as follows:

$$A^* = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in E\} \tag{3.1}$$

The functions $\mu_A: E \to [0,1]$ and $\nu_A: E \to [0,1]$ define the degree of membership. Additionally, the non-membership degree of an object is defined as $0 \leq \mu_A(x), \nu_A(x) \leq 1$, $\{\langle x, \mu_A(x), 1 - \mu_A(x)\rangle | x \in E\}$

where

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \tag{3.2}$$

where $x \in E$ for $\forall x \in E$ in the set A. Then $\pi_A(x)$ indicates the uncertainty degree of the membership of element x where $x \in E$. $\pi_A(x) = 0$ for $\forall x \in E$ for classical fuzzy sets. An IFS can be defined as $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in E\}$ in $X = \{x\}$

where

$$\mu_A(x) \to [0,1], \nu_A(x) \to [0,1], \pi_A(x) \to [0,1] \tag{3.3}$$

If the value of $\pi_A(x)$ parameter is greater, than it means that the information about x is limited. But if the value of $\pi_A(x)$ parameter is small, then it represents more information about x. Small parameter means more certainty and greater parameter means more uncertainty and intuition (Boran et al., 2009).

Assume that $\tilde{A}$ is a IFN and membership and non-membership functions of it can be shown as Eq. (3.4) and Eq. (3.5).

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{(x-a)\mu_{\tilde{A}}}{b-a} & (a \leq x < b) \\ \mu_{\tilde{A}} & (x = b) \\ \frac{(c-x)\mu_{\tilde{A}}}{c-b} & (b < x \leq c) \\ 0 & otherwise \end{cases} \tag{3.4}$$

$$\nu_{\tilde{A}}(x) = \begin{cases} \frac{(b-x+\nu_{\tilde{A}}(x-a\prime))}{b-a\prime} & (a' \leq x < b) \\ \nu_{\tilde{A}} & (x = b) \\ \frac{(x-b+\nu_{\tilde{A}}(c\prime-x))}{b-a\prime} & (b < x \leq c') \\ 0 & otherwise \end{cases} \tag{3.5}$$

Then, some arithmetic operations in IFS can be applied as following where $\tilde{A} = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in E\}$,

$\tilde{A}_1 = \{\langle x, \mu_{\tilde{A}_1}(x), \nu_{\tilde{A}_1}(x)\rangle \big| x \in E\}$ and $\tilde{A}_2 = \{\langle x, \mu_{\tilde{A}_2}(x), \nu_{\tilde{A}_2}(x)\rangle \big| x \in E\}$:

$$\tilde{A}_1 + \tilde{A}_2 = \begin{Bmatrix} [x, \mu_{\tilde{A}_1}(x) + \mu_{\tilde{A}_2}(x) - \mu_{\tilde{A}_1}(x).\mu_{\tilde{A}_2}(x), \\ \nu_{\tilde{A}_1}(x).\nu_{\tilde{A}_2}(x)] | x \in E \end{Bmatrix} \tag{3.6}$$

$$\tilde{A}_1.\tilde{A}_2 = \begin{Bmatrix} [x, \mu_{\tilde{A}_1}(x).\mu_{\tilde{A}_2}(x), \\ \nu_{\tilde{A}_1}(x) + \nu_{\tilde{A}_2}(x) - \nu_{\tilde{A}_1}(x).\nu_{\tilde{A}_2}(x)] | x \in E \end{Bmatrix} \tag{3.7}$$

$$n.\tilde{A} = \{[x, 1 - (1 - \mu_A(x))^n, (\nu_A(x))^n] | x \in E\} \tag{3.8}$$

If a problem is complicated and complex, the evaluation of the criteria is harder for the DMs. The aim of proposing the classical fuzzy sets is to deal with human perception-based uncertainty. But problems concerning the accuracy and/or completeness of the information that is incoming may arise when the number of the criteria in the problem, the size, and complexity of the problem increase. In such a case, classical fuzzy sets may become insufficient, and expressing the opinions of the DMs using IF sets may seem advantageous (Büyüközkan & Göçer, 2017).

It is indicated that the IF sets allow to involve more than one DM and make group decision for an element in a set by using functions which are non-membership and membership functions, respectively. Yet, the ability and effectiveness of IVIF sets to model and solve complex problems increase their preferability over IF sets. This is provided by the non-membership and membership functions of an element in an interval in IVIF sets (Büyüközkan et al., 2019). The IVIF sets were introduced by Atanassov and Gargov (1989) as an extension of IFSs.

Let $\tilde{\mu}_{\tilde{A}}(x)$ be the interval-valued membership function and $\tilde{\nu}_{\tilde{A}}(x)$ represents the interval-valued non-membership in an IVIFS. Then, $\tilde{A}$ IVIFS can be defined with $\tilde{\mu}_{\tilde{A}}(x) =$

$[\mu^L_{\tilde{A}}, \mu^U_{\tilde{A}}] \subset [0,1]$ and $\tilde{\nu}_{\tilde{A}}(x) = [\nu^L_{\tilde{A}}, \nu^U_{\tilde{A}}] \subset [0,1]$ intervals where $\mu^L_{\tilde{A}} = inf(\tilde{\mu}_{\tilde{A}}(x)), \mu^U_{\tilde{A}} = sup(\tilde{\mu}_{\tilde{A}}(x))$ and $\nu^L_{\tilde{A}} = inf(\tilde{\nu}_{\tilde{A}}(x)), \nu^U_{\tilde{A}} = sup(\tilde{\nu}_{\tilde{A}}(x))$.

$$0 \leq sup(\tilde{\mu}_{\tilde{A}}(x)) + up(\tilde{\nu}_{\tilde{A}}(x)) \leq 1 \tag{3.9}$$

where $\tilde{\pi}_{\tilde{A}}(x) = [\pi^L_{\tilde{A}}, \pi^U_{\tilde{A}}]$, $x \in E$.

$$\pi^L_{\tilde{A}} = 1 - \mu^U_{\tilde{A}} - \nu^U_{\tilde{A}} \text{ and } \pi^U_{\tilde{A}} = 1 - \mu^L_{\tilde{A}} - \nu^L_{\tilde{A}} \tag{3.10}$$

The lower and upper limits of and IVIF set can be obtained as in Eq. (3.11).

$$\tilde{A} = \langle \tilde{\mu}_{\tilde{A}}(x), \tilde{\nu}_{\tilde{A}}(x), \tilde{\pi}_{\tilde{A}}(x) \rangle = \langle [\mu^L_{\tilde{A}}, \mu^U_{\tilde{A}}], [\nu^L_{\tilde{A}}, \nu^U_{\tilde{A}}], [\pi^L_{\tilde{A}}, \pi^U_{\tilde{A}}] \rangle \tag{3.11}$$

Arithmetic operations of IVIF sets are shown with the following equations. Here let $\tilde{B} = \langle \tilde{\mu}_{\tilde{B}}(x), \tilde{\nu}_{\tilde{B}}(x), \tilde{\pi}_{\tilde{B}}(x) \rangle = \langle [\mu^L_{\tilde{B}}, \mu^U_{\tilde{B}}], [\nu^L_{\tilde{B}}, \nu^U_{\tilde{B}}], [\pi^L_{\tilde{B}}, \pi^U_{\tilde{B}}] \rangle$ is another IVIFS.

$$\tilde{A} \leq \tilde{B} \Leftrightarrow \mu^L_{\tilde{A}} \leq \mu^L_{\tilde{B}}, \mu^U_{\tilde{A}} \leq \mu^U_{\tilde{B}}, \nu^L_{\tilde{B}} \leq \nu^L_{\tilde{A}}, \nu^U_{\tilde{B}} \leq \nu^U_{\tilde{A}} \tag{3.12}$$

$$\tilde{A} \oplus \tilde{B} = \left(\begin{bmatrix} \mu^L_{\tilde{A}} + \mu^L_{\tilde{B}} - \mu^L_{\tilde{A}}\mu^L_{\tilde{B}}, \\ \mu^U_{\tilde{A}} + \mu^U_{\tilde{B}} - \mu^U_{\tilde{A}}\mu^U_{\tilde{B}} \end{bmatrix}, \begin{bmatrix} \nu^L_{\tilde{A}}\nu^L_{\tilde{B}}, \\ \nu^U_{\tilde{A}}\nu^U_{\tilde{B}} \end{bmatrix} \right) \tag{3.13}$$

$$\tilde{A} \ominus \tilde{B} =$$

$$\begin{cases} \left(\left[\frac{\mu^L_{\tilde{A}} - \mu^L_{\tilde{B}}}{1 - \mu^L_{\tilde{B}}}, \frac{\mu^U_{\tilde{A}} - \mu^U_{\tilde{B}}}{1 - \mu^U_{\tilde{B}}} \right], \left[\frac{\nu^L_{\tilde{A}}}{\nu^L_{\tilde{B}}}, \frac{\nu^U_{\tilde{A}}}{\nu^U_{\tilde{B}}} \right] \right), & \begin{array}{c} if\, \mu^L_{\tilde{A}} \geq \mu^L_{\tilde{B}}, \mu^U_{\tilde{A}} \geq \mu^U_{\tilde{B}}, \nu^L_{\tilde{A}} \leq \nu^L_{\tilde{B}}, \nu^U_{\tilde{A}} \leq \nu^U_{\tilde{B}} \\ and\ \nu^L_{\tilde{B}} > 0, \nu^U_{\tilde{B}} > 0 \\ and\ \nu^L_{\tilde{A}}(1 - \mu^L_{\tilde{B}}) \leq \nu^L_{\tilde{B}}(1 - \mu^L_{\tilde{A}}) \\ and\ \nu^U_{\tilde{A}}(1 - \mu^U_{\tilde{B}}) \leq \nu^U_{\tilde{B}}(1 - \mu^U_{\tilde{A}}) \end{array} \\ ([0,0], [1,1]), & Otherwise \end{cases} \tag{3.14}$$

$$\tilde{A} \otimes \tilde{B} = \left(\begin{bmatrix} \mu^L_{\tilde{A}}\mu^L_{\tilde{B}}, \\ \mu^U_{\tilde{A}}\mu^U_{\tilde{B}} \end{bmatrix}, \begin{bmatrix} \nu^L_{\tilde{A}} + \nu^L_{\tilde{B}} - \nu^L_{\tilde{A}}\nu^L_{\tilde{B}}, \\ \nu^U_{\tilde{A}} + \nu^U_{\tilde{B}} - \nu^U_{\tilde{A}}\nu^U_{\tilde{B}} \end{bmatrix} \right) \tag{3.15}$$

$$\frac{\tilde{A}}{\tilde{B}} = \begin{cases} \left(\left[\frac{\mu_{\tilde{A}}^{L}}{\mu_{\tilde{B}}^{L}}, \frac{\mu_{\tilde{A}}^{U}}{\mu_{\tilde{B}}^{U}} \right], \left[\frac{\nu_{\tilde{A}}^{L} - \nu_{\tilde{B}}^{L}}{1 - \nu_{\tilde{B}}^{L}}, \frac{\nu_{\tilde{A}}^{U} - \nu_{\tilde{B}}^{U}}{1 - \nu_{\tilde{B}}^{U}} \right], \right), & \begin{array}{c} if\, \mu_{\tilde{A}}^{L} \leq \mu_{\tilde{B}}^{L}, \mu_{\tilde{A}}^{U} \leq \mu_{\tilde{B}}^{U}, \nu_{\tilde{A}}^{L} \geq \nu_{\tilde{B}}^{L}, \nu_{\tilde{A}}^{U} \geq \nu_{\tilde{B}}^{U} \\ and\ \mu_{\tilde{B}}^{L} > 0, \mu_{\tilde{B}}^{U} > 0 \\ and\ \mu_{\tilde{A}}^{L}(1 - \nu_{\tilde{B}}^{L}) \leq \mu_{\tilde{B}}^{L}(1 - \nu_{\tilde{A}}^{L}) \\ and\ \mu_{\tilde{A}}^{U}(1 - \nu_{\tilde{B}}^{U}) \leq \mu_{\tilde{B}}^{U}(1 - \nu_{\tilde{A}}^{U}) \end{array} \\ ([0,0],[1,1]), & Otherwise \end{cases}$$

(3.16)

$$\lambda\tilde{A} = \left(\left[1 - \left(1 - \mu_{\tilde{A}}^{L}\right)^{\lambda} \right], \left[1 - \left(1 - \mu_{\tilde{A}}^{U}\right)^{\lambda} \right], \left[\left(\nu_{\tilde{A}}^{L}\right)^{\lambda} \right], \left[\left(\nu_{\tilde{A}}^{U}\right)^{\lambda} \right] \right) \qquad (3.17)$$

$$\left(\tilde{A}\right)^{\lambda} = \left(\left[\left(\mu_{\tilde{A}}^{L}\right)^{\lambda} \right], \left[\left(\mu_{\tilde{A}}^{U}\right)^{\lambda} \right], \left[1 - \left(1 - \nu_{\tilde{A}}^{L}\right)^{\lambda} \right], \left[1 - \left(1 - \nu_{\tilde{A}}^{U}\right)^{\lambda} \right] \right) \qquad (3.18)$$

3.3.2. Review on IVIF MCDM Methods

To show the usage of the AHP and VIKOR methods with IF and IVIF sets, a literature survey is conducted. The academic literature contains different scientific studies concerning the IF and IVIF sets-based MCDM applications. Each has a different scope, purpose, and application area. Büyüközkan et al. (2018) apply different IVIF MCDM methods for cloud computing technology selection. Şenel et al. (2018) analyze the failures modes and risks concerning the ports using the FMEA-based IF TOPSIS methodology. Yeni & Özçelik (2019) utilize the IVIF CODAS method for a personnel selection problem. Aviation 4.0 success factors are analyzed by a combined IF AHP and IF VIKOR methodology by Büyüközkan et al. (2020b). Further information concerning the conducted literature survey is provided in Table 3.2.

Also, studies are using the combination of AHP and VIKOR methods as an approach in the IF and IVIF environment. By considering the capability of IVIF sets to deal with uncertainty, hesitancy, and intuition in modeling and solving complex problems, the IVIF AHP and the IVIF VIKOR methods have been used as an integrated methodology in this thesis study. On the other hand, the usage of the IVIF ANP method is limited in the academic literature. Wang et al. (2016) apply the IVIF ANP method to evaluate the risks in healthcare industry. Critical factors are determined, and these factors are evaluated for nanotechnology application in construction industry using the IF ANP method by Shariati et al. (2017). Büyüközkan et al. (2017) conduct CRM partner evaluation in textile industry using the IF ANP method.

Table 3.2: Usage of IF and IVIF sets with MCDM methods

Sources	Application Area	Aim of the study	Techniques Used	Operator	Case
Abdullah & Najib (2014)	Sustainable energy	Technology selection	IF AHP	IFWA	✓
Abdullah & Najib (2016)	MCDM	Scale development	IVIF AHP	IVIFWA	x
Budak et al. (2020)	Humanitarian Relief Logistics	RTLS technology selection	IVIF DEMATEL, IVIF ANP, IVIF TOPSIS	x	✓
Büyüközkan et al. (2017)	Manufacturing	CRM partner selection	IF DEMATEL, IF ANP	IFWA	x
Büyüközkan & Göçer (2017)	Sporting good group operating	Supplier selection	IF AHP, IF AD	IFWA	✓
Büyüközkan & Güleryüz (2016)	Product development	Partner selection	IF AHP, IF TOPSIS	IFWA	✓
Büyüközkan et al. (2019)	Hazardous waste	Carrier selection	IF AHP, IF VIKOR	IEWA	✓
Büyüközkan et al. (2020a)	Airline industry	DSQ evaluation	IVIF AHP	IIFWA	✓
Büyüközkan et al. (2021a)	Airline industry	Airline selection	IVIF AHP, IVIF VIKOR	IIFWA	✓
Büyüközkan et al. (2018)	Cloud computing	Provider selection	IVIF AHP, IVIF COPRAS, IVIF MULTIMOORA, IVIF VIKOR	IIFWA	✓
Çalı & Balaman (2018)	Automotive industry	Supplier selection	IF VIKOR, IF ELECTRE	IFWA	x
Devi (2011)	Manufacturing	Robot selection	IF VIKOR	x	x

Table 3.2: Usage of IF and IVIF sets with MCDM methods (*continue*)

Sources	Application Area	Aim of the study	Techniques Used	Operator	Case
Hinduja & Pandey (2018)	Life insurance product	Performance evaluation	IF AHP	x	x
Li et al. (2018)	Innovation technology	Partner selection	IF VIKOR, Dynamic IF	DIFWG	x
Kuo & Liang (2012)	Transportation	Performance evaluation	IVIF VIKOR	x	✓
Li et al. (2019)	Steel industry	Risk evaluation	IVIF FMEA, IVIF MULTIMOORA	IVIFPWA	✓
Liu (2019)	Healthcare	Risk assessment	IVIF ANP, IVIF COPRAS	IIFOWA	x
Mousavi et al. (2016)	Investment	Portfolio selection	IF VIKOR	IFWA	x
Onar et al. (2015)	Energy	Technology selection	IVIF AHP	IIFWA	✓
Ouyang & Guo (2018)	Wastewater treatment	Paradigm selection	IF AHP	IFWA	✓
Oztaysi et al. (2017)	Energy	Technology selection	IVIF Preference Relations, IVIF TOPSIS	IVIFWA	✓
Sun (2017)	Web	Service selection	IF AHP, IF VIKOR, GRA	x	x
Vahdani et al. (2010)	Maintenance	Strategy selection	IVIF VIKOR	x	x
Wan et al. (2013)	Investment	Personnel selection	IF VIKOR	TIFWA	x
Wang et al. (2016)	Healthcare	Risk assessment	IVIF ANP IVIF COPRAS	IIFOWA	x
Yu et al. (2018)	Transitional public-private partnership	Risk evaluation	IF AHP	x	✓
Zhao et al. (2017)	Healthcare	Supplier selection	IF VIKOR, IF Entropy	SIFWA	x

The IVIF ANP method is applied to healthcare industry to assess the risks by Liu (2019). Karaşan & Kahraman (2019) apply the IF ANP method for location selection in freight village area. Cloud-based ERP systems are evaluated by Hinduja & Pandey (2019) in SMEs industry using the IF ANP method. The IF ANP method is applied to investment sector to assess the investor sentiments by Zhou et al. (2020). Yang et al. (2020) propose a method for the ANP method using the IVIF ANP method. The IVIF ANP method is applied to Fog-IoT security sector to evaluate the security attributes by Verma & Chandra (2020). There is a gap in the literature. Hence, the last case study in this thesis study uses the IVIF ANP method for the validation of the proposed model. The following section explains the computational steps of the integrated IVIF methodology and IVIF ANP method, respectively.

3.4. Proposed Methodology

In this part of the thesis study, the proposed IVIF MCDM methodologies have been introduced with their computational steps.

3.4.1. Clarification of the Proposed Methodology

In the above sections, it is explained why the MCDM approach and why AHP, VIKOR and ANP techniques were used in this thesis study. Furthermore, it has been illustrated why these techniques are applied as IVIF AHP, IVIF VIKOR and IVIF ANP. This section provides details on how these techniques are used. According to the structures and types of the focused decision-making problems in this thesis study, these techniques have been applied in some parts as an integrated IVIF MCDM approach. In some parts, however, the structure of the problem is found to be suitable for the use of the IVIF ANP methodology rather than an integrated approach. From this point of view, the computational steps of these techniques are detailed in following sections of this part. The computational steps of the methods in the proposed methodologies are detailed in the following sections separately to provide clarity about the application of these steps. On the other hand, the flow of the computational steps of the proposed methodologies are shown in Figure 3.1 and Figure 3.2 to show the overall perspective of these methodologies.

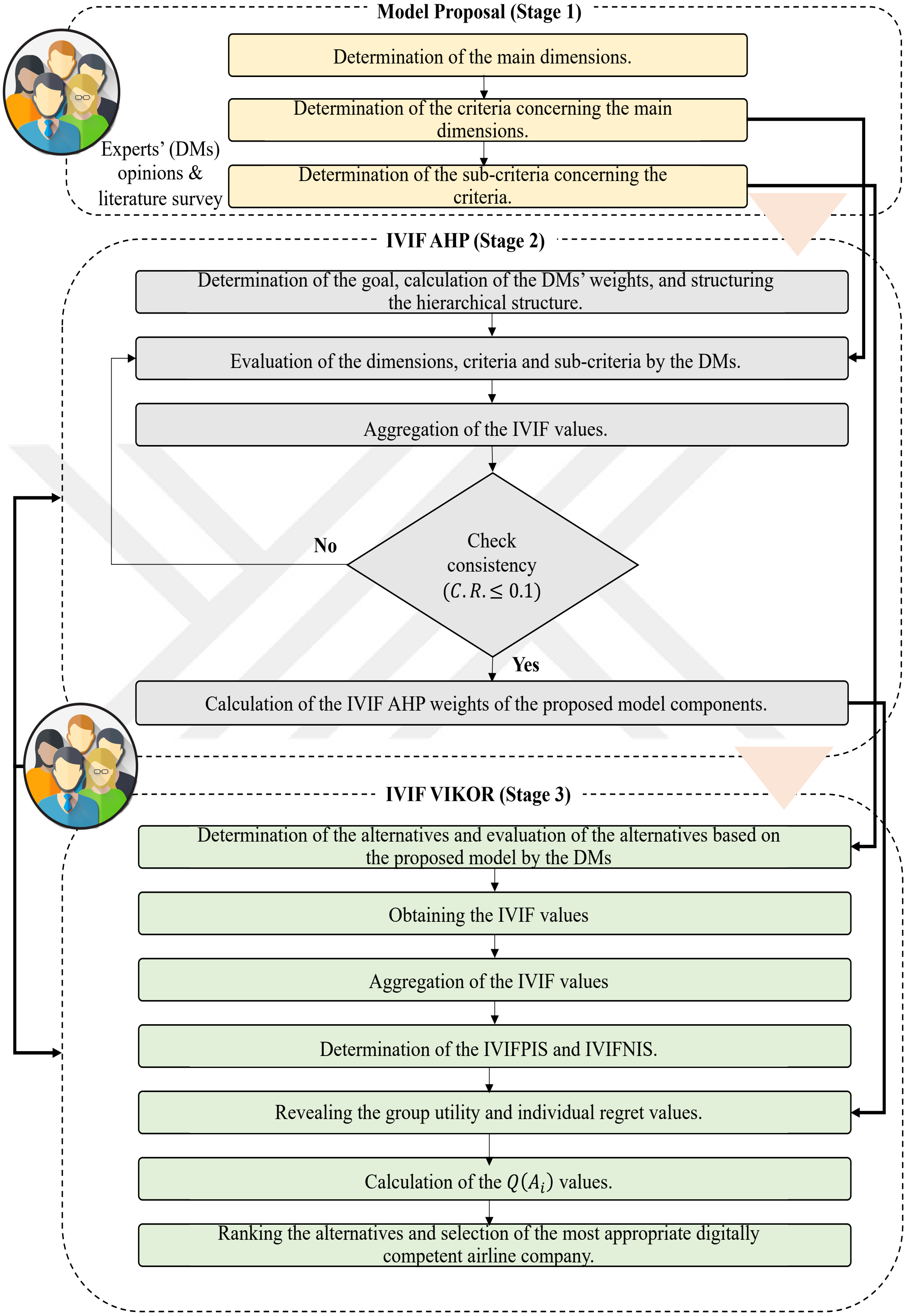


Figure 3.1: The steps of the proposed integrated IVIF MCDM methodology

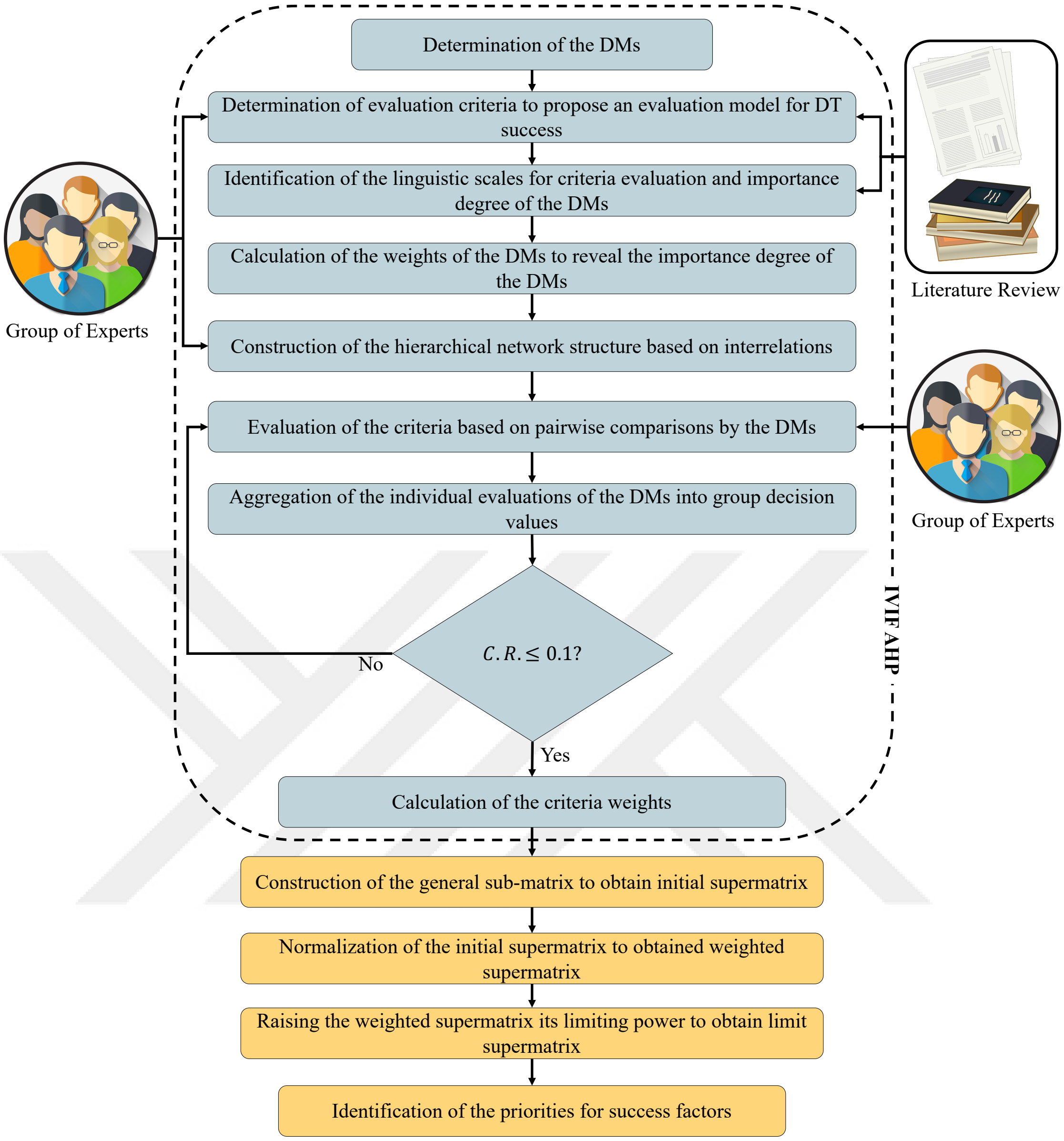


Figure 3.2: The steps of the proposed IVIF ANP methodology

3.4.2. Computational Steps of the IVIF AHP Method

Computational steps of the IVIF AHP method adopted from Abdullah and Najib (2016), and Büyüközkan et al. (2018) are presented as follows:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information and knowledge level, and willingness to help of them are considered as the determination criteria.

Step2. Determination of the goal and the evaluation criteria:

The goal is identified based on the problem and its structure. A set of evaluation criteria concerning the identified goal is determined based on a literature survey and the opinions of the DMs.

Step 3. Designation of the scales:

Appropriate evaluation scales to obtain the importance degrees and weights of the DMs and evaluate the criteria are developed or adopted from the scientific studies in the academic literature.

Step 4. Restructuring the problem:

A hierarchical structure is constructed to model and solve the decision-making problem.

Step 5. Calculation of the weights of the DMs:

The importance degree of the determined DMs is assigned using the linguistic terms given in Table 3.3 by considering the criteria introduced in Step 1. Following that, the weights of the DMs are calculated using Eq. (3.19) based on the assigned linguistic term.

$$\lambda^{(k)} = \frac{\sqrt{\frac{1}{2}\left[\left(1-\pi_{\tilde{A}}^{L^{(k)}}\right)^2+\left(1-\pi_{\tilde{A}}^{U^{(k)}}\right)^2\right]}}{\sum_{k=1}^{K}\sqrt{\frac{1}{2}\left[\left(1-\pi_{\tilde{A}}^{L^{(k)}}\right)^2+\left(1-\pi_{\tilde{A}}^{U^{(k)}}\right)^2\right]}} \tag{3.19}$$

Let $\lambda^{(k)}$ be the weight of the k^{th} DM where $\lambda^{(k)} = \left\{\lambda^{(1)}, \lambda^{(2)}, \dots, \lambda^{(K)}\right\}$ represent the set of the weights of K number of DMs and $\sum_{k=1}^{k} \lambda^{(k)} = 1$.

Table 3.3: Linguistic scale for the weights of the DMs (Büyüközkan et al., 2018)

Linguistic Expressions	**IVIF Values**	
	$\tilde{\mu}_{\tilde{A}}(x)$ $\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\tilde{v}_{\tilde{A}}(x)$ $\left[v_{\tilde{A}}^{L}, v_{\tilde{A}}^{U}\right]$
Extremely qualified (EQ)	[0.95, 1.00]	[0.00, 0.00]
Very qualified (VQ)	[0.80, 0.85]	[0.05, 0.10]
Qualified (Q)	[0.60, 0.65]	[0.10, 0.15]
Less qualified (LQ)	[0.30, 0.35]	[0.25, 0.30]
Very less qualified (VLQ)	[0.20, 0.25]	[0.30, 0.35]
Extremely less qualified (ELQ)	[0.00, 0.05]	[0.45, 0.50]

Step 6. Evaluation of the criteria:

The judgments of the DMs are obtained through the linguistic terms given in Table 3.4 based on pairwise comparisons.

Table 3.4: The linguistic scale for criteria evaluation (Abdullah and Najib, 2016)

Linguistic terms	IVIF values	
	$\tilde{\mu}_{\tilde{A}}(x)$ $\left[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U\right]$	$\tilde{v}_{\tilde{A}}(x)$ $\left[v_{\tilde{A}}^L, v_{\tilde{A}}^U\right]$
Equally important (EI)	[0.38, 0.42]	[0.22, 0.58]
Intermediate value (IV)	[0.29, 0.41]	[0.12, 0.58]
Moderately more important (MMI)	[0.10, 0.43]	[0.03, 0.57]
Intermediate value (IV2)	[0.03, 0.47]	[0.03, 0.53]
Strongly more important (SMI)	[0.13, 0.53]	[0.07, 0.47]
Intermediate value (IV3)	[0.32, 0.62]	[0.08, 0.38]
Very strongly more important (VSMI)	[0.52, 0.72]	[0.08, 0.28]
Intermediate value (IV4)	[0.75, 0.85]	[0.05, 0.15]
Extremely more important (EMI)	[1.00, 1.00]	[0.00, 0.00]
Linguistic terms	**Reciprocal IVIF values**	
	$\tilde{\mu}_{\tilde{A}}(x)$ $\left[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U\right]$	$\tilde{v}_{\tilde{A}}(x)$ $\left[v_{\tilde{A}}^L, v_{\tilde{A}}^U\right]$
Equally important (EI)	[0.22, 0.58]	[0.38, 0.42]
Intermediate value (IV)	[0.12, 0.58]	[0.29, 0.41]
Moderately more important (MMI)	[0.03, 0.57]	[0.10, 0.43]
Intermediate value (IV2)	[0.03, 0.53]	[0.03, 0.47]
Strongly more important (SMI)	[0.07, 0.47]	[0.13, 0.53]
Intermediate value (IV3)	[0.08, 0.38]	[0.32, 0.62]
Very strongly more important (VSMI)	[0.08, 0.28]	[0.52, 0.72]
Intermediate value (IV4)	[0.05, 0.15]	[0.75, 0.85]
Extremely more important (EMI)	[0.00, 0.00]	[1.00, 1.00]

Step 7. Aggregation:

First, the linguistic term-based judgments of the DMs are converted into IVIF values at this step. Following that, individual evaluations of the DMs are integrated to obtain group decision values using Eq. (3.20). The IIFWA operator proposed by Xu & Cai (2012) is utilized for the aggregation process.

$$IIFWA = \left(\begin{bmatrix} 1 - \prod_{k=1}^{K}\left(1 - \mu_{\tilde{A}}^{L}\right)^{\lambda^{(k)}}, \\ 1 - \prod_{k=1}^{K}\left(1 - \mu_{\tilde{A}}^{U}\right)^{\lambda^{(k)}} \end{bmatrix}, \begin{bmatrix} \prod_{k=1}^{K}\left(v_{\tilde{A}}^{L}\right)^{\lambda^{(k)}}, \\ \prod_{k=1}^{K}\left(v_{\tilde{A}}^{U}\right)^{\lambda^{(k)}} \end{bmatrix}\right) \tag{3.20}$$

where $\sum_{k=1}^{K} \lambda^{(k)} = 1$.

Step 8. Consistency check:

A consistency ratio $(C.R.)$ is computed at this step using the Eq. (3.21) adopted from Abdullah & Najib (2016). The ratio is used to evaluate the consistency of the evaluation of the DMs and the decision-making process. If $C.R. \leq 0.1$, then the evaluations are consistent. Otherwise, it means that there is inconsistency, and the evaluation process should be revised.

$$C.R. = \frac{RI - \frac{\sum \pi_{ij}^{U}(x)}{z}}{z-1} \tag{3.21}$$

Here, $\pi_{ij}^{U}(x)$ indicates the hesitation value (Abdullah & Najib, 2016) where z shows the number of the criteria, and RI represents randomness indices in Table 3.5.

Table 3.5: Randomness indices (Saaty, 1977)

z	1-2	3	4	5	6	7	8	9
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Step 9. Calculation of the criteria weights:

Let $w = \{w_1, w_2, \dots w_n\}$ be the set of criteria weights where $\sum_{j=1}^{n} w_j = 1$ and $w_j \geq 0, j = 1,2,\dots,n$. The weights of the criteria can be calculated through the Eq. (3.22).

$$w_j = \frac{1-\widetilde{w}_j}{n-\sum_{j=1}^{n}\widetilde{w}_j} \tag{3.22}$$

$$\widetilde{w}_j = 1 - \frac{\sum_{k=1}^{K}\frac{\lambda^{(k)}\left(\mu_{\widetilde{A}_j}^{L}+\mu_{\widetilde{A}_j}^{U}\right)}{2}}{\sqrt{\sum_{k=1}^{K}\frac{\lambda^{(k)}\left({\mu_{\widetilde{A}_j}^{L}}^{2}+{\mu_{\widetilde{A}_j}^{U}}^{2}+{\nu_{\widetilde{A}_j}^{L}}^{2}+{\nu_{\widetilde{A}_j}^{U}}^{2}\right)}{2}}}. \tag{3.23}$$

3.4.3. Computational Steps of the IVIF ANP Method

Computational steps of the classical ANP method (Cheng & Li, 2005; Lin et al., 2008; Saaty, 2001; Büyüközkan & Öztürkcan, 2010) adapted to the IVIF ANP method are illustrated in Figure 3.2 and given as follows:

Step 1. Development of the decision model:

A model should be structured based on a network system. The structure is constructed through brainstorming conducted by the DMs or literature survey.

Step 2. Computation of the Eigenvectors:

The computational steps of the IVIF AHP method are applied to obtain the relative weightings and eigenvectors by considering the structure of the ANP model.

Step 3. Construction of the General Sub-Matrix:

A general sub-matrix based on the determined relations is constructed for the supermatrix. A supermatrix is a split matrix consisting of local priority vectors entered the appropriate columns of a matrix, where each matrix segment represents a relationship between two nodes (components or clusters) (Büyüközkan & Çifçi, 2012a).

Step 4: Computation of the Limit Supermatrix:

The supermatrix must first be transformed to make it stochastic. For this purpose, the initial supermatrix should be normalized and weighted. It means that the sum of each matrix column should reach unity. A normalized supermatrix is also called a weighted supermatrix. The weighted supermatrix is then raised to limiting powers until the weights converge and remain constant. The obtained matrix is called a limit supermatrix (Büyüközkan & Çifçi, 2012a).

Step 5: Determination of the priorities:

The priorities of the criteria are obtained through the limit supermatrix.

3.4.4. Computational Steps of the IVIF VIKOR Method

Computational steps of the IVIF VIKOR method adopted from Li & Jiang (2011) and Büyüközkan et al. (2018) are presented as follows:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information, and knowledge level and willingness to help are considered as the determination criteria.

Step 2. Determination of the goal and the evaluation criteria:

The goal is identified based on the problem and its structure. A set of evaluation criteria concerning the identified goal is determined based on a literature survey and the opinions of the DMs. The evaluation criteria are used to evaluate the alternatives.

Step 3. Determination of the set of alternatives:

A set of suitable alternatives are determined at this step.

Step 4. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the alternatives over the evaluation criteria are developed or adopted from the scientific studies in the academic literature.

Step 5. Calculation of the weights of the DMs:

The importance degree of the determined DMs is assigned using the linguistic terms given in Table 3.3 by considering the criteria introduced in Step 1. Following that, the weights of the DMs are calculated using Eq. (3.19) based on the assigned linguistic term.

Step 6. Evaluation of the alternatives:

The judgments of the DMs for the alternatives are obtained based on the evaluation criteria. The linguistic terms given in Table 3.6 are used to assess the alternatives.

Step 7. Aggregation:

The linguistic terms that are used to evaluate the alternatives are transformed into IVIF values and these IVIF values are aggregated to obtained group-decision matrix $(\tilde{X})$. Let $\tilde{X}$ contain m alternatives and n criteria and consist of $\tilde{x}_{ij} = \left[\mu_{\tilde{A}}^{L}(\tilde{x}_{ij}), \mu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right], \left[\nu_{\tilde{A}}^{L}(\tilde{x}_{ij}), \nu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right]$ where $i = 1,2, \dots, m$ and $j = 1,2, \dots, n$. Aggregation is computed using the IIFWA operator proposed by Xu & Cai (2012) as indicated in Eq. (3.20).

Table 3.6: The linguistic scale to evaluate the alternatives (Büyüközkan et al., 2018)

Linguistic Expressions	IVIF Values	
	$\tilde{\mu}_{\tilde{A}}(x)$ $[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}]$	$\tilde{\nu}_{\tilde{A}}(x)$ $[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}]$
Extremely good (EG)	[0.990, 1.000]	[0.000, 0.000]
Very very good (VVG)	[0.900, 0.950]	[0.010, 0.040]
Very good (VG)	[0.800, 0.850]	[0.050, 0.100]
Good (G)	[0.700, 0.750]	[0.150, 0.200]
Medium good (MG)	[0.600, 0.650]	[0.250, 0.300]
Medium (M)	[0.500, 0.550]	[0.350, 0.400]
Medium bad (MB)	[0.400, 0.450]	[0.450, 0.500]
Bad (B)	[0.300, 0.350]	[0.550, 0.600]
Very bad (VB)	[0.200, 0.250]	[0.650, 0.700]
Very very bad (VVB)	[0.100, 0.150]	[0.750, 0.800]
Extremely bad (EB)	[0.000, 0.000]	[0.990, 1.000]

Step 8. Calculation of the positive and negative ideal solutions:

Let $(\tilde{f}_j^*)$ be the IVIF positive ideal solution (IVIFPIS) and $(\tilde{f}_j^-)$ be the IVIF negative ideal solution (IVIFNIS). $\tilde{f}_j^*$ can be obtained using Eq. (3.24) where $\tilde{f}_j^-$ can be determined using Eq. (3.25), respectively.

$$\tilde{f}_j^* = \langle [\mu_{\tilde{A}}^{L}(\tilde{x}_j^*), \mu_{\tilde{A}}^{U}(\tilde{x}_j^*)], [\nu_{\tilde{A}}^{L}(\tilde{x}_j^*), \nu_{\tilde{A}}^{U}(\tilde{x}_j^*)] \rangle \tag{3.24}$$

Here,

$$\left\langle \begin{array}{c} \left[\mu_{\tilde{A}}^{L}(\tilde{x}_j^*) = \max\limits_i \left(\mu_{\tilde{A}}^{L}(\tilde{x}_{ij})\right),\ \mu_{\tilde{A}}^{U}(\tilde{x}_j^*) = \max\limits_i \left(\mu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right)\ \right], \\ \left[\nu_{\tilde{A}}^{L}(\tilde{x}_j^*) = \min\limits_i \left(\nu_{\tilde{A}}^{L}(\tilde{x}_{ij})\right), \nu_{\tilde{A}}^{U}(\tilde{x}_j^*) = \min\limits_i \left(\nu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right)\right] \end{array} \right\rangle.$$

$$\tilde{f}_j^- = \langle [\mu_{\tilde{A}}^{L}(\tilde{x}_j^-), \mu_{\tilde{A}}^{U}(\tilde{x}_j^-)], [\nu_{\tilde{A}}^{L}(\tilde{x}_j^-), \nu_{\tilde{A}}^{U}(\tilde{x}_j^-)] \rangle \tag{3.25}$$

Here,

$$\left\langle \begin{array}{c} \left[\mu_{\tilde{A}}^{L}(\tilde{x}_j^-) = \min\limits_i \left(\mu_{\tilde{A}}^{L}(\tilde{x}_{ij})\right),\ \mu_{\tilde{A}}^{U}(\tilde{x}_j^-) = \min\limits_i \left(\mu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right)\ \right], \\ \left[\nu_{\tilde{A}}^{L}(\tilde{x}_j^-) = \max\limits_i \left(\nu_{\tilde{A}}^{L}(\tilde{x}_{ij})\right), \nu_{\tilde{A}}^{U}(\tilde{x}_j^-) = \max\limits_i \left(\nu_{\tilde{A}}^{U}(\tilde{x}_{ij})\right)\right] \end{array} \right\rangle.$$

Step 9. Computation of the group utility and individual regret values:

Let $S(A_i)$ represent the group utility value, and $R(A_i)$ indicates the individual regret. $S(A_i)$ can be computed through the Eq. (3.26) where $R(A_i)$ value can be calculated using the Eq. (3.27).

$$S(A_i) = \sum_{j=1}^{n} \left[w_j \frac{d(\tilde{f}_j^*, \tilde{x}_{ij})}{d(\tilde{f}_j^*, \tilde{f}_j^-)} \right] \quad (3.26)$$

$$R(A_i) = \max_j \left[w_j \frac{d(\tilde{f}_j^*, \tilde{x}_{ij})}{d(\tilde{f}_j^*, \tilde{f}_j^-)} \right] \quad (3.27)$$

$$d(\tilde{f}_j^*, \tilde{x}_{ij}) = \frac{1}{4} \begin{pmatrix} \left|\mu_{\tilde{A}}^L(\tilde{x}_j^*) - \mu_{\tilde{A}}^L(\tilde{x}_{ij})\right| + \left|\mu_{\tilde{A}}^U(\tilde{x}_j^*) - \mu_{\tilde{A}}^U(\tilde{x}_{ij})\right| \\ +\left|\nu_{\tilde{A}}^L(\tilde{x}_j^*) - \nu_{\tilde{A}}^L(\tilde{x}_{ij})\right| + \left|\nu_{\tilde{A}}^U(\tilde{x}_j^*) - \nu_{\tilde{A}}^U(\tilde{x}_{ij})\right| \\ +\left|\pi_{\tilde{A}}^L(\tilde{x}_j^*) - \pi_{\tilde{A}}^L(\tilde{x}_{ij})\right| + \left|\pi_{\tilde{A}}^U(\tilde{x}_j^*) - \pi_{\tilde{A}}^U(\tilde{x}_{ij})\right| \end{pmatrix} \quad (3.28)$$

$$d(\tilde{f}_j^*, \tilde{f}_j^-) = \frac{1}{4} \begin{pmatrix} \left|\mu_{\tilde{A}}^L(\tilde{x}_j^*) - \mu_{\tilde{A}}^L(\tilde{x}_j^-)\right| + \left|\mu_{\tilde{A}}^U(\tilde{x}_j^*) - \mu_{\tilde{A}}^U(\tilde{x}_j^-)\right| \\ +\left|\nu_{\tilde{A}}^L(\tilde{x}_j^*) - \nu_{\tilde{A}}^L(\tilde{x}_j^-)\right| + \left|\nu_{\tilde{A}}^U(\tilde{x}_j^*) - \nu_{\tilde{A}}^U(\tilde{x}_j^-)\right| \\ +\left|\pi_{\tilde{A}}^L(\tilde{x}_j^*) - \pi_{\tilde{A}}^L(\tilde{x}_j^-)\right| + \left|\pi_{\tilde{A}}^U(\tilde{x}_j^*) - \pi_{\tilde{A}}^U(\tilde{x}_j^-)\right| \end{pmatrix} \quad (3.29)$$

Step 10. Calculation of the $\boldsymbol{Q(A_i)}$ values:

$Q(A_i)$ values are computed using the Eq. (3.30).

$$Q(A_i) = \upsilon \left(\frac{S(A_i) - S^*(A_i)}{S^-(A_i) - S^*(A_i)} \right) + (1 - \upsilon) \left(\frac{R(A_i) - R^*(A_i)}{R^-(A_i) - R^*(A_i)} \right) \quad (3.30)$$

Here,

$$S^*(A_i) = \min_i \big(S(A_i)\big),\ S^-(A_i) = \max_i \big(S(A_i)\big)$$

$$R^*(A_i) = \min_i \big(R(A_i)\big),\ R^-(A_i) = \max_i \big(R(A_i)\big).$$

The weight of the strategy concerning the decision-making can be represented with υ. The weight υ indicates the majority of the criteria. Generally, υ can be taken as 0.5 for the maximum group utility (consensus) (Opricovic & Tzeng, 2004).

Step 11. Ranked order of the alternatives:

The ascending order of the $S(A_i)$, $R(A_i)$ and $Q(A_i)$ values are used to rank the alternatives based on the classic VIKOR method (Opricovic, 1998). Let A_i represent an alternative and be the smallest one in the ranking of $Q(A_i)$ with respect to $Q_{[1]}$. Then, it is evaluated as a compromise solution if:

I. $Q_{[2]} - Q_{[1]} \geq DQ$ the alternative A_i has an acceptable advantage where $DQ = \frac{1}{z}$. Here, let z be the number of the alternatives.

II. The alternative A_i is constant in the decision-making process and ranked order of $S_{[i]}$ and/or $R_{[i]}$ values show that it is the best If none of them is met, then it is a set of compromise solutions including:

a) The alternatives are A_i and A_{i+2} where $Q_{[A_{i+2}]} = Q_{[2]}$if only the condition II is not satisfied, or

b) The alternatives are $A_1, A_2, \dots, A_z$ if the condition I is not satisfied and A_z is determined by the $Q_{[z]} - Q_{[1]} < DQ$ relation for maximum z where $Q(A_z) = Q_{[z]}$ (This means that the ranking of these alternatives is in closeness).

