IBN HALDUN UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF MANAGEMENT

MASTER'S THESIS

DEVELOPING A DIGITAL MATURITY MODEL FOR THE NGO SECTOR USING A HYBRID PYTHAGOREAN FUZZY CRITIC & WASPAS APPROACH: APPLICATION IN TÜRKİYE

AYATULLAH MUSTAFA

THESIS ADVISOR
PROF. SELİM ZAİM

ISTANBUL, 2025

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by
AYATULLAH MUSTAFA

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THESIS JURY MEMBERS
PROF. SELİM ZAİM (TEZ DANIŞMANI)
ASSOC. PROF. EMİNE ELİF NEBATİ
ASSIST.PROF. MERVE ŞAHİN

ISTANBUL, 2025

ACADEMIC HONESTY ATTESTATION

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Full Name: Ayatullah Mustafa

Signature:

ÖZ

HIBRIT PISAGOR BULANIK ELEŞTIRMEN VE WASPAS YAKLAŞIMI KULLANARAK STK SEKTÖRÜ IÇIN DIJITAL OLGUNLUK MODELI GELIŞTIRME: TÜRKİYE'DE UYGULAMA

Mustafa, Ayatullah
İşletme Yüksek Lisans Programı
Öğrenci No.: 234040003
Open Researcher and Contributor ID (ORC-ID): 0000-0001-9312-5790
Ulusal Tez Merkezi Referans No.: 10727282

Tez Danışmanı: Prof. Dr. Selim Zaim
Haziran 2025, 89 Sayfa

Endüstriyel çağdan dijital çağa hızlı geçiş, kuruluşların operasyonel ve stratejik yapısını kökten değiştirmiş ve dijitalleşme tüm sektörler için bir öncelik haline gelmiştir. Dönüşümü uygun şekilde gerçekleştirmek için ilk adım, dijital olgunluğun ölçülmesidir. Literatürde farklı sektörler için dijital olgunluk modelleri (DMM) tartışılmış ve geliştirilmiş olsa da, STK sektörünün kendine özgü özellikleri ve zorlukları nedeniyle bu tür çalışmalar bu sektörde yetersiz kalmaktadır. Bu çalışmanın amacı, bu boşluğu doldurmak ve STK sektörüne yönelik kişiselleştirilmiş bir model önermektir. Bu çalışmada, değerlendirmede yer alan belirsizlik ve tereddüt nedeniyle Pisagor bulanık CRITIC ve WASPAS yöntemlerini birleştiren yeni bir hibrit model geliştirilmiştir. Önerilen yeni modeli doğrulamak için çalışmada Türkiye'de bir uygulama sunulmuştur. Sonuçlar, dijital olgunluğun en önemli boyutlarının strateji, paydaşlar ve operasyon olduğunu göstermektedir. Ayrıca model, misyonun yerine getirilmesi, ekosistem yönetimi ve paydaş deneyimi için uyarlanabilir süreçlere sahip STK'ların daha dijitalleştiğini göstermektedir. Öte yandan, alternatifler WASPAS tarafından değerlendirilmektedir. Sonuçlar, dijitalleşme değerlendirmesinde İstanbul'un en yüksek puanı aldığını, onu Ankara'nın küçük bir farkla izlediğini, İzmir'in ise önemli bir farkla son sırada yer aldığını göstermektedir.

Anahtar Kelimeler: Çok Kriterli Karar Verme (MCDM), Dijital Dönüşüm, Dijital Olgunluk, Pisagor Bulanık CRITIC, STK'lar, WASPAS.

ABSTRACT

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Mustafa, Ayatullah
MA in Management
Student ID: 234040003
Open Researcher and Contributor ID (ORC-ID): 0000-0001-9312-5790
National Thesis Center Reference No.: 10727282

Thesis Supervisor: Prof. Selim Zaim
June 2025, 89 Pages

The rapid shift from the industrial to the digital era has fundamentally changed organisations' operational and strategic landscape, where digitalization has become a priority for all sectors. To execute the transformation adequately, the measurement of digital maturity is the first step. Although digital maturity models (DMM) have been discussed and developed for different sectors in the literature, such studies in the NGO sector are lacking due to sector-unique characteristics and challenges. The aim of this study is to close the gap and to propose a personalized model to address the NGO sector. In this study, a novel hybrid model was developed that combines the Pythagorean fuzzy CRITIC and WASPAS methods due to the uncertainty and hesitancy contained in the evaluation. To validate the proposed novel model, an application in Türkiye is presented in the study. The results show that the most notable dimensions of digital maturity are strategy, stakeholders, and operation. In addition, the model indicates that the NGO that owns the adaptive processes for mission delivery, ecosystem management and stakeholder experience are more digitalized. On the other hand, alternatives are assessed by WASPAS. The results show that Istanbul is the highest in the digitalization assessment, followed by Ankara with a slight difference, while Izmir ranks last with a considerable gap.