4. PROPOSITION OF DIGITAL TRANSFORMATION COMPETENCY EVALUATION FRAMEWORK FOR AVIATION INDUSTRY

This chapter of the thesis study proposes a general framework for DT competency evaluation. The proposed framework consists of a DT competency evaluation (DTCE) model and the validation of the proposed model using integrated IVIF MCDM methodology. This chapter contains four main sections as follows: Literature review concerning the low-cost airline industry has been introduced in the first section. The second section proposes the DTCE model. Application of the proposed methodology to a real case in aviation industry is given in third section. Finally, results are discussed in the fourth section. Details concerning these sections are presented below.

4.1. Literature Review

In recent years, low costs have explosive, dynamic, and thrilling developments in commercial aviation history. They have restructured passenger experiences and operational practices and influenced both environmental and socio-economical areas. Furthermore, low costs have made possible what was not possible before. The number of the passengers who fly to different destinations has been increased and they made it at a lower cost. This is provided by the developed applications and reaching the cheaper tickets has become easy. The aim of launching the applications was to minimize the costs concerning the operations of air service and increase the market share. This has increased the new demands. It is worth noting a remarkable fact about low-cost airline companies that their business models have been adopted by companies from many different sectors due to the philosophy behind their business models (Ison, 2017; Büyüközkan et al., 2021a).

The origin of the low-cost business models is Pacific Southwest Airline. The business model was developed by this airline company to offer low prices to the air travelers in 1970 in the USA (Diaconu & Popescu, 2011; Dinler &Rankin, 2018). Originally, the low costs have implemented business models to provide services at secondary airports due to their capability of providing low operational costs, planning operations, rapid services, and runway availability (Álvarez-Díaz, 2019). The main consideration of these models is to simplify the operations for maximizing efficiency while minimizing the costs (Doganis, 2009; Dinler & Rankin, 2018). The short-haul point-to-point services have been adopted by most of the low costs to conduct more landings and take-offs by spending less time on the ground (Gillen & Lall, 2004; Pan & Truong, 2018). Yet, they have changed their business models and strategies to comply with the differentiated market conditions (Dziedzic & Warnock-Smith, 2016).

Lately, they are offering services at budget-friendly prices through the primary airports in the market of long-haul. Additionally, they have started to embrace business models which are hybrid (Fageda et al., 2015). Now, the differences concerning the regions, expectations of the passengers, and the intense competition in the airline market are restructuring the strategies of the low-cost airline companies (Boeing, 2017; Dinler & Rankin, 2018). In addition to all these, the market of low cost has been facing a new era which is the era of DT. The DT has been penetrating the low costs for the last decade.

Lately launched digital technologies and the DT have changed the ecosystems where the companies exist. Increased internet access and technology-based developments have differentiated customers. This has forced companies to transform in offering products and services that can adapt to changing customer demands. On the one hand, DT requires radical changes and complying with these changes by appropriate management. However, it provides numerous benefits. Hence, focusing on being competent has become an important point. DT competency can deal with the disruptive power of the DT and competition in the market of different industries (Büyüközkan et al., 2021a).

It can be clearly said that the competition in the aviation industry is highly intense, especially for low-cost airline companies. They want to increase their market share and be sustainable. Lately, they offer products and services through digital channels such as social media, mobile devices, and applications. Self-services processes, online ticketing, and experience evaluations are provided to the passengers. Each process has become digital. Now, it is possible to assess the satisfaction levels of customers based on the offered services and products using data via digital channels. Hence, customization and personalization of the provided products and services can be conducted. In such a case, DT competency levels and profiling of the low costs have become vital. When the distribution and number of the low-cost airline companies are examined all over the world, the intensity of the market can be understood (Büyüközkan et al., 2021a).

Africa region has 16 where the Asia and Pacific region have 78 low-cost airline companies. Air transportation services are offered by 21 companies in the region of Latin America and the Caribbean. The number of low-cost airline companies is 92 in the region of Europe where 8 companies serve in the region of the Middle East. 50 low-cost airline companies provide services and products in the region of North America based on data of the year 2019 (ICAO, 2019). While this is the case in the world, the number of companies providing air transportation services in Turkey is 5. These companies have made significant breakthroughs in terms of DT. The place of these low-cost airline companies in the air transportation market of Turkey cannot be denied.

The above-mentioned numbers prove the enormous competition both in the world and in Turkey. Hence, the DT competencies of the low-cost airline companies in Turkey have been focused on. For this purpose, a new DT competency evaluation (DTCE) model has been proposed in this chapter. The following section provides detailed information concerning the proposed DTCE model.

4.2.Proposed Digital Transformation Competency Evaluation (DTCE) Model

If the DT is carried out successfully, it will provide benefits such as profitability, sustainability, competitiveness, flexibility, and agility to companies in the aviation ecosystem, just as it provides to many companies. However, DT can be devastating if its requirements are not followed and cannot be sustained properly. It would be inevitable to be exposed to the devastating consequences of DT. Therefore, companies in the aviation industry need to focus on DT competency to be successful. For this purpose, a new Digital Transformation Competency Evaluation (DTCE) model is proposed in this section. To build the structure of the proposed model some important factors are identified based on the experts' opinions and literature survey. The main structure of the proposed model is shown in Figure 4.1 (Büyüközkan et al., 2021a).

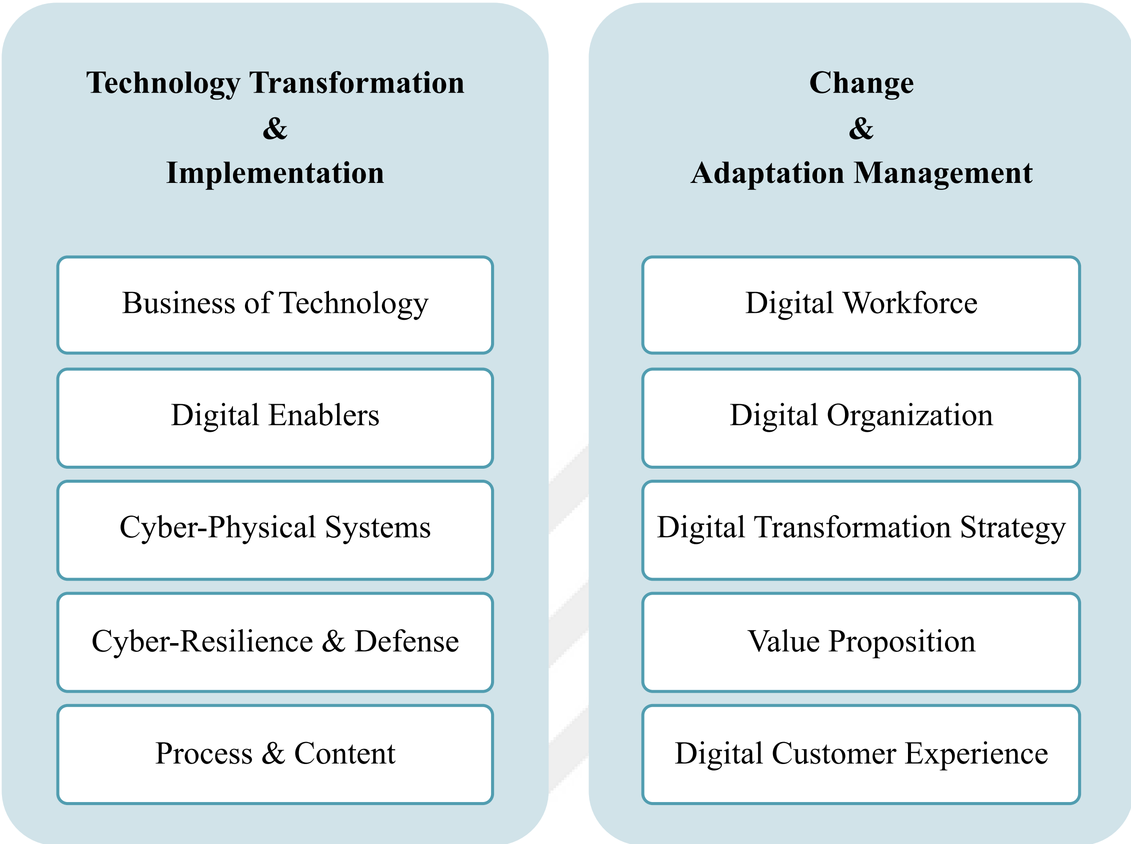


Figure 4.1: Main structure of the proposed DTCE model (Büyüközkan et al., 2021a)

Technology Transformation & Implementation (TTI):

TTI represents the conversion, transformation, or change of the technologies which already exist to more advanced versions of them. This is proceeded by considering the most up-to-date digital trends. On the other hand, the implementation of this transformation covers the application of these updated technologies to business and core technology. Furthermore, large-scale transformations should be taken into consideration during the transformation and implementation of the technologies (Erginsoy, 2019; Dhasarathy et al., 2020; Büyüközkan et al., 2021a). TTI dimension consists of 5 main criteria. Further information concerning the criteria is provided below, and the decomposed structure of the TTI dimension is shown in Figure 4. 2. Explanations of the components concerning the TTI dimension are given below.

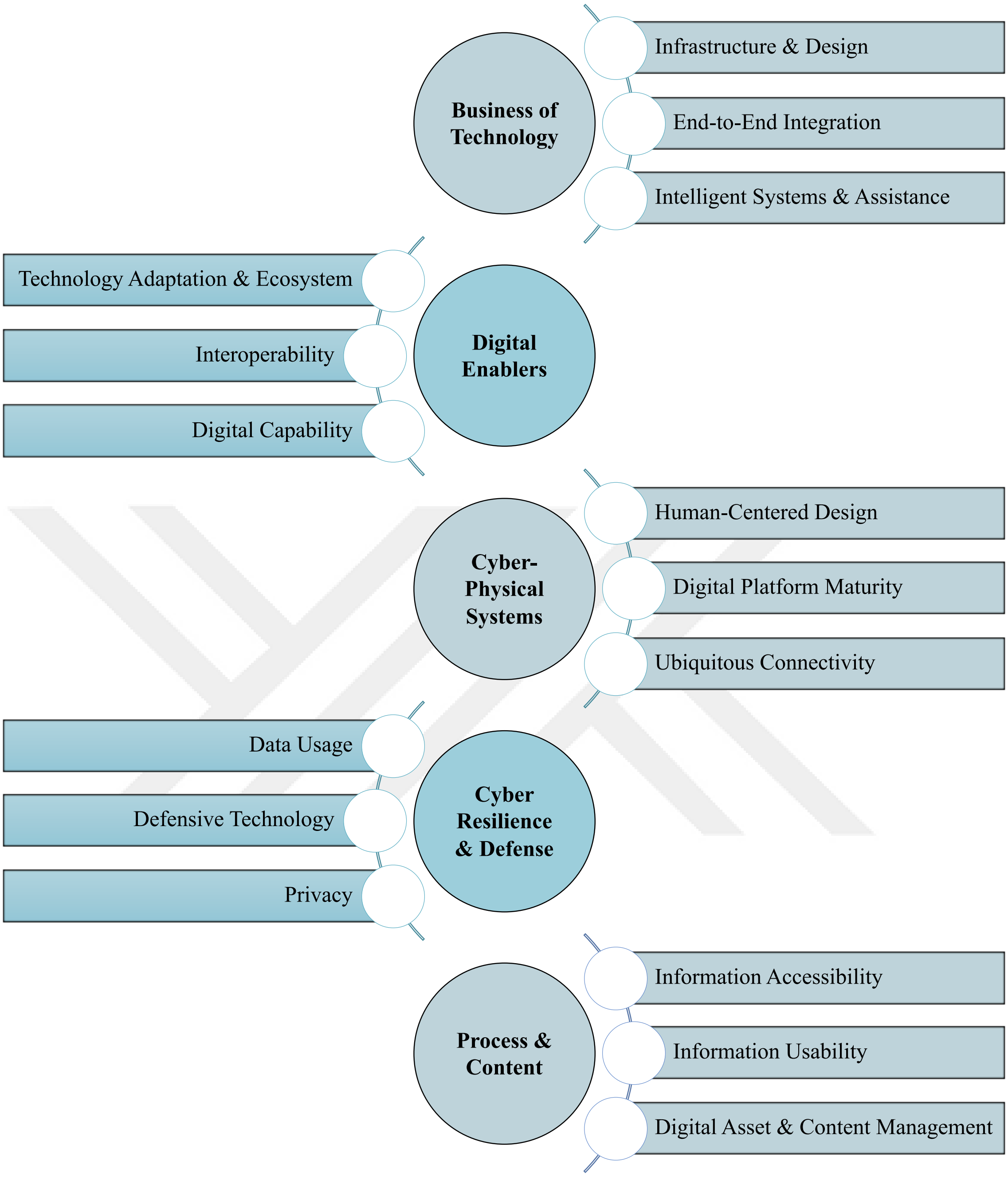


Figure 4.2: Decomposed structure of the TTI dimension (Büyüközkan et al., 2021a)

- **Business of Technology (TTI_1):** It refers to the restructuring of information technologies to enable businesses to respond agile to technology-driven market and business changes, and to promote both operational excellence and value creation. The business of technology shows how IT works and operates. It covers the reengineering "capital T" technology by digital, cloud, mixed reality, analytics, and blockchain around cyber (Briggs et al., 2017; Brigss et al., 2020).

- **Infrastructure & Digital Design (TTI_{11}):** It represents having well-designed and organized information technology systems (Gimpel & Röglinger, 2015; Expert Opinion).

- **End-to-End Integration (TTI_{12}):** It refers to the ability to integrate all business and processes from start to finish for delivering a better experience in line with the company's strategies (Expert Opinion).

- **Intelligent Systems & Assistance (TTI_{13}):** It represents the optimization of the processes with AI applications and learning algorithms for customers. It refers to providing artificial intelligent-based digital assistants who learn and can deliver meaningful conversations that will advance consumer interactions such as obtaining real-time support or payment processing (Expert Opinion).

- **Digital Enablers (TTI_2):** It represents the adoption of the emerging digital technologies including all physical and non-physical ones, software, and designs to provide technology-based digitalized processes, digital products, and services for better customer experience (Büyüközkan et al., 2021a; Expert opinion).

- **Technology Adaptation & Ecosystem (TTI_{21}):** It shows the ability to comply with the new digital technologies based on the vision, goals, and future strategies of an organization by following the most current technologies in the ecosystem (Expert opinion).

- **Interoperability (TTI_{22}):** It refers to the exchange of data between two or more systems or components and the use of the exchanged data (Geraci et al., 1991).

- **Digital Capability (TTI_{23}):** It represents the functionality, effectiveness, and operational excellence level of a digital organization. It expresses the determination, readiness, ability to be dynamic, and expertise to adopt digital technologies to develop new products and processes that complement a company's digital orientation and ensure competition in changing market conditions (Moore, 2015; Carcary et al., 2016; Khin & Ho, 2019; Expert opinion).

- **Cyber-Physical Systems (TTI_3):** It covers the existence of all digital channels, platforms, and digital contact points for customers to provide interaction with the company (Expert opinion; Khouzaimi et al., 2017).

- **Human-Centered Design (TTI_{31}):** It represents a perspective of design and a process that is iterative and that contains the users in all phases of the processes (Garcia-Lopez et al., 2020).

- **Digital Maturity (TTI_{32}):** It represents the ability to provide digitally mature, efficient, agile, and risk-tolerant digital platforms for both company and customers (Expert opinion; Kane et al., 2017; Rader, 2019).

- **Ubiquitous Connectivity (TTI_{33}):** It covers the connectivity from people to various digital technologies with insights, impressions, and engagements (SayYeah, 2018).

- **Cyber Resilience & Defense (TTI_4):** It is a level of proactive cyber defense and the ability to resist breaches of personal data. It is the security level provided by the company against accidental and unlawful destruction, loss, access, and transmission of data. It represents defense and recovery capabilities (Doughton et al., 2017; Unsworth & Ye, 2019).

- **Data Usage (TTI_{41}):** It represents data processing, classification, and retention to use (Deloitte, 2018; Expert opinion).

- **Defensive Technology (TTI_{42}):** It represents the ability to have technologies such as cloud technology, blockchain, and data analytics to support cyber-security (Gimpel & Röglinger, 2015).

- **Privacy (TTI_{43}):** It represents the ability to provide trust by the organization to its customers about their privacy concerns. It shows the safety of the customers by considering data ethics and confidentiality of them (Expert opinion; Unsworth &Ye, 2019).

- **Process & Content (TTI_5):** It represents the management of the content that the customers are facing and corporate information (Early Information Science, 2019; Expert opinion).

- **Information Accessibility (TTI_{51}):** It represents the ability to provide searchable and utilizable information (Early Information Science, 2019; Expert opinion).

- **Information Usability (TTI_{52}):** It shows the ability to provide complete, accurate, and relevant information to use (Early Information Science, 2019; Expert opinion).

- **Digital Asset & Content Management (TTI_{53}):** It explains the ability to manage web content to provide publishing workflow, authoring, and content template services in digital platforms based on digital assets such as documents, rich media, and images (Shivakumar, 2018).

Change & Adaptation Management (CAM):

It represents the capability of adapting a clear digital change vision and approach based on digital culture and transformative leadership by assessing digital capabilities, digital maturity, and defining a digital roadmap for business and people transformation, and business agility (Steward, 2017; Büyüközkan et al., 2021a). CAM dimension consists of 5 main criteria. Further information concerning the criteria and their sub-criteria is provided below. The structure of the CAM dimension is shown in Figure 4.3.

- **Digitally Competent Human Resources (CAM_{11}):** It refers to ensuring the sustainability of the existence of digitally competent and talented people within the organization and the effective management of these resources to reach the digital maturity level required in a successful digital transformation based on digital skillset, mindset, and transformative leadership (Kispeter, 2018; Cisco, 2019; Brigss et al., 2020; Solberg et al., 2020; Expert opinion).

- **Education & Training (CAM_{12}):** It refers to providing training for the employees to increase their digital awareness, digital skills, digital competency for the DT to create value for customers and to increase the provided service quality (Expert opinion).

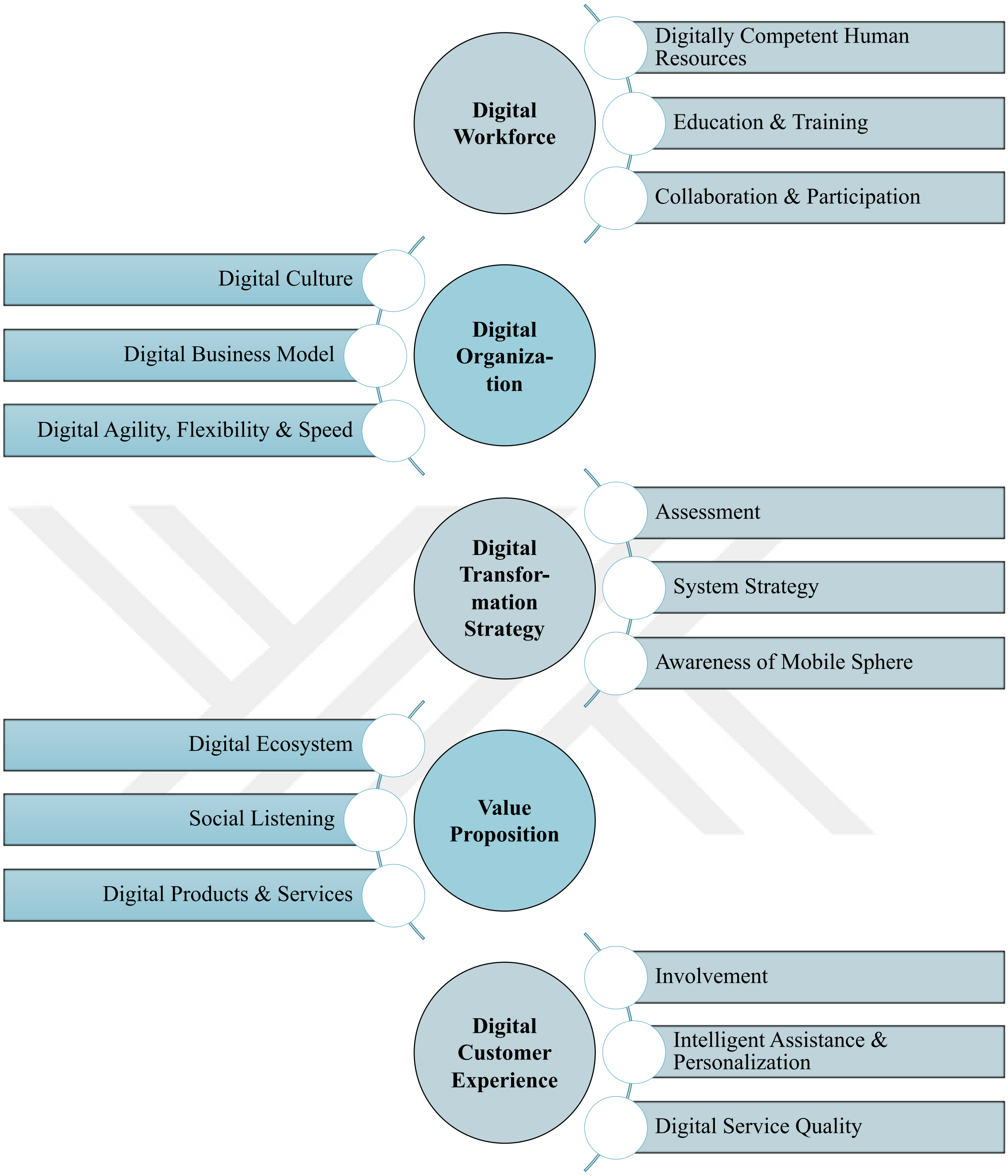


Figure 4.3: Decomposed structure of the CAM dimension (Büyüközkan et al., 2021a)

- **Collaboration & Participation (CAM_{13}):** It refers to the optimization of business skills by forming teams between departments and functions. Furthermore, it shows the level of involving the employees in all processes to increase effective information sharing, sense of belonging, motivation, digital awareness, and their competencies (Buvat et al., 2018; Expert opinion).

- **Digital Organization (CAM_2):** It refers to an organization with the ability to transit to an entirely digitized enterprise by understanding the digital maturity level of the company and the development of a governance framework (Early Information Science, 2019; Büyüközkan et al., 2021a Expert opinion).

- **Digital Culture (CAM_{21}):** It is the adoption of a culture to create an environment in which the vision is imagined and reshaped as larger than the company, new values and practices are imposed, that allows people to make an impact, uses the right tools based on information technologies, and adopts transparency regarding goals and performance (Westerman et al., 2019).

- **Digital Business Model (CAM_{22}):** It refers to the adoption of a business model that allows using digital technologies in value proposition, customer experience, etc. (SAP, 2016).

- **Digital Agility, Flexibility & Speed (CAM_{23}):** It is the ability of a business in the digital ecosystem to change or adapt rapidly in response to changes in the market with the help of cross-functional agile teams. It represents the dynamism and speed of an organization to the changing demands using digital technologies and data-driven decision-making (Buvat et al., 2018; Pereira et al., 2020).

- **Digital Transformation Strategy (CAM_3):** It expresses the adoption of a roadmap that serves the vision and goals of the organization by considering the risks, challenges, and chances to be competitive and sustainable in the digital ecosystem based on a customer-centric, digitally modified business model. It represents an overall strategy of a company for digital transformation (Expert opinion; SAP, 2016).

- **Assessment (CAM_{31}):** It represents the ability to assess internal and external risks, and successes (Expert opinion).

- **System Strategy (CAM_{32}):** It shows the ability to have a framework to understand the organizational efforts, capabilities, and market needs in a wider perspective, and understanding (SayYeah, 2018).

- **Awareness of Mobile Sphere (CAM_{33}):** It shows the ability to be aware of the extensive usage of mobile devices and applications for both digital products and services (Office of the Privacy Commissioner of Canada, 2014; Expert opinion).

- **Value Proposition (CAM_4):** It shows the ability to gain insights based on the experiences and values of the customers via digital platforms, channels, and touchpoints in a digital ecosystem by asking them (Hudadoff, 2009; Expert opinion).

- **Digital Ecosystem (CAM_{41}):** It means being informed about the latest developments in digital platforms, the internet, and technology, to be able to follow and respond to digital trends and demands in the environment, to be able to use digital technologies in line with company strategies and objectives, to be aware of the importance of digital marketing and advertising for the company in the digital environment to create value (Corver & Elkhuizen, 2014; Gimpel & Röglinger, 2015; Bauriedel et al., 2017).

- **Social Listening (CAM_{42}):** It represents being able to obtain insights from the customers, follow and meet the demands of the digital customers through digital channels such as social media platforms (Shivakumar, 2018; Expert opinion).

- **Digital Products & Services (CAM_{43}):** It represents the ability to provide appropriate products and services based on the customers' demands (Corver & Elkhuizen, 2014; Expert opinion).

- **Digital Customer Experience (CAM_5):** The presentation of a digital service quality that will enable passenger loyalty by offering a holistic digital experience where the customers are placed at the center of all processes through digital technologies, digital products, and services. It is the ability to match and connect the goals of the brand and the customers to make the customers have the willingness to recommend the digital service or digital product in the market (Capgemini, 2017; Expert opinion).

- **Involvement (CAM_{51}):** It represents the ability to provide self-services and engage the customers into the processes with omnichannel touchpoints (Expert opinion).

- **Personalization & Intelligent Assistance (CAM_{52}):** It shows the ability to fulfill the customer demands by a unique recognition, delivering personalized attention and customized offerings, and it refers to provide artificial intelligent based digital assistants who learn and could deliver meaningful conversations that will advance consumer interactions such as obtaining real-time support or payment processing (de Roys et al., 2016; Cisco, 2017).

- **Digital Service Quality (CAM_{53}):** It represents the ability to provide a certain level of service quality to meet the digital demands of the digital customers by using the emerging digital technologies (Büyüközkan et al., 2020a; Expert opinion).

4.3. Application of the Proposed Methodology

The importance of low-cost airlines for both the global economy and the economies of the countries, competition in the low-cost market, and digitalization steps of the companies have been shown in the section above. This is the same for Turkey. A fierce competition environment concerning the low-cost airline companies in Turkey has been focused. A case study is conducted to evaluate the DT competencies of the airline companies in Turkey based on the proposed DTCE model in this part of the thesis.

The integrated IVIF MCDM methodology based on the computational steps of the IVIF AHP and the IVIF VIKOR methods given above are applied. First, the criteria weights of the DTCE model are determined using the IVIF AHP method. Following that, the most digitally competent airline company is selected through the IVIF VIKOR method During this process, the computational steps of the proposed integrated IVIF MCDM methodology presented in Figure 3.1 are applied.

Calculation of the Criteria Weights with the IVIF AHP Method:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information and knowledge level about the DT process, and willingness to help are considered as the determination criteria.

Here, $DM = \{DM_1, DM_2, DM_3\}$ represents the set of DMs. A university professor, a consultant, and a company owner are selected as the DMs. Each DM has remarkable information about DT in the aviation industry. DM_1 is studying on DT in various sectors including aviation industry. DM_2 works for a consulting company that offers products and services concerning supply chain, software, and computer programming in Turkey. The company of DM_3 provides products and services such as software and hardware to airports and airlines in Turkey. All the DMs are also actively using air transportation as passengers. Due to privacy and confidentiality concerns, further information about the DMs cannot be provided.

Step2. Determination of the goal and the evaluation criteria:

The goal is to verify the validity of the proposed DTCE model in Turkey concerning the low-cost airline companies and to choose the most digitally competent company. The criteria of the proposed model are determined through a literature survey and the experts' opinions who are the DMs. The proposed model is introduced in Section 4.1.

Step 3. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the criteria are adopted from the scientific studies in the academic literature. Utilized scales are given in the steps in question.

Step 4. Restructuring the problem:

A hierarchical structure is constructed based on the proposed DTCE model. The constructed hierarchical model is presented in Figure 4.4.

Step 5. Calculation of the weights of the DMs:

The importance degrees of the determined DMs are assigned using the linguistic terms given in Table 3.3 by considering the criteria introduced in Step 1. Following that, the weights of the DMs given in Table 4.1 are calculated using Eq. (3.19) based on the assigned linguistic terms.

Step 6. Evaluation of the criteria:

The judgments of the DMs are obtained through the linguistic terms given in Table 3.4 based on pairwise comparisons. The evaluations concerning the main dimensions are given in Table 4.2. The same process is applied for all the criteria and sub-criteria. Due to page limitations some of the evaluations are provided between Table 4.3 and Table 4.8.

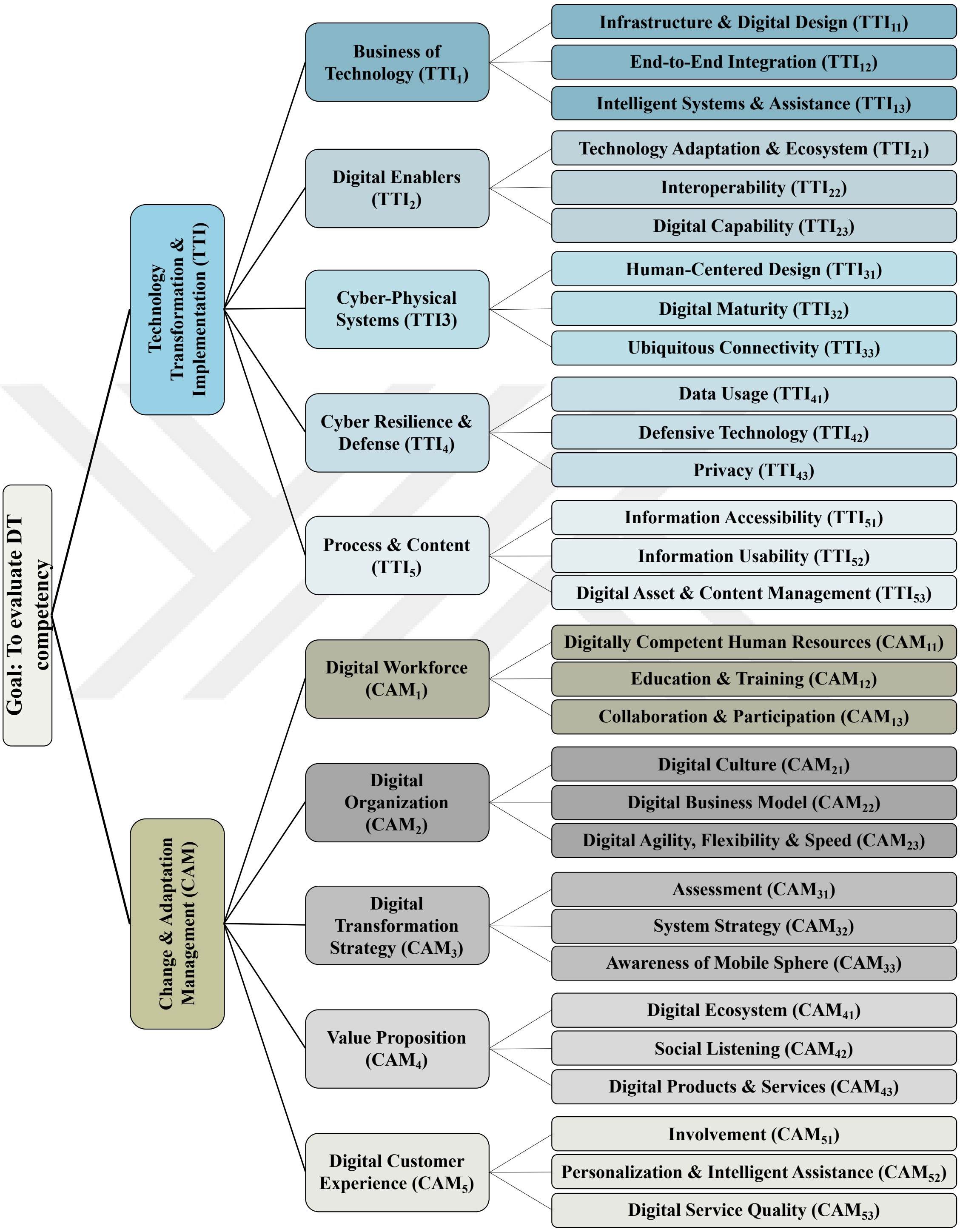


Figure 4.4: Hierarchical structure of the proposed DTCE model

Step 7. Aggregation:

The judgments of the DMs are converted into IVIF values. The individual evaluations of the DMs are aggregated to obtain group decision values using Eq. (3.20). These IVIF values are aggregated one more time to obtain main aggregated (group-decision) values and the main aggregated values concerning the main dimensions are given in Table 4.9. The same process is applied for the criteria and sub-criteria of the TTI and CAM dimensions. Main aggregated IVIF values of the criteria regarding the main dimensions are shown in Table 4.10.

Table 4.1: The importance degrees of the DMs

DMs	Importance Degrees of the DMs	IVIF values		Weights of the DMs
		$\tilde{\mu}_{\tilde{A}}(x)$ $[\mu^L_{\tilde{A}}, \mu^U_{\tilde{A}}]$	$\tilde{\nu}_{\tilde{A}}(x)$ $[\nu^L_{\tilde{A}}, \nu^U_{\tilde{A}}]$	(λ_k)
DM_1	VQ	[0.80, 0.85]	[0.05, 0.10]	0.343 (λ_1)
DM_2	Q	[0.60, 0.65]	[0.10, 0.15]	0.286 (λ_2)
DM_3	EQ	[0.95, 1.00]	[0.00, 0.00]	0.371 (λ_3)

Table 4.2: The judgments of the DMs for the main dimensions

DM_1			DM_2			DM_3		
	TTI	CAM		TTI	CAM		TTI	CAM
TTI	EI		TTI	EI		TTI	EI	
CAM	IV3	EI	CAM	EI	EI	CAM	VSMI	EI

Table 4.3: The pairwise comparisons of TTI criteria by DM_1

	TTI_1	TTI_2	TTI_3	TTI_4	TTI_5
Business of Technology (TTI_1)	EI	IV2	MMI		IV2
Digital Enablers (TTI_2)		EI			
Cyber-Physical Systems (TTI_3)		MMI	EI		
Cyber Resilience & Defense (TTI_4)	IV	IV2	IV2	EI	IV2
Process & Content (TTI_5)		MMI	MMI		EI

Table 4.4: The pairwise comparisons of TTI criteria by DM_2

	TTI_1	TTI_2	TTI_3	TTI_4	TTI_5
Business of Technology (TTI_1)	EI	MMI		IV2	MMI
Digital Enablers (TTI_2)		EI			
Cyber-Physical Systems (TTI_3)	IV	IV	EI		
Cyber Resilience & Defense (TTI_4)		MMI	IV2	EI	IV2
Process & Content (TTI_5)		MMI	MMI		EI

Table 4.5: The pairwise comparisons of TTI criteria by DM_3

	TTI_1	TTI_2	TTI_3	TTI_4	TTI_5
Business of Technology (TTI_1)	EI			IV2	IV2
Digital Enablers (TTI_2)	IV3	EI	IV2		IV2
Cyber-Physical Systems (TTI_3)	IV3		EI	IV2	IV2
Cyber Resilience & Defense (TTI_4)		SMI		EI	IV2
Process & Content (TTI_5)					EI

Table 4.6: Evaluation of the sub-criteria of CAM_3 by DM_1

	CAM_{31}	CAM_{32}	CAM_{33}
Assessment (CAM_{31})	EI	EI	EI
System Strategy (CAM_{32})		EI	EI
Awareness of Mobile Sphere (CAM_{33})			EI

Table 4.7: Evaluation of the sub-criteria of CAM_3 by DM_2

	CAM_{31}	CAM_{32}	CAM_{33}
Assessment (CAM_{31})	EI	EI	IV3
System Strategy (CAM_{32})		EI	SMI
Awareness of Mobile Sphere (CAM_{33})			EI

Table 4.8: Evaluation of the sub-criteria of CAM_3 by DM_3

	CAM_{31}	CAM_{32}	CAM_{33}
Assessment (CAM_{31})	EI	IV2	SMI
System Strategy (CAM_{32})		EI	
Awareness of Mobile Sphere (CAM_{33})		IV2	EI

Step 8. Consistency check:

The $C.R.$ values are computed at this step using the Eq. (3.21) based on the main aggregated IVIF values. $C.R.$ values are indicated in Tables 4.9, 4.10, and 4.11, respectively. It is seen that $C.R. < 0.1$ for all evaluations. All the rest of the $C.R.$ values are obtained as less than 0.1. Hence, the obtained judgments of the DMs are consistent and acceptable.

Step 9. Calculation of the criteria weights:

The weights of the criteria are calculated through the Eq. (3.22). The obtained results are presented in Table 4.12.

Table 4.9: The main aggregated IVIF values of TTI & CAM dimensions

Dimensions	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
TTI	[0.184, 0.300]	[0.443, 0.700]	[0.000, 0.373]
CAM	[0.293, 0.404]	[0.278, 0.596]	[0.000, 0.429]

$(C.R. = -0.401)$

Table 4.10: The main aggregated IVIF values of the TTI & CAM criteria

Criteria	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
TTI_1	[0.227, 0.640]	[0.016, 0.358]	[0.002, 0.757]
TTI_2	[0.233, 0.709]	[0.016, 0.291]	[0.001, 0.751]
TTI_3	[0.267, 0.688]	[0.011, 0.311]	[0.001, 0.722]
TTI_4	[0.229, 0.661]	[0.007, 0.339]	[0.001, 0.764]
TTI_5	[0.207, 0.678]	[0.006, 0.322]	[0.000, 0.787]
$(C.R. = 0.091)$			
CAM_1	[0.227, 0.694]	[0.012, 0.305]	[0.001, 0.762]
CAM_2	[0.210, 0.679]	[0.014, 0.321]	[0.000, 0.776]
CAM_3	[0.260, 0.662]	[0.010, 0.338]	[0.000, 0.730]
CAM_4	[0.266, 0.687]	[0.020, 0.311]	[0.002, 0.714]
CAM_5	[0.270, 0.653]	[0.010, 0.346]	[0.001, 0.720]

$(C.R. = 0.095)$

Following that, only the main aggregated IVIF values of the sub-criteria concerning the TTI criteria are shown in Table 4.11 due to page limitation.

Table 4.11: The main aggregated IVIF values of the sub-criteria of the TTI criteria

Sub-criteria	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
TTI_{11}	[0.187, 0.459]	[0.062, 0.541]	[0.000, 0.751]
TTI_{12}	[0.177, 0.506]	[0.103, 0.493]	[0.001, 0.721]
TTI_{13}	[0.194, 0.474]	[0.070, 0.525]	[0.001, 0.736]
$(C.R. = -0.078)$			
TTI_{21}	[0.284, 0.441]	[0.183, 0.559]	[0.000, 0.533]
TTI_{22}	[0.267, 0.502]	[0.114, 0.498]	[0.000, 0.619]
TTI_{23}	[0.224, 0.500]	[0.168, 0.500]	[0.000, 0.608]
$(C.R. = -0.003)$			
TTI_{31}	[0.222, 0.440]	[0.153, 0.560]	[0.000, 0.625]
TTI_{32}	[0.192, 0.478]	[0.126, 0.520]	[0.001, 0.682]
TTI_{33}	[0.320, 0.543]	[0.107, 0.457]	[0.001, 0.573]

$(C.R. = -0.023)$

Table 4.11: The main aggregated IVIF values of the sub-criteria of the TTI criteria (*continue)*

Sub-criteria	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
TTI_{41}	[0.324, 0.420]	[0.139, 0.576]	[0.004, 0.537]
TTI_{42}	[0.245, 0.517]	[0.231, 0.477]	[0.005, 0.524]
TTI_{43}	[0.278, 0.500]	[0.230, 0.495]	[0.004, 0.492]
$(C.R. = 0.031)$			
TTI_{51}	[0.235, 0.475]	[0.097, 0.525]	[0.000, 0.668]
TTI_{52}	[0.191, 0.510]	[0.120, 0.490]	[0.000, 0.689]
TTI_{53}	[0.194, 0.457]	[0.074, 0.543]	[0.000, 0.732]
$(C.R. = 0.095)$			

Table 4.12: Calculated IVIF AHP weights of the proposed DTCE model

Dimension	Weight	Criteria	Weight	Global Weight	Sub-criteria	Weight	Global Weight
TTI	0.3887	TTI_1	0.1954	0.0759	TTI_{11}	0.3233	0.0246
					TTI_{12}	0.3424	0.0260
					TTI_{13}	0.3343	0.0254
		TTI_2	0.2034	0.0791	TTI_{21}	0.3196	0.0253
					TTI_{22}	0.3495	0.0276
					TTI_{23}	0.3309	0.0262
		TTI_3	0.2064	0.0802	TTI_{31}	0.3029	0.0243
					TTI_{32}	0.3144	0.0252
					TTI_{33}	0.3827	0.0307
		TTI_4	0.1981	0.0770	TTI_{41}	0.3231	0.0249
					TTI_{42}	0.3373	0.0260
					TTI_{43}	0.3396	0.0262
		TTI_5	0.1967	0.0764	TTI_{51}	0.3410	0.0261
					TTI_{52}	0.3411	0.0261
					TTI_{53}	0.3179	0.0243
CAM	0.6113	CAM_1	0.1993	0.1218	CAM_{11}	0.3511	0.0428
					CAM_{12}	0.3494	0.0426
					CAM_{13}	0.2995	0.0365
		CAM_2	0.1952	0.1194	CAM_{21}	0.3547	0.0423
					CAM_{22}	0.3949	0.0471
					CAM_{23}	0.2505	0.0299
		CAM_3	0.2004	0.1225	CAM_{31}	0.3417	0.0419
					CAM_{32}	0.3404	0.0417
					CAM_{33}	0.3179	0.0390
		CAM_4	0.2041	0.1248	CAM_{41}	0.3232	0.0403
					CAM_{42}	0.3367	0.0420
					CAM_{43}	0.3401	0.0424
		CAM_5	0.2009	0.1228	CAM_{51}	0.3053	0.0375
					CAM_{52}	0.3250	0.0399
					CAM_{53}	0.3697	0.0454

Evaluation of the Alternatives with the IVIF VIKOR Method:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information and knowledge level, and willingness to help are considered as the determination criteria. Here, the DMs in the IVIF AHP process are involved in the decision-making.

Step 2. Determination of the goal and the evaluation criteria:

The goal is adopted from the IVIF AHP method, and it is determined as the evaluation of the DT competencies of the low-cost airline companies and to select the most digitally competent low-cost airline company. The criteria of the proposed DTCE model are utilized for the assessment of the alternatives.

Step 3. Determination of the set of alternatives:

A set of suitable alternatives is constructed based on 4 different low-cost airline companies. The considered criteria for the selection of the candidate alternatives are digital platforms and channels, products, and services they offer to the passengers, and potential of technology usage of the passengers of the companies. Furthermore, the determined candidates are approved by the opinions of the DMs. DMs have a remarkable amount of knowledge level and information about the determined companies. Let $A = \{A_1, A_2, A_3, A_4\}$ be the set of suitable alternatives. Detailed information about the candidate companies cannot be provided due to privacy concerns and confidentiality.

Step 4. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the alternatives over the evaluation criteria are developed or adopted from the scientific studies in the academic literature.

Step 5. Calculation of the weights of the DMs:

Calculated DMs' weights in the IVIF AHP method are used for the IVIF VIKOR process. $(\lambda_1 = 0.342,\ \lambda_2 = 0.286,\ \lambda_1 = 0.371)$.

Step 6. Evaluation of the alternatives:

The judgments of the DMs for the alternatives are obtained based on the evaluation criteria that belong to the proposed DTCE model. The linguistic terms given in Table 3.6 are used to assess the alternatives. Furthermore, the evaluation process of the alternatives over the evaluation criteria is illustrated with the hierarchical diagram given in Figure 4.5.

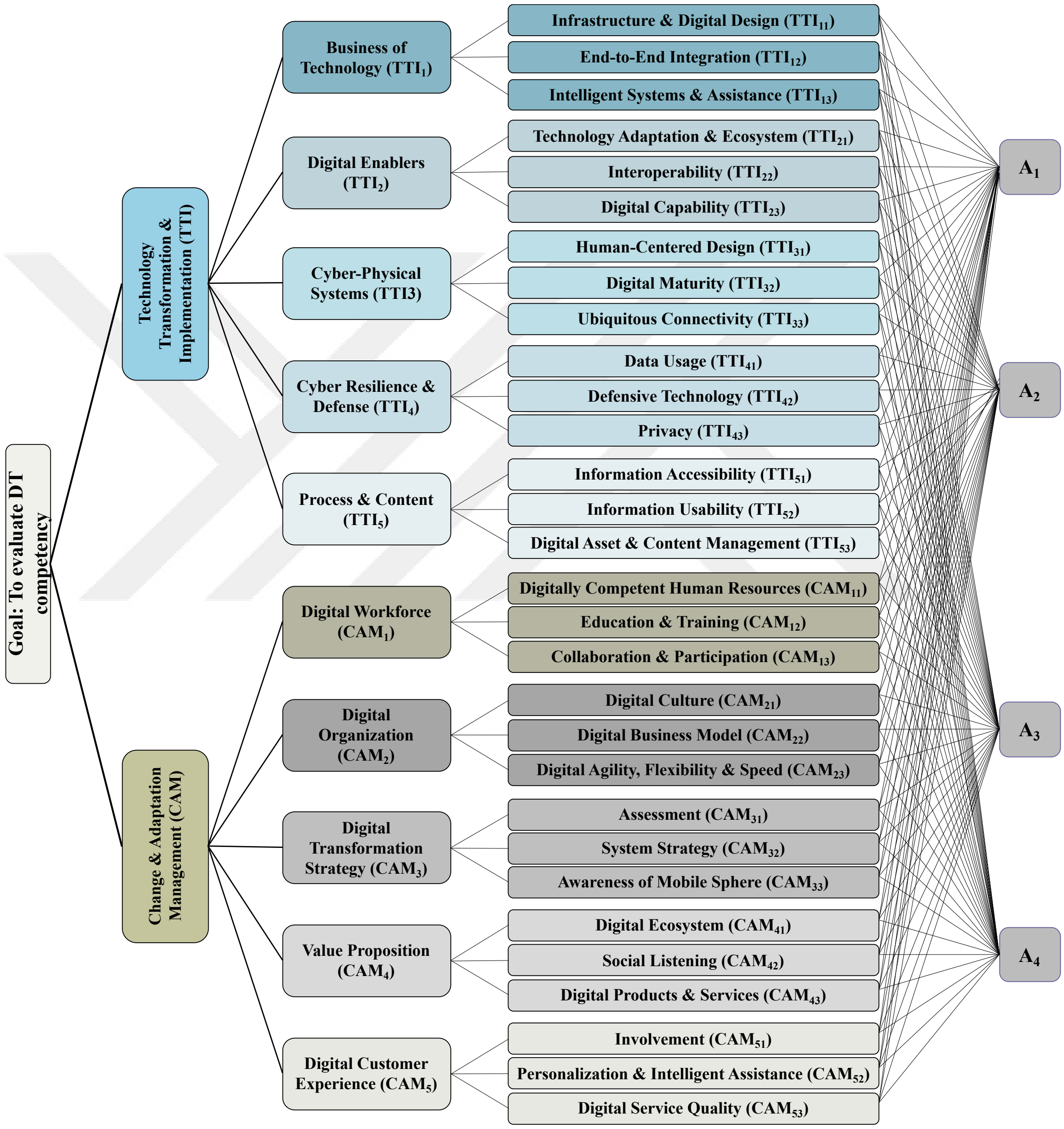


Figure 4.5: Evaluation of the alternatives through the DTCE model

The judgments of the DMs concerning the evaluation of the alternatives are illustrated in Table 4.13.

Table 4.13: Evaluation of the alternatives by the DMs

Sub-criteria	DM$_1$				DM$_2$				DM$_3$			
	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4
TTI$_{11}$	MB	MG	B	MB	MB	M	MB	MB	M	G	MB	B
TTI$_{12}$	M	G	G	MB	M	G	G	MB	MG	VG	G	B
TTI$_{13}$	EG	G	MG	MB	VG	VG	VG	MG	VVG	G	G	M
TTI$_{21}$	G	G	MG	M	MG	MG	MG	MG	G	VG	G	G
TTI$_{22}$	VG	MG	VG	G	G	G	G	M	G	G	G	MG
TTI$_{23}$	MG	VG	VG	G	G	G	MG	MB	G	VG	VG	MG
TTI$_{31}$	MG	VG	G	MB	VG	G	MG	MB	G	VG	MG	M
TTI$_{32}$	EG	VVG	G	G	VG	VG	MG	MB	VVG	VVG	VG	MG
TTI$_{33}$	VVG	EG	VG	MG	VVG	VVG	MG	M	EG	VVG	G	MG
TTI$_{41}$	EG	VVG	VG	MG	VVG	VVG	MG	M	EG	VVG	G	MG
TTI$_{42}$	VVG	VVG	G	G	VVG	VVG	MG	MB	VVG	VVG	G	MG
TTI$_{43}$	EG	VVG	VVG	VVG	VVG	VVG	VG	G	VVG	VVG	VVG	VVG
TTI$_{51}$	EG	EG	EG	EG	VVG	VVG	VG	EG	EG	EG	EG	EG
TTI$_{52}$	EG	EG	EG	VG	VVG	VVG	VG	VG	VVG	EG	VG	G
TTI$_{53}$	VVG	EG	EG	VG	EG	VVG	VG	VG	EG	EG	VG	VG
CAM$_{11}$	VG	VVG	VVG	VG	VG	VVG	VG	VG	VVG	VVG	VVG	VVG
CAM$_{12}$	VVG	VVG	VVG	VG	VVG	VVG	VG	VG	VVG	VVG	VVG	VVG
CAM$_{13}$	VG	G	VG	G	VG	VG	G	VG	G	MG	MG	MG
CAM$_{21}$	EG	G	VG	G	VVG	G	G	VG	EG	VVG	VG	MG
CAM$_{22}$	MG	G	VG	G	MG	G	G	MG	G	G	G	G
CAM$_{23}$	G	G	VG	VG	MG	MG	G	G	VG	VG	VG	VG
CAM$_{31}$	VVG	G	VG	VG	VG	MG	G	G	VVG	VG	VG	G
CAM$_{32}$	EG	VG	EG	VG	VVG	EG	VG	VG	EG	EG	VVG	VVG
CAM$_{33}$	EG	VG	VVG	VG	VVG	VVG	VG	VVG	EG	VG	EG	VG
CAM$_{41}$	G	VG	MG	G	VG	MG	VG	VG	G	G	G	G
CAM$_{42}$	VVG	VVG	VG	G	VG	VVG	VG	VG	VVG	VVG	VVG	G
CAM$_{43}$	VVG	VVG	VVG	G	VG	G	VG	M	VVG	VG	VG	MG
CAM$_{51}$	EG	VVG	VVG	MB	VVG	G	VG	M	EG	VG	VG	M
CAM$_{52}$	EG	VG	VG	G	VVG	G	VG	MG	EG	VG	VVG	G
CAM$_{53}$	EG	VVG	VVG	MG	EG	VG	MG	M	VVG	VVG	G	MG

Step 7. Aggregation:

The linguistic terms used to evaluate the alternatives are transformed into IVIF values and these IVIF values are aggregated to obtain a group-decision matrix $(\tilde{X})$ using the IIFWA operator proposed by Xu & Cai (2012) as indicated in Eq. (3.20). Only the aggregated IVIF values concerning alternative A$_1$ are illustrated in Table 4.14 due to page limitations.

Table 4.14: Aggregated IVIF values of A_1

Sub-criteria	IVIF Values					
	$[\mu_{\tilde{A}}^L$	$\mu_{\tilde{A}}^U]$	$[\nu_{\tilde{A}}^L$	$\nu_{\tilde{A}}^U]$	$[\pi_{\tilde{A}}^L$	$\pi_{\tilde{A}}^U]$
TTI_{11}	0.439	0.489	0.410	0.460	0.050	0.151
TTI_{12}	0.540	0.590	0.309	0.359	0.050	0.151
TTI_{13}	0.945	1.000	0.000	0.000	0.000	0.055
TTI_{21}	0.674	0.725	0.174	0.225	0.051	0.152
TTI_{22}	0.739	0.790	0.103	0.158	0.052	0.158
TTI_{23}	0.669	0.719	0.179	0.230	0.051	0.152
TTI_{31}	0.705	0.758	0.131	0.189	0.054	0.164
TTI_{32}	0.945	1.000	0.000	0.000	0.000	0.055
TTI_{33}	0.957	1.000	0.000	0.000	0.000	0.043
TTI_{41}	0.981	1.000	0.000	0.000	0.000	0.019
TTI_{42}	0.900	0.950	0.010	0.040	0.010	0.090
TTI_{43}	0.955	1.000	0.000	0.000	0.000	0.045
TTI_{51}	0.981	1.000	0.000	0.000	0.000	0.019
TTI_{52}	0.955	1.000	0.000	0.000	0.000	0.045
TTI_{53}	0.978	1.000	0.000	0.000	0.000	0.022
CAM_{11}	0.845	0.900	0.028	0.071	0.029	0.127
CAM_{12}	0.900	0.950	0.010	0.040	0.010	0.090
CAM_{13}	0.768	0.819	0.075	0.129	0.052	0.157
CAM_{21}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{22}	0.641	0.691	0.207	0.258	0.051	0.153
CAM_{23}	0.720	0.772	0.115	0.174	0.054	0.165
CAM_{31}	0.878	0.932	0.016	0.052	0.016	0.106
CAM_{32}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{33}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{41}	0.733	0.784	0.110	0.164	0.052	0.158
CAM_{42}	0.878	0.932	0.016	0.052	0.016	0.106
CAM_{43}	0.878	0.932	0.016	0.052	0.016	0.106
CAM_{51}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{52}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{53}	0.976	1.000	0.000	0.000	0.000	0.024

Step 8. Calculation of the positive and negative ideal solutions:

IVIFPIS $(\tilde{f}_j^*)$ and IVIFNIS $(\tilde{f}_j^-)$ values are calculated through the Eq. (3.24) and Eq. (3.25), respectively. Obtained IVIFPIS and IVIFNIS values are given in Table 4.15 and Table 4.16.

Table 4.15: Positive ideal solutions $(\tilde{f}_j^*)$ (IVIFPIS)

Sub-criteria	$\tilde{\mu}_{\tilde{A}}(x)$ $[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U]$		$\tilde{\nu}_{\tilde{A}}(x)$ $[\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U]$		$\tilde{\pi}_{\tilde{A}}(x)$ $[\pi_{\tilde{A}}^L, \pi_{\tilde{A}}^U]$	
TTI_{11}	0.617	0.668	0.228	0.280	0.052	0.155
TTI_{12}	0.742	0.793	0.100	0.155	0.052	0.158
TTI_{13}	0.945	1.000	0.000	0.000	0.000	0.055
TTI_{21}	0.720	0.772	0.115	0.174	0.054	0.165
TTI_{22}	0.739	0.790	0.103	0.158	0.052	0.158
TTI_{23}	0.775	0.826	0.068	0.122	0.052	0.156
TTI_{31}	0.775	0.826	0.068	0.122	0.052	0.156
TTI_{32}	0.945	1.000	0.000	0.000	0.000	0.055
TTI_{33}	0.957	1.000	0.000	0.000	0.000	0.043
TTI_{41}	0.981	1.000	0.000	0.000	0.000	0.019
TTI_{42}	0.900	0.950	0.010	0.040	0.010	0.090
TTI_{43}	0.955	1.000	0.000	0.000	0.000	0.045
TTI_{51}	0.990	1.000	0.000	0.000	0.000	0.010
TTI_{52}	0.981	1.000	0.000	0.000	0.000	0.019
TTI_{53}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{11}	0.900	0.950	0.010	0.040	0.010	0.090
CAM_{12}	0.900	0.950	0.010	0.040	0.010	0.090
CAM_{13}	0.768	0.819	0.075	0.129	0.052	0.157
CAM_{21}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{22}	0.739	0.790	0.103	0.158	0.052	0.158
CAM_{23}	0.775	0.826	0.068	0.122	0.052	0.156
CAM_{31}	0.878	0.932	0.016	0.052	0.016	0.106
CAM_{32}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{33}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{41}	0.733	0.784	0.110	0.164	0.052	0.158
CAM_{42}	0.900	0.950	0.010	0.040	0.010	0.090
CAM_{43}	0.878	0.932	0.016	0.052	0.016	0.106
CAM_{51}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{52}	0.981	1.000	0.000	0.000	0.000	0.019
CAM_{53}	0.976	1.000	0.000	0.000	0.000	0.024

Table 4.16: Negative ideal solutions ($\tilde{f}_j^-$) (IVIFNIS)

Sub-criteria	$\tilde{\mu}_{\tilde{A}}(x)$ $[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U]$		$\tilde{v}_{\tilde{A}}(x)$ $[v_{\tilde{A}}^L, v_{\tilde{A}}^U]$		$\tilde{\pi}_{\tilde{A}}(x)$ $[\pi_{\tilde{A}}^L, \pi_{\tilde{A}}^U]$	
TTI_{11}	0.365	0.415	0.485	0.535	0.050	0.151
TTI_{12}	0.365	0.415	0.485	0.535	0.050	0.151
TTI_{13}	0.501	0.551	0.347	0.398	0.051	0.153
TTI_{21}	0.612	0.663	0.232	0.285	0.052	0.156
TTI_{22}	0.614	0.665	0.231	0.283	0.052	0.155
TTI_{23}	0.593	0.645	0.248	0.302	0.053	0.159
TTI_{31}	0.439	0.489	0.410	0.460	0.050	0.151
TTI_{32}	0.593	0.645	0.248	0.302	0.053	0.159
TTI_{33}	0.574	0.624	0.275	0.326	0.050	0.151
TTI_{41}	0.574	0.624	0.275	0.326	0.050	0.151
TTI_{42}	0.593	0.645	0.248	0.302	0.053	0.159
TTI_{43}	0.863	0.921	0.022	0.063	0.016	0.115
TTI_{51}	0.976	1.000	0.000	0.000	0.000	0.024
TTI_{52}	0.768	0.819	0.075	0.129	0.052	0.157
TTI_{53}	0.800	0.850	0.050	0.100	0.050	0.150
CAM_{11}	0.845	0.900	0.028	0.071	0.029	0.127
CAM_{12}	0.845	0.900	0.028	0.071	0.029	0.127
CAM_{13}	0.703	0.755	0.132	0.191	0.054	0.165
CAM_{21}	0.703	0.755	0.132	0.191	0.054	0.165
CAM_{22}	0.641	0.691	0.207	0.258	0.051	0.153
CAM_{23}	0.720	0.772	0.115	0.174	0.054	0.165
CAM_{31}	0.720	0.772	0.115	0.174	0.054	0.165
CAM_{32}	0.845	0.900	0.028	0.071	0.029	0.127
CAM_{33}	0.836	0.890	0.032	0.077	0.033	0.132
CAM_{41}	0.705	0.758	0.131	0.189	0.054	0.164
CAM_{42}	0.733	0.784	0.110	0.164	0.052	0.158
CAM_{43}	0.614	0.665	0.231	0.283	0.052	0.155
CAM_{51}	0.468	0.518	0.382	0.432	0.050	0.151
CAM_{52}	0.674	0.725	0.174	0.225	0.051	0.152
CAM_{53}	0.574	0.624	0.275	0.326	0.050	0.151

Step 9. Computation of the group utility and individual regret values:

The group utility $S(A_i)$ values are calculated using Eq (3.26). Following that, the individual regret $R(A_i)$ values are computed using the Eq. (3.27). The obtained results are presented in Table 4.17.

Table 4.17: Calculated $S(A_i)$ and $R(A_i)$ values

Alternatives	$S(A_i)$	$S^*(A_i)$	$S^-(A_i)$	$R(A_i)$	$R^*(A_i)$	$R^-(A_i)$
A_1	0.209	0.209	0.883	0.047	0.040	0.047
A_2	0.344	0.209	0.883	0.042	0.040	0.047
A_3	0.439	0.209	0.883	0.040	0.040	0.047
A_4	0.883	0.209	0.883	0.045	0.040	0.047

Step 10. Calculation of the $Q(A_i)$ values:

$Q(A_i)$ values are calculated using the Eq. (3.30). Obtained $Q(A_i)$ values are given in Table 4.18.

Table 4.18: Obtained $Q(A_i)$ values

Alternatives	$Q(A_i)$
A_1	0.500
A_2	0.214
A_3	0.171
A_4	0.874

Step 11. Ranked order of the alternatives:

The ascending order of the $S(A_i)$, $R(A_i)$ and $Q(A_i)$ values are used to rank the alternatives. The obtained results are shown in Table 4.19.

Table 4.19: The ranked order of the alternatives

Alternatives	$S(A_i)$	Order	$R(A_i)$	Order	$Q(A_i)$	Order
A_1	0.209	1	0.047	4	0.500	3
A_2	0.344	2	0.042	2	0.214	2
A_3	0.439	3	0.040	1	0.171	1
A_4	0.883	4	0.045	3	0.874	4

By considering the first condition of the VIKOR method, following equation is provided:

$0.2387 - 0.1787 = 0.06 < \frac{1}{4} = 0.25.$

The result is not greater than 0.25 and due to this, the first condition is not met. Following this, the second condition of the VIKOR method should be utilized. Table 4.19 shows that the most appropriate alternative is A_3 based on $Q(A_i)$ values. Furthermore, this is provided by the $R(A_i)$ values, and the third alternative has an acceptable stability in the decision-making process through consensus for $\upsilon = 0.5$. A_2 alternative follows the A_3 as the second. Hence, it can be said that the second condition of the VIKOR method is met and ranked order of the alternatives over $Q(A_i)$ is $LCA_3 \succ LCA_2 \succ LCA_1 \succ LCA_4$.

4.4. Results and Discussion

The results of the conducted case study reveal that Change & Adaptation Management has greater importance. Even if the DT is provided by technological development, it is not just about technology but also it is about management. Figure 4.6 shows the weights and importance degree of the two main dimensions of the DTCE model.

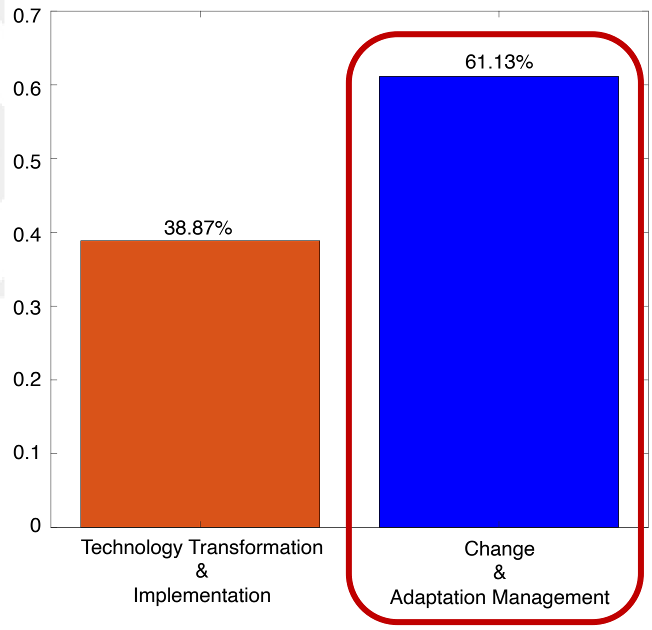


Figure 4.6: The weights of the main dimensions

A research report published by Deloitte and named MIT Sloan Management Review reveals that the main driver of the DT process is the strategy, not the technology (Kane et al., 2015). This fact approves the obtained results of the conducted case study since the management process is directly related to strategy (Büyüközkan et al., 2021a). Figures 4.7 and 4.8 show the distribution and importance degrees of the criteria concerning the proposed DTCE model.

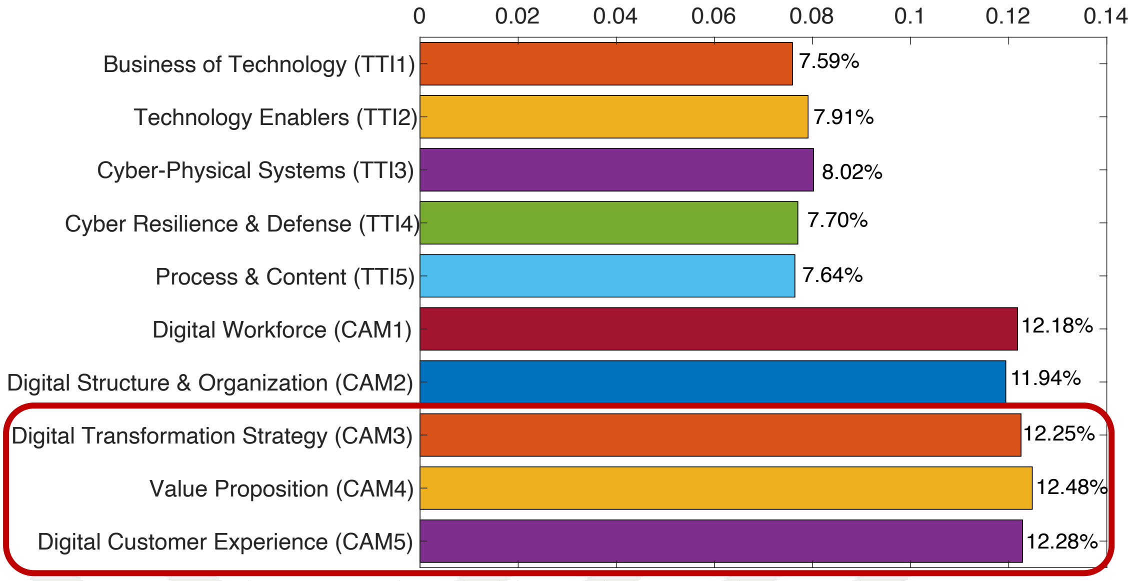


Figure 4.7: The priorities of the TTI and CAM criteria

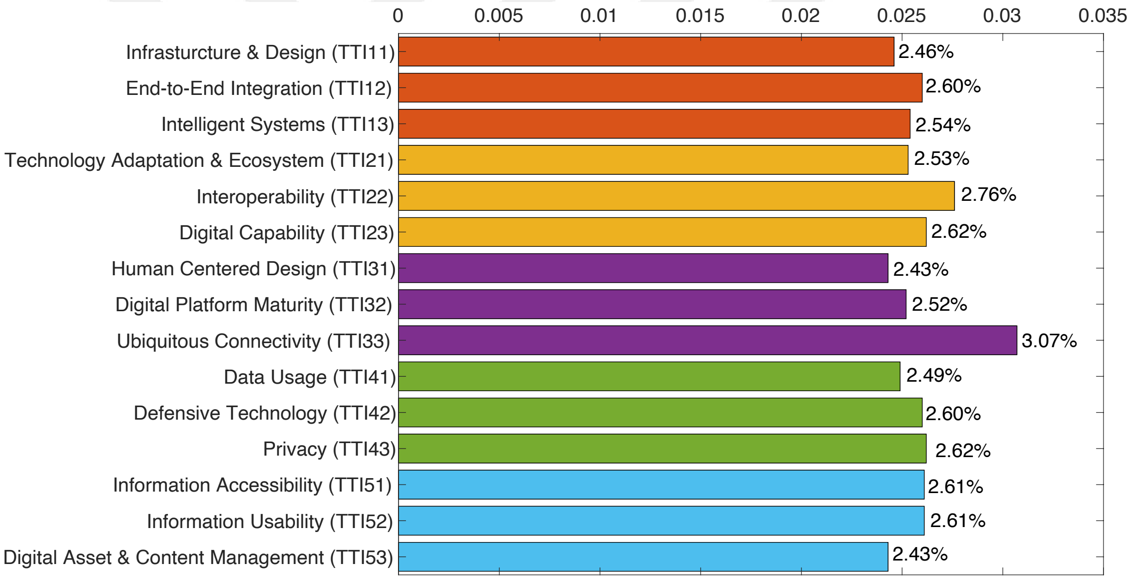


Figure 4.8: Importance degrees of the sub-criteria of the TTI criteria

The results of the applied IVIF AHP method are summarized in Figures 4.8 and 4.9. It is seen that the Value Proposition, DT Strategy, and Digital Customer Experience have the greater significance among all the criteria. Consequently, the visualized results of the IVIF AHP method for the sub-criteria of the DTCE criteria given in Figure 4.9 and Figure 4.10 show together that the Digital Business Model, Digital Service Quality, Digitally Competent Human Resources, Education & Training, Digital Products & Services, Digital Culture, Social Listening, and Assessment have the greater significance among the other sub-criteria.

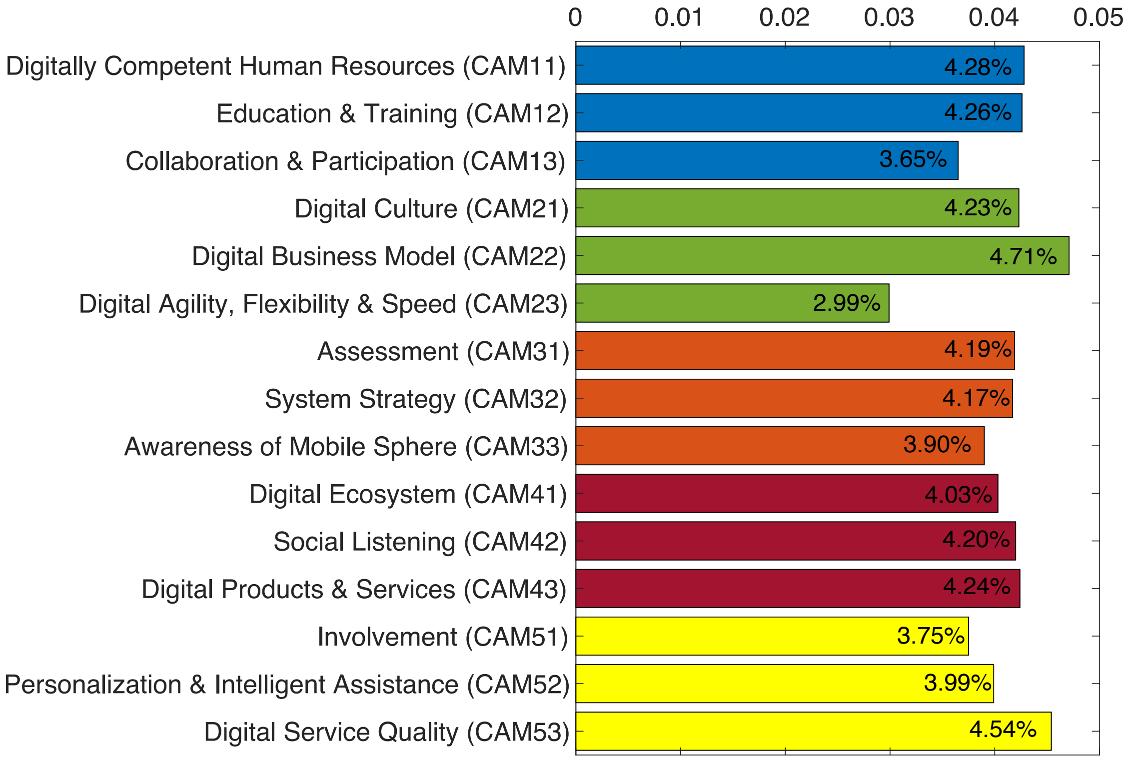


Figure 4.9: Importance degrees of the sub-criteria of the CAM criteria

The airline industry has been guided by the business models and philosophies adopted by low-cost airline companies from past to present. The low-cost carriers have adopted complex business models and many changes, and they have been facing DT lately. In today’s modern world, digital customers and their digital expectations are driving the DT process. A remarkable amount of the world population has integrated digital technologies into their daily lives, and this has changed the classical expectations radically. People are becoming digital technology users. Following this, the speed and desire of the air travelers for the digital services and products offered by the low-cost airline companies have increased. Hence, the digital demands of the digital customers and passengers must be satisfied through the appropriate digital channels at the right time in the right way. The above-mentioned issues made the competency in the DT process one of the important milestones. It is seen that the competency level will determine the places of the low-cost airline companies in the digital ecosystem (Büyüközkan et al., 2021a).

Low-cost airline companies have a high ability to change. Their main goal is to provide services at low prices for air travelers by wasting less time on the ground and this is provided by the optimized operations. Hence, they have increased their investments in the technologies. Yet, the DT process is progressed by an appropriate management philosophy. In this case, having a perspective of strategic management has become crucial. Low-cost airline companies should seek the answers about the adoption of transformation. The main objective should correctly be determined. Possible future scenarios should be focused on by placing the customers at the center. Applying the right strategies and roadmaps by determining the external and internal factors is vital for airline companies in the DT process. DT strategies focusing on digital customer experience and service quality should be supported by digitally competent human resources including transformative leadership (Büyüközkan et al., 2021a).

Ultimately, the competency in the DT process is related to correct management and this can be supported by correct strategies based on the value proposition for digital customer experience. The focus should be on management and digital transformation strategies (Büyüközkan et al., 2021a). By considering this, DT strategy analysis has been focused on in the next chapter.

5. PROPOSITION OF DIGITAL TRANSFORMATION STRATEGY EVALUATION FRAMEWORK FOR AVIATION INDUSTRY

This chapter of the thesis study proposes a framework for DT strategy evaluation. The proposed framework consists of a SWOT model and the validation of the proposed model using integrated IVIF MCDM methodology. This chapter contains four main sections as follows: Literature review concerning SWOT analysis has been introduced in the first section. The second section proposes the SWOT model. Application of the proposed methodology to a real case in aviation industry is given in third section. Finally, results are discussed in the fourth section. Details concerning these sections are presented below.

5.1. Literature Review

Appropriate strategic management and selection of the strategies are necessary for profitability, competitiveness, and sustainability of the airline companies during the DT process which is a holistic management philosophy. DT which has no clear and concrete definition yet has become a buzzword and popular both in the industries and academic fields. It can be explained as the utilization of the new digital technologies such as cloud, social media, mobile, big data, and connectivity for improving the customer experiences, transactions and creating new business models (Kovynyov & Mikut, 2018). The DT process has been influencing the products and the services that the companies offer, processes, management concepts, and organizational structure. Furthermore, it contains the transformation and differentiation of the basic business operations (Matt et al., 2015). The goal of the DT process is to conduct improvements and developments for an asset. This is driven by the remarkable changes in its features and technologies such as information, computing, communication, and connection are integrated during this change (Vial, 2019).

Digital technologies have become a power in the hands of people during the DT processes. This has made the DT a necessity for the companies. Hence, the companies can survive and ensure profitability and sustainability in a digital ecosystem. Digital channels are used by potential customers, and they are driving the DT process based on their demands for digital products and services. The emerging technologies and developments concerning technology have differentiated the interaction style of the people. The increased usage of the internet and digital platforms such as mobile applications and social media have made the daily routines of both companies and people integrated. The global internet access is about 76% and half of this rate shows the active social media users (Büyüközkan & Göçer, 2018).

Even though the DT process has various domains, components, drivers, and characteristics and is a result of digital technologies, it is driven by strategy, not by technology (Kane et al., 2015; Büyüközkan et al., 2021a,b). Hence, focusing on DT strategies is vital for the companies. The real-time-based and right information can be ensured by the DT strategies to obtain competitive advantages. In such a case, the road map that the companies are going to adopt should be the focus area.

The needs, goals, visions, and wishes of the companies have become more digital under the influence of DT. But the determination of the correct DT strategies can be ambiguous, complex, and uncertain. Having no idea about the starting point and determination of the most appropriate strategy may arise questions (Esri, 2017). Therefore, the evaluation of the DT strategies and selection of the most appropriate strategy or strategies are significant. There is no need to show a proof that the DT has influenced different sectors all over the world. Airline industry is one of them.

A 4.8% increase is expected in passenger traffic between 2015 and 2035. It is indicated that more than a billion passengers who are potential passengers are waiting for services and the number of these passengers is increasing. However, there is a clear change in the profiles of passengers. Now, they are digital passengers due to the usage of digital technologies. Furthermore, there is growth concerning the new travel technologies. The usage of smartphones is about 90% in Europe. Following that, laptops are used about 46% while tablets are used about 80%. Additionally, the percentage of the growth of new travel technologies is indicated as 15% in air transportation. Connectivity is expected by the passengers of today (Streichfuss & Peschl, 2017). It is declared that the DT will deeply influence the travel business and air travelers until 2025 and these changes should be complied with by the airline companies. Therefore, the organizational structures of the airline companies, their investments in technology should be upgraded.

Better service quality can be provided with training of the staff and collaboration. Furthermore, competitive advantages can be obtained through digital platforms, customer segmentation, digital trust, rapid adoption of technological developments, and customer relationship management strategies (Büyüközkan et al., 2021b).

If it is needed to be summarized the above-mentioned statements, there are changes in customer behavior, demands of the digital passengers. To comply with the DT and the technology effect in air transportation, airline companies should focus on the analysis of external and internal environments. There is a need for a road map for DT by the airline companies. Hence, in this part, DT strategy analysis in the airline industry has been focused on. A case study is conducted. However, strategy analysis and the selection of the most appropriate strategy may be a complex decision-making problem (Büyüközkan et al., 2021b). Furthermore, DT itself is a holistic transformation and it contains uncertainty and various conflicting criteria. In such a case, consistency, reliability, and profession are needed. Hence, a novel methodology is utilized in this chapter.

The integrated IVIF AHP and IVIF VIKOR methodology proposed in Chapter 3 is used in this chapter for DT strategy analysis and for the selection of the most appropriate DT strategy. Furthermore, SWOT analysis is integrated with them due to its limitations about the quantification. As a result, a SWOT-based IVIF AHP and IVIF VIKOR methodology has been applied. A SWOT analysis is conducted with the help of experts from the industry. The SWOT factors are prioritized, and their weights are obtained using the IVIF AHP method. Following that, the DT strategies are evaluated, and the most appropriate DT strategy is selected through the IVIF VIKOR method. For this purpose, literature concerning the SWOT analysis and usage of SWOT analysis with analytical methods are illustrated.

The literature on strategic management contains various tools concerning strategic cases. A balanced scorecard, benchmarking and SWOT analysis are some of the strategic management tools. SWOT analysis which its origin is unknown has started to appear in the 1960s in the literature. With this method being seen in the literature, it coincides with the beginning of the strategy concept's use in the field of business management. SWOT concept contains four main dimensions. These are strengths (S), weaknesses (W), opportunities (O), and threats (T), respectively. The name SWOT is an abbreviation consisting of the initial letters of these main dimensions (Büyüközkan et al., 2021b).

SWOT analysis enables companies to make internal and external environmental analysis. Although it is a simple analysis method, it is a very effective and powerful method (Thompson et al., 2015; Khan, 2018). It is known as a strategic planning framework that enables companies to make strategic decisions. This method not only enables companies to analyze their current situation, but also gives answers to their questions about where and how they want to be in the future.

The basis of the SWOT analysis that is used in the strategic management processes is a matrix containing external and internal factors. S and W criteria are included in the internal factors while the O and T criteria are included in the external factors of the SWOT matrix. Various and several strategies may be revealed based on this structure of SWOT analysis. The overall structure of a SWOT matrix can be represented as in Table. 5.1. This matrix provides to see opportunities concerning the market and threats related to the future while it helps to reveal the deficiencies or capabilities of an organization. Various strategies related to the dimensions and factors of the SWOT matrix can be obtained. Four main possible strategies from these various strategies are shown in Table. 5.1.

SWOT analysis is applicable by both practitioners in business life and academicians, and it has a wide range of usability in the literature. Different studies have been conducted based on different purposes in various areas in the literature (Ghazinoory et al., 2011; Gürel & Tat, 2017). But this is not the only attractive aspect of the SWOT analysis. Some advantages that make using this method attractive. Gürel & Tat (2017) have revealed some advantages of the SWOT analysis method as follows (Büyüközkan et al., 2021b):

- A roadmap allowing to navigate from general to specific can be obtained,
- Positive and negative points concerning external and internal environments of the organization can be focused,
- Advantages can be gained by using opportunities. At the same time, the impact of threats can be reduced or eliminated by detecting weaknesses.

- A strategic infrastructure that allows group discussion and group decision-making can be created.
- It can be used at different levels of organizations, industries, or countries.

However, SWOT analysis has also some limitations. Some of these limitations can be summarized as follows (Helms & Nixon, 2010; Büyüközkan et al., 2021b)):

- It is an oversimplified method, and it contains vagueness and uncertainty,
- The model may not reflect today's complex conditions,
- SWOT model should contain customer perspective,
- A methodology should be used to support this analysis method,
- The success of the model depends on the experts involved or consensus,
- SWOT analysis may not contain the experiences, skills, attitudes, or believes of the experts and top managers,
- The method can be insufficient to reveal the hierarchy between the elements,
- The analysis method contains human perception.

Table 5.1: A SWOT matrix and the possible strategies (Ghazinoory et al., 2011)

SWOT matrix	Strengths (S)	Weaknesses (W)
Opportunities (O)	**SO strategy** represents the usage of the strengths of the organization to take advantage of opportunities.	**WO strategy** shows the elimination of the weaknesses by using the advantages of the opportunities.
Threats (T)	**ST strategy** represents the usage of the strengths to avoid and eliminate threats.	**WT strategy** indicates the minimization or reduction of the weaknesses of the organization to eliminate or avoid threats.

The advantages of the SWOT analysis make it possible to use this method, while the disadvantages make it clear that the method should be supported. It can be stated that the most obvious limitation of this analysis method is the inability to quantify the elements during the decision-making processes (Büyüközkan et al., 2021b,c). It is indicated that methodologies should be used.

Table 5.2: MCDM utilization in some SWOT-based studies (2011-2021)

Source	Aim of the study	Application area	Utilized method(s)
Ekmekçioglu et al. (2011)	To select the most appropriate site.	Energy industry	Fuzzy AHP, Fuzzy TOPSIS
Jeyaraj et al. (2012)	To select the most appropriate strategy.	Textile industry	Fuzzy ANP
Sevkli et al. (2012)	To select the most appropriate strategy.	Airline industry	Fuzzy ANP
Arshadikhamseh & Fazayeli (2013)	To select the most appropriate strategy.	Medication and drug distribution	Fuzzy ANP
Forghani &Izadi (2013)	To select the most appropriate contractor.	Energy industry	Fuzzy VIKOR, Fuzzy TOPSIS
Hatami-Marbini et al. (2013)	To select the most appropriate growth strategy.	Manufacturing	Fuzzy CRM
Cevik Onar et al. (2014)	To select the most appropriate decision.	Electronic industry	Interval Type-2 fuzzy MCDM, hesitant fuzzy
Demirtas et al. (2014)	To select the most appropriate project management methodology.	Banking industry	Fuzzy AHP
Esmaeili et al. (2014)	To select the most appropriate strategy.	Oil industry	Fuzzy AHP, Fuzzy TOPSIS
Nikjoo & Saeedpoor (2014)	To prioritize the components of SWOT matrix	Insurance industry	IF DEMATEL
Arabzad et al. (2015)	To select supplier selection and allocate orders.	Energy industry	Fuzzy TOPSIS

Table 5.2: Some SWOT-based studies with fuzzy extension MCDM in the last ten years (*continue*)

Source	Aim of the study	Application area	Utilized method(s)
Shakeri et al. (2015)	To select private sector.	Water treatment	AHP, Fuzzy ELECTRE
Ramkumar et al. (2016)	To assess the risks in supply chain.	Supply chain	Modified Fuzzy ANP
Tavakoli et al. (2016)	To develop strategies for consulting engineers.	Consulting engineers	Fuzzy DEMATEL
Tavana et al. (2016)	To identify the strategic priorities for outsourcing reverse logistics	Logistics	IF AHP
Khaba & Bhar (2017)	To quantify the factors concerning coal mining.	Coal mining industry	Fuzzy DEMATEL
Ervural et al. (2018)	To select the most appropriate strategy.	Energy industry	ANP, Fuzzy TOPSIS
Khan (2018)	To select the most appropriate strategy.	Natural gas industry	Modified fuzzy goal programming
Büyüközkan & Ilıcak (2019)	To select the most appropriate strategy.	Social media	Multi preference relation
Karimi et al. (2019)	To select the most appropriate strategy.	Ceramic and tile industry	Fuzzy ANP, Grey Relation Analysis
Khatir & Akbarzadeh (2019)	To select the most appropriate strategy.	Science and technology	Fuzzy ANP, Fuzzy DEMATEL, Fuzzy TOPSIS
Kramar et al. (2019)	To select the most appropriate strategy.	Urban mobility	Fuzzy AHP
Solangi et al. (2019)	To select the most appropriate strategy.	Energy industry	AHP, Fuzzy TOPSIS
Xu & Dong (2019)	To select the most appropriate strategy.	Coal to chemical industry	Fuzzy ANP, Fuzzy DEMATEL, Fuzzy SAW, Fuzzy TOPSIS, Fuzzy VIKOR, Fuzzy Vector Projection
Anser et al. (2020)	To assess the projects related to renewable energy industry.	Renewable energy	AHP, Fuzzy VIKOR

Table 5.2: Some SWOT-based studies with fuzzy extension MCDM in the last ten years (*continue*)

Source	Aim of the study	Application area	Utilized method(s)
Papapostolou et al. (2020)	To determine a national strategic plan.	Renewable energy sources	AHP, Fuzzy TOPSIS
Wang et al. (2020)	To select the most appropriate renewable energy resource.	Energy industry	Fuzzy AHP
Büyüközkan et al. (2021b)	To determine the DT strategies	Aviation industry	Fuzzy AHP, Fuzzy MARCOS, Fuzzy TOPSIS, Fuzzy VIKOR
Büyüközkan et al. (2021c)	To select the most appropriate strategy	Health tourism	Hesitant fuzzy linguistic AHP, Hesitant fuzzy linguistic MABAC
Gholizadeh et al. (2021)	To determine strategies for natural resources.	Natural resources	Fuzzy AHP

There are different criteria in a SWOT matrix and in the determination of a strategy is a decision-making process. Hence, MCDM methods can be used to support and quantify the SWOT analysis. But also, disadvantages of the analysis show that there are complexity and vagueness. Ambiguity and prioritization of the elements are not considered (Khan, 2018). Fuzzy MCDM methods may be helpful to eliminate this uncertainty. However, the existence of the experts and human perception in this analysis method may rise intuition. In this case, it is wise to expand the MCDM methods to an IF environment. SWOT analysis is used with different fuzzy MCDM methods and their extensions to solve different decision-making problems for various purposes. A literature survey has been conducted to show the applicability of SWOT analysis with fuzzy MCDM methods in the literature. The results of the conducted literature survey are given in Table 5.2.

Table 5.2 shows that the SWOT analysis is used with different MCDM methods in the studies concerning the decision-making problems in various application areas. Therefore, the use of SWOT analysis in this study has been fully justified, based on the above-mentioned advantages, its widespread use in different fields, and its integration with

MCDM methods. Furthermore, the conducted literature survey reveals that most of the studies used the AHP method for prioritizing the SWOT factors and determining their weights. Additionally, recent studies are using the fuzzy AHP method as combined with SWOT analysis. Besides, studies using SWOT analysis needed a selection method such as fuzzy TOPSIS and fuzzy ELECTRE or fuzzy VIKOR methods for strategy selection. Table 5.2 proves that the SWOT analysis is applicable with combined MCDM methods. Furthermore, it is seen that most of the SWOT-based studies are utilizing fuzzy MCDM methods. There is limited number of studies using fuzzy extensions such as hesitant, neutrosophic, IF sets to deal with the complexity, vagueness, hesitation, and intuition. There is a gap in the literature in this manner.

By considering the gap in the academic literature, this chapter proposes a novel approach. A SWOT-based IVIF AHP and IVIF VIKOR methodology is used for the DT strategy analysis.

5.2. Proposed Digital Transformation Strategy Evaluation Model

SWOT factors are identified through a detailed literature survey and the opinions of the experts who are the DMs for the case study. The components of the constructed SWOT model are given as follows (Taneja, 2011; Westerman et al., 2011; Westerman et al., 2014; Bourne, 2015; Rogers, 2016; DGCA, 2019; Kaur & Bath, 2019; Büyüközkan et al., 2020a; Büyüközkan et al., 2020b; Büyüközkan et al., 2021a; Büyüközkan et al., 2021b):

- **Strengths (S) Factors (Büyüközkan et al., 2021b):**
  - S_1: The establishment of the innovation laboratories and the existence of collaboration, technology partnerships (DGCA, 2019)
  - S_2: Mobile/web-based steps and improvements in determination of information management strategies (Expert Opinion)
  - S_3: Innovation in technology & development of digital platforms and channels (Expert Opinion)
  - S_4: Value creation & proposition (Westerman et al., 2014; Büyüközkan et al., 2020b, Büyüközkan et al., 2021a)
  - S_5: Recognition & segmentation of the customers (Taneja, 2011)

- **Weaknesses (W) Factors (Büyüközkan et al., 2021b):**
  - W_1: Inappropriate transformation and adoption of business models for digital transformation (Westerman et al., 2011)
  - W_2: Ineffective use of competent human resources (DGCA, 2019)
  - W_3: Cooperation insufficiency between departments (Bourne, 2015)
  - W_4: Tardiness of decision-making mechanisms & competing with IT priorities (Bourne, 2015)
  - W_5: Inadequate customer empowerment for digital technologies (Expert Opinion)
- **Opportunities (O) Factors (Büyüközkan et al. 2021b):**
  - O_1: Emerging digital technologies, greater agility & flexibility (Bourne, 2015)
  - O_2: Increased cyber-physical touchpoints & more customer data (Westerman et al., 2014; Kaur & Bath, 2019)
  - O_3: Interaction & collaboration with customers via digital channels (Westerman et al., 2014)
  - O_4: Increased number of digital passengers (Expert Opinion)
  - O_5: Differentiated customer experience & service quality perception (Rogers, 2016; DGCA, 2019; Kaur & Bath, 2019; Büyüközkan et al., 2020a)
- **Threats (T) Factors (Büyüközkan et al. 2021b):**
  - T_1: Dependence on external technologies for some areas (DGCA, 2019)
  - T_2: Cyber security & privacy concerns (DGCA, 2019)
  - T_3: Incorrect definition of digital passengers (Expert Opinion)
  - T_4: Change in value perception & disruptive power of digital transformation (Rogers, 2016; DGCA, 2019; Büyüközkan et al., 2020a, Büyüközkan et al.,2021a)
  - T_5: New employment areas & human resource needs brought by technology (DGCA, 2019)

5.3. Application of the Proposed Methodology

The priority weights of the SWOT criteria/factors are computed through the IVIF AHP method. Following that, alternative DT strategies based on the SWOT model are prioritized and the most appropriate alternative is selected with the IVIF VIKOR method.

During the application of the proposed methodology in the aviation industry, the computational steps that are given in Chapter 3 are applied.

Calculation of the Criteria Weights with the IVIF AHP Method:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information and knowledge level about the DT process and willingness to help are considered as the determination criteria. Let $DM = \{DM_1, DM_2, DM_3\}$ be the set of DMs. A senior vice president of corporate innovation and projects of an airline company is determined as the DM_1. Following that, DM_2 is selected from the same company and department. DM_3 is the founder of a company. The company offers products and services for the aviation industry. All the DMs are also actively using air transportation as passengers. Due to privacy and confidentiality concerns, further information about the DMs cannot be provided.

Step 2. Determination of the goal and the evaluation criteria:

The goal is to analyze the DT strategies and select the most appropriate DT strategy or strategies. A SWOT model is constructed for this goal. SWOT factors are identified through a detailed literature survey and the opinions of the experts who are the DMs for the case study. Constructed SWOT matrix is shown in Figure 5.1 (Taneja, 2011; Westerman et al., 2011; Westerman et al., 2014; Bourne, 2015; Rogers, 2016; DGCA, 2019; Kaur & Bath, 2019; Büyüközkan et al., 2020a; Büyüközkan et al., 2020b; Büyüközkan et al., 2021a; Büyüközkan et al., 2021b).

Step 3. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the criteria are adopted from the scientific studies in the academic literature. Utilized scales are given in the steps in question.

Step 4. Restructuring the problem:

The hierarchical structure is constructed based on the SWOT matrix. The constructed hierarchical model is presented in Figure 5.2.