Keywords: Digital Maturity, Digital Transformation, Multi-Criteria Decision-Making (MCDM), NGOs, Pythagorean Fuzzy CRITIC, WASPAS.

DEDICATION

It is dedicated to my mother, father, sister, and my beloved family, whose unwavering support, sacrifices, and encouragement have made this achievement possible.

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In the name of Allah, the Most Gracious, the Most Merciful. All praise is due to Allah (ﷻ), Lord of the worlds, whose boundless mercy, wisdom, and guidance enabled me to begin, persevere, and complete this journey. Without His grace, strength, and will, none of this would have been possible. Peace and blessings be upon the Prophet Muhammad ﷺ, whose teachings that urge us for obtaining knowledge, sincerity, and excellence in every endeavor.

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Finally, I present my endless love and respect to my family especially to my mother, whose prayers, and encouragement were the true driving force behind this journey.

Ayatullah Mustafa
İSTANBUL, 2025

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	Artificial Intelligence
CRITIC	Criteria Importance Through Intercriteria Correlation
DM	Decision Maker
DMM	Digital Maturity Model
DT	Digital Transformation
MCDM	Multi-Criteria Decision-Making
NGO	Non-Governmental Organization
NDMM	Non-Governmental Organization Digital Maturity Model
PF	Pythagorean Fuzzy
WASPAS	Weighted Aggregated Sum Product Assessment
μ	Degree of Membership
ν	Degree of Non-Membership
π	Degree of Hesitancy
$\otimes$	Pythagorean Fuzzy Product
$\sum$	Summation
$\leq$	Less than or Equal to
$\geq$	Greater than or Equal to
λ	Optimality Coefficient
$\in$	Belongs to (Set Membership)

CHAPTER I

INTRODUCTION

The rapid technological advancement and the widespread integration of digital products and services into everyday life reshape organisational structures, business models, and value-creation processes. Organisations must now navigate disruptive technological, organisational, and social changes, as failure to keep pace with digital transformation can lead to obsolescence in highly competitive markets (Beno et al., 2022). Therefore, organisations across industries reconsider their strategies and embrace digital transformation as a fundamental priority to remain competitive (Andersson et al., 2018; Gimpel et al., 2018). Notably, digital transformation is not just a technological shift but a strategic imperative that enables organisations to increase agility, streamline operations, and adapt to market dynamism. Despite its potential benefits, studies show that only a quarter of organisations have successfully achieved their desired digital transformation outcomes due to this process's complexity and organisation-wide impact (Eren & Çağla, 2022; Hess, 2016).

The digital transformation challenges go beyond the implementation of new technologies as Organisations must cope with evolving customer expectations, strict regulatory requirements, and shrinking profit margins, all of which make the transformation process more complex (Smolinski et al., 2017). To navigate these challenges successfully, digital transformation must be driven by strategy rather than technology alone. Scholars argue that it should be treated as an independent, overarching strategic initiative rather than a subset of functional or organisational strategies (Hess et al., 2016; Ismail, Khater & Zaki, 2017; Matt, Hess & Benlian, 2015; McDonald, 2012; Singh & Hess, 2017). A well-structured digital transformation strategy allows organisations to systematically assess risks and opportunities, coordinate initiatives, and prioritize digital adoption (Singh & Hess, 2017). Accordingly, businesses around the world have made significant investments in digital

transformation technology, with an estimated $2 trillion spent by 2020, demonstrating the importance of this shift (Al Najjar et al., 2022).

In a world where automated processes and smart tools are now ingrained in almost every facet of socioeconomic life, the impact of digital technologies on NGOs has grown. NGOs are more likely to increase resilience, adjust to shifting conditions, and maintain their influence over time if they successfully include digital solutions in their plans (Bălăcescu, 2021). NGOs can reconsider how they communicate, make decisions, and provide services by implementing digital transformation tools, which are more than just an operational progress. In response, businesses have shifted to electronic service models, which optimize resource allocation, cut expenses, and streamline administrative procedures (Al Shobaki et al., 2022; Owda et al., 2019). NGOs are a powerful economic force in addition to their social achievements. The nonprofit sector makes significant contributions to national economies and is a significant employer in many areas. For instance, with 12.5 million paid employees, NGOs make up the third-largest employment in the US (Salamon & Newhouse, 2020). Comparably, the industry employs 28.3 million full-time equivalent (FTE) workers in Europe, accounting for roughly 13% of the labor force (Salamon & Sokowlowski, 2018). NGOs have a significant economic impact that goes beyond employment because of the significant economic activity they produce through their spending. According to an Irish study, the economic worth of volunteering alone was assessed at €649 million per year, with over 300,000 volunteers putting in 67 million hours, contributing €24.98 billion to the economy in 2017 (Indecon, 2020). These numbers show how important NGOs are to both social progress and long-term economic viability.

The necessity for NGOs to embrace digital transformation is further highlighted by the ongoing Fourth Industrial Revolution (Industry 4.0). Innovative technologies like automation, artificial intelligence, cloud computing, and smart apps are what define this era (Akter et al., 2022; Parida et al., 2019). These developments are changing organisation strategies, redefining old management techniques, and developing new service delivery models (Venkatraman, 2017). By implementing these technologies, NGOs can increase their overall effect by improving donor engagement, operational efficiency, and data-driven decision-making (Assaf & Tsionas, 2018; Satar et al.,

2024a; Westerman et al., 2014). Digital platforms and tools have provided NGOs with an unprecedented opportunity to widen their audience, establish new channels for stakeholder engagement, and accelerate processes (Gooyabadi et al., 2023).

To effectively guide an organisation through the transition toward digital transformation, it is essential to begin with a comprehensive self-assessment of its current level of digital maturity. Basically, this assessment is conducted using a digital maturity model, which serves as a strategic framework for evaluating progress, identifying critical areas for improvement, and navigating the complex challenges associated with digital transformation. The ability of an organisation to innovate, adapt, and strategically implement digital technologies is increasingly recognized as a key determinant of sustained success in a rapidly evolving digital landscape. The concept of maturity models dates back to the 1970s, when Gibson and Nolan (1974) along with Crosby (1979) presented the concept of advancing stages of maturity. Following this, the Capability Maturity Model (CMM) was developed in the 1980s, which helped to establish maturity models as a common method for evaluating organisational growth and strategic planning (Mettler, 2011). In relation to digital transformation, maturity represents an organisation’s capability to fully embed digital functionalities into its fundamental operations.

Digital maturity models offer a key framework for assessing progress, but only if they are well tailored to an organisation's particular difficulties, challenges and objectives. Adaptability is required since no one model can fully capture the complexity of an organisation's transformation journey. Organisations can utilize on their current strengths and address critical areas for growth by customizing these models to meet their unique requirements. This guarantees that organisations tailor their digital transformation processes to be strategic and long-term, hence staying ahead in an increasingly technologically advanced environment.

1.1. Research Problem

In an era defined by rapid technological advancement, digital transformation has become an imperative across all sectors, compelling organisations to strategically adapt and evolve. A critical initial step in guiding this pervasive transformation

involves evaluating an organisation's digital maturity. While numerous industries have successfully embarked on structured digital journeys, Non-Governmental Organisations (NGOs) demonstrably lag in this crucial transition. This disparity primarily stems from the absence of a tailored digital maturity model that adequately addresses their unique characteristics, operational realities, and inherent challenges. Despite their vital function in global development, NGOs currently lack a dedicated framework to effectively assess their digital readiness. Consequently, there is an urgent and essential need to propose a novel digital maturity model specifically designed for the NGO sector. Such a model would enable these organisations to accurately evaluate their current digital capabilities and, crucially, to design an informed roadmap for their digital transformation. This research will leverage a hybrid Multi-Criteria Decision-Making (MCDM) method to systematically translate expert opinions into quantifiable data, thereby providing a robust and objective assessment framework.

1.2. Research Objective and Research Question

This study provides insightful path for digitalization to various nonprofit stakeholders. It equips nonprofit staff with the know-how to successfully manage digital transformation, improves decision-makers' ability to align technology with organisational goals, and provides leaders with a systematic approach to help nonprofits reach digital maturity.

1.2.1. Research Objectives

i. To propose a new hybrid decision-support tool integrating **Pythagorean Fuzzy CRITIC** and **WASPAS** methods for assessing and prioritizing digital transformation initiatives in NGOs.

ii. To develop a **Digital Transformation Maturity Model (DMM)** specifically designed to evaluate the digital maturity levels of NGOs and guide them through digital capability improvement.

iii. To translate the expertise and insights of NGO stakeholders into quantifiable decision criteria using **fuzzy linguistic modeling** under uncertainty.

iv. To assess and rank key digital transformation enablers, helping NGOs allocate limited resources more effectively and strategically.

v. To provide an adaptable , evidence-based maturity framework that supports NGOs in drawing tailored roadmaps toward sustainable digital transformation.

These objectives collectively aim to bridge the methodological and practical void in how NGOs approach digital transformation planning and evaluation, especially in the absence of tailored maturity models grounded in multi-criteria analysis.

1.2.2. Research Questions

To fulfill the above objectives, the study will address the following research questions:

i. What are the key dimensions and indicators that define digital maturity in the context of NGOs?

ii. Do these dimensions have the same effect or importance?

iii. How can a robust and adaptable Digital Maturity Model be designed to reflect the operational realities and strategic needs of nonprofit organisations?

iv. In what ways can Pythagorean Fuzzy CRITIC and WASPAS MCDM techniques be integrated into a decision-support framework to help NGOs prioritize digital initiatives?

v. How effective is the proposed model in guiding NGOs toward digital transformation when applied in real-world organisational settings?