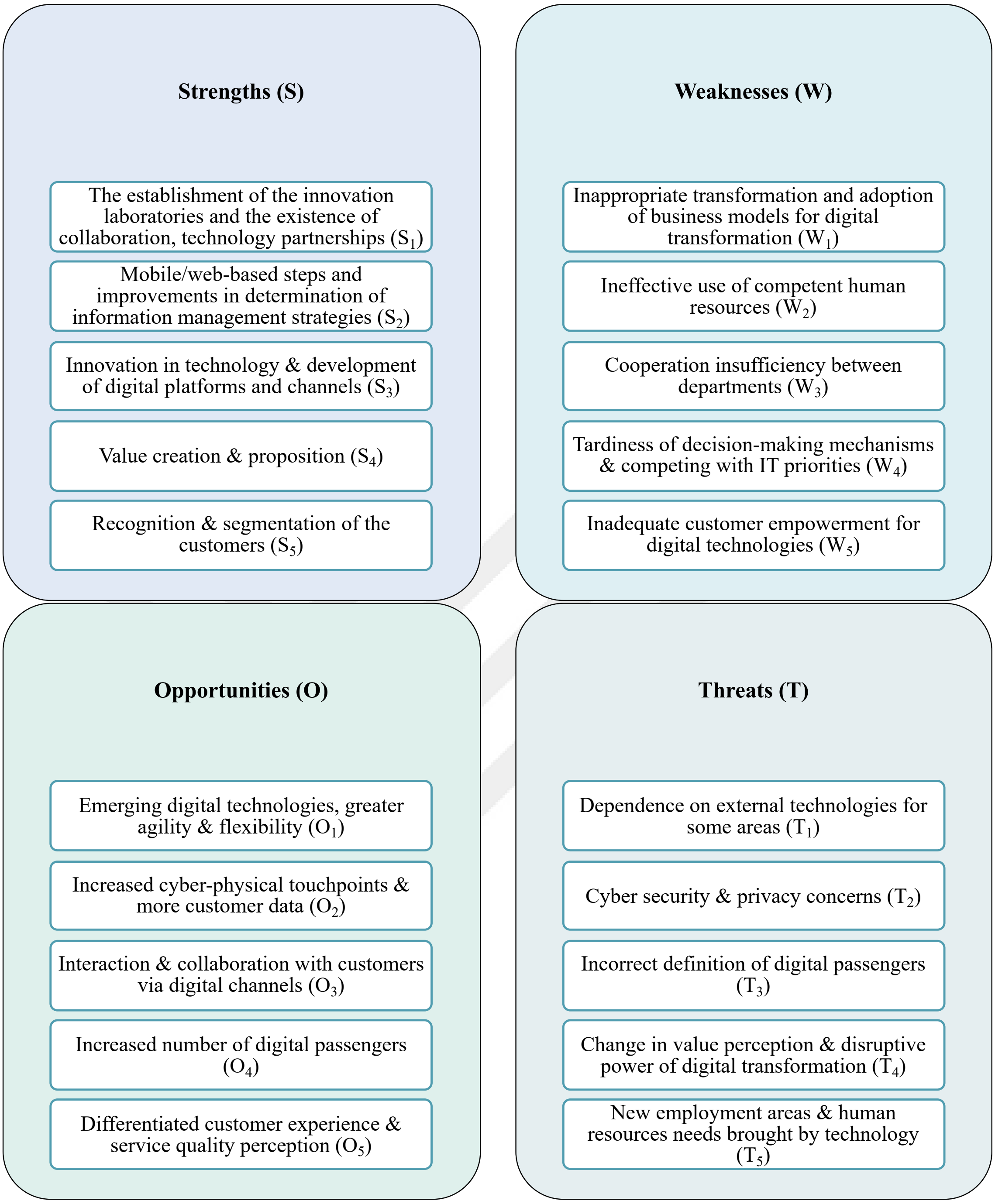


Figure 5.1: Constructed SWOT matrix (Büyüközkan et al., 2021b)

Step 5. Calculation of the weights of the DMs:

The importance degree of the determined DMs is assigned using the linguistic terms given in Table 3.3 by considering the criteria introduced in Step 1. Following that, the weights of the DMs given in Table 5.3 are calculated using Eq. (3.19) based on the assigned linguistic terms.

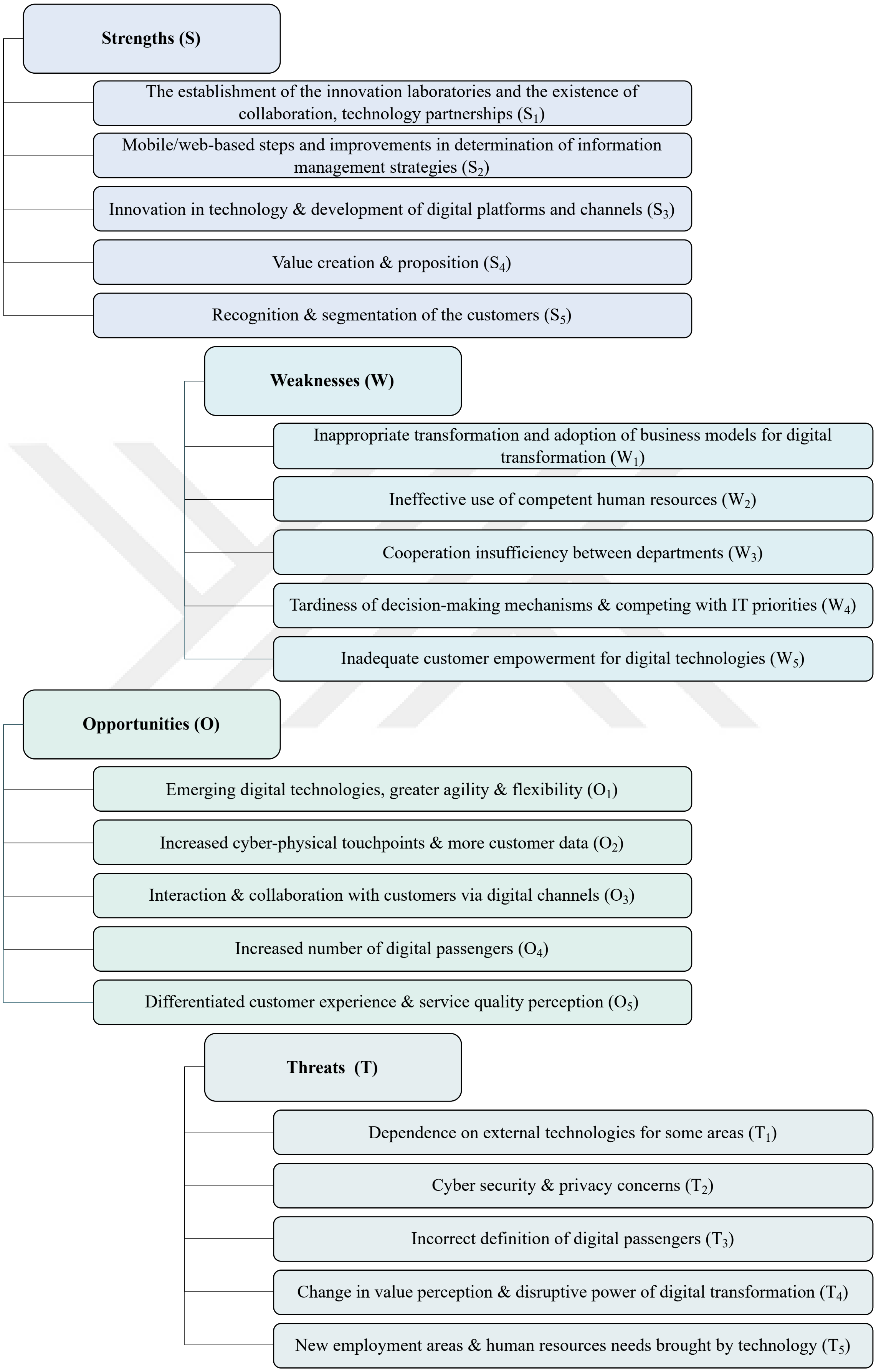


Figure 5.2: The hierarchical structure of the SWOT model (Büyüközkan et al., 2021b)

Table 5.3: The importance degrees of the DMs

DMs	Importance Degrees of the DMs	IVIF values		Weights of the DMs
		$\tilde{\mu}_{\tilde{A}}(x)$ $[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U]$	$\tilde{\nu}_{\tilde{A}}(x)$ $[\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U]$	
DM_1	EQ	[0.95, 1.00]	[0.00, 0.00]	0.371
DM_2	Q	[0.60, 0.65]	[0.10, 0.15]	0.286
DM_3	VQ	[0.80, 0.85]	[0.05, 0.10]	0.343

Step 6. Evaluation of the criteria:

The judgments of the DMs are obtained through the linguistic terms given in Table 3.4 based on pairwise comparisons. Due to page limitations, only the evaluations of the SWOT dimensions are provided. The evaluations concerning the SWOT dimensions are given in Tables 5.4, 5.5, and 5.6, respectively. The same evaluation process and pairwise comparisons are applied for the SWOT criteria. Following that, the judgments of the DM_1 for the evaluation of the criteria concerning the SWOT dimensions are given from Table 5.7 to Table 5.10, respectively.

Table 5.4: The evaluation of the SWOT dimensions by DM_1

	S	W	O	T
Strength (S)	EI	MMI	EI	IV
Weaknesses (W)		EI		
Opportunities (O)		IV2	EI	IV
Threats (T)		IV		EI

Table 5.5: The evaluation of the SWOT dimensions by DM_2

	S	W	O	T
Strength (S)	EI	VSMI	EI	MMI
Weaknesses (W)		EI		
Opportunities (O)		SMI	EI	MMI
Threats (T)		MMI		EI

Table 5.6: The evaluation of the SWOT dimensions by DM_3

	S	W	O	T
Strength (S)	EI	IV4	IV	IV2
Weaknesses (W)		EI		
Opportunities (O)		IV3	EI	IV2
Threats (T)		IV2		EI

Table 5.7: The evaluation of the Strengths criteria by the DM_1

Criteria	S_1	S_2	S_3	S_4	S_5
S_1	EI	EI		IV2	SMI
S_2		EI		MMI	
S_3	MMI	IV2	EI	MMI	IV2
S_4				EI	
S_5		MMI		MMI	EI

Table 5.8: The evaluation of the Weaknesses criteria by the DM_1

Criteria	W_1	W_2	W_3	W_4	W_5
W_1	EI	SMI	SMI	SMI	IV2
W_2		EI	SMI	SMI	SMI
W_3			EI	SMI	SMI
W_4				EI	IV2
W_5					EI

Table 5.9: The evaluation of the Opportunities criteria by the DM_1

Criteria	O_1	O_2	O_3	O_4	O_5
O_1	EI			IV2	
O_2	IV	EI	MMI	IV2	IV2
O_3	MMI		EI	IV2	IV
O_4				EI	
O_5	SMI			IV2	EI

Table 5.10: The evaluation of the Threats criteria by the DM_1

Criteria	T_1	T_2	T_3	T_4	T_5
T_1	T_1	EI			
T_2	T_2	MMI	EI	IV2	IV2
T_3	T_3	IV2		EI	MMI
T_4	T_4	MMI			EI
T_5	T_5	SMI			

Step 7. Aggregation:

The judgments of the DMs are converted into IVIF values. The individual evaluations of the DMs are aggregated to obtain group decision values using Eq. (3.20).

The main aggregated IVIF values (group decision) concerning the SWOT dimensions are presented in Table 5.11. Additionally, same process is applied for the SWOT criteria. The main aggregated IVIF values concerning the SWOT criteria are shown in the Tables from 5.12 to 5.15, respectively.

Table 5.11: Main aggregated IVIF values concerning the *SWOT* dimensions

SWOT Dimensions	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
S	[0.453, 0.618]	[0.044, 0.380]	[0.002, 0.503]
W	[0.199, 0.566]	[0.085, 0.432]	[0.001, 0.716]
O	[0.296, 0.606]	[0.057, 0.392]	[0.002, 0.647]
T	[0.235, 0.606]	[0.048, 0.390]	[0.004, 0.717]

$(C.R. = 0.085)$

Table 5.12: Main aggregated IVIF values concerning the *Strengths* criteria

Strengths criteria	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
S_1	[0.307, 0.657]	[0.014, 0.343]	[0.001, 0.679]
S_2	[0.288, 0.694]	[0.028, 0.304]	[0.002, 0.684]
S_3	[0.235, 0.630]	[0.006, 0.370]	[0.000, 0.759]
S_4	[0.203, 0.718]	[0.021, 0.281]	[0.001, 0.777]
S_5	[0.227, 0.674]	[0.011, 0.326]	[0.000, 0.761]

$(C.R. = 0.097)$

Table 5.13: Main aggregated IVIF values concerning the *Weaknesses* criteria

Weaknesses criteria	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$	$\left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right]$
W_1	[0.245, 0.652]	[0.008, 0.348]	[0.000, 0.748]
W_2	[0.302, 0.669]	[0.018, 0.331]	[0.001, 0.680]
W_3	[0.263, 0.679]	[0.019, 0.320]	[0.001, 0.718]
W_4	[0.212, 0.675]	[0.018, 0.325]	[0.000, 0.770]
W_5	[0.196, 0.700]	[0.019, 0.300]	[0.000, 0.785]

$(C.R. = 0.095)$

Table 5.14: Main aggregated IVIF values concerning the *Opportunities* criteria

Opportunities criteria	$[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}]$	$[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}]$	$[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}]$
O_1	[0.209, 0.686]	[0.023, 0.313]	[0.001, 0.767]
O_2	[0.278, 0.639]	[0.008, 0.360]	[0.001, 0.713]
O_3	[0.315, 0.654]	[0.016, 0.345]	[0.001, 0.669]
O_4	[0.183, 0.715]	[0.011, 0.285]	[0.000, 0.806]
O_5	[0.266, 0.680]	[0.018, 0.319]	[0.001, 0.717]

$(C.R. = 0.096)$

Table 5.15: Main aggregated IVIF values concerning the *Threats* criteria

Threats criteria	$[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}]$	$[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}]$	$[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}]$
T_1	[0.202, 0.715]	[0.018, 0.285]	[0.000, 0.780]
T_2	[0.252, 0.621]	[0.006, 0.378]	[0.001, 0.743]
T_3	[0.208, 0.654]	[0.006, 0.346]	[0.000, 0.786]
T_4	[0.245, 0.670]	[0.011, 0.330]	[0.001, 0.745]
T_5	[0.239, 0.711]	[0.022, 0.287]	[0.001, 0.739]

$(C.R. = 0.090)$

Step 8. Consistency check:

The $C.R.$ values are computed at this step using the Eq. (3.21). The $C.R.$ values are shown in Tables from Table 5.11 to 5.15. For all $C.R.$ values the condition of $C.R. < 0.1$ has been satisfied. Hence, the obtained judgments from the DMs are consistent and acceptable.

Step 9. Calculation of the criteria weights:

The weights of the criteria are calculated through the Eq. (3.22). The obtained results are presented in Table 5.16.

Evaluation of the Alternatives with the IVIF VIKOR Method:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information, and knowledge level and willingness to help are considered as the determination criteria. The same group of experts in the IVIF AHP part is involved in the evaluation process conducted in the IVIF VIKOR part.

Step 2. Determination of the goal and the evaluation criteria:

The goal is determined as the evaluation of the determined DT strategies by considering the proposed SWOT model and its factors. A set of evaluation criteria (proposed SWOT criteria) concerning the identified goal is determined based on a literature survey and the opinions of the DMs. The evaluation criteria are used to evaluate the alternatives.

Table 5.16: The weights of SWOT dimensions and criteria

Dimensions	Weights	Criteria	Local Weights	Global Weights
S	0.2755	S_1	0.2056	0.0567
		S_2	0.2071	0.0570
		S_3	0.1928	0.0531
		S_4	0.1975	0.0544
		S_5	0.1970	0.0543
W	0.2264	W_1	0.1979	0.0448
		W_2	0.2072	0.0469
		W_3	0.2035	0.0461
		W_4	0.1956	0.0443
		W_5	0.1958	0.0443
O	0.2541	O_1	0.1959	0.0498
		O_2	0.2002	0.0509
		O_3	0.2064	0.0525
		O_4	0.1944	0.0494
		O_5	0.2032	0.0516
T	0.2439	T_1	0.2002	0.0488
		T_2	0.1971	0.0481
		T_3	0.1949	0.0475
		T_4	0.2023	0.0493
		T_5	0.2055	0.0501

Step 3. Determination of the set of alternatives:

A set of suitable alternatives is constructed based on SWOT factors. 8 different DT strategies are determined by a literature survey and the opinions of the DMs. These alternative strategies are constructed based on the SWOT model given in Figure 5.1. Let $A = \{A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8\}$ be the set of suitable alternatives. The determined alternatives are shown in Figure 5.3.

Step 4. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the alternatives over the evaluation criteria are adopted from the scientific studies in the academic literature. The used scale is given in Chapter 3.

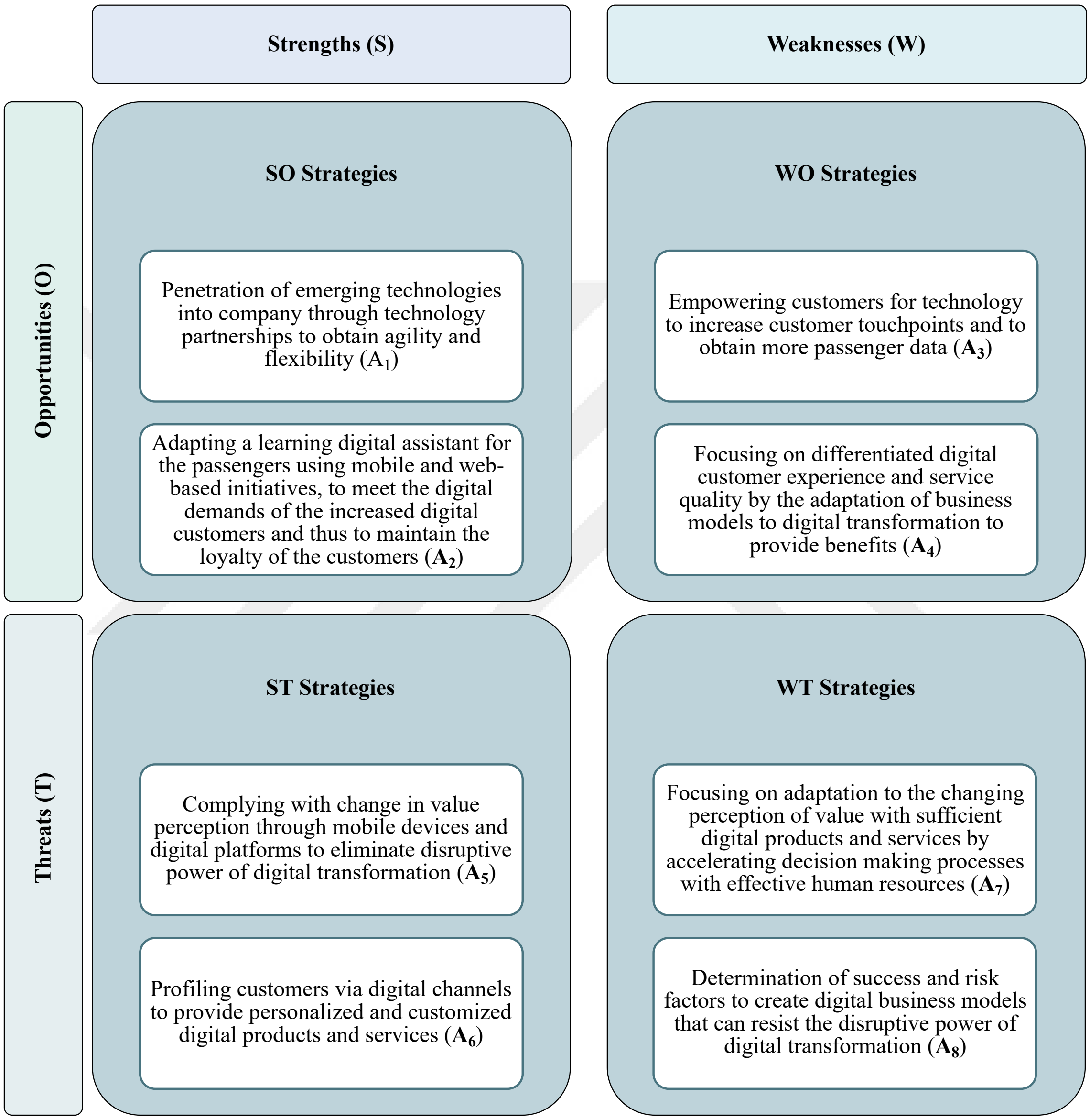


Figure 5.3: Determined strategies for DT

Step 5. Calculation of the weights of the DMs:

The weights of the DMs given in Table 5.3 in the IVIF AHP part are used at this step. ($\lambda_1 = 0.371,\ \lambda_2 = 0.286,\ \lambda_3 = 0.343$).

Step 6. Evaluation of the alternatives:

The judgments of the DMs for the alternatives are obtained based on the evaluation criteria. The linguistic terms given in Table 3.6 are used to assess the alternatives. Furthermore, evaluation of the alternatives over the SWOT criteria is illustrated on a hierarchical diagram in Figure 5.4. The linguistic evaluations of the alternatives are presented in Tables 5.17, 5.18, and 5.19, respectively.

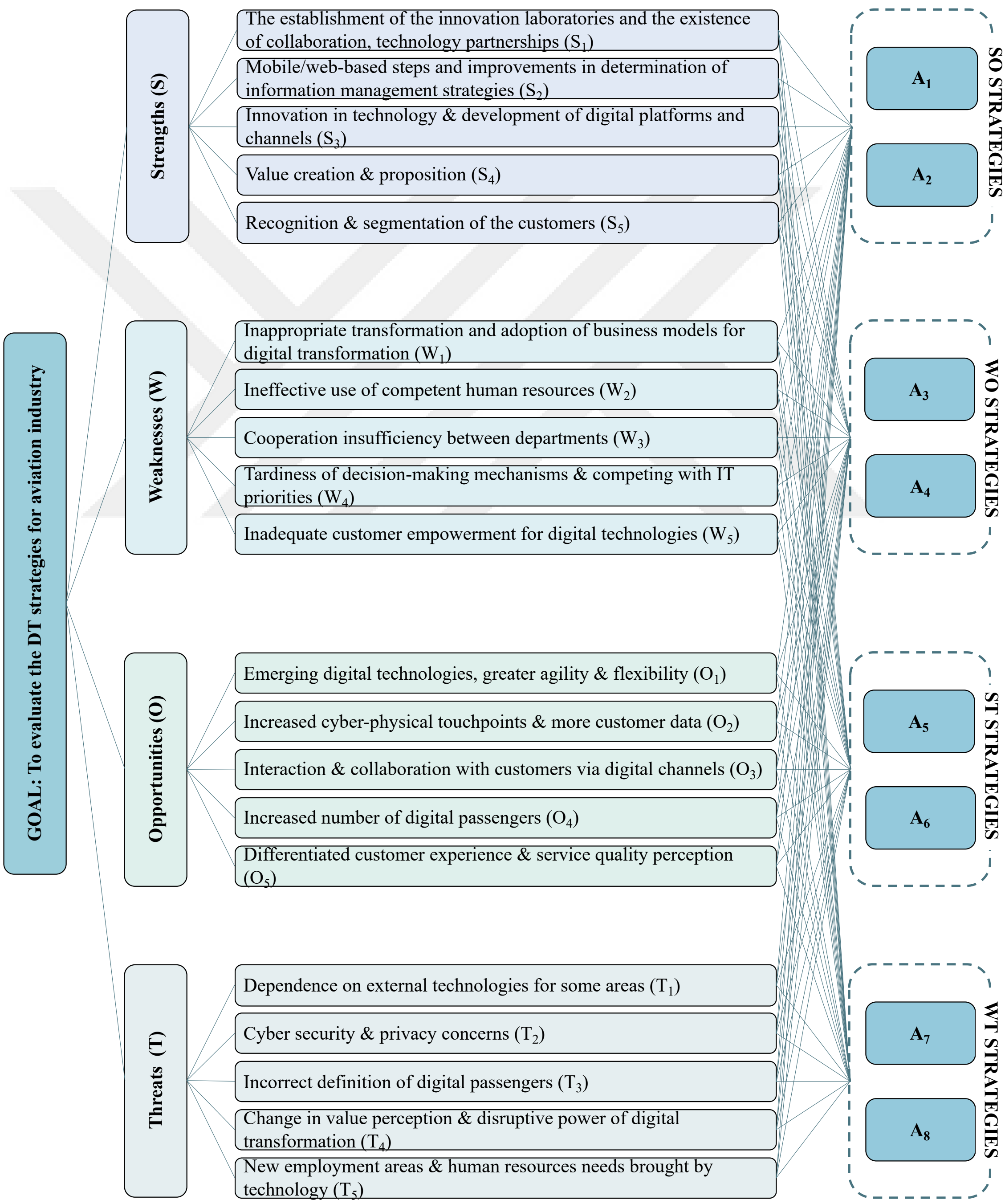


Figure 5.4: Evaluation of the DT strategies

Step 7. Aggregation:

The linguistic terms used to evaluate the alternatives are transformed into IVIF values and these IVIF values are aggregated to obtain a group-decision matrix $(\tilde{X})$ by using the IIFWA operator proposed by Xu & Cai (2012) as indicated in Eq. (3.20).

Table 5.17: Evaluation of the alternatives by the DM_1

Criteria	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	VB	VVG	M	VVG	G	VVG	VVG	VVG
S_2	MG	MG	MG	VVG	VG	VG	G	VVG
S_3	MG	MG	MG	VVG	G	VG	G	VVG
S_4	MG	VVG	G	VVG	G	VVG	VVG	VVG
S_5	G	VVG	VG	VVG	G	VVG	VVG	VVG
W_1	M	G	MG	VVG	G	G	VVG	MG
W_2	G	VVG	MG	MG	VG	VG	G	VVG
W_3	G	G	G	MG	VVG	VVG	VVG	G
W_4	VG	VVG	VG	VVG	G	G	VVG	G
W_5	G	MG	VG	G	VG	G	G	MG
O_1	VVG	VVG	VVG	VVG	VG	VVG	VVG	VVG
O_2	VVG	VVG	VVG	VVG	VVG	VVG	VG	VVG
O_3	VVG	VVG	VVG	VVG	VG	VVG	VVG	G
O_4	VVG	G	VG	G	VG	VVG	VVG	VVG
O_5	G	VVG	G	VVG	VVG	VVG	VVG	G
T_1	VVG	M	G	G	VG	B	VVG	MG
T_2	VVG	VVG	VG	VVG	VVG	VVG	VVG	VVG
T_3	VVG	MG	G	VG	VG	VVG	VG	G
T_4	G	G	VG	G	G	VVG	G	VVG
T_5	M	M	MG	M	M	M	G	MG

Step 8. Calculation of the positive and negative ideal solutions:

The IVIFPIS $(\tilde{f}_j^*)$ values are calculated using 3.24 and the IVIFNIS $(\tilde{f}_j^-)$ values are computed through Eq. (3.25), respectively. The obtained results concerning the IVIFPIS and IVIFNIS values are given in Table 5.20 and Table 5.21, respectively.

Step 9. Computation of the group utility and individual regret values:

$S(A_i)$ values are computed through the Eq. (3.26) where $R(A_i)$ values are calculated using the Eq. (3.27). To run the Eq. (3.26) and Eq. (3.27), the IVIF AHP weights given in Table 5.16 are used and the weighted evaluation matrix is obtained. Following this, $S(A_i)$ and $R(A_i)$ values are given in Table 5.22.

Table 5.18: Evaluation of the alternatives by the DM_2

Criteria	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	VVB	VG	MB	VG	MG	VG	VG	VG
S_2	M	M	M	VG	G	G	MG	VG
S_3	M	M	M	VG	MG	G	MG	VG
S_4	M	VG	MG	VG	MG	VG	VG	VG
S_5	MG	VG	G	VG	MG	VG	VG	VG
W_1	MB	MG	M	VG	MG	MG	VG	M
W_2	MG	VG	M	M	G	G	MG	VG
W_3	MG	MG	MG	M	VG	VG	VG	MG
W_4	G	VG	G	VG	MG	MG	VG	MG
W_5	MG	M	G	MG	G	MG	MG	M
O_1	VG	VG	VG	VG	G	VG	VG	VG
O_2	VG	VG	VG	VG	VG	VG	G	VG
O_3	VG	VG	VG	VG	G	VG	VG	MG
O_4	VG	MG	G	MG	G	VG	VG	VG
O_5	MG	VG	MG	VG	VG	VG	VG	MG
T_1	VG	MB	MG	MG	G	VB	VG	M
T_2	VG	VG	G	VG	VG	VG	VG	VG
T_3	VG	M	MG	G	G	VG	G	MG
T_4	MG	MG	G	MG	MG	VG	MG	VG
T_5	MB	MB	M	MB	MB	MB	MG	M

Table 5.19: Evaluation of the alternatives by the DM_3

Criteria	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	B	EG	MG	EG	VG	EG	EG	EG
S_2	G	G	G	EG	VVG	VVG	VG	EG
S_3	G	G	G	EG	VG	VVG	VG	EG
S_4	G	EG	VG	EG	VG	EG	EG	EG
S_5	VG	EG	VVG	EG	VG	EG	EG	EG
W_1	MG	VG	G	EG	VG	VG	EG	G
W_2	VG	EG	G	G	VVG	VVG	VG	EG
W_3	VG	VG	VG	G	EG	EG	EG	VG
W_4	VVG	EG	VVG	EG	VG	VG	EG	VG
W_5	VG	G	VVG	VG	VVG	VG	VG	G
O_1	EG	EG	EG	EG	VVG	EG	EG	EG
O_2	EG	EG	EG	EG	EG	EG	VVG	EG
O_3	EG	EG	EG	EG	VVG	EG	EG	VG
O_4	EG	VG	VVG	VG	VVG	EG	EG	EG
O_5	VG	EG	VG	EG	EG	EG	EG	VG
T_1	EG	MG	VG	VG	VVG	MB	EG	G
T_2	EG	EG	VVG	EG	EG	EG	EG	EG
T_3	EG	G	VG	VVG	VVG	EG	VVG	VG
T_4	VG	VG	VVG	VG	VG	EG	VG	EG
T_5	MG	MG	G	MG	MG	MG	VG	G

Step 10. Calculation of the $Q(A_i)$ values:

$Q(A_i)$ values computed using the Eq. (3.30) are given in Table 5.23.

Table 5.20: Calculated IVIFPIS ($\tilde{f}_j^*$) values

Criteria	$\mu_{\tilde{A}}^L$	$\mu_{\tilde{A}}^U$	$\nu_{\tilde{A}}^L$	$\nu_{\tilde{A}}^U$	$\pi_{\tilde{A}}^L$	$\pi_{\tilde{A}}^U$
S_1	0.945	1.000	0.000	0.000	0.000	0.055
S_2	0.945	1.000	0.000	0.000	0.000	0.055
S_3	0.945	1.000	0.000	0.000	0.000	0.055
S_4	0.945	1.000	0.000	0.000	0.000	0.055
S_5	0.945	1.000	0.000	0.000	0.000	0.055
W_1	0.945	1.000	0.000	0.000	0.000	0.055
W_2	0.945	1.000	0.000	0.000	0.000	0.055
W_3	0.945	1.000	0.000	0.000	0.000	0.055
W_4	0.945	1.000	0.000	0.000	0.000	0.055
W_5	0.823	0.881	0.039	0.089	0.030	0.138
O_1	0.945	1.000	0.000	0.000	0.000	0.055
O_2	0.945	1.000	0.000	0.000	0.000	0.055
O_3	0.945	1.000	0.000	0.000	0.000	0.055
O_4	0.945	1.000	0.000	0.000	0.000	0.055
O_5	0.945	1.000	0.000	0.000	0.000	0.055
T_1	0.945	1.000	0.000	0.000	0.000	0.055
T_2	0.945	1.000	0.000	0.000	0.000	0.055
T_3	0.945	1.000	0.000	0.000	0.000	0.055
T_4	0.945	1.000	0.000	0.000	0.000	0.055
T_5	0.717	0.769	0.119	0.177	0.054	0.164

Step 11. Ranked order of the alternatives:

The ascending order of the $S(A_i)$, $R(A_i)$ and $Q(A_i)$ values are used to rank the alternatives. The obtained results are shown in Table 5.24.

When Table 5.24 is examined, it is seen that the first condition of the VIKOR method is not satisfied. Therefore, the second condition of the VIKOR method should be met. According to this $R(A_i)$ values provide the same result with the $Q(A_i)$ values. A_6 is the best DT strategy and A_4 and A_7 strategies follow the A_6. The second condition of the VIKOR method is satisfied. Hence, the ranked order of the alternative DT strategies is provided as $A_6 \succ A_4 \succ A_7 \succ A_8 \succ A_5 \succ A_2 \succ A_3 \succ A_1$.

Table 5.21: Calculated IVIFNIS ($\tilde{f}_j^-$) values

Criteria	$\mu_{\tilde{A}}^L$	$\mu_{\tilde{A}}^U$	$\nu_{\tilde{A}}^L$	$\nu_{\tilde{A}}^U$	$\pi_{\tilde{A}}^L$	$\pi_{\tilde{A}}^U$
S_1	0.210	0.260	0.639	0.690	0.050	0.151
S_2	0.614	0.665	0.231	0.283	0.052	0.155
S_3	0.614	0.665	0.231	0.283	0.052	0.155
S_4	0.614	0.665	0.231	0.283	0.052	0.155
S_5	0.717	0.769	0.119	0.177	0.054	0.164
W_1	0.512	0.563	0.335	0.386	0.051	0.153
W_2	0.614	0.665	0.231	0.283	0.052	0.155
W_3	0.614	0.665	0.231	0.283	0.052	0.155
W_4	0.717	0.769	0.119	0.177	0.054	0.164
W_5	0.614	0.665	0.231	0.283	0.052	0.155
O_1	0.823	0.881	0.039	0.089	0.030	0.138
O_2	0.823	0.881	0.039	0.089	0.030	0.138
O_3	0.717	0.769	0.119	0.177	0.054	0.164
O_4	0.717	0.769	0.119	0.177	0.054	0.164
O_5	0.717	0.769	0.119	0.177	0.054	0.164
T_1	0.310	0.361	0.539	0.589	0.050	0.151
T_2	0.823	0.881	0.039	0.089	0.030	0.138
T_3	0.614	0.665	0.231	0.283	0.052	0.155
T_4	0.717	0.769	0.119	0.177	0.054	0.164
T_5	0.512	0.563	0.335	0.386	0.051	0.153

Table 5.22: The group utility $S(A_i)$ and the individual regret $R(A_i)$ values

DT strategies	$S(A_i)$	$R(A_i)$
A_1	0.582	0.0570
A_2	0.293	0.0570
A_3	0.541	0.0570
A_4	0.183	0.0494
A_5	0.416	0.0543
A_6	0.196	0.0488
A_7	0.208	0.0509
A_8	0.284	0.0525

Table 5.23: Calculated $Q(A_i)$ values

DT strategies	$Q(A_i)$
A_1	1.000
A_2	0.638
A_3	0.949
A_4	0.034
A_5	0.623
A_6	0.017
A_7	0.155
A_8	0.348

Table 5.24: The ranked order of the alternatives

DT Strategies	$S(A_i)$	Order	$R(A_i)$	Order	$Q(A_i)$	Order
A_1	0.582	8	0.0570	6	1.000	8
A_2	0.293	5	0.0570	6	0.638	6
A_3	0.541	7	0.0570	6	0.949	7
A_4	0.183	1	0.0494	2	0.034	2
A_5	0.416	6	0.0543	5	0.623	5
A_6	0.196	2	0.0488	1	0.017	1
A_7	0.208	3	0.0509	3	0.155	3
A_8	0.284	4	0.0525	4	0.348	4

5.4. Results and Discussion

The results of the study show that the most important dimensions are Strengths and Opportunities. When Table 5.16 and Figure 5.5 are examined, it is seen that there is almost no difference between the internal (S and W) and external factors (O and T).

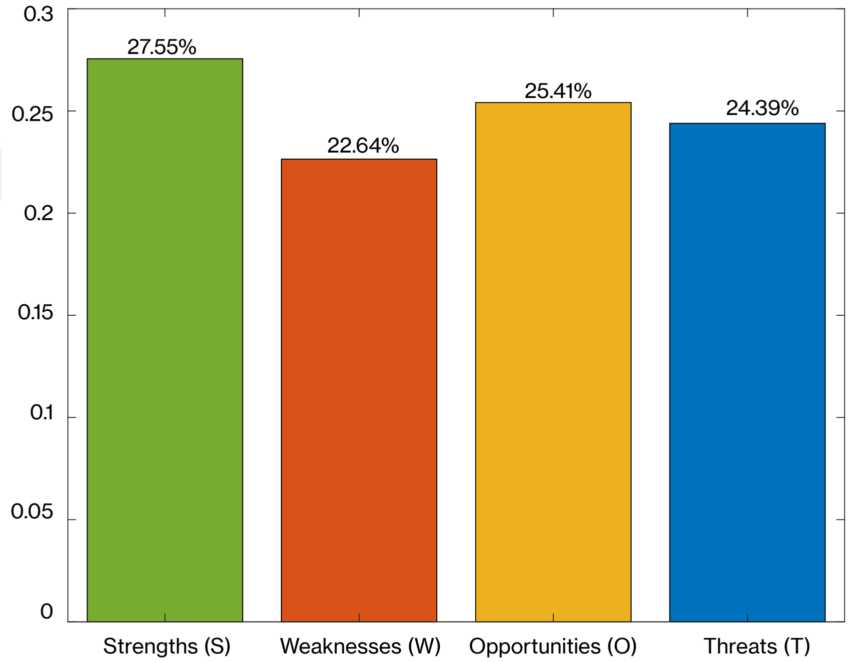


Figure 5.5: The weights of the SWOT dimensions

It can be said that the determination of the DT strategies needs a balance both in the company and its environment. Following that, the weights of the SWOT factors/criteria are shown in Figures 5.6, 5.7, 5.8, and 5.9, respectively. It is revealed that the development of information management strategies and mobile/web-based initiatives are the most prior strength of the airline companies in Turkey. However, the companies have a lack of competent human resources.

Figure 5.6: The weights of the Strengths' criteria

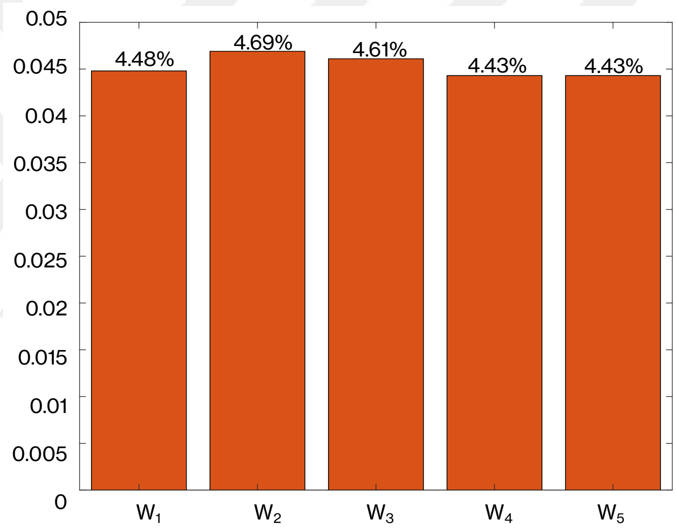


Figure 5.7: The weights of the Weaknesses' criteria

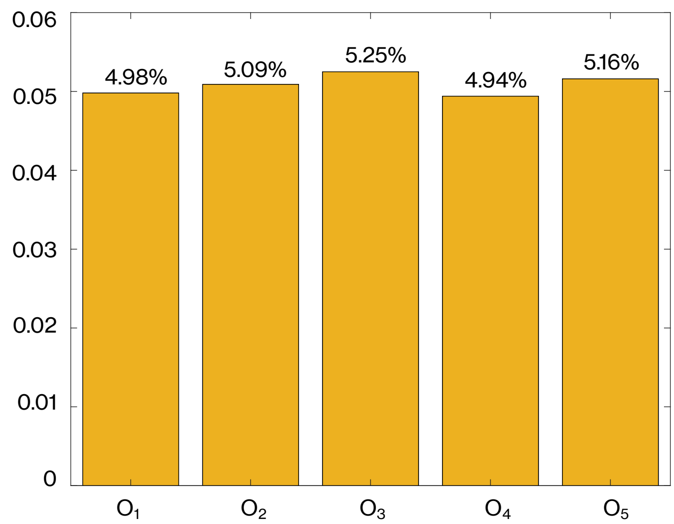


Figure 5.8: The weights of the Opportunities' criteria

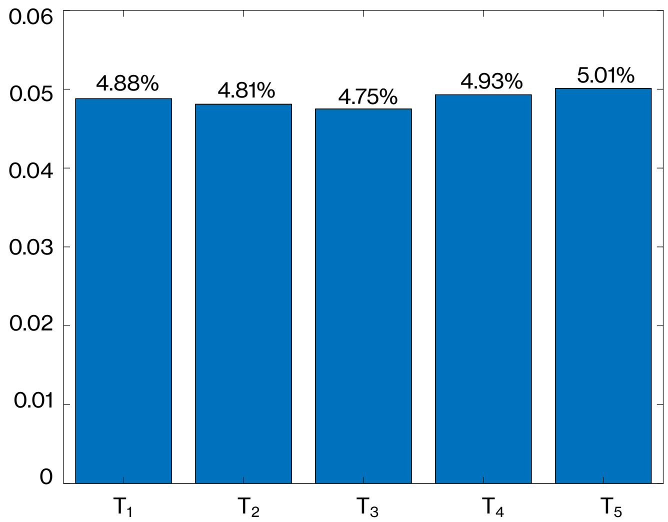


Figure 5.9: The weights of the *Threats'* criteria

The airline companies can use the increased cyber-physical touchpoints and enhanced passenger data as a tool to obtain a competitive advantage. However, the results show that the new employment areas and human resource needs brought by technology are the most significant threats for airline companies. The strategy selection process reveals the DT strategies that should be focused on. The most appropriate strategy is determined as "Profiling customers via digital channels to provide personalized and customized digital products and services." "Focusing on differentiated digital customer experience and service quality by the adaptation of business models to digital transformation to provide benefits." Follows the most appropriate strategy. Finally, "To focus on adaptation to the changing perception of value with sufficient digital products and services by accelerating decision-making processes with effective human resources." has been seen in the third place (Büyüközkan et al., 2021b). The obtained first three strategies are remarkable when they are compared. The foundations of all three strategies show the same point. The focus should be on customers, profiling the customers, differentiated customer experience, and change in value perception. These keywords show that digitalized customer experience and meeting the demands of digital customers are important key areas. At this point, focusing on the changing service quality perception would be the right move (Büyüközkan et al., 2021b).

6. PROPOSITION OF DIGITAL TRANSFORMATION SUCCESS EVALUATION FRAMEWORK FOR AVIATION INDUSTRY

This chapter of the thesis study proposes a generic framework for DT success evaluation. The proposed framework consists of a generic success evaluation model and the validation of the proposed model using the IVIF ANP methodology. This chapter contains four main sections as follows: Literature review concerning the success in DT has been introduced in the first section. The second section proposes the DT success evaluation model. Application of the proposed methodology to a real case in aviation industry is given in the third section. Finally, the results are discussed in the fourth section. Details concerning these sections are presented below.

6.1. Literature Review

DT is an evolutionary process based on leveraging digital technologies and capabilities to drive value creation through business models, operational processes, and customer experiences. Today, digital technologies are rapidly developing and being adopted (Morakanyane et al., 2017; Morakanyane et al., 2020). Today's technology users adapt to new technologies much more quickly. It is estimated that the number of connected devices will exceed 25 billion by 2020 (Gimpel & Röglinger, 2015). These technologies are pervading organizations, redrawing the rules of operation (Berman & Marshall, 2014; Loebbecke & Picot, 2015) and inventing new customer relationships, operations, and business models (Berman, 2012; Luna-Reyes & Gil-Garcia, 2014; Matt et al., 2015) and thereby changing the business competitive landscape (Morakanyane et al., 2020). Almost all societies, individuals, and businesses have adopted digital products and services in their daily lives. The impact of digitalization is enormous, forcing companies around the world to act and react to changing business rules.

While striking examples of digitalization and DT around the world reveal the disruptive power of DT, it has revealed that business models should be re-evaluated and demolished before they are destroyed by others. Companies have had to deal with both digitally born companies and customers who hold digital technology at the same time. Firms have faced fundamental changes, challenges, and opportunities. Moreover, they have now started to struggle in different areas such as customer, data, value proposition, organization, operations, and transformation management (Gimpel & Röglinger, 2015).

DT affects all organizations in all sectors of the world. Therefore, taking advantage of digital opportunities is very important (Fitzgerald, 2013; Morakanyane et al., 2020). The way to this is a successful DT. Westerman et al. (2011) state that the re-thinking of the business models, customer experience, and operational processes are the major initiatives of the DT process. They also indicate that the DT process should be driven from the top, not the bottom to up. The way of driving the transformation process is more critical than “whats”. Detailed content, extended vision, and governance for the change are needed. It is stated that a successful DT is possible not by creating a new organization, but by reshaping the organization to leverage existing valuable strategic assets in new ways.

A successful DT may be possible by transforming organizations by taking advantage of the opportunities provided by new technologies rather than the application of new technologies. Steward (2017) emphasizes the importance of organizational change management to be capable of success in the DT process. CGI (2018) highlights the importance of the creation of a collaboration-based work environment, a strong frontline for better customer experience, focusing on the expectations of the employee concerning the digital age. McKinsey (2018) determine five categories for a successful transformation process: Digital and traditional methods-based frequent communication; Having the right leader with a digital perspective and understanding; Capable future workforce; Encouragement of the people to make them work in new ways; Upgrading the everyday tools digitally. Morakanyane et al. (2020) reveal the determination of the transformed areas, digital drivers and trigger, development and adoption of a digital vision, and establishment of the digital culture and organization as the critical success factors for DT.

Success in DT is crucial for the companies. There are various domains revealed in the literature. This is also an important focus point for industries based on the results of the industrial reports given above. This is also supported by the obtained literature survey results in Chapter 2. However, when the literature is examined, it is seen that the importance of success in DT is highlighted in many resources but on the other hand, there are limited structures or models for DT success. Therefore, there is a need for such a model in the academic literature. For this purpose, a new DT success model is proposed in the next section. Detailed information and explanations about the proposed model are given in the following section.

6.2. Proposed Digital Transformation Success Evaluation Model

The proposed model has been structured based on detailed literature survey results and experts' opinions. The main components of the proposed model are shown in Figure 6.1.