1.3. Research Novelty

This research introduces a novel and tailored approach to digital transformation in the nonprofit sector by addressing a significant gap in existing digital maturity models. While the demand for digitalization is widely acknowledged, as 76% of NGOs recognizing its importance, but only a quarter of them have established clear strategies or timelines to apply digital transformation (TechSoup, 2020). This highlights a critical disconnect between awareness and actionable strategy within the sector. This thesis fills the gaps in existing digital maturity models by creating a valid and trustworthy digital transformation maturity model (DMM) specifically for non-governmental

organisations (NGOs). Although previous studies have attempted to develop digital maturity models, many of them have only addressed specific aspects of the topic, such as reviewing previous research, developing theoretical models without emphasizing their relevance to the real world, or testing the models without fully addressing the fundamentals of creating them.

This research proposes a comprehensive and integrated NGOs digital maturity model that not only assesses digital maturity but also provides an analytical tool to help organisations examine the elements driving their digital transformation journey and evaluate their digital maturity level. What distinguishes this study methodologically is the integration of advanced multi-criteria decision-making (MCDM) techniques—**Pythagorean Fuzzy CRITIC and WASPAS**—into the design and evaluation process of the maturity model. These methods allow for more nuanced handling of expert judgment under uncertainty and enable robust prioritization of digital transformation initiatives. This dual-layered analytical approach ensures that the model is not only comprehensive in structure but also practically applicable for informed strategic planning and decision-making in resource-constrained nonprofit environments. NGOs can efficiently plan, prioritize, and execute digital transformation projects with the support of a well-organized digital maturity model (Al-Najjar et al., 2023). The Assessment of digital maturity equips nonprofit staff with the know-how to successfully manage digital transformation, improves decision-makers' ability to align technology with organisational goals, and provides consultants with a systematic approach to help nonprofits reach digital maturity. The research supports nonprofits' long-term sustainability and digital effectiveness by addressing these perspectives.

1.4. Research Structure

This research is organized into 6 chapters. Chapter 1 explains the motivation and novelty of the research while the rest of the chapters are organized as follows: Chapter 2 provides a background and literature review on DT and DMMs. Chapter 3 provides the details of research methodology and techniques explanation. In Chapter 4 the research proposed digital maturity model and dimensions are provided. A case study in Türkiye is presented in Chapter 5, demonstrating the findings and discussion as well as the managerial implications. Lastly, some concluding remarks are given in Chapter 6.

CHAPTER II

LITERATURE REVIEW

2.1. Theoretical Background

In the contemporary digital era, society and organisations are experiencing a thorough and continuous shift marked by the infusion of emerging technologies into every aspect of life and work. This widespread evolution, commonly referred to as digital transformation (DT), represents a global megatrend that surpasses industries and geographies (Brynjolfsson, 2014). DT has significantly reshaped organisational landscapes, with companies aiming to improve operational efficiency, responsiveness, and innovation through strategic adoption of digital technologies (Fitzgerald, 2013; Henriette, 2015). The transition from the industrial to the digital era has elevated DT to a central strategic priority across sectors. Organisations have introduced new executive roles, such as the Chief Digital Officer (CDO), to lead digital initiatives and manage complex change processes (Christofi, 2024). In contrast to traditional Information Technology (IT) management, DT is not restricted to technological infrastructures. It encompasses a broader, transformative process that integrates digital systems—including computing, connectivity, and data analytics—across organisational functions to enhance overall performance (Firk et al., 2021; Vial, 2019). This holistic orientation has urged the academian's and professionals' interest, as demonstrated by growing volumes of research, discourse at international conferences, and increased digital transformation search trends (Hanelt et al., 2021).

Beyond a mere buzzword, DT embodies a fundamental organisational reorientation. Tumbas, Berente, and vom Brocke (2018) assert that DT extends beyond the IT function, permeating all business domains and sectors. Accordingly, in a systematic review of 134 DT definitions, Gong and Ribiere (2021) proposed a multidimensional framework positioning DT as a strategic change process that redefines value propositions through digital capabilities. Similarly, Morakanyane et al. (2017) view

DT as an evolutionary pathway, wherein digital tools are leveraged to revamp business models, streamline operations, and enrich customer experiences. From a managerial lens, Kraus et al. (2021) highlight DT as a process of continuous adaptation to shifting digital landscapes and stakeholder demands, while others underline its operational implications—necessitating new competencies and the realignment of organisational processes (Xing et al., 2024; Al-Ali & Marks, 2022). In alignment with academic interpretations, global technology consulting firms have also framed DT in strategic terms. Accenture (2022) describes DT as the systematic deployment of digital technologies to achieve deep-seated business change. Gartner (Ismail, 2019) interprets it as a route to building resilient and forward-looking business models, and Forrester positions DT as a mean to innovate or optimize internal and external processes in response to evolving customer needs (Transformation Archives, n.d.). Earlier interpretations of DT echo its transformative essence. Verdino (2015) defined it as the link between evolving digital customer expectations and the lagging responsiveness of analog-era institutions. Saldanha (2019) portrayed DT as a vital ingredient in the emerging industrial paradigm, emphasizing the integration of people, systems, and operations. Similarly, Solis (2016) described it as the synchronization of technologies, models, and processes designed to create value in an increasingly digital economy.

The increasing recognition of DT as a pillar of strategic competitiveness is reinforced by global market trends. Siebel (2019) notes that nearly 90% of organisations are undergoing some form of digital transformation, while IDC (2024) forecasts global DT spending to exceed $4 trillion by 2027. These investments underscore the role of DT in optimizing resource allocation, enhancing operational efficiencies, and catalyzing innovation (Schallmo & Williams, 2018). DT, therefore, is not merely a technical shift—it is a transformation of organisational logic that disrupts established routines, reshapes stakeholder expectations, and compels cultural and managerial innovation (Verhoef, 2021). Despite the extensive exploration of DT within large enterprises and digital-native organisations (Verhoef et al., 2021a, 2021b), there remains a notable gap in understanding how DT unfolds in mission-driven and resource-constrained contexts, such as non-governmental organisations (NGOs). These organisations often work under distinct value structures and resources, making the direct application of existing DT frameworks challenging. This low representation calls for more detailed research on DT dynamics in the nonprofit sector. As

organisations across sectors strive to navigate these transformations, understanding and enhancing digital maturity becomes crucial—especially for underexplored entities such as NGOs. Kiefer et al. (2021) emphasize that to fully capitalize on digital technologies, organisations must orchestrate a multidisciplinary and readiness-driven approach to strategy development and execution.

This broad scope has led to the emergence of the concept of *Digital Maturity* (DM), which captures an organisation's capacity and readiness to implement and sustain DT efforts (Buckle, 2018). DM is increasingly seen as a composite measure of both technological capabilities and the managerial readiness required to effectively deploy digital solutions (Aras & Büyüközkan, 2023; Gökalp & Martinez, 2022). To facilitate assessment and strategic guidance, maturity models have become instrumental tools, allowing organisations to benchmark their digital evolution and chart pathways toward enhanced digital performance. Therefore, maturity models are instruments to benchmark and assess the organisations' level which guides the growth through a strategic roadmap accordingly (Mettler et al., 2020). These models conduct the assessment through several dimensions which guides the enhancement and growth inside the organisation (Dahlin, 2020). There are different maturity models we can detect in the literature review as they should be structured and adapted to the unique challenges and characteristics of a specific sector (Piccarozzi et al., 2018). This can enable the board of members to examine their real current level of digital capabilities and draw for their sustainable digital maturity action plan.

2.2. Digital Maturity Models in Literature

2.2.1. Definition and Historical Evolution of Digital Maturity Models

The concept of maturity models has its roots in the systematic evaluation of organisational capabilities. These models are typically defined as multistage frameworks that describe typical patterns of development across a selected domain (Poeppelbuss et al., 2011). Maturity models serve as diagnostic tools to evaluate an organisation's level of competency, capability, and sophistication in each area by applying a defined set of evaluative criteria (De Bruin et al., 2005). Within the domain of digital transformation, the Digital Maturity Model (DMM) has emerged as a pivotal

instrument, providing both a measurement framework and a strategic guide to assess and enhance an organisation's digital readiness. The DMM functions not only as a tool for evaluation but also as a strategic compass to help organisations navigate the increasingly complex digital landscape. It assesses digital maturity across multiple dimensions, such as strategy, operations, culture, and technology, and aligns these with broader digital transformation goals (Avila & Smith, 2015). More than a static tool, the DMM is a dynamic and evolving model that reflects the continuous nature of digital advancement. As organisations strive to reach digital maturity, the definition of that maturity itself is constantly being redefined—emphasizing that digital maturity is an aspirational target rather than a fixed endpoint (Newman, 2017).