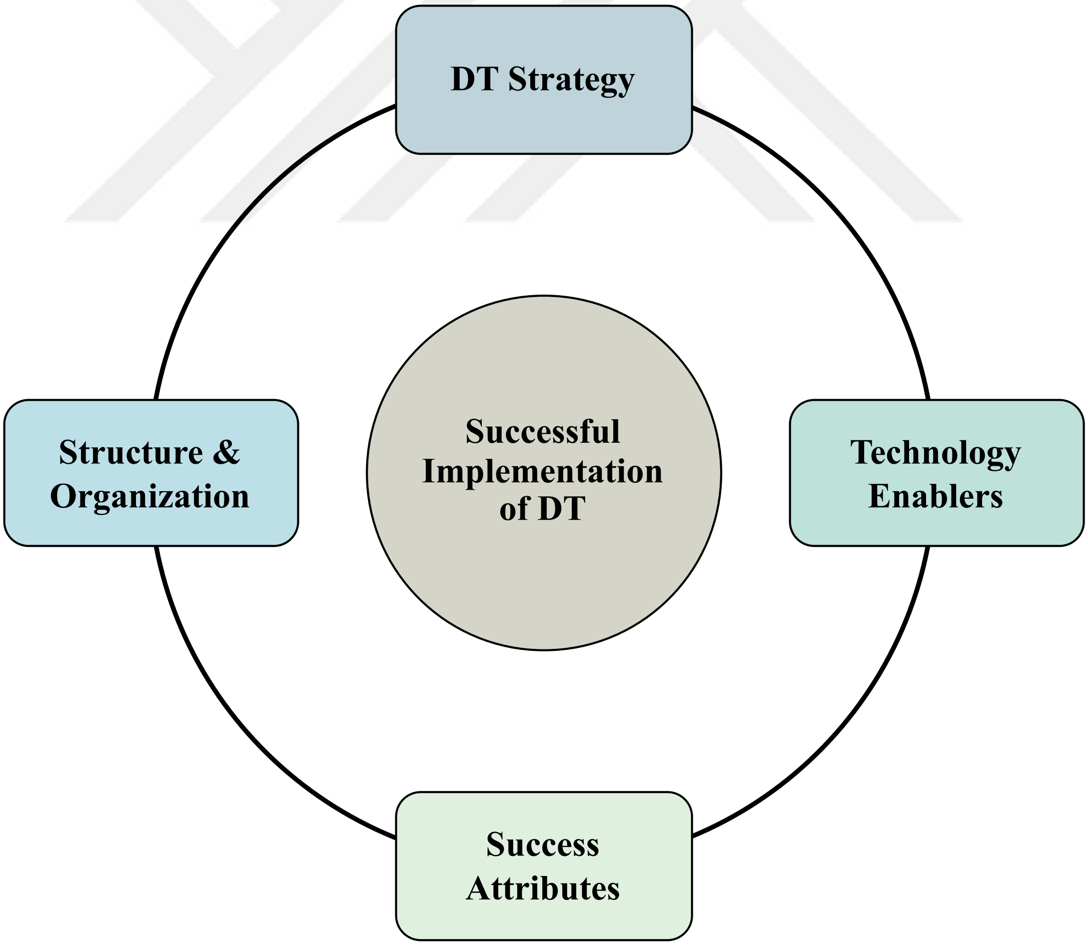


Figure 6.1: Proposed DT success evaluation model

Each component of the proposed model has its criteria. The components of the proposed model are explained as follows:

Digital Transformation Strategy (DTS):

It is the adoption of a roadmap serving the vision and goals of the organization by considering the risks, challenges, and chances to be competitive and sustainable in the digital ecosystem (SAP, 2016).

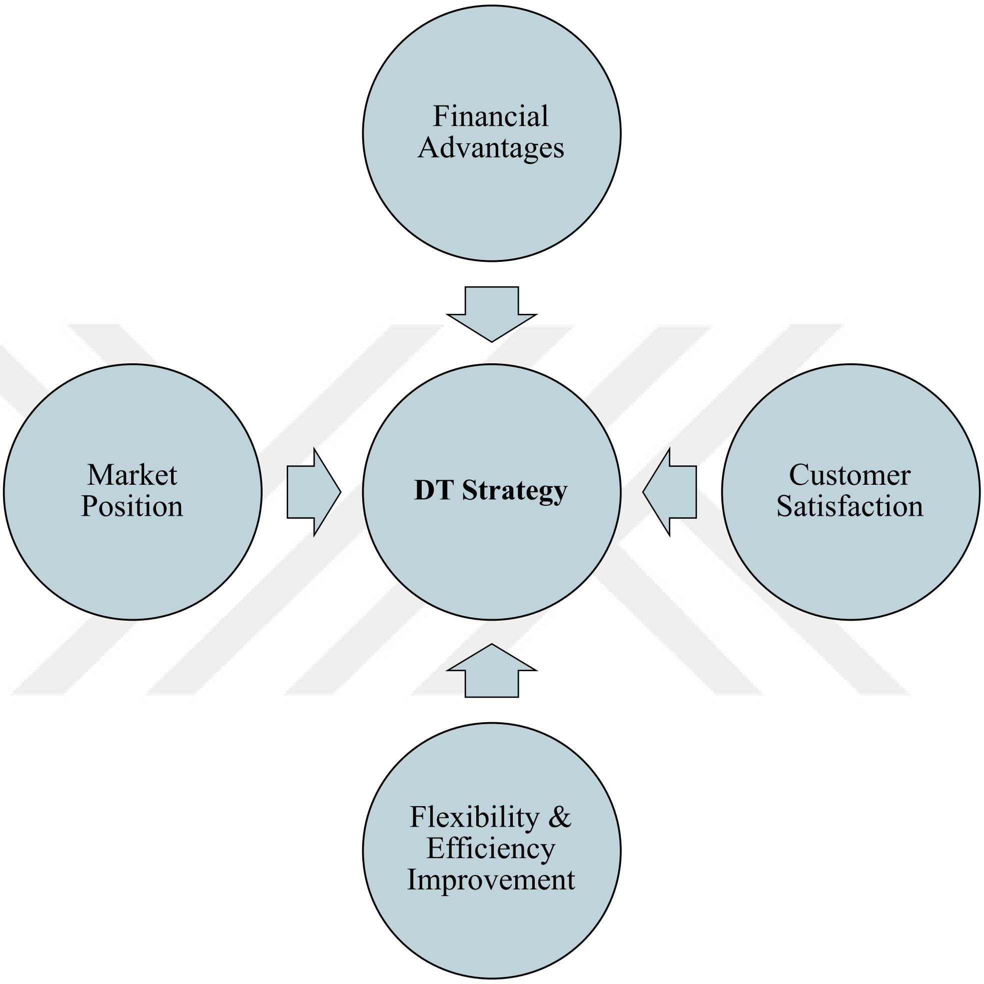


Figure 6.2: Decomposed structure of DTS dimension

Decomposed structure of the DTS dimension of the proposed success model is presented in Figure 6.2. Explanations of the criteria concerning the DTS dimension are given as follows:

- **Market Position (DTS_1):** Market positioning represents sources of value for the customer achieved by a firm relative to competitors in the market. Then, it may refer to the position achieved through the deployment of resources that create a competitive advantage in line with the needs of target customers (Lagat & Frankwick, 2015).

- **Financial Advantages (DTS_2):** It refers to one of the sources of environmental marketing that provides financial and economic competitiveness (Miles & Covin, 2000).

- **Customer Satisfaction (DTS_3):** It expresses the result of the psychological process in which the customer compares the perceived job performance level with the expectations based on different standards (Niezurawski et al., 2003; Biesok & Wyród-Wróbel, 2011).

- **Flexibility & Efficiency Improvement (DTS_4):** Efficiency is defined as a measure of operational excellence or productivity and is one of the central terms used to measure and assess the performance of the organizations (Mouzas, 2006; Mouzas, 2011). On the other hand, while flexibility is defined as the ability to react in its simplest form in the literature, it has different definitions (Soffer, 2005). For example, Shi & Daniels (2003) defines e-business flexibility as the ability to react to changes by leveraging collaborative information technologies. From this point of view, flexibility and efficiency improvement can be defined as the ability to react to the fast changes in the DT process by using information and emerging digital technologies and improve productivity and operational excellence.

Structure and Organization (SO):

It refers to an organization that has a structure with the ability to transit to an entirely digitized enterprise by understanding the digital maturity level of the company and the development of a governance framework (Early Information Science, 2019; Expert opinion).

Decomposed structure of the SO dimension of the model is presented in Figure 6.3. Explanations of the criteria regarding the SO dimension are given as follows:

- **Digital Business Model (SO_1):** It refers to the adoption of a business model that allows using digital technologies in the value proposition, customer experience, etc. (SAP, 2016).

- **Digital Security (SO_2):** It represents the security of the data provided by the converged technologies such as mobile computing social media and cloud computing. It is the security of the accesses of the workplace, network, application, and end point (PwC, 2013).

- **Digital Culture (SO_3):** It is the adoption of a culture to create an environment in which the vision is imagined and reshaped as larger than the company, new values and practices are imposed, that allows people to make an impact, uses the right tools based on information technologies, and adopts transparency regarding goals and performance (Westerman et al., 2019).

- **Investor Ownership (SO_4):** It represents the ability of a company itself to have an investor or investors for the digital technologies and DT process (Expert opinion).

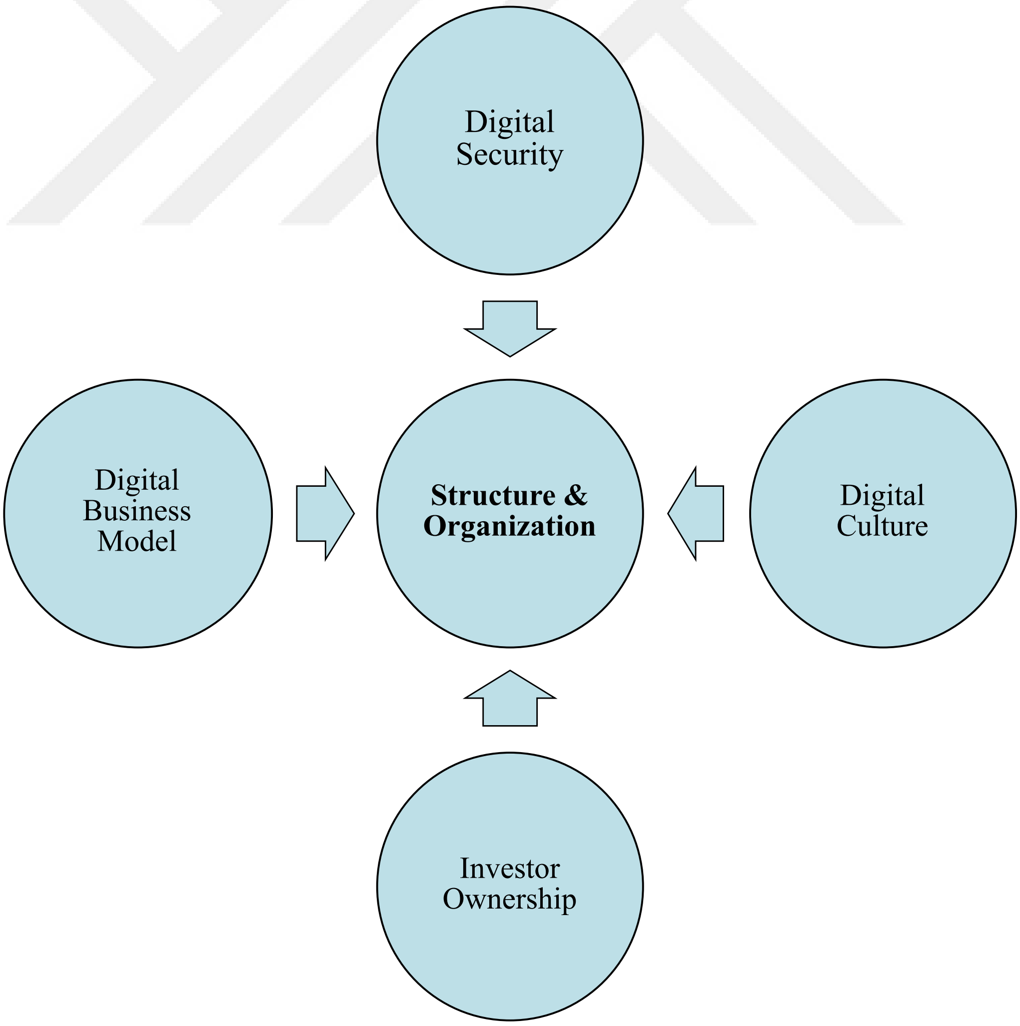


Figure 6.3: Decomposed structure of SO dimension

Technology Enablers (TE):

It represents the utilization of digital technologies providing DT for improved digitalized processes, digital products, and services for a better customer experience (Büyüközkan et al., 2021a; Expert opinion).

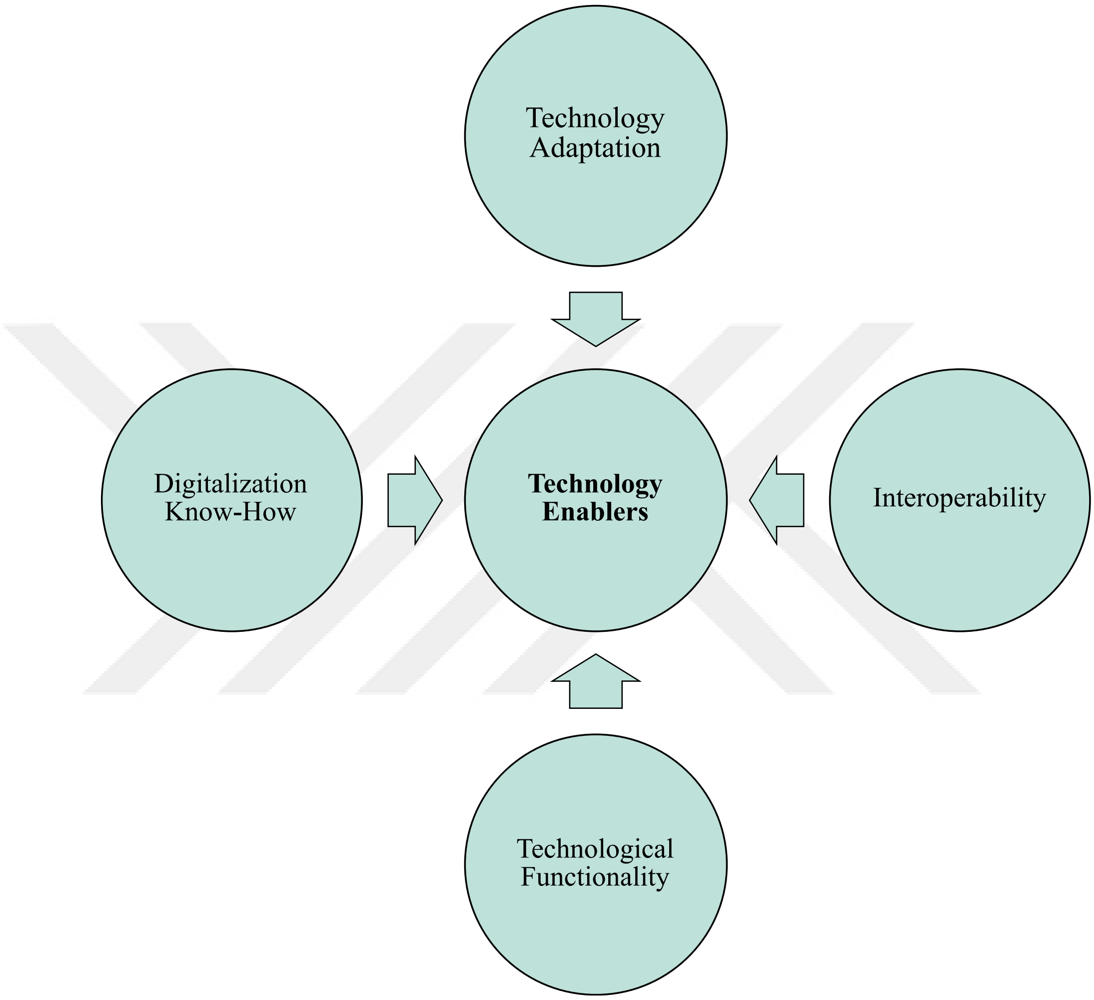


Figure 6.4: Decomposed structure of TE dimension

Decomposed structure of the TE dimension of the model is presented in Figure 6.4. Explanations of the criteria regarding the TE dimension are given as follows:

- **Digitalization Know-How (TE_1):** Know-how is defined as representing an understanding of the principles underlying phenomena, understanding of the procedures required to manufacture each component, and an understanding of how these components must be put together to function as a system (Garud, 1997). Moreover, in the literature, it is expressed that know-how is created by the "learning by doing" process and learning by doing is expressed as a process in which knowledge about how to perform a task is accumulated over time with experience (Arrow, 1971; Dutton & Thomas, 1985; Argote & Epple, 1990; Garud, 1997). Based on the definitions above, digitalization know-how can be defined as gaining experience by applying the principles underlying the phenomenon of digitalization by learning by doing.

- **Technology Adaptation (TE_2):** Adaptation is defined as the process of changing existing conditions (Majchrzak et al., 2000). Hence, it may be defined as the ability to comply with the new digital technologies and change the current technologies based on the vision, goals, and future strategies of an organization by following the most current technologies in the ecosystem (Expert opinion).

- **Interoperability (TE_3):** It refers to the exchange of data between two or more systems or components and the use of the exchanged data (Geraci et al., 1991).

- **Technological Functionality (TE_4):** Functionality indicates the characteristics of services and digital channel availability (Arias & Maçada, 2018). While functionality describes what the product does, it refers to the usefulness, sustainability, and reliability of the features of the product or device (McNamara & Kirakowski, 2006). From this point of view, technological functionality can be defined as expressing the characteristics, reliability, and sustainability of digital technologies that ensure their suitability and usability.

Digital Transformation Success Attributes (SA):

It indicates the ability to have the features for successful DT to be competitive, sustainable and increase market share and profit by providing better customer experience and service quality (Expert opinion). Decomposed structure of the *Success Attributes* component of the proposed model is presented in Figure 6.5. Explanations of the criteria regarding the Technology Enablers dimension are given as follows:

- **Digital Service Quality (SA_1):** Service quality can be defined as a service provider's ability to satisfy customers in a way that can improve business performance (Ramya et al., 2019). Service quality is defined by many authors in the literature as the difference between what customers think a company should offer and the company's actual service performance (Parasuraman et al., 2005). Traditional service quality refers to the quality of all non-internet-based customer interactions and experiences with companies. Parasuraman et al. (2005) focus on electronic service quality after technological developments, internet access, and launched websites. Zeithaml et al. (2000) state that the quality of a website is not only related to the interaction of the customers with the site but also it is related to post-interaction services. Hence, electronic service quality covers all the phases of the interaction conducted by the customers. Based on the above-mentioned explanations, DSQ can be explained as the difference between customer expectations regarding the product and service offered by the company with digital technologies and the actual performance of the company, and the level of satisfaction of customers during and after interaction with digital technologies.

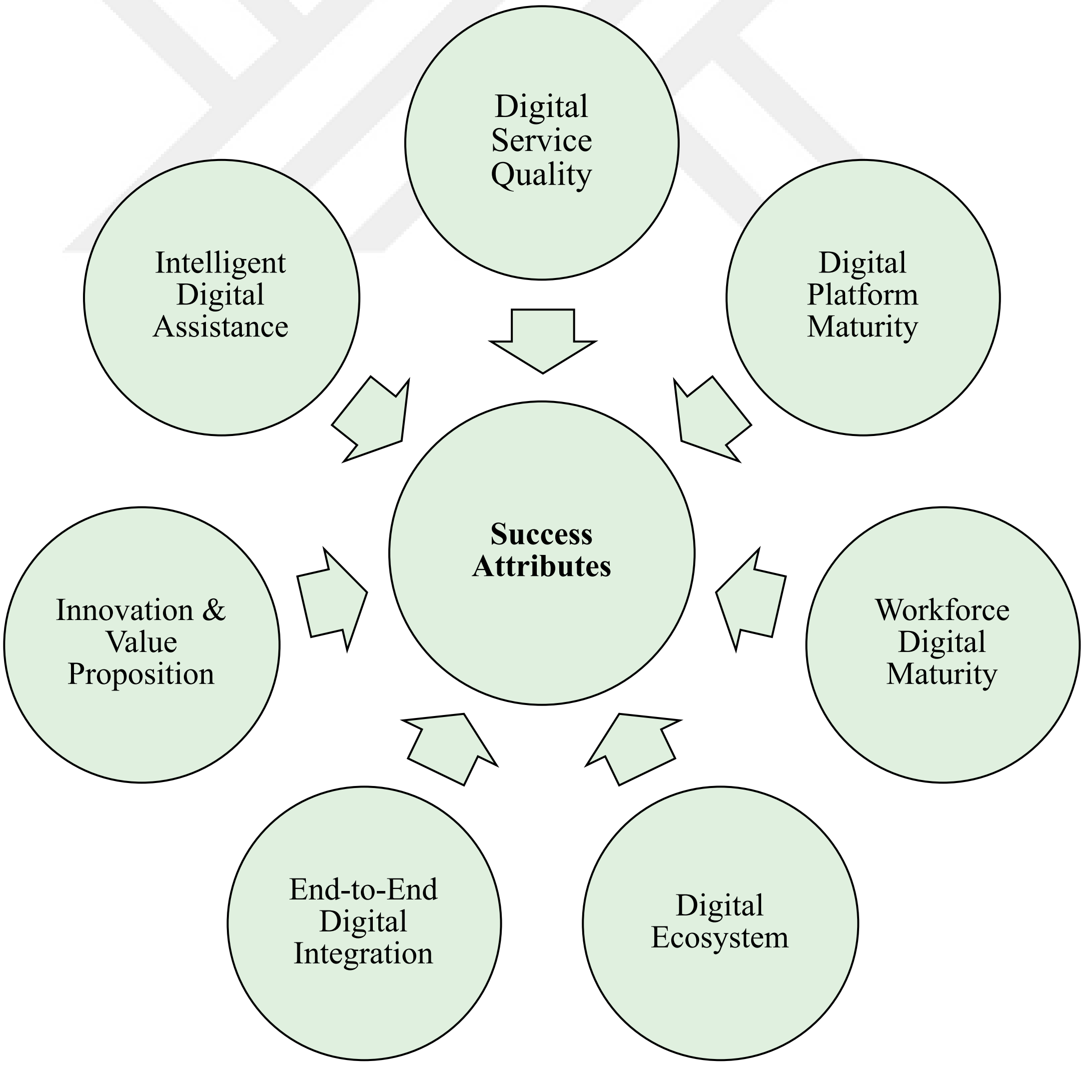


Figure 6.5: Decomposed structure of Success Attributes

- **Digital Platform Maturity (SA_2):** Digital maturity can be defined as the renewal of new business models to increase efficiency, to become a more agile, risk-tolerant, collaborative, and learning company, and to apply digital technologies as an operation that continues to grow and develop in this process (Rader, 2019). It represents the ability to adapt the organization to compete effectively in a digital ecosystem and it represents an ongoing and continuous process of adaptation to a changing digital landscape by implementing digital technologies and strategies with digital workforce and culture (Kane et al., 2017). Hence, digital platform maturity can be defined as the maturity level of the digital platforms in terms of efficiency, agility, maintainability, adaptability, functionality, robustness, risk tolerance and strategy.

- **Workforce Digital Maturity (SA_3):** The digital workforce needs an organization-wide digital workplace where information sharing, customer-centricity, and talent management are the key attributes (CGI, 2018). The digital workforce may refer to the workforce that is supported by the digital workspace where the applications are needed and can be easily accessed from anywhere, anytime, on any device, and encouraged to establish a new balance between users and information technologies (Forbes Insights, 2017). It refers to the ability of the acquisition, holding and sustaining the people and human resources that are digitally competent and transformation of the existing workforce based on digital leadership (Expert opinion). Hence, it is the maturity level of the digital workforce.

- **Digital Ecosystem (SA_4):** A digital ecosystem is an ecosystem in which additional digital products are created from the combination of digital components that combine to provide a coherent set of functions. A software-based digital ecosystem refers to the combination of a digital platform. It is the ecosystem that is dynamic with the growth, development, and participation of new companies (Um et al., 2015). Interactive organizations enabled by modularity, digitally interconnected, and not managed by a hierarchical authority are defined as digital ecosystems (Jacobides et al., 2018). Digital ecosystems are defined as loose networks of interactive organizations enabled and digitally connected by modularity, influencing, and being influenced by each other's offerings (Valdez-De-Leon, 2019).

- **End-to-End Digital Integration (SA_5):** It refers to highly specialized integrated digital systems with high flexibility and consistency (Siemens AG, 2019). Hence, it may be defined as the ability to integrate all business and processes from start to finish in a consistent, flexible, and reliable way to deliver a better experience in line with the company's strategies.

- **Innovation & Value Proposition (SA_6):** Innovation is a process that includes all stages of change, production, and consumption from the emergence of the idea to its commercialization to achieve change and novelty with technology, science, management, and economy (Twiss & Goodridge, 1989; Timur & Antanas, 2017). Hassan (2012) states that the value proposition was defined as a clear promise that a company will deliver a specific package of value-creating benefits to its customers by Buttle (2009). Value proposition, which is related to both the customer and the company's internal use, expresses exactly what the company or organization aims to add and provide to the customer's life (Lanning, 1998; Lindič & Da Silva, 2011).

- **Intelligent Digital Assistance (SA_7):** Digital assistants are technologies that perform routine tasks of users by interacting with the Internet of Things (IoT) devices and digital services, based on users' data, and providing personalized responses to users (Ebbers et al., 2020). Intelligent digital assistants are artificial intelligence-based technologies. Hence, intelligent digital assistance can be defined as the service and response provided by these technologies to the users.

6.3. Application of the Proposed Methodology

In this section, the computational steps of the IVIF ANP method given in Section 3 in Chapter 3 are applied. A case study is conducted in the Turkish aviation industry based on the proposed DT success evaluation model that is proposed in Section 6.2.

Here let $DM = \{DM_1, DM_2, DM_3\}$ be the set of DMs and it is representing the group of experts. DM_1 and DM_2 are the university professors who have remarkable amount of knowledge about DT in aviation industry. Finally, DM_3 is an expert from the aviation industry and has also information about the DT processes in aviation industry. All the experts are also actively using the air transportation as passengers. Hence, they have remarkable information level about the passenger side. Further information concerning the DMs cannot be provided due to privacy concerns and confidentiality. The importance degrees of the DMs are determined based on the linguistic terms in Table 3.3 given in Chapter 3.

The importance degrees of the DMs are Extremely Qualified (EQ), Very Qualified (VQ) and Qualified (Q), respectively. The weights of the DMs are calculated based on the determined importance degrees by using Eq. (3.19). Let $\lambda = \{\lambda_1, \lambda_2, \lambda_3\}$ be the set of the DMs' weights. The computed DMs' weights are $\lambda_1 = 0.371, \lambda_2 = 0.343$ and $\lambda_3 = 0.286$, respectively. DMs who are the experts approved that the success attributes and the other dimensions are related. Hence the ANP method is utilized. Followed steps are given as follows:

Step 1. Development of the decision model:

The model proposed in Section 6.2 is used for the decision model. The structured model is reconstructed based on direct or indirect relations through brainstorming conducted by the DMs and literature survey.

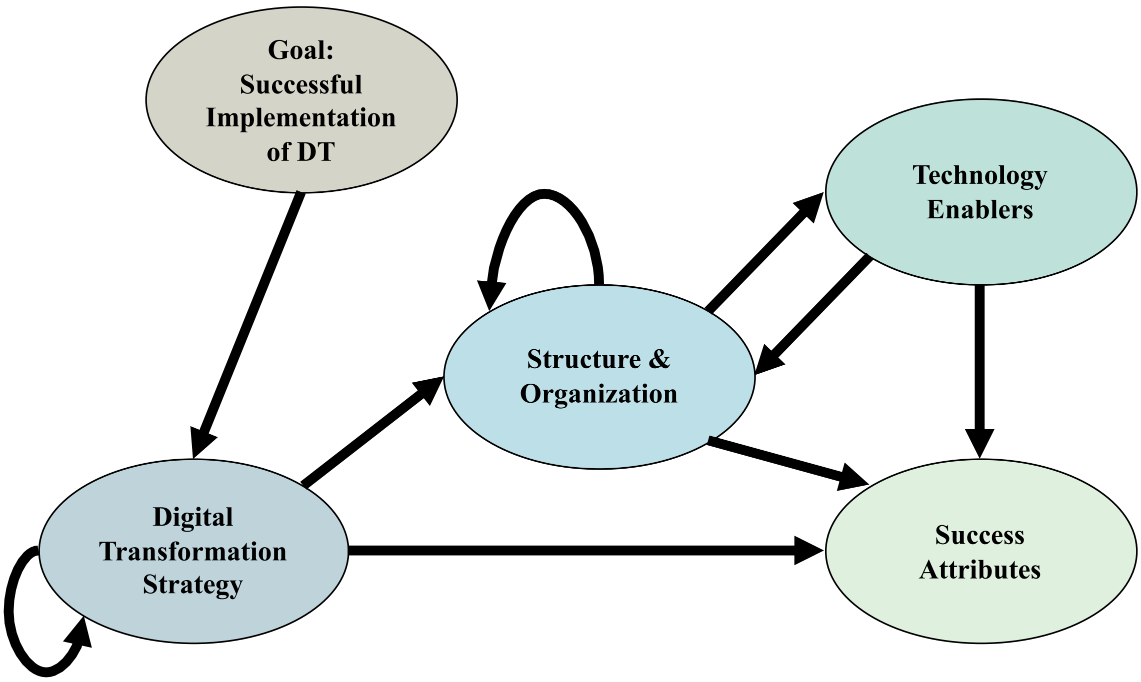


Figure 6.6: Graphical representation of the proposed model

The graphical representation of the proposed evaluation framework is given in Figure 6.6. Following that evaluation network for achieving DT success is shown in Figure 6.7. The hierarchical evaluation network is presented in Figure 6.8. It represents the detailed version of the evaluation network for achieving DT success and shows the evaluation network in a hierarchical structure.

Step 2. Application of the IVIF AHP method:

The computational steps of the IVIF AHP method are applied to obtain the relative weights and eigenvectors by considering the structure of the ANP model. The pairwise comparisons of the criteria concerning the DTS with respect to the goal by the DMs are given in Tables 6.1, 6.2, and 6.3, respectively. Following that, the IVIF AHP Entropy weights are given in Table 6.4.

Table 6.1: Pairwise comparisons of DTS criteria with respect to the goal by DM_1

	DTS_1	DTS_2	DTS_3	DTS_4
Market Position (DTS_1)	EI	IV2	IV	EI
Financial Advantages (DTS_2)		EI	SMI	IV3
Customer Satisfaction (DTS_3)			EI	IV
Flexibility & Efficiency Improvement (DTS_4)				EI

Table 6.2: Pairwise comparisons of DTS criteria with respect to the goal by DM_2

	DTS_1	DTS_2	DTS_3	DTS_4
Market Position (DTS_1)	EI		EI	EI
Financial Advantages (DTS_2)	MMI	EI	MMI	IV3
Customer Satisfaction (DTS_3)			EI	
Flexibility & Efficiency Improvement (DTS_4)			MMI	EI

Table 6.3: Pairwise comparisons of DTS criteria with respect to the goal by DM_3

	DTS_1	DTS_2	DTS_3	DTS_4
Market Position (DTS_1)	EI	MMI	MMI	MMI
Financial Advantages (DTS_2)		EI	SMI	SMI
Customer Satisfaction (DTS_3)			EI	
Flexibility & Efficiency Improvement (DTS_4)			EI	EI

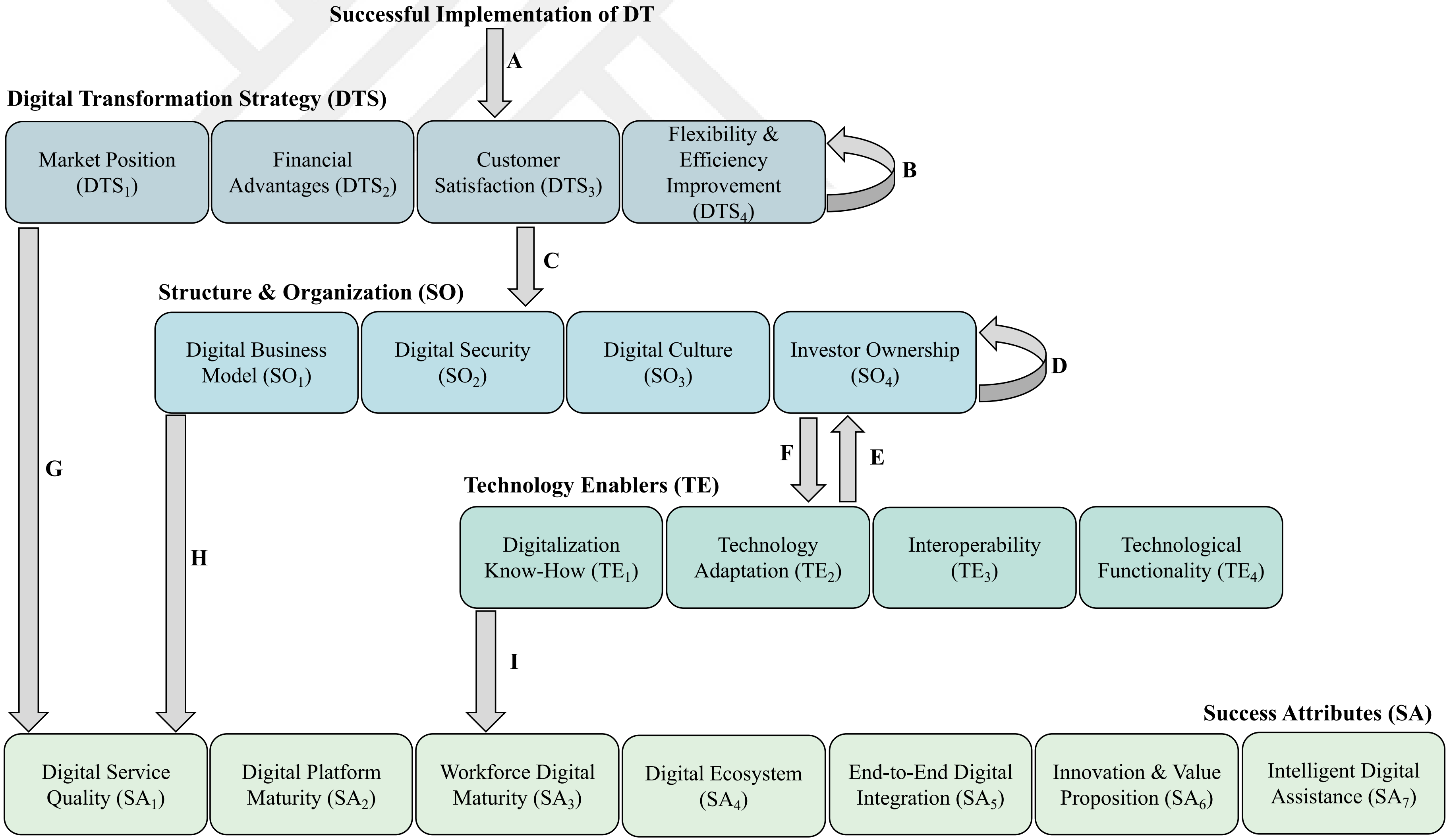


Figure 6.7. Evaluation network for achieving DT success

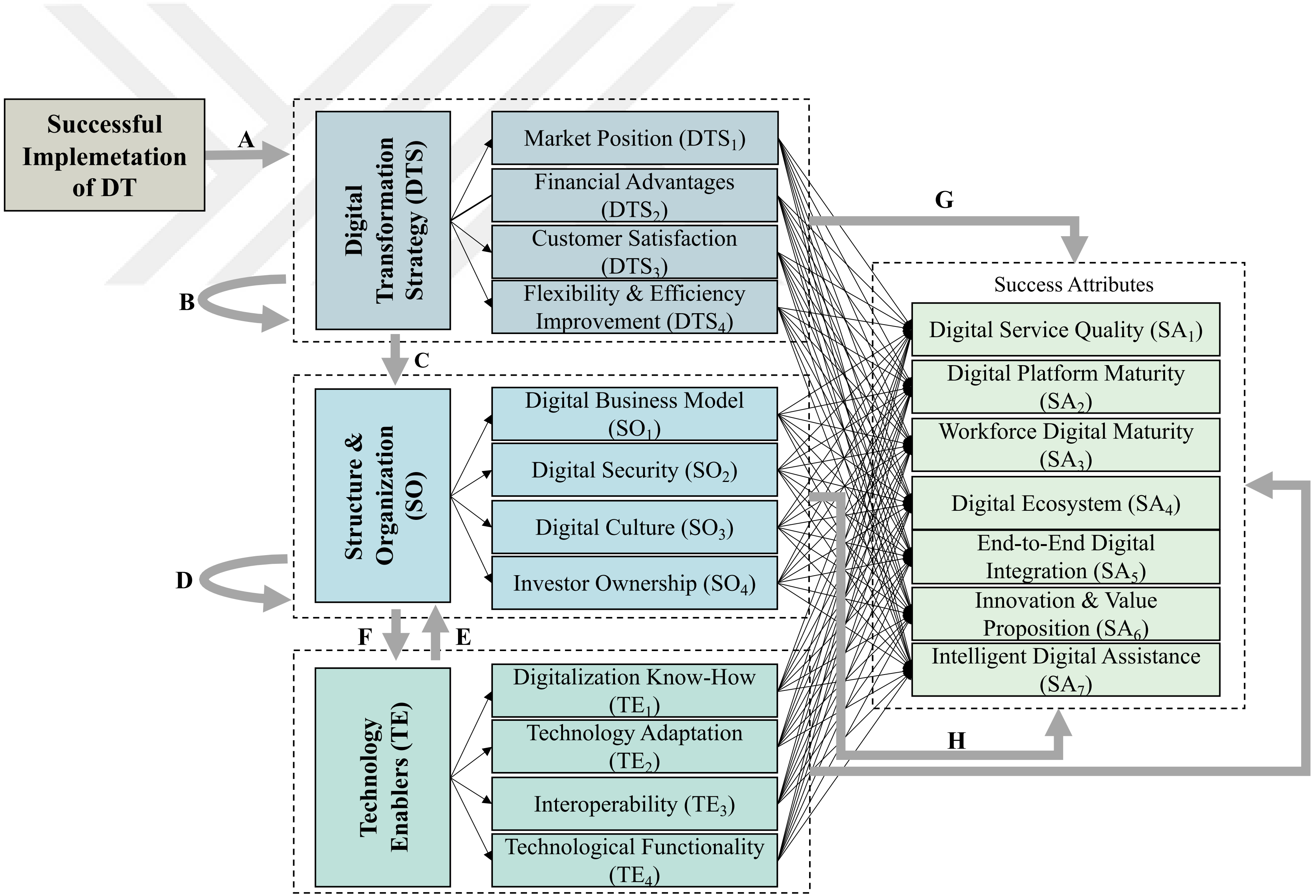


Figure 6.8: Hierarchical evaluation network

Table 6.4: IVIF AHP entropy weights of the DTS criteria with respect to Goal

DTS Criteria	Entropy Weights
Market Position (DTS_1)	0.249
Financial Advantages (DTS_2)	0.256
Customer Satisfaction (DTS_3)	0.250
Flexibility & Efficiency Improvement (DTS_4)	0.245

$(C.R. = 0.0895)$

Following that the pairwise comparisons of the criteria concerning the SO dimension concerning Digital Business Model, Digital Security, Digital Culture, and Investor Ownership are computed. Finally, the entropy weights of the criteria are obtained. The evaluations of the criteria concerning the Structure and Organization regarding the Digital Business Model are shown in Tables 6.5, 6.6 and 6.7, respectively. The computed entropy weights with respect to the Digital Business Model are given in Table 6.8.

Table 6.5: Evaluation of SO criteria with respect to *Digital Business Model* by DM_1

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI		IV3	IV3
Digital Security (SO_2)	MMI	EI	IV3	IV3
Digital Culture (SO_3)			EI	
Investor Ownership (SO_4)			MMI	EI

Table 6.6: Evaluation of SO criteria with respect to *Digital Business Model* by DM_2

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI		MMI	
Digital Security (SO_2)	IV	EI	MMI	
Digital Culture (SO_3)			EI	
Investor Ownership (SO_4)	IV	IV	IV3	EI

Table 6.7: Evaluation of SO criteria with respect to *Digital Business Model* by DM_3

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI		SMI	SMI
Digital Security (SO_2)	SMI	EI	SMI	SMI
Digital Culture (SO_3)			EI	
Investor Ownership (SO_4)			IV	EI

Table 6.8: Entropy weights of the SO criteria with respect to *Digital Business Model*

Structure & Organization Criteria	Entropy Weights
Digital Business Model (SO_1)	0.262
Digital Security (SO_2)	0.262
Digital Culture (SO_3)	0.232
Investor Ownership (SO_4)	0.244

$(C.R. = 0.0832)$

The evaluations of the criteria concerning the SO regarding the Digital Security are shown in Tables 6.9, 6.10, and 6.11, respectively. The computed entropy weights concerning the Digital Security are given in Table 6.12.

Table 6.9: Evaluation of SO criteria with respect to *Digital Security* by DM_1

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	EI	MMI	MMI
Digital Security (SO_2)		EI	MMI	MMI
Digital Culture (SO_3)			EI	MMI
Investor Ownership (SO_4)				EI

Table 6.10: Evaluation of SO criteria with respect to *Digital Security* by DM_2

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	IV	IV2	IV2
Digital Security (SO_2)		EI	IV2	IV2
Digital Culture (SO_3)			EI	IV
Investor Ownership (SO_4)				EI

Table 6.11: Evaluation of SO criteria with respect to *Digital Security* by DM_3

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	IV	IV	IV
Digital Security (SO_2)		EI	MMI	MMI
Digital Culture (SO_3)			EI	MMI
Investor Ownership (SO_4)				EI

Table 6.12: Entropy weights of the SO criteria with respect to *Digital Security*

Structure & Organization Criteria	Entropy Weights
Digital Business Model (SO_1)	0.251
Digital Security (SO_2)	0.249
Digital Culture (SO_3)	0.250
Investor Ownership (SO_4)	0.250

$(C.R. = 0.0620)$

The pairwise comparisons of the criteria concerning the SO with respect to the Digital Culture are shown in Tables 6.13, 6.14, and 6.15, respectively. The computed entropy weights concerning the Digital Culture are given in Table 6.16.

Table 6.13: Evaluation of SO criteria with respect to *Digital Culture* by DM_1

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI		VSMI	SMI
Digital Security (SO_2)	IV2	EI	EI	IV
Digital Culture (SO_3)			EI	MMI
Investor Ownership (SO_4)				EI

Table 6.14: Evaluation of SO criteria with respect to *Digital Culture* by DM_2

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	EI	IV	IV
Digital Security (SO_2)		EI	MMI	SMI
Digital Culture (SO_3)			EI	
Investor Ownership (SO_4)			IV3	EI

Table 6.15: Evaluation of SO criteria with respect to *Digital Culture* by DM_3

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	MMI	SMI	MMI
Digital Security (SO_2)		EI		VSMI
Digital Culture (SO_3)		IV3	EI	IV3
Investor Ownership (SO_4)				EI

Table 6.16: Entropy weights of the SO criteria with respect to *Digital Culture*

Structure & Organization Criteria	Entropy Weights
Digital Business Model (SO_1)	0.260
Digital Security (SO_2)	0.254
Digital Culture (SO_3)	0.244
Investor Ownership (SO_4)	0.242

$(C.R. = 0.0925)$

Finally, the evaluations of the criteria concerning the SO regarding the Investor Ownership are shown in Tables 6.17, 6.18, and 6.19, respectively. The computed entropy weights concerning the Digital Culture are given in Table 6.20.

Table 6.17: Evaluation of SO criteria with respect to *Investor Ownership* by DM_1

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	EI		
Digital Security (SO_2)		EI	EI	IV
Digital Culture (SO_3)	MMI		EI	MMI
Investor Ownership (SO_4)	MMI			EI

Table 6.18: Evaluation of SO criteria with respect to *Investor Ownership* by DM_2

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI	IV		
Digital Security (SO_2)		EI		
Digital Culture (SO_3)	IV	IV	EI	
Investor Ownership (SO_4)	MMI	MMI	IV	EI

Table 6.19: Evaluation of SO criteria with respect to *Investor Ownership* by DM_3

	SO_1	SO_2	SO_3	SO_4
Digital Business Model (SO_1)	EI			IV
Digital Security (SO_2)	MMI	EI	IV	IV
Digital Culture (SO_3)	MMI		EI	IV
Investor Ownership (SO_4)				EI

Table 6.20: Entropy weights of the SO criteria with respect to *Investor Ownership*

Structure & Organization Criteria	Entropy Weights
Digital Business Model (SO_1)	0.251
Digital Security (SO_2)	0.255
Digital Culture (SO_3)	0.249
Investor Ownership (SO_4)	0.245

$(C.R. = 0.0888)$

The pairwise comparisons and the computation of the entropy weights of the other criteria based on the relationships are conducted in the same way. Following steps cannot be provided due to page limitations.

Step 3. Construction of the General Sub-Matrix:

A general sub-matrix based on the determined relations is constructed for the supermatrix. The construction process of the general sub-matrix is shown in Figure 6.9, and it is given in Table 6.21.

A supermatrix is a split matrix consisting of local priority vectors entered the appropriate columns of a matrix, where each matrix segment represents a relationship between two nodes (components or clusters).

The supermatrix based on the constructed general sub-matrix is structured as in Figure 6.10 and Figure 6.11. Obtained entropy weights by the IVIF AHP method based on the constructed decision model and relations are used in the initial supermatrix. The initial matrix is given in Table 6.22.