Historically, we can trace the origin of maturity models through the seminal work of Richard L. Nolan, who introduced the "Stages of Growth" model for IT organisations in 1973. This early model established the groundwork for understanding IT development as a structured, staged process. Shortly thereafter, Philip B. Crosby contributed to this lineage with the Quality Management Maturity Grid (QMMG) in 1979—a matrix-style framework for assessing the quality orientation of organisational processes. Grounded in total quality management principles, Crosby's model outlined five progressive stages applied across multiple dimensions, helping organisations measure the institutionalization of quality practices (Crosby, 1996). This foundational work inspired subsequent models, most notably the Capability Maturity Model (CMM) developed by the Software Engineering Institute in the 1980s (Humphrey, 1988). Originally designed for software development processes, the model later evolved into the Capability Maturity Model Integration (CMMI), which offers a holistic assessment framework encompassing software engineering, acquisition, and service delivery. The CMMI's success inspired many maturity models across various domains, each tailored to distinct organisational contexts' specific needs and challenges. Today, maturity models are employed across numerous disciplines, including business process management (Fisher, 2004; Rosemann et al., 2004), project management (Project Management Institute, 2013), analytics (Davenport & Harris, 2017), innovation (Nauyalis, 2018), corporate performance (Aho, 2009), and IT strategy (Pereira & Serrano, 2020). In digital transformation, notable models include the Digitalization Maturity Model (Klötzer & Pflaum, 2017), Digital Enterprise Models in Industry 4.0 (Rumpenhorst, 2016), IMPULS Industry 4.0 Readiness Model

(Goericke & Lichtblau, 2019), and the Industry 4.0 Maturity Model (Gökalp et al., 2017). These models differ in structure and application but collectively offer a diverse toolkit for assessing digital progression across organisations.

Digital maturity models can generally be categorized into three types: descriptive models that provide insight into the current organisational state, prescriptive models that guide action and planning, and comparative models that enable benchmarking against peers (De Bruin et al., 2005). Despite their widespread use, maturity models have not escaped criticism. Scholars have pointed out that practitioners develop many without adequate empirical validation and thus lack contextual specificity (Lacerda & von Wangenheim, 2018; dos Santos-Neto & Costa, 2019). Moreover, critics argue that traditional models are often too static to adapt to dynamic business environments or too generic to suit sector-specific needs (O'Reilly, 2019). Nonetheless, empirical research proves the merit of maturity models towards the improvement of organisational performance. For instance, Canetta et al. (2018) argue that maturity models impact effectiveness positively when aligned with digital strategies. Demir (2018), in a study of 74 research and technology-intensive organisations in Türkiye, demonstrated that maturity models—when integrated with innovation—can enhance an organisation's responsiveness to environmental change and shifting customer behavior. Similarly, Gökalp and Martinez (2021) developed and validated a holistic digital transformation maturity model, which successfully helped organisations identify capability gaps and develop targeted roadmaps for advancement.

Achieving digital maturity, however, is not without its challenges. Especially in the initial phases, the absence of a systematic digital strategy has frequently remained the primary impediment to transformation (Kane et al., 2015). The situation is worsened by competing priorities, ambiguous commitment by leadership, and the fragmented nature of technology investments. A coherent digital strategy must transcend functional silos and address the organisation as a whole—its culture, structure, and human capital—ensuring that digital technologies are not only adopted but also effectively embedded (Kane et al., 2019). In this regard, the digital maturity model becomes an essential management tool. It supports organisations through various stages of digital transformation by identifying current shortcomings, prioritizing critical focus areas, and highlighting where initial steps should be taken (Deloitte,

2018). The DMM helps organisations build a robust digital foundation while adapting to continuous technological disruption by coordinating workforce engagement, cultural evolution, and strategic alignment.

2.2.2. Overview of DMMs in Literature

Over the past two decades, academic interest in maturity models has increased, reflecting the growing significance of structured approaches to assess organisational development in an increasingly digital landscape. According to Becker et al. (2010), academic publications on maturity models increased from just 20 in 1994 to 115 by 2008, a trend that has continued to gain momentum in response to rapid technological advancement and widespread digital adoption across sectors. This expansion has been mirrored in academic discourse and the applied work of consulting firms such as Gartner, Forrester, Deloitte, PwC, and BCG, which have adapted theoretical models into sector-specific frameworks for strategic decision-making and service enhancement.

In the literature, a broad range of Digital Maturity Models (DMMs) has emerged to evaluate organisations' digital readiness. Academic and practitioner efforts generally develop these models and typically focus on criteria or dimensions representative of the multifaceted nature of digital transformation. While some models may focus more on industries or organisational contexts in their applications, practically all models guide organisations toward incremental maturity by providing diagnostic assessments and strategic direction. Digital maturity models commonly consist of multiple dimensions—such as strategy, culture, processes, technology, governance, or customer orientation—each representing a fundamental aspect of organisational development. These dimensions are intended to be distinct, measurable, and actionable, enabling organisations to assess their status across several critical areas. As digital transformation is an ongoing and adaptive process, the maturity models have evolved to accommodate changing business environments. The newer models emphasize agility, innovation, and contextuality to maintain relevance through ongoing technological and market disruptions.

Despite a recent trend toward sector-specific adaptations, a core set of general-purpose maturity models is still applicable across industries. These provide foundational structures from which customized models are often derived. Today's diversity in maturity models reflects the complexity of digital transformation and the necessity of context-aware tools for strategic planning. Table 2.1 provides a comparative overview of prominent digital maturity models developed since 2015. The keywords used in the search engine are "digital maturity", "digital transformation", and "digitalization". We consider those studies published in academic journals indexed in SCOPUS and Google Scholar after 2015.

Table 2.1. Summary of DMMs in Academic Papers

Author	**Year**	**Domain**	**No. of dimensions**	**Applied techniques**	**Main Dimensions**
Lichtblau et al.	2015	Manufacturing	6	Questionnaire survey	-Strategy and organization -Smart factory -Smart operations -Smart products -Data-driven services- Employees.
Valdez-De-Leon	2016	Telecom	7	Three-stage development approach	- Strategy - Organisation - Customer - Ecosystem - Operations - Technology – Innovation

Table 2.1. (cont.)

Berghaus & Back	2016	General Business	9	Quantitative(online-questionnaire based on 5-step Likert-scale)	customer experience, product innovation, strategy, organization, processdigitization, collaboration, information technology, culture and ex-pertise, transformation management
KPMG	2016	Generic	5	non-linear, self-assessment	- Strategy - Governance - Talent - Process – Infrastructure
Klötzer & Pflaum	2017	Industry 4.0	9	Maturity model for Digitalization	1. Competence(s), 2. Innovation Culture, 3. Cooperation, 4. Strategy Development, 5. Process Organization, 6. Complementary IT System, 7. Smart Product and Factory, 8. Offering to Customer, 9. Structural Organization
De Carolis et al.	2017	Manufacture	6	Scoring method	- organization, technology- monitoring and control- process.
Bibby & Dehe	2018	Manufacture	3	Questionnaire survey, Scoring method	1. Factory of the Future, 2. People and Culture, 3. Strategy

Table 2.1. (cont.)

Mittal et al.	2018	Manufacture	5	Review	- Technology - Organisation - Products - Ecosystem - Value Chain
Keskin et al.	2019	Generic	6	AHP and TOPSIS	Product and services - Manufacturing and Operations- Strategy and Organization - Supply Chain -Business Model -Legal Considerations
Büyüközkan & Güler	2020	SME	4	Hesitant Fuzzy Linguistic (HFL) Analytic Hierarchy Process (AHP) and HFL Additive Ratio assessment (ARAS)	-Culture - organisation - technology – insights
Hizam Hanafiah et al.	2020	Industry 4.0	6	Review	- Technology -People – Strategy -Leadership - Process – Innovation

Table 2.1. (cont.)

Ifenthaler & Egloffstein	2020	Education	6	Quantitative(interview based on 5-step Lik-ert-scale)	Equipment - strategy - Organisation - Employees - Culture - Digital Learning
Nerima & Ralyté	2021	Public Organisation	5	Questionnaire, self-assessment tool	strategy - IT governance - Data - Organisation -Process
Raza et al.	2023	SME	5	Interviews, Delphi method.	- Strategy - Organisation - People and Culture - Technology – Partners
Pinto et al.	2023	Retail	5	Questionnaire, Delphi method	Strategy- market- operations- culture- technology
Nebati	2023	Defense industry	5	SF-AHP and SF-TODIM methods	-Leadership - Technology – Organisation and digital culture -Strategy - Operation
Perera et al.	2023	Design and Construction	5	questionnaire survey	- Digitalization of Services - Software/Hardware Capability - ICT Spend - Training - R&D

Table 2.1. (cont.)

Haryanti et al.	2023	Generic	7	Delphi method	- Organisation Structure - Technology - Strategy - Customer - Employee - Culture – Transformation processes
Utama et al.	2024	Transportation	6	Questionnaire, using structural equation modelling (SEM) technique	- Peopleware - Online Presence - Technical Solutions - Orgware - Software – Hardware
Bosek-Rak	2024	Corporate	4	Questionnaire, using the IDT metric method	-Strategy- Financing- Technology- Organisation
Zhu	2025	Enterprises	6	best–worst method with the entropy model	-Digital strategy and leadership- Digital technology adoption- Data management and analytics capability - Employee digital literacy- Digital customer relationship management- Digital innovation capability

Table 2.2. Summary of DMMs in Industry Reports and Consultancy Firms

Author	Year	Domain	No. of dimensions	Applied techniques	Main Dimensions
McKinsey	2016	Generic	4	Survey—representative sample of authorities/ departments	- Strategy - Culture - Organisation – Capabilities
PwC	2016	Generic	4	linear, 3rd party assisted	- Process and Infrastructure - Digital Sales - Customer Involvement - People and Culture
Gill & Van Boskirk	2016	Generic	4	Quantitative (interview based on 4-step Lik-ert-scale)	- Technology - Insight - Organisation – Culture
Dell Tech-nologies	2018	Technology	4	Mix of quali-tative and quantitative(online-questionnaire based on 6-step Likert-scale)	IT strategy, digital future, competi-tion, investment

Table 2.2. (cont.)