Table 6.21: General sub-matrix notation for supermatrix

	Goal	DTS	SO	TE	SA
Goal	0	0	0	0	0
DTS	**A**	**B**	0	0	0
SO	0	**C**	**D**	**E**	0
TE	0	0	**F**	0	0
SA	0	**G**	**H**	**I**	***I***

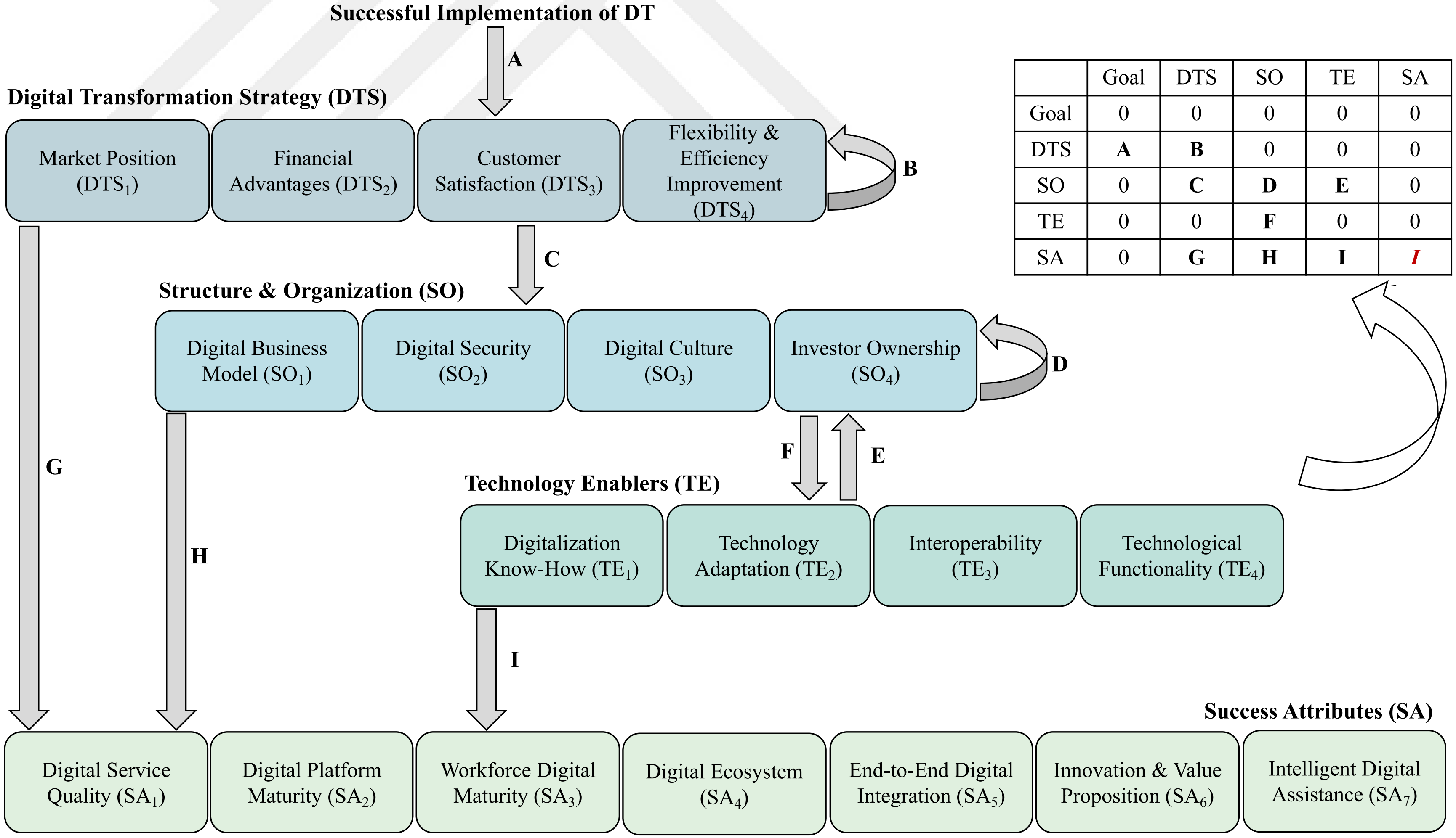
Step 4: Computation of the Limit Supermatrix:

The supermatrix must first be transformed to make it stochastic. To do this, the initial supermatrix should be normalized and weighted. It means that the sum of each matrix column should reach unity. A normalized supermatrix is also called a weighted supermatrix. The computed weighted supermatrix is shown in Table 6.23.

The weighted supermatrix is then raised to limiting powers until the weights converge and remain constant. The obtained matrix is called a limit supermatrix. In this case, the weighted supermatrix should be raised to the power $2k + 1$ until the stabilization of the weights. Here, k represents an arbitrarily large number (Kayakutlu & Büyüközkan, 2011). For the thesis study, convergence is observed when the supermatrix is raised to the 27th power. Finally, reached limit supermatrix is given in Table 6.24.

Step 5: Determination of the priorities:

The obtained priorities of the criteria through the limit supermatrix are given in Table 6.24. The limit supermatrix contains the priority weights of the DT success criteria/attributes with respect to the goal. Following that, the priority weights of the DT success criteria/attributes can be obtained with respect to the criteria concerning the DTS, SO, and TE.



	Goal	DTS	SO	TE	SA
Goal	0	0	0	0	0
DTS	**A**	**B**	0	0	0
SO	0	**C**	**D**	**E**	0
TE	0	0	**F**	0	0
SA	0	**G**	**H**	**I**	***I***

Figure 6.9: Construction of the general sub-matrix

	Goal	DTS	SO	TE	SA
Goal	0	0	0	0	0
DTS	A	B	0	0	0
SO	0	C	D	E	0
TE	0	0	F	0	0
SA	0	G	H	I	*I*

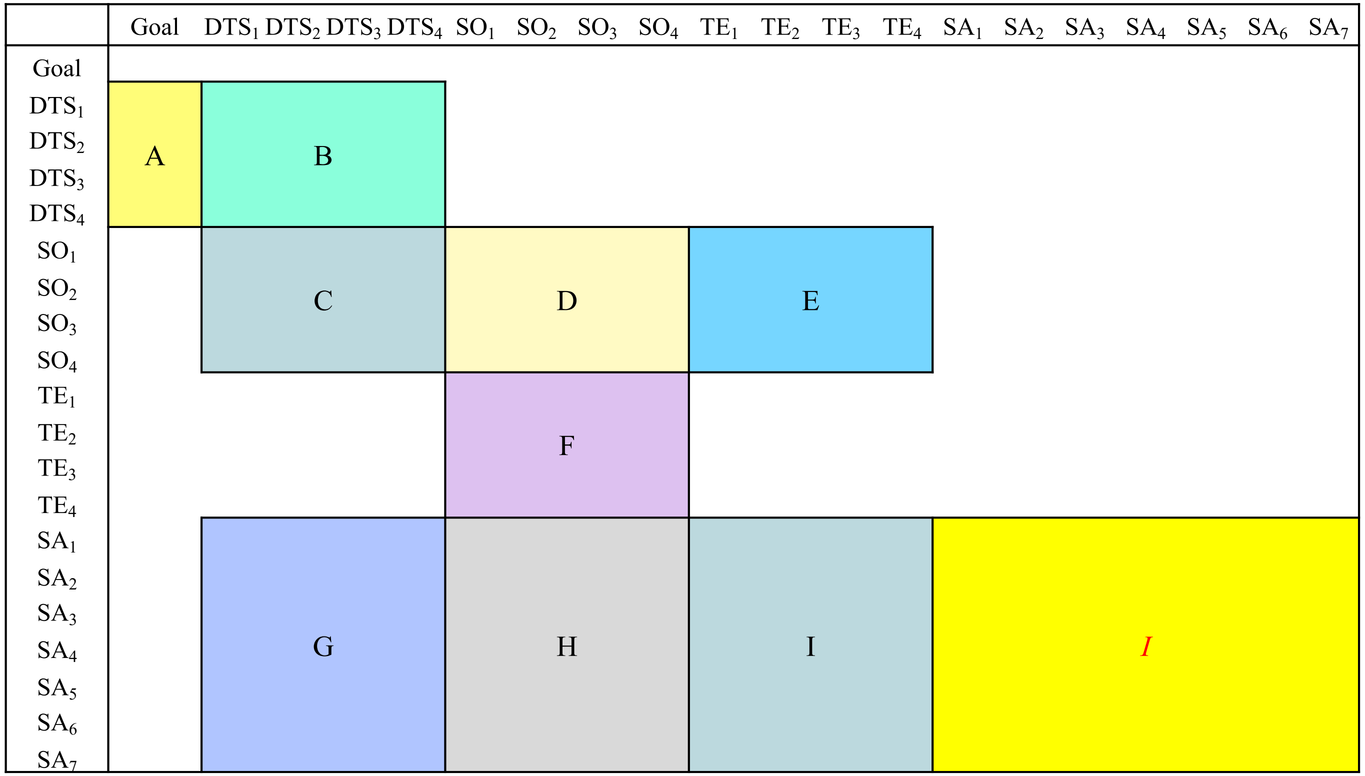


Figure 6.10: Construction of the initial supermatrix step 1

	Goal	DTS	SO	TE	SA
Goal	0	0	0	0	0
DTS	A	B	0	0	0
SO	0	C	D	E	0
TE	0	0	F	0	0
SA	0	G	H	I	*I*

	Goal	DTS_1	DTS_2	DTS_3	DTS_4	SO_1	SO_2	SO_3	SO_4	TE_1	TE_2	TE_3	TE_4	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6	SA_7
Goal																				
DTS_1	$w_{A_{11}}$	$w_{B_{11}}$	$w_{B_{12}}$	$w_{B_{13}}$	$w_{B_{14}}$															
DTS_2	$w_{A_{21}}$	$w_{B_{21}}$	$w_{B_{22}}$	$w_{B_{23}}$	$w_{B_{24}}$															
DTS_3	$w_{A_{31}}$	$w_{B_{31}}$	$w_{B_{32}}$	$w_{B_{33}}$	$w_{B_{34}}$															
DTS_4	$w_{A_{41}}$	$w_{B_{41}}$	$w_{B_{42}}$	$w_{B_{43}}$	$w_{B_{44}}$															
SO_1		$w_{C_{11}}$	$w_{C_{12}}$	$w_{C_{13}}$	$w_{C_{14}}$	$w_{D_{11}}$	$w_{D_{12}}$	$w_{D_{13}}$	$w_{D_{14}}$	$w_{E_{11}}$	$w_{E_{12}}$	$w_{E_{13}}$	$w_{E_{14}}$							
SO_2		$w_{C_{21}}$	$w_{C_{22}}$	$w_{C_{23}}$	$w_{C_{24}}$	$w_{D_{21}}$	$w_{D_{22}}$	$w_{D_{23}}$	$w_{D_{24}}$	$w_{E_{21}}$	$w_{E_{22}}$	$w_{E_{23}}$	$w_{E_{24}}$							
SO_3		$w_{C_{31}}$	$w_{C_{32}}$	$w_{C_{33}}$	$w_{C_{34}}$	$w_{D_{31}}$	$w_{D_{32}}$	$w_{D_{33}}$	$w_{D_{34}}$	$w_{E_{31}}$	$w_{E_{32}}$	$w_{E_{33}}$	$w_{E_{34}}$							
SO_4		$w_{C_{41}}$	$w_{C_{42}}$	$w_{C_{43}}$	$w_{C_{44}}$	$w_{D_{41}}$	$w_{D_{42}}$	$w_{D_{43}}$	$w_{D_{44}}$	$w_{E_{41}}$	$w_{E_{42}}$	$w_{E_{43}}$	$w_{E_{44}}$							
TE_1						$w_{F_{11}}$	$w_{F_{12}}$	$w_{F_{13}}$	$w_{F_{14}}$											
TE_2						$w_{F_{21}}$	$w_{F_{22}}$	$w_{F_{23}}$	$w_{F_{24}}$											
TE_3						$w_{F_{31}}$	$w_{F_{32}}$	$w_{F_{33}}$	$w_{F_{34}}$											
TE_4						$w_{F_{41}}$	$w_{F_{42}}$	$w_{F_{43}}$	$w_{F_{44}}$											
SA_1		$w_{G_{11}}$	$w_{G_{12}}$	$w_{G_{13}}$	$w_{G_{14}}$	$w_{H_{11}}$	$w_{H_{12}}$	$w_{H_{13}}$	$w_{H_{14}}$	$w_{I_{11}}$	$w_{I_{12}}$	$w_{I_{13}}$	$w_{I_{14}}$	1	0	0	0	0	0	0
SA_2		$w_{G_{21}}$	$w_{G_{22}}$	$w_{G_{23}}$	$w_{G_{24}}$	$w_{H_{21}}$	$w_{H_{22}}$	$w_{H_{23}}$	$w_{H_{24}}$	$w_{I_{21}}$	$w_{I_{22}}$	$w_{I_{23}}$	$w_{I_{24}}$	0	1	0	0	0	0	0
SA_3		$w_{G_{31}}$	$w_{G_{32}}$	$w_{G_{33}}$	$w_{G_{34}}$	$w_{H_{31}}$	$w_{H_{32}}$	$w_{H_{33}}$	$w_{H_{34}}$	$w_{I_{31}}$	$w_{I_{32}}$	$w_{I_{33}}$	$w_{I_{34}}$	0	0	1	0	0	0	0
SA_4		$w_{G_{41}}$	$w_{G_{42}}$	$w_{G_{43}}$	$w_{G_{44}}$	$w_{H_{41}}$	$w_{H_{42}}$	$w_{H_{43}}$	$w_{H_{44}}$	$w_{I_{41}}$	$w_{I_{42}}$	$w_{I_{43}}$	$w_{I_{44}}$	0	0	0	1	0	0	0
SA_5		$w_{G_{51}}$	$w_{G_{52}}$	$w_{G_{53}}$	$w_{G_{54}}$	$w_{H_{51}}$	$w_{H_{52}}$	$w_{H_{53}}$	$w_{H_{54}}$	$w_{I_{51}}$	$w_{I_{52}}$	$w_{I_{53}}$	$w_{I_{54}}$	0	0	0	0	1	0	0
SA_6		$w_{G_{61}}$	$w_{G_{62}}$	$w_{G_{63}}$	$w_{G_{64}}$	$w_{H_{61}}$	$w_{H_{62}}$	$w_{H_{63}}$	$w_{H_{64}}$	$w_{I_{61}}$	$w_{I_{62}}$	$w_{I_{63}}$	$w_{I_{64}}$	0	0	0	0	0	1	0
SA_7		$w_{G_{71}}$	$w_{G_{72}}$	$w_{G_{73}}$	$w_{G_{74}}$	$w_{H_{71}}$	$w_{H_{72}}$	$w_{H_{73}}$	$w_{H_{74}}$	$w_{I_{71}}$	$w_{I_{72}}$	$w_{I_{73}}$	$w_{I_{74}}$	0	0	0	0	0	0	1

Figure 6.11: Construction of the initial supermatrix step 2

Table 6.22: Initial supermatrix

	Goal	DTS_1	DTS_2	DTS_3	DTS_4	SO_1	SO_2	SO_3	SO_4	TE_1	TE_2	TE_3	TE_4	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6	SA_7
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_1	0.249	0.243	0.258	0.245	0.257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_2	0.256	0.254	0.259	0.229	0.253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_3	0.250	0.251	0.239	0.278	0.237	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_4	0.245	0.252	0.245	0.247	0.253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_1	0	0.227	0.244	0.248	0.238	0.262	0.251	0.260	0.251	0.245	0.255	0.263	0.252	0	0	0	0	0	0	0
SO_2	0	0.241	0.251	0.247	0.268	0.262	0.249	0.254	0.255	0.253	0.249	0.265	0.256	0	0	0	0	0	0	0
SO_3	0	0.275	0.256	0.254	0.254	0.232	0.250	0.244	0.249	0.247	0.247	0.246	0.250	0	0	0	0	0	0	0
SO_4	0	0.257	0.249	0.251	0.240	0.244	0.250	0.242	0.245	0.256	0.248	0.226	0.242	0	0	0	0	0	0	0
TE_1	0	0	0	0	0	0.272	0.255	0.245	0.261	0	0	0	0	0	0	0	0	0	0	0
TE_2	0	0	0	0	0	0.243	0.241	0.247	0.246	0	0	0	0	0	0	0	0	0	0	0
TE_3	0	0	0	0	0	0.236	0.254	0.247	0.236	0	0	0	0	0	0	0	0	0	0	0
TE_4	0	0	0	0	0	0.249	0.250	0.260	0.257	0	0	0	0	0	0	0	0	0	0	0
SA_1	0	0.143	0.146	0.147	0.147	0.147	0.144	0.150	0.150	0.144	0.142	0.148	0.143	**1**	0	0	0	0	0	0
SA_2	0	0.145	0.147	0.144	0.144	0.144	0.146	0.145	0.147	0.148	0.145	0.145	0.148	0	**1**	0	0	0	0	0
SA_3	0	0.144	0.144	0.145	0.144	0.146	0.145	0.146	0.142	0.142	0.143	0.140	0.147	0	0	**1**	0	0	0	0
SA_4	0	0.140	0.144	0.143	0.142	0.145	0.142	0.144	0.143	0.147	0.140	0.147	0.139	0	0	0	**1**	0	0	0
SA_5	0	0.155	0.157	0.155	0.156	0.156	0.154	0.155	0.154	0.156	0.155	0.155	0.154	0	0	0	0	**1**	0	0
SA_6	0	0.139	0.130	0.135	0.136	0.132	0.133	0.132	0.131	0.133	0.140	0.133	0.135	0	0	0	0	0	**1**	0
SA_7	0	0.133	0.132	0.130	0.131	0.130	0.136	0.128	0.132	0.131	0.134	0.132	0.134	0	0	0	0	0	0	**1**

Table 6.23: The weighted supermatrix

	Goal	DTS_1	DTS_2	DTS_3	DTS_4	SO_1	SO_2	SO_3	SO_4	TE_1	TE_2	TE_3	TE_4	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6	SA_7
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_1	0.249	0.081	0.086	0.082	0.086	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_2	0.256	0.085	0.086	0.076	0.084	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_3	0.250	0.084	0.080	0.093	0.079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_4	0.245	0.084	0.082	0.082	0.084	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_1	0	0.076	0.081	0.083	0.079	0.087	0.084	0.087	0.084	0.122	0.128	0.132	0.126	0	0	0	0	0	0	0
SO_2	0	0.080	0.084	0.082	0.089	0.087	0.083	0.085	0.085	0.126	0.125	0.133	0.128	0	0	0	0	0	0	0
SO_3	0	0.092	0.085	0.085	0.085	0.077	0.083	0.081	0.083	0.123	0.123	0.123	0.125	0	0	0	0	0	0	0
SO_4	0	0.086	0.083	0.084	0.080	0.081	0.083	0.081	0.082	0.128	0.124	0.113	0.121	0	0	0	0	0	0	0
TE_1	0	0	0	0	0	0.091	0.085	0.082	0.087	0	0	0	0	0	0	0	0	0	0	0
TE_2	0	0	0	0	0	0.081	0.080	0.082	0.082	0	0	0	0	0	0	0	0	0	0	0
TE_3	0	0	0	0	0	0.079	0.085	0.082	0.079	0	0	0	0	0	0	0	0	0	0	0
TE_4	0	0	0	0	0	0.083	0.083	0.087	0.086	0	0	0	0	0	0	0	0	0	0	0
SA_1	0	0.048	0.049	0.049	0.049	0.049	0.048	0.050	0.050	0.072	0.071	0.074	0.071	1	0	0	0	0	0	0
SA_2	0	0.048	0.049	0.048	0.048	0.048	0.049	0.048	0.049	0.074	0.073	0.073	0.074	0	1	0	0	0	0	0
SA_3	0	0.048	0.048	0.048	0.048	0.049	0.048	0.049	0.047	0.071	0.072	0.070	0.074	0	0	1	0	0	0	0
SA_4	0	0.047	0.048	0.048	0.047	0.048	0.047	0.048	0.048	0.073	0.070	0.073	0.069	0	0	0	1	0	0	0
SA_5	0	0.052	0.052	0.052	0.052	0.052	0.051	0.052	0.051	0.078	0.078	0.078	0.077	0	0	0	0	1	0	0
SA_6	0	0.046	0.043	0.045	0.045	0.044	0.044	0.044	0.044	0.067	0.070	0.067	0.067	0	0	0	0	0	1	0
SA_7	0	0.044	0.044	0.043	0.044	0.043	0.045	0.043	0.044	0.065	0.067	0.066	0.067	0	0	0	0	0	0	1

Table 6.24: The limit supermatrix (M^{27})

M^{27}	Goal	DTS_1	DTS_2	DTS_3	DTS_4	SO_1	SO_2	SO_3	SO_4	TE_1	TE_2	TE_3	TE_4	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6	SA_7
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DTS_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TE_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TE_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TE_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TE_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_1	0.1462	0.1453	0.1463	0.1467	0.1464	0.1462	0.1452	0.1473	0.1472	0.1452	0.1443	0.1470	0.1445	1	0	0	0	0	0	0
SA_2	0.1455	0.1456	0.1461	0.1451	0.1453	0.1455	0.1460	0.1458	0.1462	0.1467	0.1457	0.1455	0.1471	0	1	0	0	0	0	0
SA_3	0.1442	0.1443	0.1441	0.1445	0.1439	0.1445	0.1442	0.1445	0.1434	0.1429	0.1437	0.1423	0.1457	0	0	1	0	0	0	0
SA_4	0.1427	0.1419	0.1434	0.1430	0.1426	0.1437	0.1428	0.1434	0.1433	0.1450	0.1415	0.1449	0.1410	0	0	0	1	0	0	0
SA_5	0.1554	0.1550	0.1557	0.1552	0.1556	0.1554	0.1548	0.1551	0.1547	0.1555	0.1552	0.1551	0.1545	0	0	0	0	1	0	0
SA_6	0.1342	0.1356	0.1326	0.1342	0.1345	0.1333	0.1336	0.1331	0.1330	0.1334	0.1365	0.1333	0.1340	0	0	0	0	0	1	0
SA_7	0.1318	0.1323	0.1319	0.1313	0.1315	0.1314	0.1334	0.1308	0.1322	0.1314	0.1331	0.1320	0.1332	0	0	0	0	0	0	1

6.4.Results and Discussion

The priority weights of DT success attributes with respect to the goal are shown in Table 6.25 based on the limit supermatrix. Table 6.25 and Figure 6.12 show that the most important factor for success in the DT process is End-to-End Digital Integration. Digital Service Quality and Digital Platform Maturity factors follow the most prior success factor.

Table 6.25: Priorities of the SAs with respect to *Goal*

Success Attributes (Ranked Order)	Weights
End-to-End Digital Integration (SA_5)	0.1554
Digital Service Quality (SA_1)	0.1462
Digital Platform Maturity (SA_2)	0.1455
Workforce Digital Maturity (SA_3)	0.1442
Digital Ecosystem (SA_4)	0.1427
Innovation & Value Proposition (SA_6)	0.1342
Intelligent Digital Assistance (SA_7)	0.1318

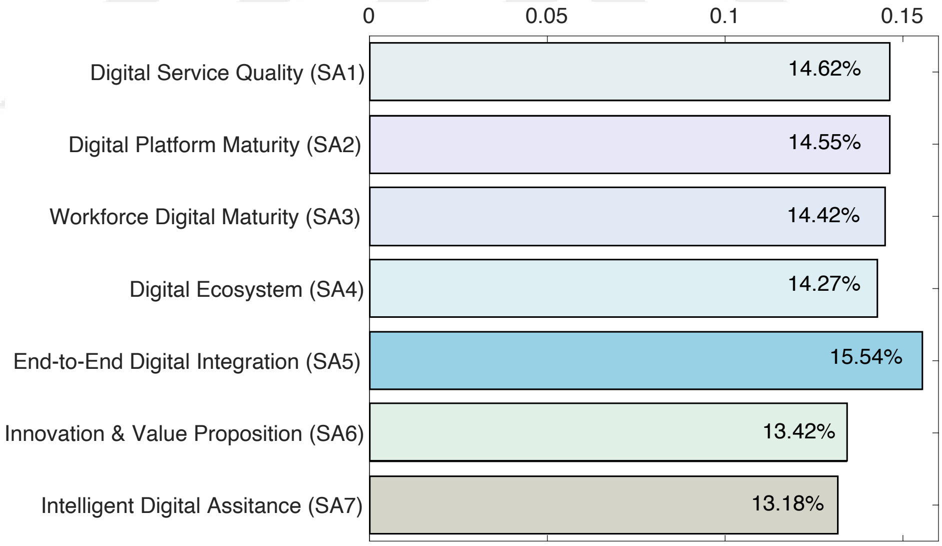


Figure 6.12. Importance degrees of the success attributes with respect to *Goal*

Table 6.26 shows the approximate patterns regarding the distribution of the weights of the DT success factors. The companies in the aviation industry in Turkey should focus on End-to-End Digital Integration. Integrated digitalized systems provide better service quality for passengers and customers. Also, all the stakeholders in the aviation ecosystem may proceed all the processes in a systematic way that may provide profit, sustainability, and competitiveness. SQ and customer experience have always been important. Now, in such a transformation process and in an ecosystem where competition is intense, service quality has become more important than ever for companies in the aviation industry. When the obtained results are examined, the fact that the next important success attribute that is digital service quality supports this situation. When the success attributes are examined in terms of other criteria, another important success criterion that goes head-to-head with digital service quality is digital platform maturity. Digital platforms are points where companies come into direct contact with both their employees and customers. In this case, while platform maturity provides operational integrity and flow for employees, they provide better service quality, customer satisfaction and loyalty to customers, and passengers.

All success factors are essential for DT. However, when looking at the distribution of priority weights, comments are made on three prominent criteria. Therefore, end-to-end digital integration, digital service quality and digital platform maturity should be at the focus of aviation companies.

Table 6.26: The priorities of SAs with respect to DTS, SO and TE criteria

Order	DTS_1	DTS_2	DTS_3	DTS_4	SO_1	SO_2	SO_3	SO_4	TE_1	TE_2	TE_3	TE_4
1	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5	SA_5
2	SA_2	SA_1	SA_1	SA_1	SA_1	SA_2	SA_1	SA_1	SA_2	SA_2	SA_1	SA_2
3	SA_1	SA_2	SA_2	SA_2	SA_2	SA_1	SA_2	SA_2	SA_1	SA_1	SA_2	SA_3
4	SA_3	SA_3	SA_3	SA_3	SA_3	SA_3	SA_3	SA_3	SA_4	SA_3	SA_4	SA_1
5	SA_4	SA_4	SA_4	SA_4	SA_4	SA_4	SA_4	SA_4	SA_3	SA_4	SA_3	SA_4
6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6	SA_6
7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7	SA_7

7. PROPOSITION OF DIGITAL SERVICE QUALITY EVALUATION FRAMEWORK FOR AVIATION INDUSTRY

This chapter of the thesis study proposes a generic framework for digital service quality (DSQ) performance evaluation. The proposed framework consists of a generic DSQ model and the validation of the proposed model using integrated IVIF MCDM methodology. This chapter contains four main sections as follows: Literature review concerning the service quality (SQ) has been introduced in the first section. The second section proposes the DSQ model. Application of the proposed methodology to a real case in aviation industry is given in third section. Finally, results are discussed in the fourth section. Details concerning these sections are presented below.

7.1. Literature Review

This section examines the service, quality, and service quality (SQ) concepts, respectively. Following this, the SQ measurement is illustrated. Utilized SQ models in the literature are surveyed. The usage of the MCDM methods in SQ concepts is revealed. DT and change in customer concept are explained and the definition of DSQ is given.

Service Concept:

Service which has no concrete characteristics shows the satisfaction of customer demands. It can be explained as economic activity providing time, place, shape, and psychological benefits. Although there is a wide academic acceptance that the service concept is the central component of service designing, the basis of this concept is the customer. Hence, it can be clearly said that customer perception is a critical point in service management (Büyüközkan et.al., 2011) since the customers do not perceive does not exist (Edvardsson & Olsson, 1996). One of the purposes of marketing activities is customer satisfaction (Holbrook, 1994; Hapsari et.al., 2016).

There are many theories concerning this aim. The “Expectancy-Disconfirmation Theory” is one of the important theories in the literature related to customer satisfaction. This theory emphasizes the expectation, performance, disconfirmation, and satisfaction towards customer satisfaction concerning the service concept (Lewin, 1938). Conducted studies in the literature show that the expectations generally have a function about customers’ evaluation of service performance (Oliver, 1981; Tse & Wilton, 1988) as a reference point. However, there are many strives about how expectations can be involved to service measurement best (Carman, 1990; Babakus & Boller, 1992; Brown et al., 1993). Hence, a model integrating service expectations of customers was developed by Parasuraman et.al., (1985). There are two different levels that customers use to evaluate SQ based on this model, and these are desired service and adequate service (Parasuraman et.al., 1994).

Quality Concept:

The difficulty of definition and measurement of quality stems from the good industry; therefore, it is possible to run across different definitions (Parasuraman et al., 1985). Quality can be explained as an attitude, and it is a form of all evaluations concerning a good (Parasuraman et.al., 1985). On the other hand, perceived quality is related to the satisfaction level of the expectations (Oliver, 1981). It is indicated that the quality is an intangible and ambiguous structure (Parasuraman et.al., 1985; Parasuraman et.al., 1988; Parasuraman et.al., 1994; Büyüközkan et.al., 2011). There may be different expressions such as goodness, poshness, brightness, or heaviness that are used for quality (Crosby, 1979) but quality vitalisms are not statements that can be expressed easily by customers (Takeuchi & Quelch, 1983). Quality can be explained as the degree of conformity to a certain standard in a traditional manner (Venkatraman, 2007). However, the definition of quality is dynamic since its application by different organizations. Furthermore, its invisible nature and definition change over time (Shieh & Wu, 2002; Chen & Chen, 2010a,b). It is seen that quality provides a performance level exceeding the customer expectations in general (Sallis, 1993). This results in customer satisfaction. If a customer wants to buy the same product again it can be fathomed out that the customer has positive experiences with the product. Additionally, this result is spread from mouth to mouth to other potential customers.

Service Quality Concept:

It can be said that the quality has a multi-dimensional structure. From this point of view, it is clear to say that it is hard to define and measure SQ (Büyüközkan et.al., 2011). Due to this reason, SQ is intangible and obscure (Parasuraman et.al., 1985; Büyüközkan et.al., 2011). This situation relies on a belief in service performance that reflects the expectations and desires of the customer (Oliver, 1981; Tse & Wilton, 1988) and it is possible to define SQ as the difference between expectations of customers from service and perceived service (Büyüközkan et.al., 2011).

Garvin (1983), measures quality with the number of encountered internal and external errors but it is insufficient just having information about good quality to obtain and understand SQ. Hence, it is hard to evaluate quality without tangible evidence and because of the intangibility of service. Furthermore, making comments about perceived service and SQ by customers can be difficult.

High service quality levels should be provided to reach success in organizations (Rudie & Wansley, 1985; Thompson et.al., 1985; Parasuraman et.al., 1988). SQ is intangible and abstruse (Parasuraman et.al., 1985) due to intangibility, heterogeneity, and inseparableness on the contrary of quality of good that can be measured with robustness or number of defects (Crosby, 1979; Garvin 1983; Büyüközkan et.al., 2011). Hence, perceived quality needs to be mentioned at this point (Parasuraman et.al., 1988). Perceived quality involving subjective responses of somebody rather than a feature of something or event, is a highly relative concept (Holbrook & Corfman, 1985; Parasuraman et.al., 1988). SQ is related to perceived customer satisfaction, and it is hard to disconnect them. Hence, it can be said that there is a relationship between SQ, perceived value, and customer satisfaction (Hapsari et.al., 2016). Observed SQ can be defined as the difference between the perceived service and the expectations of customers (Büyüközkan et al., 2011; Hapsari, et.al., 2016).

A model developed by Hapsari et.al. (2016) given in Figure 7.1 is based on this relationship. It can be made an inference that there is a strong invisible connection between quality, service, and customer based on above-mentioned relationship. This structure reveals that the SQ depends on the service provided by organizations to customers and customer satisfaction based on the perception about the served service.

Evaluation of the SQ by the customers is necessary to satisfy customer expectations and obtain loyalty. However, SQ measurement tools and methods are needed to eliminate the ambiguous atmosphere of SQ due to its sophisticated structure.

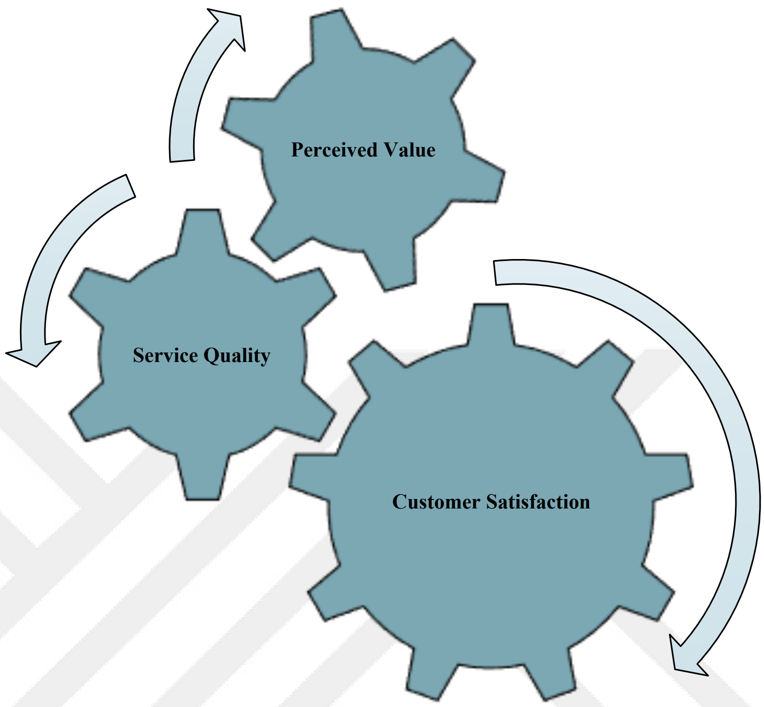


Figure 7.1: Customer satisfaction, perceived value, and SQ (Hapsari et al., 2016)

Service Quality Measurement:

Even though there are different models and approaches in the literature developed to measure SQ, there is no directly accepted measurement model yet (Koçoğlu & Aksoy, 2012). Therefore, concrete tools are needed to reduce the abstractness of SQ. The most known and common of the developed models is the SERVQUAL model.

SERVQUAL model is a multiple-item scale to measure customer perceptions of SQ. It was developed by Parasuraman et al. (1988) to evaluate the customer perceptions about the service provided by the organizations. This model was derived from research that was conducted before (Sasser et al., 1978; Gronroos, 1982; Lehtinen & Lehtinen, 1982).

SERVQUAL scale contains perceived quality (Parasuraman et al., 1988). Definition of the SQ model is the first step of this scale (Parasuraman et al., 1985). The proposed SERVQUAL model has two parts as consumer and marketer. These two parts have different components in terms of quality. While the consumer component of the model covers the word-of-mouth communications, expected service, and perceived service, the marketer component consists of service delivery, translation of perceptions into SQ needs, and management perceptions of consumer expectations. SQ is defined as a function of the gap between these components based on expectations and perceptions. This measurement scale has 5 main dimensions (Parasuraman et.al., 1988). These dimensions are given in as follows (Parasuraman et al., 1988):

- **Tangibles:** Represents equipment, appearance of personnel and physical facilities.
- **Reliability:** Indicates the skill of performing the made commitment on service dependably and accurately.
- **Responsiveness:** Shows willingness to help customers and ensure prompt service.
- **Assurance:** Covers notion and grace of employees and their capability to reveal trust and confidence.
- **Empathy:** Highlights providing the customers of a firm, valuing, individualized attention.

SERVQUAL model has a wide range of usability. Table 7.1 shows some of the studies in the academic literature based on the application areas.

It is seen that the SERVQUAL model is applicable in different industrial areas, and it has been used for different purposes. Furthermore, there are various SQ measurement models and methods in the academic literature. To illustrate this, a literature review has been conducted. The obtained results of the conducted literature review are shown in Table 7.2 and Table 7.3. When Table 7.2 is examined, it is seen that there are various SQ models.

The basis of the most of these models is the SERVQUAL model. The classical SQ model SERVQUAL was updated and rearranged according to the problem, industrial areas, and goal of the studies. The current studies have been influenced by technological developments. Hence, utilized criteria, dimensions, or items were updated. Following that, Table 7.3 shows that the studies in the last 10 years are related to the internet and mobile devices. Hence, the number of studies concerning the measurement of electronic SQ is high.

Table 7.1: Some application areas of the SERVQUAL model

Sectors of Studies	**Some of Sources**
Airline	Hussain et.al. (2015); Chen (2016a); Büyüközkan et al. (2020a,c).
Certification and Inspection	Liu et.al. (2015).
Communication	Huang et.al. (2015).
Education	Gregory (2019).
Finance	Yüksel & Dinçer (2020).
Food and Restaurant	Namin (2017).
Healthcare	Singh & Prasher (2019).
Hotel and Tourism	Nguyen (2021).
IS / ICT	Wismantoro et al. (2020).
Internet Banking	Raza et al. (2020).
Logistics	Meidutė-Kavaliauskienė et al. (2020).
Shipping/Marine Services	Sari et.al. (2016).
Public Services	Ocampo (2019).
Shipping	Chen et al. (2009).
Transportation	Awasthi et.al. (2011); Valenzo-Jiménez et al. (2019).
Travel Agencies	Karbassi Yazdi & Beishami (2019).
Web Portals	Cristobal et al. (2007);
Wireless Systems	Song & Jamalipour (2008).

In addition to electronic SQ studies, there are mobile SQ-based studies in the literature. Huang et al. (2015) used the analytical method for mobile SQ by utilizing "efficiency, system availability, content, privacy, fulfillment, responsiveness, compensation, billing" dimensions.

"Content, accuracy, ease of use, speed, aesthetics, security, diverse mobile application service features, mobile convenience, reliability, responsiveness, competence, courtesy, credibility, access, communication, understanding the customer, continuous improvement" dimensions are used by Jun & Palacios (2016) in a conceptual study for mobile SQ. Arcand et al. (2017) utilize "security and privacy, practicity, design and aesthetics, sociality, enjoyment" dimensions for mobile SQ analysis by an analytical technique.

Wang et al. (2019) study mobile SQ by an analytical method based on “interaction quality, environment quality, outcome quality, inertia, continuance intention” dimensions. Furthermore, the types of the studies in Table 7.3 and the mobile SQ-based studies are categorized based on analytical, conceptual, and review studies. The distribution of the types of the published studies in the academic literature for the last 10 years is presented in Figure 7.2.

Table 7.2: Some of the SQ measurement models in the literature

Source	Model	Purpose	Item
Parasuraman et al. (1988)	SERVQUAL	To assess the perception of SQ of customers.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy
Knutson et al. (1990)	LODGSERV	To measure the expectations of customers in the hotel experiences.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy
Cronin Jr. & Taylor (1994)	SERVPERF	To measurement the performance of a service provider based on perceptions of customer in terms of SQ.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy
Stevens et al. (1995)	DINESERV	To assess the SQ in restaurants.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy
Mei et al. (1999)	HOLSERV	To evaluate the SQ in hospitality industry.	1) Employees 2) Tangibles 3) Reliability
Frost & Kumar (2000)	INTSERVQUAL	To measure internal SQ in a large service organization.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy

Table 7.2: Some of the SQ measurement models in the literature (*continue*)

Source	Model	Purpose	Item
Zeithaml et al. (2000)	eSQ	To measure the perceived e-SQ.	1) Reliability 2) Responsiveness 3) Access 4) Flexibility 5) Ease of navigation 6) Efficiency 7) Assurance/trust 8) Security/privacy 9) Price 10) Knowledge 11) Site aesthetics 12) Customization/ Personalization 13) Perceived price 14) Price knowledge
Robledo (2001)	SERVPEX	To measure the SQ of airlines.	1) Tangibles 2) Reliability 3) Customer care
Yoo & Donthu (2001)	SITEQUAL	To measure the perceived quality of an Internet shopping site.	1) Ease of use 2) Aesthetic design 3) Processing speed 4) Security
Barnes and Vidgen (2002)	WEBQUAL 4.0	To assess the quality of web sites.	1) Usability 2) Information quality 3) Service interaction quality
Raajpoot (2002)	TANGSERV	To measure tangible quality in foodservice industry.	1) Layout/design 2) Ambiance/social 3) Building 4) Employees 5) Product/services 6) Cleanliness 7) Interior decorations

Table 7.2: Some of the SQ measurement models in the literature (*continue*)

Source	Model	Purpose	Item
Khan (2003)	ECOSERV	To assess the quality expectations of ecotourists.	1) Ecotangibles 2) Assurance 3) Reliability 4) Responsiveness 5) Empathy 6) Tangibles
Wolfinbarger & Gilly (2003)	eTAILQ	To measure and predict online retailer quality.	1) Website design 2) Fulfillment/ Reliability 3) Privacy/security 4) Customer service
Sigala (2004)	ASP-QUAL	To measure the SQ of application service provider.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy 6) Trust 7) Business understanding 8) Benefit and risk share 9) Conflict 10) Commitment
Webb & Webb (2004)	SITEQUAL	To measure the overall quality of B2C electronic commerce web sites.	1) Reliability 2) Assured empathy 3) Tangibility 4) Navigability 5) Relevant representation 6) Accuracy 7) Security
Gounaris (2005)	INDSERV	To assess the perceived SQ in the B2B context	1) Potential quality 2) Hard process quality 3) Soft process quality 4) Output quality

Table 7.2: Some of the SQ measurement models in the literature (*continue*)

Source	Model	Purpose	Item
Kyrillidou & Giersch (2005)	DigiQUAL	To measure the SQ of digital libraries.	1) Design features 2) Accessibility/ Navigability 3) Interoperability 4) Digital library as community for users 5) Developers and reviewers 6) Collection building 7) Role of federations 8) Copyright 9) Resource use 10) Evaluating collections 11) Digital library sustainability
Parasuraman et al. (2005)	E-S-QUAL	To measure the SQ delivered by websites on which customers shop online.	1) Efficiently 2) Fulfillment 3) System availability 4) Privacy
Abdullah (2006)	HEdPERF	To evaluate the SQ of higher education.	1) Non-academic aspects 2) Academic aspects 3) Reliability 4) Empathy
Bauer et al. (2006)	eTRANSQUAL	To measure SQ based on transaction process in online shopping.	1) Functionality/ Design 2) Enjoyment 3) Process, reliability 4) Responsiveness
Agrawal et al. (2007)	EGOSQ	To assess the SQ of e-governance online services.	1) Reliability 2) Assurance 3) Resourcefulness
Cristobal et al. (2007)	PeSQ	To measure the perceived e-SQ.	1) Web design 2) Customer service 3) Assurance 4) Order management

Table 7.2: Some of the SQ measurement models in the literature (*continue*)

Source	Model	Purpose	Item
Loiacono et al. (2007)	WEBQUAL	To measure the evaluation of consumers about websites.	1) Informational fit-to-task 2) Tailored information 3) Trust 4) Response time 5) Ease of understanding 6) Intuitive operations 7) Visual appeal, 8) Innovativeness 9) Emotional appeal 10) Consistent image 11) On-line completeness 12) Relative advantage
Yusoff et al. (2008)	FM-SERVQUAL	To assess the SQ provided by local authorities to the public.	1) Responsiveness 2) Professionalism 3) Empathy 4) Reliability 5) Tangibles 6) Assurance
Lu et al. (2009)	M-SERVICE QUALITY	To measure mobile SQ in future mobile commerce.	1) Interaction quality 2) Environment quality 3) Outcome quality
Pollack (2009)	HSQM	To evaluate the loyalty of customers based on customer satisfaction.	1) Interaction quality 2) Physical environment quality 3) Outcome quality
Chahal & Kumari (2010)	HCSQ	To measure healthcare SQ.	1) Physical environment quality 2) Interaction quality 3) Outcome quality 4) Service quality 5) Image
Ding et al. (2011)	e-SELFQUAL	To measure online self-SQ.	1) Perceived control 2) Service convenience 3) Customer service 4) Service fulfillment

Table 7.2: Some of the SQ measurement models in the literature (*continue)*

Source	Model	Purpose	Item
Zaidi & Qteishat (2011)	e-GSQA	To determine the e-SQ from the citizen's point of view based on e-government service delivery.	1) System quality 2) Process quality 3) Information quality
Papadomich-elaki & Mentzas (2012)	e-GOVQUAL	To measure the SQ of governmental sites for citizens.	1) Ease of use 2) Trust 3) Functionality of the interaction environment 4) Reliability 5) Content & appearance of information 6) Citizen support (interactivity)
Chou & Chiang (2013)	SaaS-QUAL	To measure the quality of software-as-a-service.	1) Rapport 2) Flexibility 3) Competence-based trust 4) Openness-based trust 5) Relational norms 6) Satisfaction
Miller et al. (2013)	ISS-QUAL	To measure the SQ of information systems functions.	1) Service delivery 2) Service product 3) Service environment
Cid-López et al. (2015)	SICTQUAL	To assess the SQ in the ICT sector based on ICT segments.	1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance 5) Empathy 6) Services 7) Applications technologies

Table 7.2: Some of the SQ measurement models in the literature (*continue)*

Source	Model	Purpose	Item
Huang et al. (2015)	M-S-QUAL	To measure mobile SQ.	1) Efficiency 2) System availability 3) Content 4) Privacy 5) Fulfillment 6) Responsiveness 7) Compensation 8) Content 9) Billing
Lee (2017)	HEALTHQUAL	To measure healthcare SQ.	1) Empathy 2) Tangibles 3) Safety & efficiency aspects 4) Degree of improvements of care service
Caber & Albayrak (2018)	DAILYSERVE	To assess the SQ of daily tours.	1) Transportation 2) Tour guide 3) Food & beverage facility 4) Shopping facility 5) Stopover facility 6) Museums and sites
Marimon et al. (2019)	CC-QUAL	To evaluate the quality of collaborative consumption services based on customer perceptions.	1) Site organization 2) platform responsiveness 3) legal protection 4) trustworthiness 5) hedonics, 6) tangibles 7) peer service provider 8) social interaction
Büyüköz-kan et al. (2020a)	DSQ	To assess the SQ perception of digital customers and to measure the DSQ.	1) Digital tangibles 2) reliability 3) digital interaction 4) digital trust 5) customer centricity

Table 7.3: Types of the published e-SQ-based studies

Source	Type	Utilized Dimensions
Bakır & Atalık (2021).	Analytical	Information quality, system quality, service quality
Kalia & Paul (2021).	Analytical	Efficiency, fulfillment, system availability, privacy, responsiveness, compensation, contact
Lionello et al. (2020)	Review	Aesthetic design, fulfillment, ease of use, personalization, information quality, technical quality, security, customer service
Rahahleh et al. (2020)	Analytical	Reliability, responsiveness, ease of use, privacy, information quality
Raza et al. (2020)	Analytical	Site organization, reliability, responsiveness, user friendliness, personal need, efficiency
Kaya et al. (2019)	Analytical	Website design, fulfillment, security, customer service
Zhou et al. (2019)	Analytical	Functional completeness, performance, interface and interaction, content and information, support, or service
Rahi & Ghani (2019)	Analytical	Assurance, customer service, effort expectancy, intention, performance expectancy, reliability, website design
Shankar & Jebarajakirthy (2019)	Analytical	Reliability, privacy and security, website design, customer service and support, trust, consumer involvement, e-banking loyalty
Theodosiou et al. (2019)	Analytical	Security and privacy, fulfillment and reliability, customer service, website design, informativeness, customization
Ghosh (2018)	Analytical	Efficiency, system availability, fulfillment, privacy
Choi & Kim (2018)	Analytical	Informativeness, product diversity, communication possibility, responsiveness
Goutam & Gopalakrishna (2018)	Analytical	Efficiency, system availability, fulfillment, privacy
Iqbal et al. (2018)	Analytical	E-search, e-response, e-transaction, e-payment, e-assurance and trust, e-help and e-technologies, post-sales support, website design and functionality
Goel (2017)	Review	Efficiency, system availability, fulfillment, privacy

Table 7.3: Types of the published e-SQ-based studies (*continue*)

Source	Type	Utilized Dimensions
Oni et al. (2016)	Analytical	Reliability, responsiveness, availability, competence, security and privacy, service portfolio
Wang et al. (2016)	Analytical	Efficiency, system availability, fulfillment, privacy
Blut (2016)	Analytical	Website design, fulfillment, customer service, security, and privacy
Kao & Lin et al. (2016)	Analytical	Attractiveness of selection, information quality, ease of use, technical quality, reliability, functional benefit, emotional benefit
Kang et al. (2016)	Analytical	Efficiency, system availability, fulfillment, privacy
Blut et al. (2015)	Review	Website design, fulfillment, customer service, security, efficiency, system availability, privacy, responsiveness, contact
Elsharnouby & Mahrous (2015)	Analytical	Efficiency, availability, fulfillment, privacy, responsiveness, compensation, contact, attitude, intention, co-creation
Wu et al. (2015)	Analytical	Reliability, responsiveness, information, security, ease of use, trust
Stegaru et al. (2015)	Analytical	Business quality, operational quality, system quality
Einasto (2014)	Conceptual	User-friendliness, reliability, assurance, security, speed, credibility, relevance, clarity, competence, feedback, dialogue, participating, responsiveness, empathy, aesthetics
Stiglingh (2014)	Conceptual	Fulfillment, efficiency, system availability, security, convenience, incentive, reliability, assurance, empathy, responsiveness”
Vos et al. (2014)	Analytical	Ease of use, e-scape and responsiveness, customization and assurance, e-loyalty, e-satisfaction, e-trust”
Águila-Obra et al. (2013)	Analytical	Efficiency, privacy and security, fulfillment and reliability, enjoyment, customer service and communication”

Table 7.3: Types of the published e-SQ-based studies (*continue*)

Source	Type	Utilized Dimensions
Suh et al. (2013)	Analytical	Team identification, ease of use, security, reliability, information, appearance, satisfaction, revisitation
Pearson et al. (2012)	Analytical	Efficiency, fulfillment, system availability, privacy
Sabiote et al. (2012)	Analytical	Ease of use, availability, efficacy, privacy, relevant information
Chang et al. (2012)	Analytical	Efficiency, information quality, responsiveness, privacy
Büyüközkan & Çifçi (2012a)	Analytical	Tangibles, responsiveness, reliability, information quality, assurance, empathy
Hsu et al. (2012)	Analytical	Website design, security, customer relationships, enjoyment
Carlson & O'Cass (2011)	Analytical	Environment quality, delivery quality, outcome quality
Finn (2011)	Analytical	Aesthetics, personalization, security, assurance, accessibility, reliability, information, responsiveness, site design, ease of use, navigation, intuitiveness, returnability, customer support, customer satisfaction
Lee & Wu (2011)	Analytical	Efficiency, fulfillment, system availability, privacy
Tsao & Tseng (2011)	Analytical	Efficiency, reliability, fulfillment, privacy and safety, responsiveness, compensation, contact
Hu & Liao (2011)	Analytical	Efficiency, system availability, responsiveness, compensation, contact, tangibility, privacy, reliability, reputation, continuous improvement, personalization, benefit

When these studies are examined in terms of the utilized analytical methods, it is seen that the utilization of the MCDM methods in SQ analysis is extensive. Kuo (2011) uses the interval-valued fuzzy MCDM method to improve SQ concerning the airlines. A hybrid MCDM approach is applied by Tseng (2011) to the SQ expectation. Chou & Cheng (2012) evaluate the SQ of a website for professional accounting firms with a hybrid MCDM approach. Afkham et al. (2012) evaluate the SQ in the healthcare industry using fuzzy MCDM methods. The fuzzy MCDM model is utilized to evaluate SQ in the hotel industry by Zoraghi et al. (2013). Akdag et al. (2014) use the fuzzy MCDM approach to evaluate the SQ of hospitals. The SQ of airports is analyzed using the fuzzy MCDM method by Pandey (2016). Hsu & Shih (2016) assess the e-SQ of the websites concerning the rental houses using MCDM methods. The SQ of airlines is evaluated through an integrated fuzzy decision-making approach by Perçin (2018). Bakır et al. (2019) examine the SQ concerning the low-cost airline companies by utilizing a combined MCDM approach. Further information concerning the types of the utilized MCDM methods in the academic literature in different industries is provided in Table 7.4.

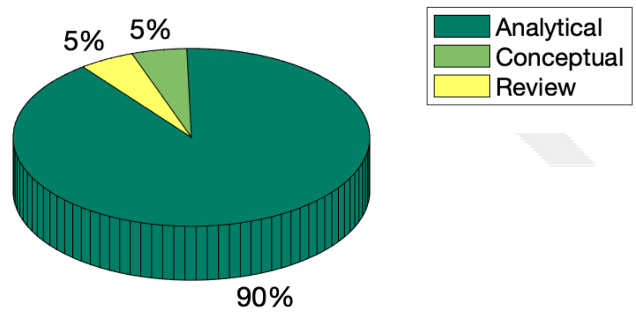


Figure 7.2: Types of the studies in the literature for the last 10 years (%)

Figure 7.2 shows the distribution of the types of the studies in the last 10 years. The number of the analytical approach based SQ studies is quite high while the conceptual and review studies are limited. A literature review has been conducted for MCDM utilization in SQ studies, and the results are shared in Table 7.4. Table 7.4 shows that the SQ concept was studied in different areas in the academic literature and the usage of the MCDM methods as analytical techniques is quite common. This justifies the usage of MCDM methods in the thesis study. Besides, most of the studies shown in Table 7.4 are using classical or fuzzy MCDM methods. The number of studies using more complex typologies of fuzzy extensions is limited. The AHP method has been widely used in the literature for the evaluation of SQ. However, the number of studies using fuzzy extension based for SQ analysis is limited. Hence, this thesis study has on originality.

Table 7.4: SQ studies with MCDM approach (2011-2021)

Source	Application Area	Utilized Method
Awasthi et al. (2011)	Transportation	Fuzzy TOPSIS
Büyüközkan et al. (2011)	Healthcare	Fuzzy AHP
Kuo & Liang (2011).	Airports	VIKOR, GRA
Liou et al. (2011a,b)	Airlines	VIKOR, GRA
Büyüközkan & Çifçi (2012b)	Healthcare	Fuzzy AHP, Fuzzy TOPSIS
Chang (2014)	Healthcare	Fuzzy VIKOR
Shahin et al. (2014)	Hotel & Tourism	Fuzzy AHP
Gopalan & Satpathy (2015)	Retail	Fuzzy AHP
Lupo (2015)	Airports	ELECTRE III
Chen (2016a)	Airlines	DEMATEL, ANP
Chen (2016b)	Library	DEMATEL
Ulkhaq et al. (2016)	Restaurant	Fuzzy AHP
Li et al. (2017)	Airlines	Fuzzy AHP, 2-Tuple FL
Yang et al. (2017)	Education	DANP, VIKOR
Gupta (2018)	Airlines	BWM, VIKOR
Rezaei et al. (2018)	Airlines	BWM
Deveci et al. (2019)	Transportation	IVIF QFD
La Fata et al. (2019)	Healthcare	Fuzzy ELECTRE III, IPA
Lupo & Bellomo (2019)	Restaurant	Fuzzy Hierarchical TOPSIS
Ocampo et al. (2019)	Government Agencies	AHP, TOPSIS
Singh & Prasher (2019)	Healthcare	Fuzzy AHP
Tuzkaya et al. (2019)	Healthcare	IVIF PROMETHEE
Büyüközkan et al. (2020a)	Airlines	IVIF AHP
Li & He (2020)	Healthcare	Linguistic Preference
Moslem & Çelikbilek (2020)	Transportation	Grey AHP, MOORA
Yucesan & Gul (2020)	Healthcare	Pythagorean Fuzzy AHP, Fuzzy TOPSIS
Bakır & Atalık (2021)	Airlines	Fuzzy AHP, Fuzzy MARCOS
Büyüközkan et al. (2021c)	Airlines	IFCM

The number of studies concerning the e-SQ and mobile SQ based on a review or conceptual is limited. Furthermore, conducted literature survey results show that there are studies concerning the electronic or mobile SQ, but DT impact has not been covered yet. DT has changed the behavior of the customers. They are using digital technologies for the products and services offered by the companies. Their demands and expectations are digital now. Companies must meet the digital expectations of the digital customers to be sustainable, increase their market share, be preferable by the customers again, increase competitiveness and profit. This is provided by offering a better customer experience and SQ. The classical SQ perception has been replaced by DSQ. However, there is no appropriate measurement method to measure, evaluate and assess the DSQ. No studies are proposing a DSQ model in the academic literature (Büyüközkan et al., 2020a). There is a gap in the academic literature based on the review results given in Tables 7.2, 7.3, and 7.4. Hence, a new DSQ model is proposed in this chapter of the thesis study.

DT and the Change of Customers:

DT has been started with the launched digital technologies. Lately, the use of these emerging technology has increased. However, the necessity to comply with these changes and transformations not to be influenced by the disruptive power of the DT has forced the companies to change their business models, processes, and way of doing business of the companies. The influence of digital technologies can be summarized as follows (Rogers, 2016; Büyüközkan et al., 2020a):

- Value creation which is directly related to the connection with customers is determined through digital technologies.
- Communication with the customers and their comments provide the dynamic participation of the customers in the processes. This makes the customers a driving force for success.
- The way of thinking for understanding the value creation for the customers has changed by the digital technologies.

Hence, it can be said that the emerging digital technologies have influenced value, competition, data, customers, and innovation areas that are the key strategic areas (Rogers, 2016). Furthermore, the customer perspective should be focused. The changes concerning the customer perspective can be summarized as follows (Rogers, 2016; Büyüközkan et al., 2020a):

- The customers of the mass market have evolved to the customers of a dynamic network.
- Single-way communication from the company to the customers has evolved to two-way communication.
- Even though the first effect of the DT is on the company, customers have the power.
- Active support, purchasing, and loyalty have become focus points instead of marketing for making the customers only buy.
- The value perception of the customers has differentiated rapidly.

Today, customers are interacting with both companies and each other. At the same time, they influence each other, and they can evaluate the companies. Purchasing, evaluation, discovering behavior of the customers have changed by the digital tools and technologies. The way of communication and connection has differentiated. Hence, it is obvious that the most strategic focus point is the customers (Rogers, 2016). There is an obvious change of customers through the DT. In such a case SQ should be focused. Yet, digital expectations of digital customers should be considered. At this point, the SQ models proposed in the academic literature may become insufficient to measure DSQ. Hence, there is a need for a genuine DSQ model.

Furthermore, there are various studies concerning SQ, service performance, e-SQ, and online SQ in the academic literature. However, there are no studies concerning e-service performance and DSQ concepts in the literature (Jansen & Ølnes, 2016). The following section contains detailed information about the proposed DSQ model.

Digital Service Quality (DSQ):

SQ can be defined as a service provider's ability to satisfy customers in a way that can improve business performance (Ramya et al., 2019). SQ is defined by many authors in the literature as the difference between what customers think a company should offer and the company's actual service performance (Parasuraman et al., 2005). Traditional SQ refers to the quality of all non-internet-based customer interactions and experiences with companies. Parasuraman et al. (2005) focus on electronic SQ after technological developments, internet access, and launched websites. Zeithaml et al. (2000) state that the quality of a website is not only related to the interaction of the customers with the site but also it is related to post-interaction services. Hence, electronic SQ covers all the phases of the interaction conducted by the customers. Based on the above-mentioned explanations, DSQ can be explained as "the difference between customer expectations regarding the product and service offered by the company with digital technologies and the actual performance of the company, and the level of satisfaction of customers during and after interaction with digital technologies".

7.2. Proposed Digital Service Quality (DSQ) Model

The proposed DSQ model consists of five main dimensions. These are Digital Tangibles, Reliability, Digital Interaction, Digital Trust, and Customer Centricity. Both the main dimensions and the criteria of these main dimensions are determined through a detailed literature survey and experts' opinions.

The basis of the proposed DSQ model is the SERVQUAL model. Face-to-face interview method with the industrial experts is conducted more than one time to determine the dimensions. There is no DSQ model in the academic literature when the industrial reports and scientific papers are examined. Due to this fact, the opinions of the experts are used as the basis of the proposed model. The opinions of experts are supported by the literature survey. The main dimensions of the proposed DSQ model are shown in Figure 7.3. The main dimensions of the proposed model can be explained as follows (Büyüközkan et al., 2020a):

- **Digital Tangibles (DTN):** It consists of the facilities and equipment which are digitalized, computational power embedded interfaces, and customized objects that can be networked and connected wirelessly or connected to different forms of representations that are digital (Price et al., 2013).

- **Reliability (RLB):** It represents the ability to fulfill the promised products and services and manage the exceptions concerning the processes effectively (Neill, 2015).

- **Digital Interaction (DIN):** It represents the digital platform-based human-machine dialogue, and digital communication networks between the companies and the customers (Entefy, 2016).

- **Digital Trust (DTR):** It shows the ability to provide confidence and conserve, and to acquire the value of shareholders and customers through digital channels during the offered digital services (Neill, 2015).

- **Customer Centricity (CCN):** It represents the ability to fulfill the emotional needs of the customers by putting them at the center of an organization for their experience of innovative service delivery based on an "outside-in" approach. (Rawat, 2016).

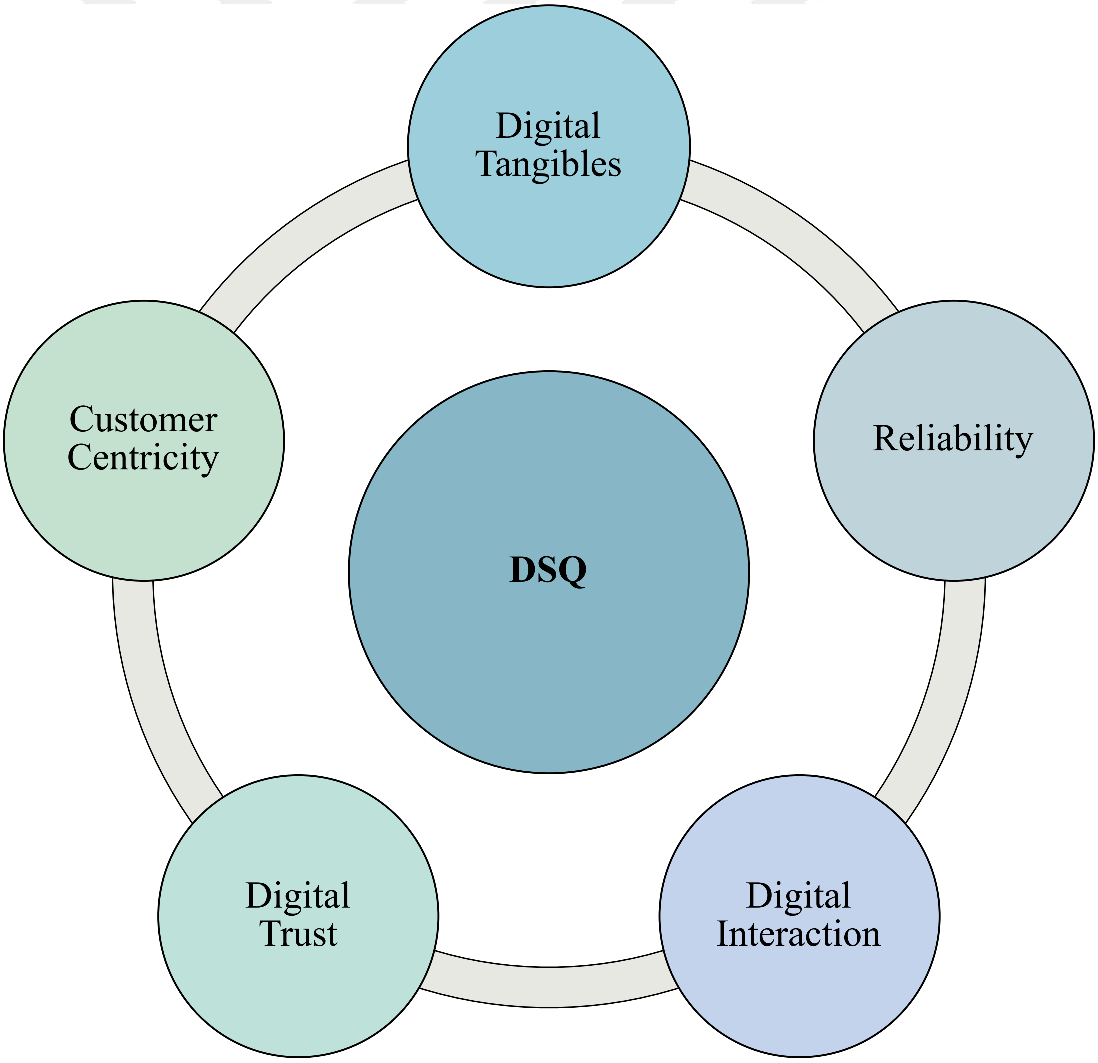


Figure 7.3: The proposed DSQ model (Büyüközkan et al., 2020a)

Each dimension has its criteria. These criteria concerning the main dimensions of the proposed model are determined in the same way as the determination process of the main dimensions. To show the structure of the proposed DSQ model, decomposed version of the proposed DSQ model is shown in Figure 7.4.

The criteria of **Digital Tangibles** can be explained as follows (Büyüközkan et al., 2020a):

- **Interoperability (DTN_1):** Represents being capable of exchanging and using the information of the software and computer systems (Sá et al., 2016).

- **Usability (DTN_2):** Shows the simplified user experience and digital channel usage for the users (Arias & Maçada, 2018).

- **Functionality (DTN_3):** Indicates the characteristics of services and digital channel availability (Arias & Maçada, 2018).

- **Efficiency (DTN_4):** Represents the being capable of accessible and providing suitable information and product with minimum effort (Hanna & Alawneh, 2010).

- **Technology architecture (DTN_5):** Shows the way of using and observing the digital infrastructure and receiving feedback (KPMG, 2017).

- **Mobile applications (DTN_6):** Indicates the ability to offer interaction between the customers and the company and provide service delivery via mobile applications (Hyvönen, 2018).

- **Suitability (DTN_7):** Represents the being capable of complying with the used services and service channels and operating these services and service channels (Hanna & Alawneh, 2010).

The criteria of **Reliability** can be explained as follows (Büyüközkan et al., 2020a):

- **Digital maturity (RLB_1):** Represents the level of being complete and mature to conduct developments for a system (Schumacher et al., 2016).

- **Robustness (RLB_2):** Shows the ability to continue to perform a digital service even though the restrictions of the specifications concerning the digital services are violated (Hanna & Alawneh, 2010).

- **Credibility (RLB_3):** Indicates the level of power that guarantees the customers do not leave the services offered by the company by meeting the demands of the customers over the promised digital services (Neill, 2015).

- **Data quality (RLB_4):** Represents providing quality data that create a trust for the staff, customers, and suppliers (Morlion, 2018).

- **Information consistency (RLB_5):** Shows the usability, clarity, accuracy, and relevancy of the information content (Hoong, 2013).

- **Effective knowledge management (RLB_6):** Indicates the ability to structure the content of the knowledge, technology, and people to meet the goals of the company (Bots & Bruijn, 2002).

- **IT resilience (RLB_7):** Expresses the flexibility and resistance capability for the protection of the data, effective reaction for the unplanned activities, acceleration of the business initiatives driven by the data during the destructive situations (Goodwin & Smith, 2018).

- **Maintainability (RLB_8):** Shows the ability to provide modifiable, changeable, stable, testable, analyzable, and compatible service channels (Hanna & Alawneh, 2010).

The criteria of **Digital Interaction** can be explained as follows (Büyüközkan et al., 2020a):

- **Digital readiness (DIN_1):** Refers to the level of ability that the firm makes transformative changes and applications in digital technologies used in the workplace for employees (CrossKnowledge, 2015).

- **Collaboration (DIN_2):** Demonstrates the ability to create products or services with a perspective based on the inclusion of customers' opinions and suggestions both inside and outside the organization (Corver & Elkhuizen, 2014).

- **Mobile communication (DIN_3):** Shows the capability and level of interacting and communicating with customers through mobile devices in the palm of their hand, providing the opportunity to share information and make transactions (Büyüközkan et al., 2020a).

- **Social media integrity (DIN_4):** Demonstrates the ability to monitor and share user behavior to provide better service by listening to the voice of the consumer in an unlimited environment (Crawford-Browne & Banerji, 2015; Entefy, 2016; Rawat, 2016; Büyüközkan et al., 2020a).

- **Agility (DIN_5):** Expresses the ability to quickly create solutions required for changes and improvements with customers by listening to customers and learning from customers (Crawford-Browne & Banerji, 2015).

- **Gamification (DIN_6):** It Indicates the ability to use game elements, techniques, and design to encourage interaction with a product or service and increase organizational productivity and learning (Narayan, 2017).

- **Human-machine dialogue (DIN_7):** It shows the level of having computer systems and user experience platforms that communicate verbally or in writing with a person (Khouzaimi et al., 2017).

The criteria of **Digital Trust** can be explained as follows (Büyüközkan et al., 2020a):

- **Cyber security (DTR_1):** It indicates the ability to build trust in the security systems to protect customers' data and other data against cyber threats (Mattila & Seppälä, 2016).

- **Privacy (DTR_2):** Refers to the level of competence in protecting customer privacy by not sharing the information provided by the consumer (Neill, 2015).

- **Transparency (DTR_3):** Shows the level of being open and informative about how customer data is used and processed (Neill, 2015; Sá et al., 2016).

- **Identifiability (DTR_4):** It refers to an accurate statement of the identity of both the service provider and the service that is involved in (Mattila & Seppälä, 2016).

- **Online integrity (DTR_5):** Refers to the level and capability of enabling users to do their work online (Sá et al., 2016).

- **Service availability (DTR_6):** It refers to the ability to offer 24/7 available service provided by the service provider, supported by good technical conditions (Sá et al., 2016).

- **Accountability (DTR_7):** Refers to the feature of a data processing system that allows users to verify whether the system is functioning as expected, revealing the responsible component in case of deviation from the expected and capable of convincing the third party by producing evidence whether any error has occurred (Castelluccia et al., 2011).

The criteria of **Customer Centricity** can be explained as follows (Büyüközkan et al., 2020a):

- **Accessibility (CCN_1):** Refers to enabling customers to decide for themselves under which conditions, when, and in what way they will communicate with both the organization and service channels (Crawford-Browne & Banerji, 2015).

- **Self-service capability (CCN_2):** Shows the level of adoption of customers to be able to make their processes with the help of self-service tools without any technical support or information technology intervention (Kerravala & Miller, 2017).

- **Customer insights (CCN_3):** Represents the ability of companies to turn customer data and analysis results of that data into products, information, and services that customers value (Rawat, 2016).

- **Customer segmentation (CCN_4):** It indicates the complete and accurate analysis of customers and understanding how to talk to customers by choosing suitable channels for customer behavior accordingly (Experian, 2012).

- **Proactive customer service (CCN_5):** Shows the ability to respond to customer expectations through digital channels and provide quick solutions for the first time without customer follow-up (Crawford-Browne & Banerji, 2015).

- **Customer empowerment (CCN_7):** It represents the controlling, feedback-giving, or transferring power of customers. It is the ability to provide feedbacks on the offered services and goods by the company from the customers. It expresses the control of the customers on the variables concerning the brand. It is to give the control of the decisions related to the brand to the customers instead of employees (Wright et al., 2006; Pranic & Roehl, 2012; Bansal & Bansal, 2018; Mohammad, 2020).

7.3. Application of the Proposed Methodology

The importance of the customer and the offered SQ level for the companies cannot be denied in almost every sector. This is true for sure for the aviation industry. It has a network-like structure and connects the whole world. Besides, the demand for air transportation has increased lately and the customer base of this industry is very large, and the diversity level is high. The usage of digital technologies such as social media platforms, mobile applications and increased rate of internet usage put the passengers at the center of all processes concerning their travel journey from beginning to the end. Passengers have become digital and mobile (Taneja, 2016). They proceed processes such as online ticketing, providing flight information, baggage tracking, evaluation of the travel experience through the digital technologies. Today, it is possible to follow the status of your baggage. The information concerning the line that the baggage is delivered to the passengers after landing can be provided through the mobile applications. Also, the processes are digital. Meeting the digital expectations of the digital customers has increased the intensity of the competition in the airline market. Due to this fact, a new DSQ model is proposed in the section above. When this is the case, the airline companies in Turkey have taken enormous steps to comply with the necessities of the DT process to meet the customer demands. Hence, a case study concerning the Turkish airline industry is conducted. The complexity of the airline industry and the DT process have been taken into consideration. The possibility of the hesitations and intuition that may arise, the selected MDM methods are expanded into IVIF environment. Hence, the integrated IVIF MCDM methodology proposed in Chapter 3 is utilized for the case study. The weights of the criteria concerning the proposed DSQ model are calculated using the IVIF AHP method. Following this, DSQ performance evaluation process for four low-cost airline companies is conducted and the airline company offering the best DSQ is selected through the IVIF VIKOR method. The computational steps of the proposed integrated IVIF AHP and IVIF VIKOR methodology given in Chapter 3 are applied as following:

Calculation of the Criteria Weights with the IVIF AHP Method:

Step 1. Determination of the DMs:

A group of experts who are DMs is constructed to proceed the decision-making process. The background, education level, experience level, information and knowledge level about the DT process, and willingness to help are considered as the determination criteria. Here, $DM = \{DM_1, DM_2, DM_3\}$ represents the group of the DMs. DM_1 and DM_2 work for an airline company in Turkey. While the first DM works as the SVP of corporate innovation and projects of the company, the second DM who is conducting a Ph.D. education works for the corporate innovation and projects in the same company. DM_3 is the founder and owner of a company offering simulator, hardware, software, and automation technologies to the Turkish aviation industry. All the DMs are also actively using air transportation as passengers. Due to privacy and confidentiality concerns, further information about the DMs and their companies cannot be provided.

Step2. Determination of the goal and the evaluation criteria:

The goal is to verify the validity of the proposed DSQ model in Turkey concerning the airline industry and evaluate the DSQ performances of the airline companies. The criteria of the proposed model are determined through a literature survey and the experts' opinions who are the DMs.

Step 3. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the criteria are adopted from the scientific studies in the academic literature. Utilized scales are given in the relevant steps.

Step 4. Restructuring the problem:

The proposed DSQ model-based problem contains 5 main dimensions and their 35 criteria. The proposed model has been restructured to model and solve the problem in a hierarchical structure. The constructed hierarchical model is given in Figure 7.4.

Step 5. Calculation of the weights of the DMs:

The importance degrees of the determined DMs are assigned using the linguistic terms given in Table 3.3 by considering the criteria introduced in Step 1. Following that, the weights of the DMs given in Table 7.5 are calculated using Eq. (3.19) based on the assigned linguistic terms.

Table 7.5: The importance degrees of the DMs

DMs	Importance Degrees of the DMs	IVIF values		Weights of the DMs (λ_k)
		$\tilde{\mu}_{\tilde{A}}(x)$ $\left[\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U\right]$	$\tilde{\nu}_{\tilde{A}}(x)$ $\left[\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U\right]$	
DM_1	EQ	[0.95, 1.00]	[0.00, 0.00]	0.371 (λ_1)
DM_2	Q	[0.60, 0.65]	[0.10, 0.15]	0.286 (λ_2)
DM_3	VQ	[0.80, 0.85]	[0.05, 0.10]	0.343 (λ_3)

Step 6. Evaluation of the criteria:

The judgments of the DMs are obtained through the linguistic terms given in Table 3.4 based on pairwise comparisons. The evaluations of the DMs concerning the main dimensions are given in Tables 7.6, 7.7, and 7.8, respectively. The same process is applied for the criteria concerning the dimensions of the proposed DSQ model. Due to the page limitations, only the evaluations regarding the Digital Tangibles (DTN) criteria are given in Tables 7.9, 7.10, and 7.11, respectively.

Table 7.6: The evaluations of main dimensions by the DM_1

	DTN	RLB	DIN	DTR	CCN
Digital Tangibles (DTN)	EI				IV
Reliability (RLB)	MMI	EI	MMI		SMI
Digital Interaction (DIN)	SMI		EI		SMI
Digital Trust (DTR)	SMI	MMI	IV3	EI	SMI
Customer Centricity (CCN)					EI

Table 7.7: The evaluations of main dimensions by the DM_2

	DTN	RLB	DIN	DTR	CCN
Digital Tangibles (DTN)	EI				MMI
Reliability (RLB)	MMI	EI	IV		IV3
Digital Interaction (DIN)	MMI		EI		SMI
Digital Trust (DTR)	SMI	SMI	MMI	EI	IV3
Customer Centricity (CCN)					EI

Table 7.8: The evaluations of main dimensions by the DM_3

	DTN	RLB	DIN	DTR	CCN
Digital Tangibles (DTN)	EI	MMI	MMI		IV2
Reliability (RLB)		EI	IV		
Digital Interaction (DIN)			EI		
Digital Trust (DTR)	MMI	IV2	IV2	EI	IV2
Customer Centricity (CCN)		IV2	IV2		EI

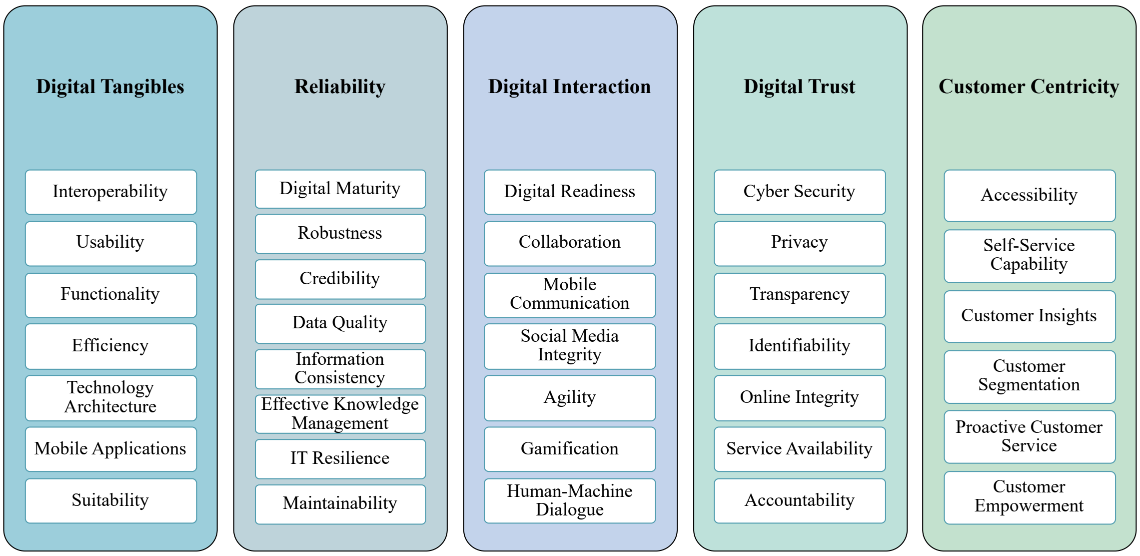


Figure 7.4: Hierarchical structure of the proposed DSQ model (Büyüközkan et al., 2020a)

Table 7.9: The evaluations concerning the DTN criteria by the DM_1

	DTN_1	DTN_2	DTN_3	DTN_4	DTN_5	DTN_6	DTN_7
Interoperability (DTN_1)	EI	IV2					
Usability (DTN_2)		EI		MMI			SMI
Functionality (DTN_3)	IV2	MMI	EI	IV		SMI	MMI
Efficiency (DTN_4)	SMI			EI			
Technology Architecture (DTN_5)	MMI	IV2	SMI	MMI	EI	SMI	MMI
Mobile Applications (DTN_6)	MMI	SMI		MMI		EI	SMI
Suitability (DTN_7)	IV2			SMI			EI

Table 7.10: The evaluations concerning the DTN criteria by the DM_2

	DTN_1	DTN_2	DTN_3	DTN_4	DTN_5	DTN_6	DTN_7
Interoperability (DTN_1)	EI	MMI					
Usability (DTN_2)		EI		SMI			
Functionality (DTN_3)	MMI	MMI	EI	IV2	IV	SMI	SMI
Efficiency (DTN_4)	SMI			EI			
Technology Architecture (DTN_5)	IV2	IV2		MMI	EI	SMI	SMI
Mobile Applications (DTN_6)	IV2	IV2		IV2		EI	SMI
Suitability (DTN_7)	MMI	SMI		SMI			EI

Table 7.11: The evaluations concerning the DTN criteria by the DM_3

	DTN_1	DTN_2	DTN_3	DTN_4	DTN_5	DTN_6	DTN_7
Interoperability (DTN_1)	EI	IV2				MMI	
Usability (DTN_2)		EI			MMI	SMI	SMI
Functionality (DTN_3)	MMI	IV2	EI	IV2	MMI	IV2	IV2
Efficiency (DTN_4)	MMI	IV2		EI	MMI	MMI	
Technology Architecture (DTN_5)	IV2				EI		
Mobile Applications (DTN_6)					IV2	EI	
Suitability (DTN_7)	SMI			IV2	MMI	IV2	EI

Step 7. Aggregation:

The judgments of the DMs are converted into IVIF values. The individual evaluations of the DMs are aggregated to obtain group decision values using Eq. (3.20). Following this, the individual aggregated IVIF values are aggregated one more time to obtain main aggregated (group-decision) values. Main aggregated IVIF values concerning the main dimensions are given in Table 7.12. The same process is applied for the criteria of the main dimensions. The main aggregated IVIF values of the criteria concerning are given in tables from Table 7.13 to 7.17.

Table 7.12: Main aggregated (group) IVIF values concerning the main dimensions

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Digital Tangibles (DTN)	0.254	0.669	0.016	0.330	0.001	0.729
Reliability (RLB)	0.287	0.673	0.013	0.326	0.001	0.700
Digital Interaction (DIN)	0.240	0.699	0.023	0.300	0.001	0.737
Digital Trust (DTR)	0.298	0.680	0.010	0.320	0.000	0.693
Customer Centricity (CCN)	0.217	0.664	0.024	0.335	0.001	0.758

($C.R. = 0.099$)

Step 8. Consistency Check:

All the $C.R.$ values that are calculated using Eq. (3.21) and given in Tables from 7.12 to 7.17 are less than 0.1. Hence, the evaluations are consistent.

Step 9. Calculation of the criteria weights:

The weights of the criteria are calculated through Eq. (3.22). The obtained results are presented in Table 7.18. After obtaining the IVIF AHP weights, the IVIF VIKOR steps should be followed.

Table 7.13: Main aggregated (group) IVIF values concerning the DTN criteria

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Interoperability (DTN_1)	0.212	0.818	0.002	0.182	0.000	0.786
Usability (DTN_2)	0.235	0.807	0.001	0.193	0.000	0.764
Functionality (DTN_3)	0.341	0.746	0.002	0.252	0.002	0.657
Efficiency (DTN_4)	0.258	0.814	0.002	0.185	0.001	0.739
Technology Architecture (DTN_5)	0.437	0.775	0.004	0.225	0.000	0.559
Mobile Applications (DTN_6)	0.139	0.789	0.002	0.211	0.000	0.860
Suitability (DTN_7)	0.165	0.802	0.002	0.198	0.000	0.833

($C.R. = 0.096$)

Table 7.14: Main aggregated (group) IVIF values concerning the RLB criteria

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Digital Maturity (RLB_1)	0.271	0.838	0.001	0.162	0.000	0.728
Robustness (RLB_2)	0.298	0.863	0.002	0.137	0.000	0.700
Credibility (RLB_3)	0.291	0.821	0.000	0.179	0.000	0.709
Data Quality (RLB_4)	0.264	0.819	0.001	0.181	0.000	0.735
Information Consistency (RLB_5)	0.519	0.816	0.002	0.184	0.000	0.479
Effective Knowledge Management (RLB_6)	0.175	0.843	0.000	0.157	0.000	0.824
IT Resilience (RLB_7)	0.201	0.857	0.000	0.143	0.000	0.799
Maintainability (RLB_8)	0.190	0.855	0.001	0.145	0.000	0.809

($C.R. = 0.098$)

Table 7.15: Main aggregated (group) IVIF values concerning the DIN criteria

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Digital Readiness (DIN_1)	0.292	0.788	0.003	0.212	0.000	0.705
Collaboration (DIN_2)	0.258	0.770	0.001	0.230	0.000	0.741
Mobile Communication (DIN_3)	0.267	0.796	0.002	0.204	0.000	0.731
Social Media Integrity (DIN_4)	0.247	0.815	0.003	0.185	0.000	0.750
Agility (DIN_5)	0.440	0.780	0.005	0.220	0.000	0.556
Gamification (DIN_6)	0.131	0.826	0.002	0.174	0.000	0.868
Human-Machine Dialogues (DIN_7)	0.106	0.824	0.002	0.176	0.000	0.891

$(C.R. = 0.095)$

Table 7.16: Main aggregated (group) IVIF values concerning the DTR criteria

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Cyber Security (DTR_1)	0.363	0.792	0.002	0.207	0.001	0.635
Privacy (DTR_2)	0.335	0.807	0.002	0.193	0.000	0.663
Transparency (DTR_3)	0.250	0.797	0.002	0.203	0.000	0.748
Identifiability (DTR_4)	0.252	0.787	0.003	0.213	0.000	0.745
Online Integrity (DTR_5)	0.446	0.776	0.008	0.224	0.000	0.546
Service Availability (DTR_6)	0.136	0.819	0.002	0.181	0.000	0.862
Accountability (DTR_7)	0.108	0.838	0.001	0.162	0.000	0.891

$(C.R. = 0.099)$

Table 7.17: Main aggregated (group) IVIF values concerning the CCN criteria

	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$
Accessibility (CCN_1)	0.235	0.732	0.003	0.268	0.000	0.762
Self-Service Capability (CCN_2)	0.243	0.720	0.007	0.280	0.000	0.750
Customer Insights (CCN_3)	0.256	0.732	0.003	0.268	0.000	0.741
Customer Segmentation (CCN_4)	0.254	0.736	0.003	0.263	0.001	0.742
Proactive Customer Service (CCN_5)	0.332	0.755	0.009	0.244	0.000	0.659
Customer Empowerment (CCN_6)	0.133	0.768	0.007	0.231	0.001	0.860

$(C.R. = 0.098)$

Table 7.18: The obtained results (IVIF AHP weights)

Dimension	Weights	Criteria	Local weights	Global weights
Digital Tangibles (DTN)	0.19872	Interoperability (DTN_1)	0.14046	0.02791
		Usability (DTN_2)	0.14247	0.02831
		Functionality (DTN_3)	0.14935	0.02968
		Efficiency (DTN_4)	0.14465	0.02875
		Technology Architecture (DTN_5)	0.15570	0.03094
		Mobile Applications (DTN_6)	0.13204	0.02624
		Suitability (DTN_7)	0.13532	0.02689

Table 7.18: The obtained results (IVIF AHP weights) (*continue*)

Dimension	Weights	Criteria	Local weights	Global weights
Reliability (RLB)	0.20340	Digital Maturity (RLB_1)	0.12562	0.02555
		Robustness (RLB_2)	0.12754	0.02594
		Credibility (RLB_3)	0.12679	0.02579
		Data Quality (RLB_4)	0.12488	0.02540
		Information Consistency (RLB_5)	0.13751	0.02797
		Effective Knowledge Management (RLB_6)	0.11799	0.02400
		IT Resilience (RLB_7)	0.12027	0.02446
		Maintainability (RLB_8)	0.11939	0.02428
Digital Interaction (DIN)	0.19966	Digital Readiness (DIN_1)	0.14743	0.02943
		Collaboration (DIN_2)	0.14413	0.02878
		Mobile Communication (DIN_3)	0.14556	0.02906
		Social Media Integrity (DIN_4)	0.14421	0.02879
		Agility (DIN_5)	0.15652	0.03125
		Gamification (DIN_6)	0.13252	0.02646
		Human-Machine Dialogues (DIN_7)	0.12963	0.02588
Digital Trust (DTR)	0.20526	Cyber Security (DTR_1)	0.15085	0.03096
		Privacy (DTR_2)	0.14926	0.03064
		Transparency (DTR_3)	0.14246	0.02924
		Identifiability (DTR_4)	0.14239	0.02923
		Online Integrity (DTR_5)	0.15492	0.03180
		Service Availability (DTR_6)	0.13153	0.02700
		Accountability (DTR_7)	0.12858	0.02639
Customer Centricity (CCN)	0.19297	Accessibility (CCN_1)	0.16598	0.03203
		Self-Service Capability (CCN_2)	0.16614	0.03206
		Customer Insights (CCN_3)	0.16817	0.03245
		Customer Segmentation (CCN_4)	0.16831	0.03248
		Proactive Customer Service (CCN_5)	0.17654	0.03407
		Customer Empowerment (CCN_6)	0.15486	0.02988

Evaluation of the Alternatives with the IVIF VIKOR Method:

Step 1. Determination of the DMs:

The same group of experts involved in the IVIF AHP process is involved in the IVIF VIKOR method.

Step 2. Determination of the goal and the evaluation criteria:

The goal is to evaluate the airline companies according to their DSQ performances. For this purpose, the evaluation criteria in the proposed DSQ model are used.

Step 3. Determination of the set of alternatives:

A set of suitable alternatives is constructed based on four different airline companies in Turkey. Digital platforms and channels used by the companies are taken into consideration for the determination of the alternatives. Following that, offered products and services by the companies are focused. Finally, the potential of the technology usage of the customers is conceived. Furthermore, the determined candidates are approved by the opinions of the DMs. DMs have a remarkable amount of knowledge level and information about the determined companies. Let $A = \{A_1, A_2, A_3, A_4\}$ be the set of suitable alternatives. Detailed information about the candidate companies cannot be provided due to privacy concerns and confidentiality.

Step 4. Designation of the scales:

Appropriate evaluation scales to obtain the importance degree and weights of the DMs and evaluate the alternatives over the evaluation criteria are adopted from the scientific studies in the academic literature. The utilized scales are given in the relevant step.

Step 5. Calculation of the weights of the DMs:

The weights of the DMs calculated at the initial phase of the IVIF AHP are used. The weights are given in Table 7.5.

Step 6. Evaluation of the alternatives:

The judgments of the DMs for the alternatives are obtained based on the evaluation criteria in the proposed DSQ model. The linguistic terms given in Table 3.6 are used to assess the alternatives. The evaluation process is shown in Figure 7.5. Furthermore, the evaluation of the alternatives by the DMs using the linguistic terms are given in Tables 7.19, 7.20, and 7.21, respectively.

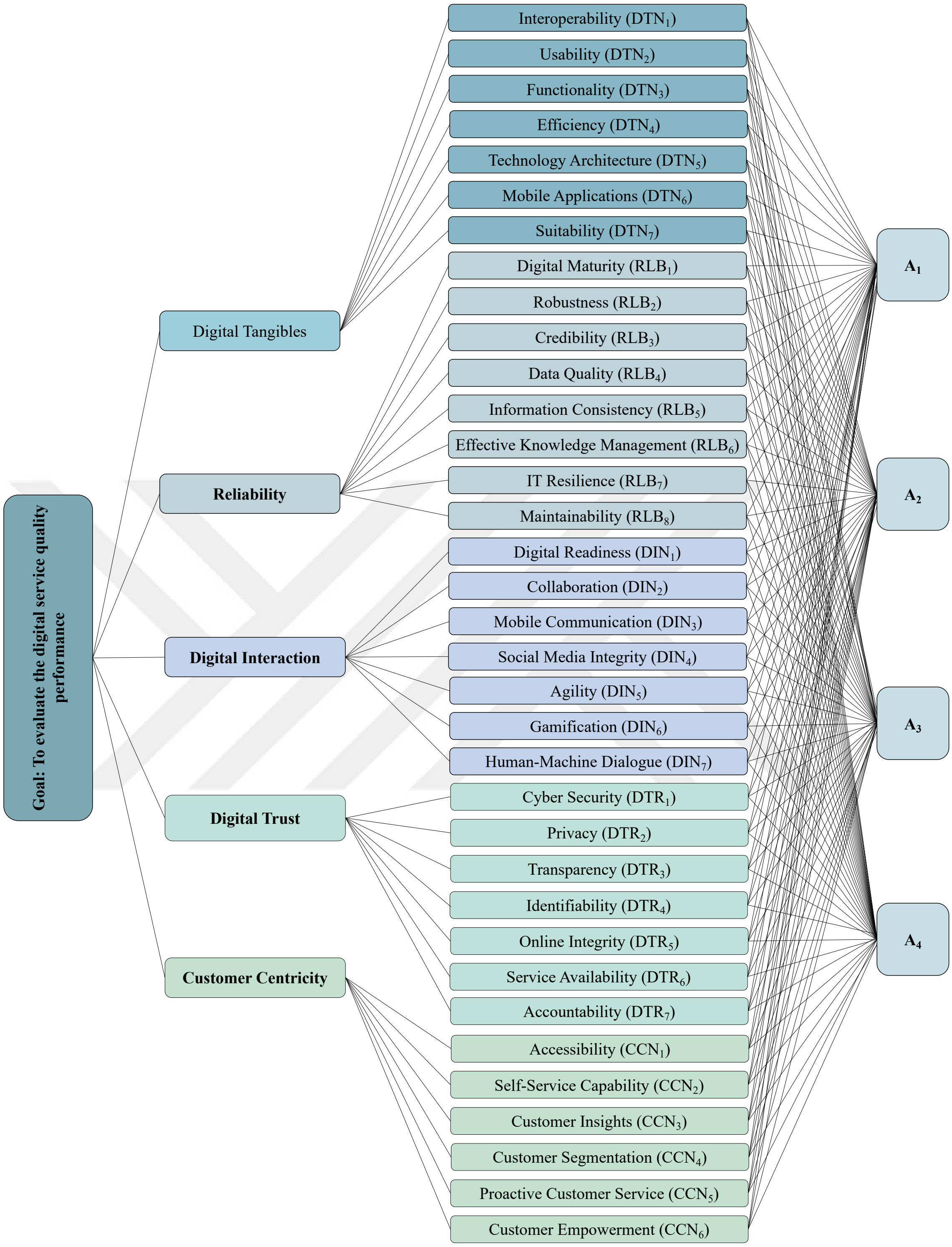


Figure 7.5: Evaluation of the alternatives over the DSQ model

Step 7. Aggregation:

The linguistic terms used to evaluate the alternatives are transformed into IVIF values and these IVIF values are aggregated to obtained group-decision matrix $(\tilde{X})$ using the IIFWA operator proposed by Xu & Cai (2012) as indicated in Eq. (3.20).

Table 7.19: Evaluation of the alternatives by the DM_1

DSQ Criteria	A_1	A_2	A_3	A_4
Interoperability (DTN_1)	VVG	VG	VG	MB
Usability (DTN_2)	VG	VVG	VVG	M
Functionality (DTN_3)	VG	VG	VVG	M
Efficiency (DTN_4)	VVG	VVG	VVG	M
Technology Architecture (DTN_5)	EG	VG	VG	M
Mobile Applications (DTN_6)	VVG	EG	VG	G
Suitability (DTN_7)	EG	VVG	VVG	MG
Digital Maturity (RLB_1)	VVG	VVG	VVG	M
Robustness (RLB_2)	VVG	VVG	VVG	MG
Credibility (RLB_3)	EG	EG	EG	MG
Data Quality (RLB_4)	EG	VVG	VVG	MG
Information Consistency (RLB_5)	VVG	VVG	VVG	MG
Effective Knowledge Management (RLB_6)	VG	VVG	VVG	MG
IT Resilience (RLB_7)	VG	EG	VVG	MG
Maintainability (RLB_8)	EG	EG	EG	G
Digital Readiness (DIN_1)	VVG	VVG	VVG	MG
Collaboration (DIN_2)	VVG	VVG	EG	MG
Mobile Communication (DIN_3)	VG	VG	VG	MG
Social Media Integrity (DIN_4)	VG	VG	VG	MG
Agility (DIN_5)	VVG	VVG	VVG	M
Gamification (DIN_6)	G	G	G	M
Human-Machine Dialogues (DIN_7)	VG	VVG	G	M
Cyber Security (DTR_1)	VG	VG	VG	M
Privacy (DTR_2)	VVG	VVG	VVG	MG
Transparency (DTR_3)	VG	VG	VG	G
Identifiability (DTR_4)	VG	VG	VG	MG
Online Integrity (DTR_5)	EG	VVG	VVG	MG
Service Availability (DTR_6)	VG	VG	VG	MG
Accountability (DTR_7)	VVG	VVG	VVG	MG
Accessibility (CCN_1)	EG	EG	VVG	MG
Self-Service Capability (CCN_2)	EG	EG	VVG	MG
Customer Insights (CCN_3)	EG	EG	EG	G
Customer Segmentation (CCN_4)	EG	VVG	VVG	MG
Proactive Customer Service (CCN_5)	VG	VG	VG	MG
Customer Empowerment (CCN_6)	EG	EG	EG	G

Table 7.20: Evaluation of the alternatives by the DM_2

DSQ Criteria	A_1	A_2	A_3	A_4
Interoperability (DTN_1)	VG	G	VVG	B
Usability (DTN_2)	G	VG	VVG	MB
Functionality (DTN_3)	G	G	VVG	MB
Efficiency (DTN_4)	VG	VG	EG	MB
Technology Architecture (DTN_5)	VVG	G	EG	MB
Mobile Applications (DTN_6)	VG	VVG	EG	MG
Suitability (DTN_7)	VVG	VG	EG	M
Digital Maturity (RLB_1)	VG	VG	EG	MB
Robustness (RLB_2)	VG	VG	EG	M
Credibility (RLB_3)	VVG	VVG	EG	M
Data Quality (RLB_4)	VVG	VG	EG	M
Information Consistency (RLB_5)	VG	VG	EG	M
Effective Knowledge Management (RLB_6)	G	VG	EG	M
IT Resilience (RLB_7)	G	VVG	EG	M
Maintainability (RLB_8)	VVG	VVG	EG	MG
Digital Readiness (DIN_1)	VG	VG	EG	M
Collaboration (DIN_2)	VG	VG	VVG	M
Mobile Communication (DIN_3)	G	G	VVG	M
Social Media Integrity (DIN_4)	G	G	VVG	M
Agility (DIN_5)	VG	VG	VVG	MB
Gamification (DIN_6)	MG	MG	VVG	MB
Human-Machine Dialogues (DIN_7)	G	VG	EG	MB
Cyber Security (DTR_1)	G	G	EG	MB
Privacy (DTR_2)	VG	VG	EG	M
Transparency (DTR_3)	G	G	EG	MG
Identifiability (DTR_4)	G	G	EG	M
Online Integrity (DTR_5)	VVG	VG	EG	M
Service Availability (DTR_6)	G	G	EG	M
Accountability (DTR_7)	VG	VG	EG	M
Accessibility (CCN_1)	VVG	VVG	EG	M
Self-Service Capability (CCN_2)	VVG	VVG	EG	M
Customer Insights (CCN_3)	VVG	VVG	VVG	MG
Customer Segmentation (CCN_4)	VVG	VG	VG	M
Proactive Customer Service (CCN_5)	G	G	G	M
Customer Empowerment (CCN_6)	VVG	VVG	VVG	MG

Table 7.21: Evaluation of the alternatives by the DM_3

DSQ Criteria	A_1	A_2	A_3	A_4
Interoperability (DTN_1)	EG	VVG	VVG	M
Usability (DTN_2)	VVG	EG	EG	MG
Functionality (DTN_3)	VVG	VVG	EG	MG
Efficiency (DTN_4)	EG	EG	EG	MG
Technology Architecture (DTN_5)	EG	VVG	VVG	MG
Mobile Applications (DTN_6)	EG	EG	VVG	VG
Suitability (DTN_7)	EG	EG	EG	G
Digital Maturity (RLB_1)	EG	EG	EG	MG
Robustness (RLB_2)	EG	EG	EG	G
Credibility (RLB_3)	EG	EG	EG	G
Data Quality (RLB_4)	EG	EG	EG	G
Information Consistency (RLB_5)	EG	EG	EG	G
Effective Knowledge Management (RLB_6)	VVG	EG	EG	G
IT Resilience (RLB_7)	VVG	EG	EG	G
Maintainability (RLB_8)	EG	EG	EG	VG
Digital Readiness (DIN_1)	EG	EG	EG	G
Collaboration (DIN_2)	EG	EG	EG	G
Mobile Communication (DIN_3)	VVG	VVG	VVG	G
Social Media Integrity (DIN_4)	VVG	VVG	VVG	G
Agility (DIN_5)	EG	EG	EG	MG
Gamification (DIN_6)	VG	VG	VG	MG
Human-Machine Dialogues (DIN_7)	VVG	EG	VG	MG
Cyber Security (DTR_1)	VVG	VVG	VVG	MG
Privacy (DTR_2)	EG	EG	EG	G
Transparency (DTR_3)	VVG	VVG	VVG	VG
Identifiability (DTR_4)	VVG	VVG	VVG	G
Online Integrity (DTR_5)	EG	EG	EG	G
Service Availability (DTR_6)	VVG	VVG	VVG	G
Accountability (DTR_7)	EG	EG	EG	G
Accessibility (CCN_1)	EG	EG	EG	G
Self-Service Capability (CCN_2)	EG	EG	EG	G
Customer Insights (CCN_3)	EG	EG	EG	VG
Customer Segmentation (CCN_4)	EG	EG	EG	G
Proactive Customer Service (CCN_5)	VVG	VVG	VVG	G
Customer Empowerment (CCN_6)	EG	EG	EG	VG

Step 8. Calculation of the positive and negative ideal solutions:

IVIFPIS ($\tilde{f}_j^*$) values are obtained using Eq. (3.24), and IVIFNIS ($\tilde{f}_j^-$) values are calculated using Eq. (3.25) and they are shown in Table 7.22.

Table 7.22: Obtained ($\tilde{f}_j^*$) and ($\tilde{f}_j^-$) values

IVIFPIS ($\tilde{f}_j^*$)						IVIFNIS ($\tilde{f}_j^-$)					
$\mu_{\tilde{A}}^L$	$\mu_{\tilde{A}}^U$	$\nu_{\tilde{A}}^L$	$\nu_{\tilde{A}}^U$	$\pi_{\tilde{A}}^L$	$\pi_{\tilde{A}}^U$	$\mu_{\tilde{A}}^L$	$\mu_{\tilde{A}}^U$	$\nu_{\tilde{A}}^L$	$\nu_{\tilde{A}}^U$	$\pi_{\tilde{A}}^L$	$\pi_{\tilde{A}}^U$
0.945	1.000	0.000	0.000	0.000	0.055	0.411	0.461	0.437	0.488	0.051	0.152
0.955	1.000	0.000	0.000	0.000	0.045	0.512	0.563	0.335	0.386	0.051	0.153
0.955	1.000	0.000	0.000	0.000	0.045	0.512	0.563	0.335	0.386	0.051	0.153
0.976	1.000	0.000	0.000	0.000	0.024	0.512	0.563	0.335	0.386	0.051	0.153
0.981	1.000	0.000	0.000	0.000	0.019	0.512	0.563	0.335	0.386	0.051	0.153
0.981	1.000	0.000	0.000	0.000	0.019	0.717	0.769	0.119	0.177	0.054	0.164
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.976	1.000	0.000	0.000	0.000	0.024	0.512	0.563	0.335	0.386	0.051	0.153
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.990	1.000	0.000	0.000	0.000	0.010	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.990	1.000	0.000	0.000	0.000	0.010	0.717	0.769	0.119	0.177	0.054	0.164
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.871	0.925	0.018	0.056	0.019	0.111	0.614	0.665	0.231	0.283	0.052	0.155
0.871	0.925	0.018	0.056	0.019	0.111	0.614	0.665	0.231	0.283	0.052	0.155
0.955	1.000	0.000	0.000	0.000	0.045	0.512	0.563	0.335	0.386	0.051	0.153
0.809	0.868	0.047	0.100	0.033	0.143	0.512	0.563	0.335	0.386	0.051	0.153
0.945	1.000	0.000	0.000	0.000	0.055	0.512	0.563	0.335	0.386	0.051	0.153
0.933	1.000	0.000	0.000	0.000	0.067	0.512	0.563	0.335	0.386	0.051	0.153
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.933	1.000	0.000	0.000	0.000	0.067	0.717	0.769	0.119	0.177	0.054	0.164
0.933	1.000	0.000	0.000	0.000	0.067	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.933	1.000	0.000	0.000	0.000	0.067	0.614	0.665	0.231	0.283	0.052	0.155
0.976	1.000	0.000	0.000	0.000	0.024	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.717	0.769	0.119	0.177	0.054	0.164
0.981	1.000	0.000	0.000	0.000	0.019	0.614	0.665	0.231	0.283	0.052	0.155
0.823	0.881	0.039	0.089	0.030	0.138	0.614	0.665	0.231	0.283	0.052	0.155
0.981	1.000	0.000	0.000	0.000	0.019	0.717	0.769	0.119	0.177	0.054	0.164

Step 9. Computation of the group utility and individual regret values:

The group utility values $S(A_i)$, and the individual regret values $R(A_i)$ are computed through the Eq. (3.26) and Eq. (3.27), respectively. Obtained $S(A_i)$ and $R(A_i)$ values are given in Table 7.23.

Table 7.23: Obtained $S(A_i)$ and $R(A_i)$ values

Alternatives	$S(A_i)$	$R(A_i)$
A_1	0.076	0.0072
A_2	0.066	0.0072
A_3	0.009	0.0039
A_4	0.637	0.0279

Step 10. Calculation of the $Q(A_i)$ values:

$Q(A_i)$ values are computed using the Eq. (3.30). Obtained $Q(A_i)$ values are given in Table 7.24.

Table 7.24: Obtained $Q(A_i)$ values

Alternatives	$Q(A_i)$
A_1	0.1222
A_2	0.1145
A_3	0.0000
A_4	1.0000

Step 11. Ranked order of the alternatives:

The ascending order of the $S(A_i)$, $R(A_i)$ and $Q(A_i)$ values are used to rank the alternatives. The results are given in Table 7.25.

Table 7.25: The ranked order of the alternatives

Alternatives	$S(A_i)$	Order	$R(A_i)$	Order	$Q(A_i)$	Order
A_1	0.076	3	0.0072	2	0.1222	3
A_2	0.066	2	0.0072	2	0.1145	2
A_3	0.009	1	0.0039	1	0.0000	1
A_4	0.637	4	0.0279	4	1.0000	4

The first condition of the VIKOR method is $Q_{[2]} - Q_{[1]} \geq DQ$ where $DQ = \frac{1}{z}$ (Opricovic, 1998). According to the condition, $0.1147 - 0.0000 < 0.25$. Hence, the first condition is not satisfied. For this reason, second condition should be met. When, $S(A_i)$ values compared with $Q(A_i)$ values, it is seen that the ranked order of the alternatives is the same. Furthermore, the ranked order of the alternatives is supported by the $R(A_i)$ values. Hence, the order of the alternatives can be indicated as $A_3 \succ A_2 \succ A_1 \succ A_4$. The best alternative is the A_3 with the highest DSQ performance.

7.4. Results and Discussion

The results of the analysis are presented in Table 7.18. To make more clear comments about the obtained results, they have been visualized. The importance degrees of the main dimensions are given in Figure 7.6. Figure 7.6 shows that the most significant focus point is Digital Trust. Reliability follows Digital Trust. Digital Interaction should be offered appropriately by the airline companies for better DSQ after providing reliability. Digital interaction should be supported by the Digital Tangibles. Finally, Customer Centricity can be provided for the customers.

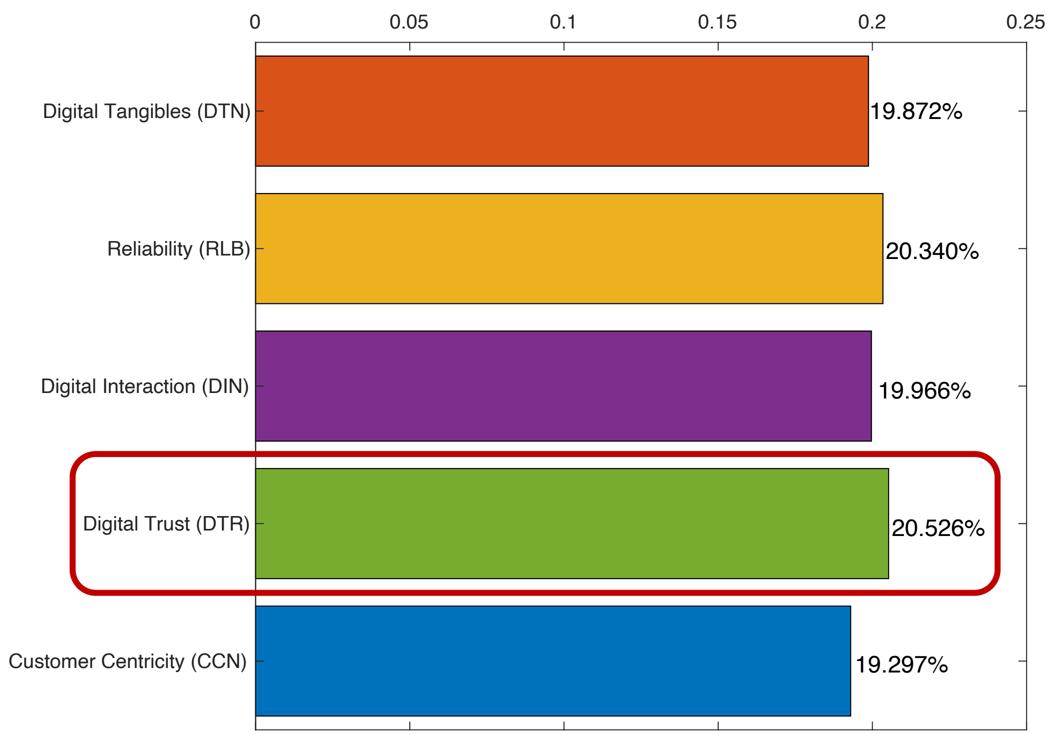


Figure 7.6: Importance degrees of the dimensions of the DSQ model

Following the main dimensions, the criteria of each dimension should be focused on separately. Figure 7.7 shows the importance degree of the Digital Tangibles criteria. The importance degrees of the Reliability criteria are shown in Figure 7.8.

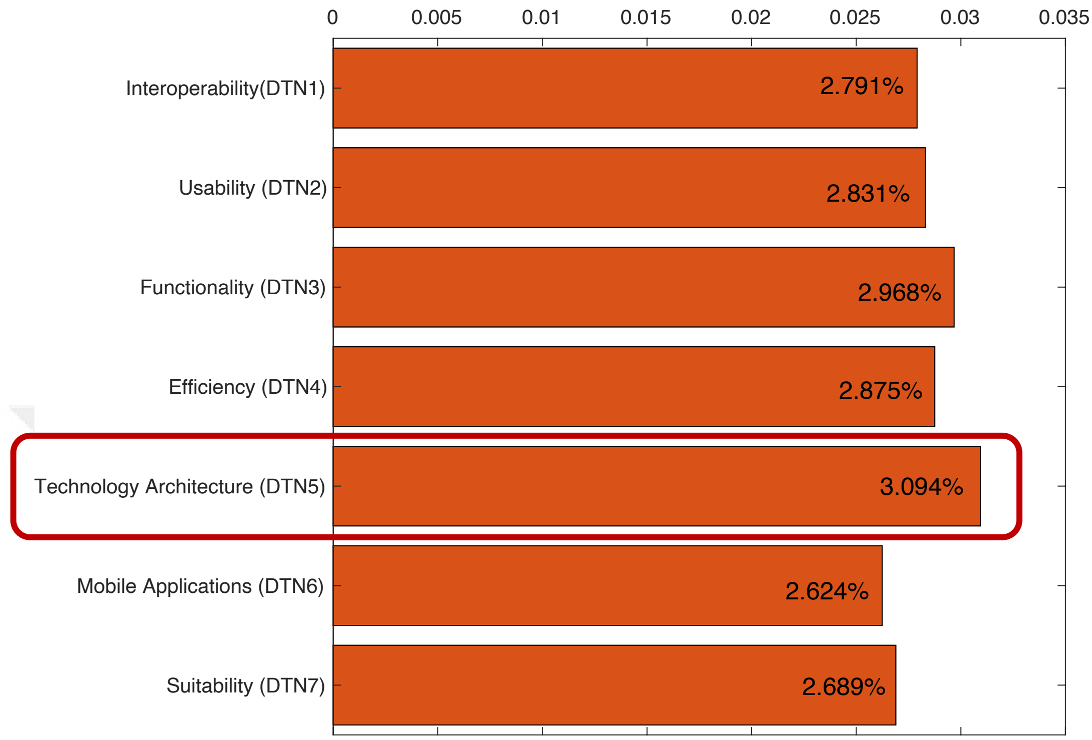


Figure 7.7: The importance degrees of the DTN criteria

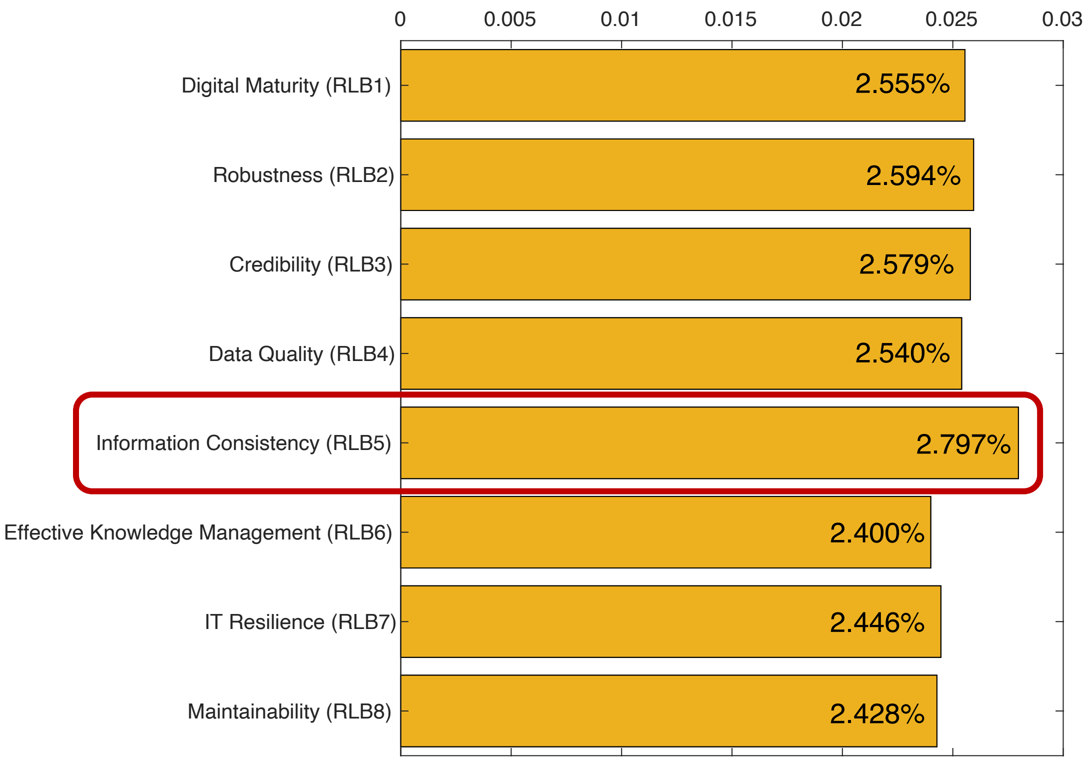


Figure 7.8: The importance degrees of the RLB criteria

Following the importance degrees of the Digital Tangibles and Reliability criteria, the importance degrees of the Digital Interaction, Digital Trust, and Customer Centricity criteria are illustrated in Figures, 7.9, 7.10, and 7.11, respectively.

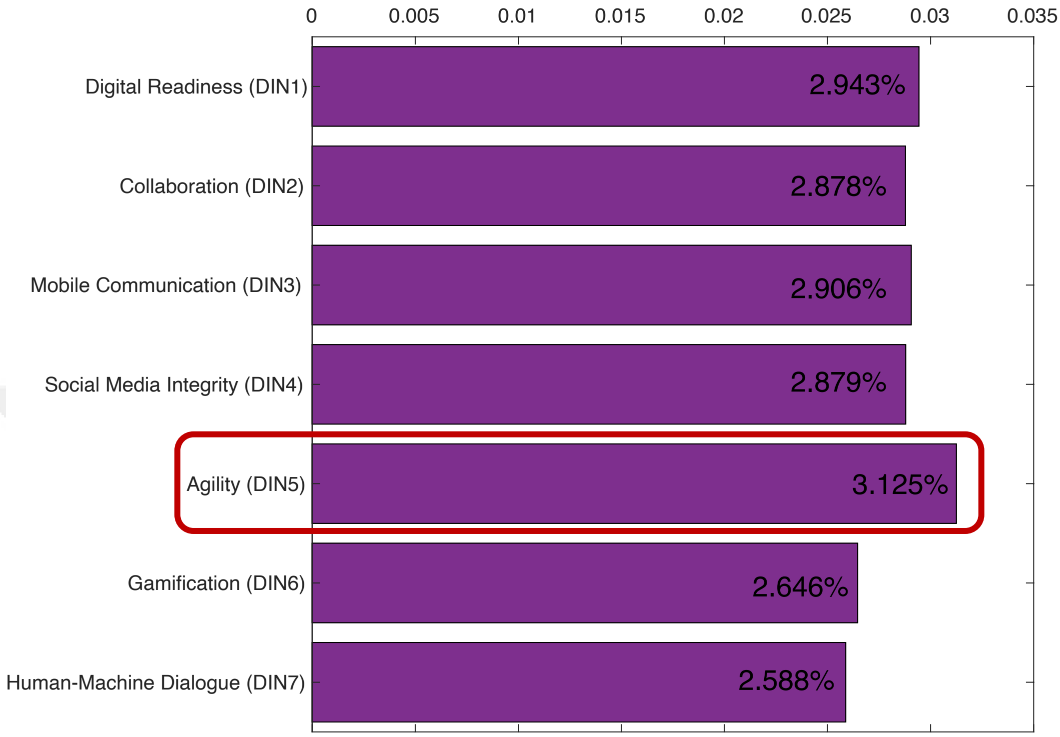


Figure 7.9: The importance degrees of the DIN criteria

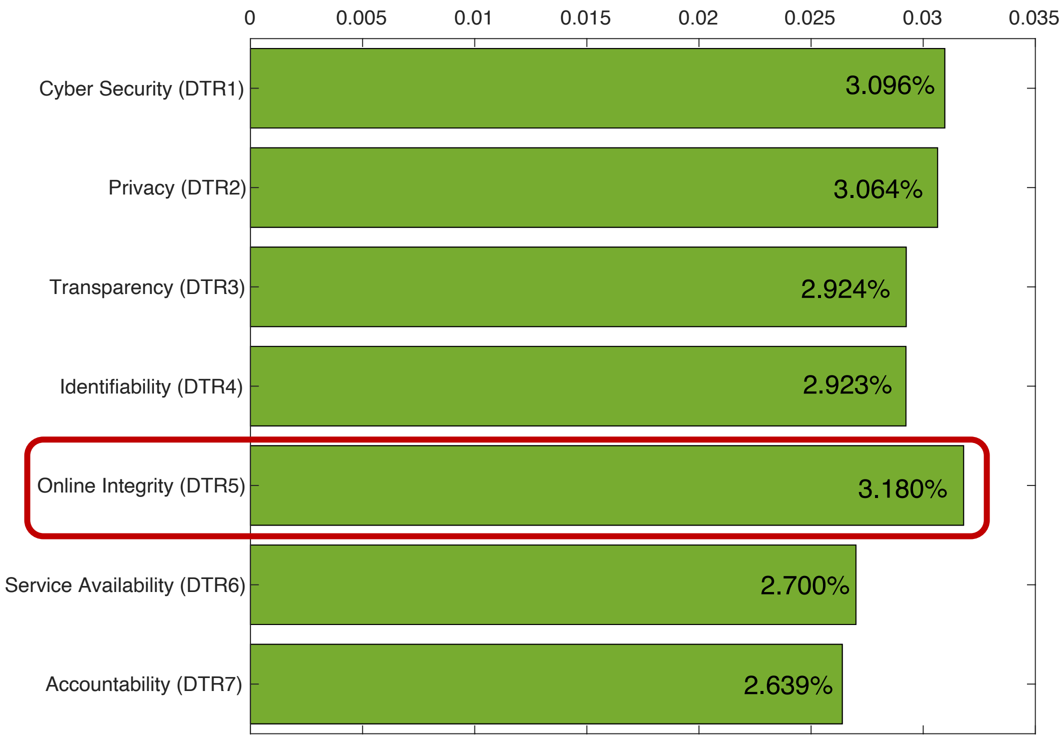


Figure 7.10: The importance degrees of the DTR criteria

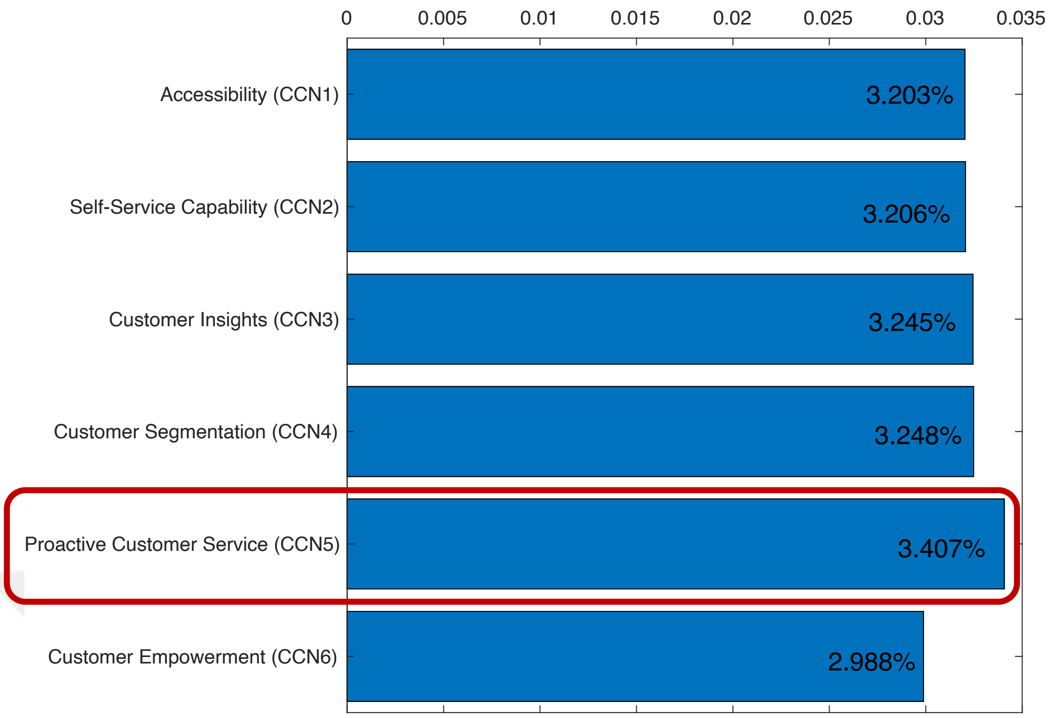


Figure 7.11: The importance degrees of the CCN criteria

When all the criteria are examined simultaneously to see the big picture, the results visualized in Figure 7.12 are obtained.

Even if all the criteria have great significance for better DSQ, proactive customer experience, cyber security, customer insights, customer empowerment, privacy, and customer segmentation are the critical factors that airline companies should focus on.

The potential of digital customers in the airline industry is remarkable, and the DT has influenced the sector. The intense competition in the market has become more intense due to being a member of a digital ecosystem. Airline companies have started to search for ways to be competitive, profitable, and sustainable in such an ecosystem. Hence, focusing on SQ has become more crucial than ever. Yet, emerged digital technologies and digitalized processes have differentiated customer profiles. They have become digital, and the classical SQ perception has been replaced by DSQ perception. Due to this fact, a new DSQ model has been proposed in this study. The proposed model has been analyzed and validated in the Turkish airline industry based on the steps taken by the airline companies in Turkey with a DT perspective.

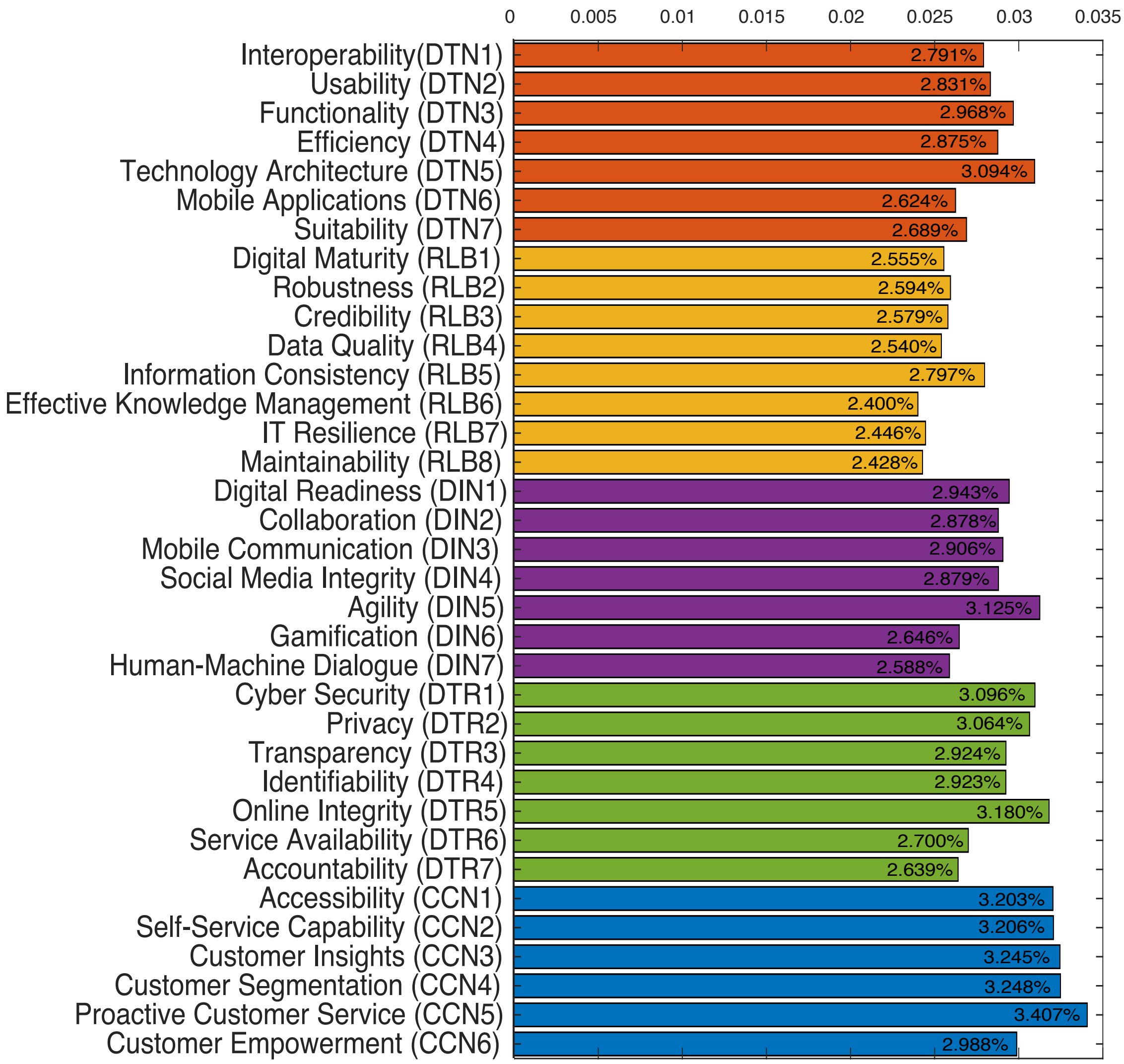


Figure 7.12: Overall results

Trust may increase the preferability of airline companies. The higher the trust of customers, the higher the level of SQ. Digital technologies and platforms used for the processes have made the confidence issues priority. Companies should provide confidence for their customers. If the customers of an airline company feel confident about the company and trust digitally, the willingness to demand and receive products and services will be higher. Beyond this, reliability should support trust. If an airline company is reliable, and customers trust the company, the customers want to interact with the company, its digital platforms, and its channels. The results of the analysis also support this implication. Because the dimension that has the highest importance after trust and reliability is Digital Interaction.

Airline companies should provide the promised digital products and services to their potential passengers. The potential passengers always want to contact the company through the digital technologies that they use. Mobile applications and social media platforms are some of the digital platforms that airline companies must provide to their passengers. In this way, the passengers can interact with the companies. But such platforms and technologies need technical competency. Hence, at the same time, Digital Tangibles should be focused on.

The efficiency, convenience, and functionality of these technologies create a desire for interaction, and customers feel trust and reliability for the company. If the customers interact with the company, then they want to be at the center. At first glance, one might expect the most critical factor to be keep the customer at the center. But first, potential passengers should trust the company. Potential travelers should feel secure about the digital technologies, products, and services the company offers. If the customer feels safe, then the customer tends to interact with the company. With the adequacy of opportunities provided by digital technologies after the interaction, the idea of being at the center of the processes may appear. The inability in functionality, efficiency, continuity, and comfort will keep the potential passengers away from the idea of being at the center and being involved in all processes.

To provide better service and products, the companies should focus on different factors. But the architecture of the platforms and technologies can drive a better experience concerning the service and products offered by the company. Inadequacy of architecture would negatively influence the effectiveness of the digital channels that the passengers use. When the reliability dimension is focused, it is seen that credibility, IT resilience, and effective knowledge management criteria have the highest significance. Gamification has greater importance for digital interaction. Social media integrity and mobile communication follow it. The airline companies should support mobile and social media platforms. Today, these platforms and technologies have the highest usage rate in the daily lives of people. However, they also want to feel enjoy. Hence, the customers should be involved in the processes with a game-based approach. Gamification can be helpful to make the customers understand and learn the processes concerning the usage of such platforms easily.

Furthermore, cyber security is one of the leading areas that companies should focus on. The higher cyber security level provides a feeling of safety. Companies must guarantee that the information that the customers share is protected. Following that, the availability of the service that the company offers is vital. Privacy follows cyber security and service availability.

The customers expect proactive customer service. Furthermore, customer insights are crucial for airline companies to make strategic decisions, but at the same time, the passengers should be promoted and supported for the usage of digital technologies. If they are not empowered, they do not have the willingness to use these technologies. Furthermore, customer insights to offer personalized and customized products and services, cannot be obtained.

Finally, when the results of the Chapter 4 are compared with the results of this chapter, it is seen that the ranked order of the airline companies are the same as follows: $A_3 \succ A_2 \succ A_1 \succ A_4$. Perhaps the most striking finding of these results is that there is a clear relationship between airline companies' DT competencies and their DSQ performances. In this case, it can be said that the higher the DT competence level of a company, the higher the DSQ performance.

8. CONCLUSIONS AND PERSPECTIVE

In recent years, the acceleration in technological developments and the widespread availability of technology have triggered the DT process that radically changes all the routines of both individuals and companies. While people started to carry out almost all processes regarding their product and service demands through digital channels, companies offering products and services had to respond to customer demands through these channels. This situation inevitably compelled companies to see DT as a necessity rather than an option to compete, retain market share, increase their profitability, and maintain their existence in the ecosystem they are in. Moreover, companies that are currently trying to keep up with DT have also started to struggle with companies born digitally. This situation has given the people who use technology to give direction to the sectors. Digital technology users, who can easily share their expectations, experiences, and thoughts about a product or service and have a high level of interaction with companies and other people, have become the factors that directly determine the preferability of a company.

DT is extremely important for almost all industries all over the world. Because in addition to the advantages it provides, not fulfilling the requirements and not keeping up with the transformation may result in exposure to the destructive effect of DT. At this point, it is necessary to consider DT at more than one point, rather than thinking of it as a one-dimensional technology adaptation and application. Therefore, this thesis study was conducted by focusing on DT. In this thesis study, it was aimed to provide a scientific approach that guides companies and organizations in their DT processes based on 5 stages. With this point of view, the followed steps, performed studies, applied methods, and obtained findings in this thesis study are detailed in Figure 8.1.

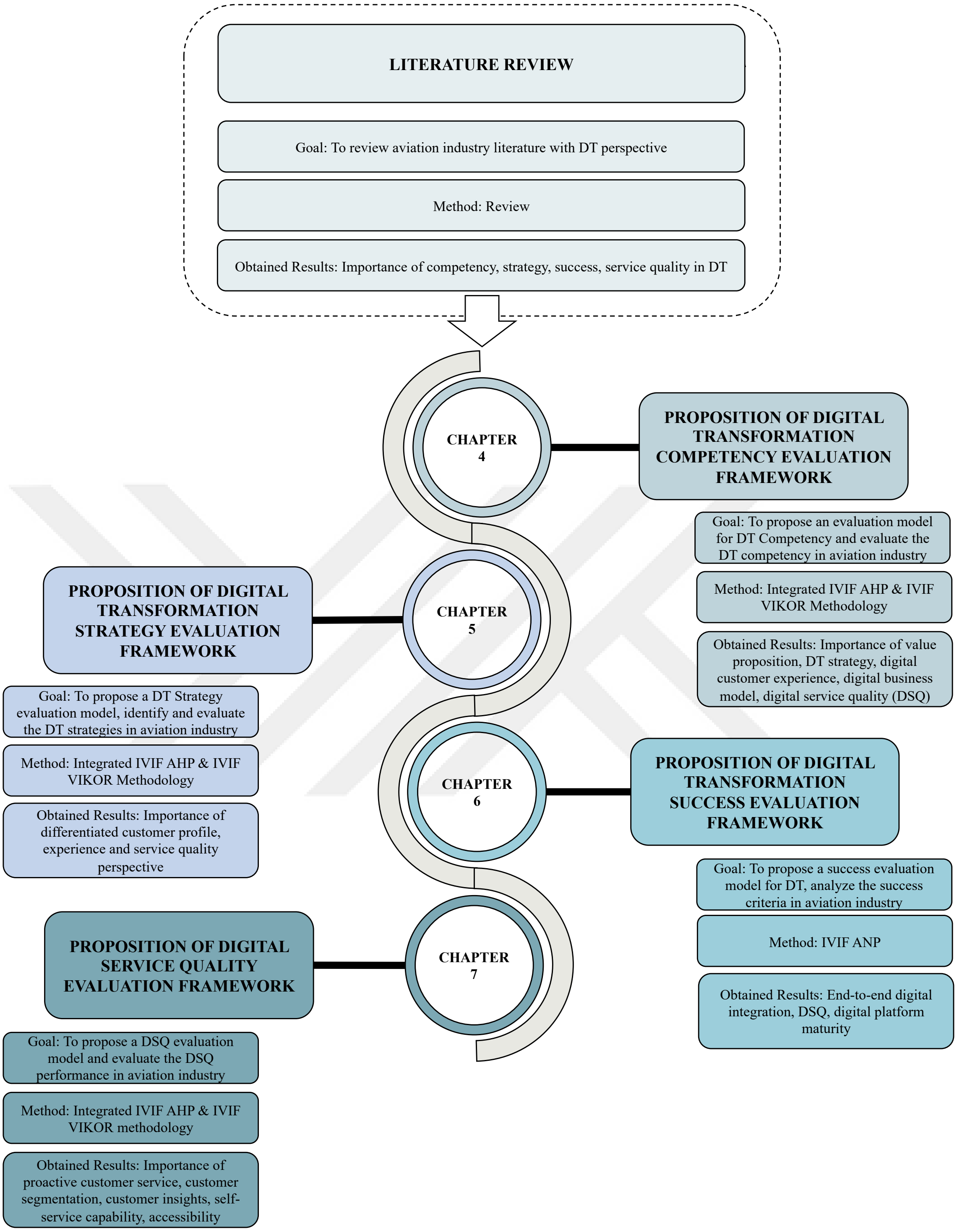


Figure 8.1: Followed steps in the thesis study

In the first stage of the thesis study, a literature survey on DT was carried out. The main purpose of this stage is to identify the gaps in the academic literature. It has been seen that the DT perspective in the academic literature is still new. The scientific studies in the aviation industry with DT perspective is relatively limited. The definition of digital

aviation industry was unclear. Most of the studies concerning the aviation industry highlights technology implementation rather than a generic DT perspective. On the other hand, these studies have the common perspectives such as customer, the change in the customer profile, the digitalization of the customer experience, the importance of the strategy, and the success in DT.
Four different evaluation frameworks have been proposed in this thesis study based on the results of the conducted literature review. Each framework consists of an evaluation model and a methodology. The proposed models are based on the scientific studies, industrial reports, and the experts' opinions. Since the DT concept is a new concept in every sense and is a management philosophy, more than one factor should be considered. At this point, it seems advantageous to use MCDM methods. Hence, MCDM approached has been adopted in this thesis study. The AHP, ANP and VIKOR methods are utilized. To eliminate the uncertainty, human perception, intuition, and hesitation in the decision-making process conducted by the DMs, these methods are expanded to IVIF environment by considering the advantages of the IVIF sets. In some parts of the thesis study, the IVIF AHP and IVIF VIKOR techniques were applied as an integrated IVIF MCDM methodology according to the structure and purpose of the problem discussed, while only the IVIF ANP method was used in some parts.

In the second stage of the thesis study, a new and generic DTCE model consisting of 2 main dimensions has been proposed to evaluate the DT competency. These are Technology Transformation & Implementation and Change & Adaptation Management. Each dimension has 5 criteria and each criteria contains 3 sub-criteria. The proposed model was validated in Turkish low-cost airline industry applying the integrated IVIF AHP and IVIF VIKOR methodology on a real case. The weights of the criteria were obtained using the IVIF AHP and the most digitally competent low-cost airline company was selected through the IVIF VIKOR method. Results show that although DT starts with technological developments, it is about the management of change and adaptation rather than technology or its implementation. Value proposition, DT strategy and digital customer experience are important for competency. The obtained results support the results of the conducted literature survey. Success and competency can be provided with an appropriate management philosophy. The management should be supported with the correct DT strategies to meet the expectations of the digital customers and provide a better digital experience.

In the third stage of the thesis study, a SWOT model has been proposed based on 4 main dimensions and 20 criteria. The criteria of the proposed model were obtained based on literature review and experts' opinions. 8 different DT strategies were determined according to constructed SWOT model. The proposed model was validated in a case study concerning the Turkish aviation industry using integrated IVIF AHP and IVIF VIKOR methodology. The weights of the SWOT criteria were computed utilizing the IVIF AHP method and the alternative DT strategies were evaluated using the IVIF VIKOR method. The most important strategies were revealed as (1) "Profiling customers via digital channels to provide personalized and customized digital products and services.", (2) "Focusing on differentiated digital customer experience and service quality by the adaptation of business models to digital transformation to provide benefits." Follows the most appropriate strategy. (3) "Focusing on adaptation to the changing perception of value with sufficient digital products and services by accelerating decision making processes with effective human resources".

In the fourth stage of the thesis study a new and generic success evaluation model was proposed for DT process. The proposed model consists of DT Strategy, Structure & Organization, and Technology Enablers dimensions and success attributes have been revealed related to these dimensions. The proposed model was validated in Turkish aviation industry. Based on assumption of the interrelations between the evaluation criteria the IVIF ANP methodology was applied to a real case to analyze the success criteria. The most three prior success factors are End-to-End Digital Integration, DSQ and Digital Platform Maturity. The obtained results of the analysis supported the importance of the DSQ. It is indicated that SQ is quite important and critical for competitiveness, and long-term profitability can be reached with a high level of SQ (Moore, 1987; Barbara, 1989; Ghobadian et al., 1994).

All the completed stages of the thesis study have the common finding that is customer. SQ has always been an important area for the companies. Therefore, based on the obtained results, SQ in DT was focused on in the Fifth stage of the thesis study. In this stage, a new and generic DSQ model has been proposed. A detailed literature survey was carried out from a SQ perspective for model proposition. It was seen that there are different SQ models proposed in the academic literature for different purposes in different application areas based on the classical SERVQUAL model (Parasuraman et al., 1985). It has been observed that mobile and electronic SQ models are common and popular in the literature. The examined SQ models revealed that most of them were updated and rearranged based on the SERVQUAL model depending on the purpose and application area. The most striking finding in the SQ literature was that the proposed models changed in parallel with the developments in technology. The effect of DT brought about by today's technological developments, have carried the perception of SQ to a completely different level due to changing customer profile to meet the digital expectations of the digital customers. At this point, it may be the case that the previously suggested models may be insufficient in measuring and evaluating today's SQ. Jansen & Ølnes (2016) stated that there are different studies related to e-SQ, service performance, online SQ in the literature but there are no studies concerning the e-service performance and DSQ concepts. Based on the results of the conducted literature review the gap concerning the DSQ literature has been revealed and the DSQ model has been proposed. The proposed model consists of Digital Tangibles, Reliability, Digital Interaction, Digital Trust, Customer Centricity dimensions and their 35 criteria. The proposed model, analyzed with a real case in the Turkish low-cost airline industry using the integrated IVIF AHP and IVIF VIKOR methodology. The weights of the criteria were calculated using the IVIF AHP method and the DSQ performances of different airline companies were evaluated through the IVIF VIKOR method. The obtained results showed that the most important dimension is Digital Trust, Reliability follows the Digital Trust. Following them, Digital Interaction has a greater importance. Furthermore, it was seen that proactive customer experience, cyber security, customer insights, customer empowerment, privacy and customer segmentation are the critical factors for airline companies.

This thesis study contributes to the literature by being the first study which evaluate the DT competencies, DT strategies, and DSQ performances of the companies in the aviation industry with integrated IVIF AHP and IVIF VIKOR methodology and analyze the DT success criteria using IVIF ANP methodology. Additionally, the proposed frameworks for DT competency, DT strategy, DSQ and DT success guides the companies in their DT journey. Finally, this thesis study reveals the impact of DT competency level on DSQ performance.

For future studies, the proposed model can be improved. The number of the DMs can be increased. Different analytical methods can be applied, and the results can be compared. Scenario analysis and sensitivity analysis can be conducted.

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