Bain and Company	2019	Generic	4	Self-assessment tool.	- Business Model - Digital Strategy - Enablers - Orchestration
DE-SI	2020	Social	5	Quantitative	connectivity, human capital, use of internet, integration of digital technol-ogy, digital pub-lic services
UK Consumer Digital Index	2021	Consumption	3	Structured survey	digital pay-ments, digital services, digital technology in daily life
Ernst & Young	2022	Generic	3	Self-assessment tool.	- Strategy - Operations - Control & Measurement
Impuls (Industrie 4.0 Readiness)	2022	Industry 4.0	6	Self-assessment tool.	- Strategy - Organisation - Smart Factory - Smart Operations - Smart Products - Data-driven Services
World Economic Forum	2022	Generic	3	quantitative and qualitative analyses	- Company Transformation - Market Transformation - Workforce Transformation

The Tables show that maturity models concentrates on five or six dimensions whether in the academic papers, industry reports or consultancy firms. Some of these papers give original names to the maturity models or generate more adabtable names to their scope of work. “Customer”, “Strategy”, “Operation”, “Organization” and “Technology” are frequently used as digital maturity dimensions. On the other hand, “Ecosystem management”, “Leadership” and “Workforce” are interesting by less preferred dimensions.

Majority of these studies determined different maturity factors under maturity dimensions. The assessments are generally made based on the competency of organisation concerning these factors. Some of these studies preferred preparing questionnaires about maturity factors. According to these assessments, the dimensions iportance are assesed and accordingly the maturity level of the organisations is determined as maturity with respect to dimensions and the overall digital maturity.

CHAPTER III

METHODOLOGY

3.1. Pythagorean Fuzzy Sets (PFS) and Their Advantages

Building upon the intuitionistic fuzzy sets, Yager, (2013, 2014) developed the Pythagorean fuzzy sets (PFSs), enhancing the representation of uncertainty. Unlike IFSs, where the membership and non-membership degrees must sum to a value less than or equal to one, PFSs allow the sum of their squares to be less than or equal to one. This innovation presents a broader and more flexible environment of uncertainty, making PFSs particularly effective in modeling real-world phenomena. The application of PFSs has been particularly beneficial across diverse fields, including business, management, healthcare, technology, psychology, and intelligent systems. Aggregation operators (AOs) are central to combining uncertain or imprecise data into meaningful decision-making inputs. Recent contributions, such as those by Moslem, (2024), Peng and Yuan, (2016), Rehman et al., (2016), and Wang and Garg, (2020), have significantly advanced the development of aggregation methods under fuzzy environments, tailored explicitly to urban transportation and complex technological integrations.

3.2. Justification for Methodological Choice

The motivation behind the selection of the Pythagorean fuzzy CRITIC-WASPAS hybrid model is: First, PFSs offer greater flexibility in modeling uncertainty compared to traditional fuzzy approaches (Yager, 2013). Their ability to capture nuanced levels of vagueness makes them particularly suitable for evaluating complex, technology-driven decision scenarios. Second, the CRITIC method provides an objective means of determining criterion weights based on statistical measures of contrast intensity and correlation (Diakoulaki et al., 1995). Unlike subjective methods like AHP and VIKOR, CRITIC minimizes dependency on human judgment (Anjum, 2024). Finally,

WASPAS (Zavadskas et al., 2012; Chakraborty, 2014) effectively handle conflicting criteria, the WASPAS method combines the WSM and WPM techniques (Altın, 2020). Moreover, Chakraborty, (2014) reports that the WASPAS methodology is more accurate than the WSM and WPM approaches. WASPAS method has a number of benefits. Firstly, it offers a series of concise and understandable procedures that make its application easier. Furthermore, it is beneficial for carrying out a thorough rating of options. They alone are less suited to rapidly evolving decision contexts without integration with a flexible fuzzy modeling technique (Sancar, 2025). By integrating CRITIC and the WASPAS techniques within a Pythagorean fuzzy setting, we can meet two important objectives: firstly, weighting the importance of criteria. Secondly, reliable ranking of alternatives. This provides a solid and comprehensive decision-making framework.

3.3. Structure of the Study

This study adopts a two-stage methodological framework. In the first stage, the Pythagorean fuzzy CRITIC method is employed to determine the objective weights of criteria. In the second stage, the alternatives are ranked using the Pythagorean fuzzy WASPAS method. Experts provide evaluations using linguistic variables, which are then converted into Pythagorean fuzzy numbers to address inherent uncertainties. The CRITIC method utilizes the standard deviation and correlation coefficients from the evaluation matrix to calculate objective criteria weights. Following this, the WASPAS method, combining Weighted Sum Model (WSM) and Weighted Product Model (WPM) approaches, is applied to rank the alternatives.

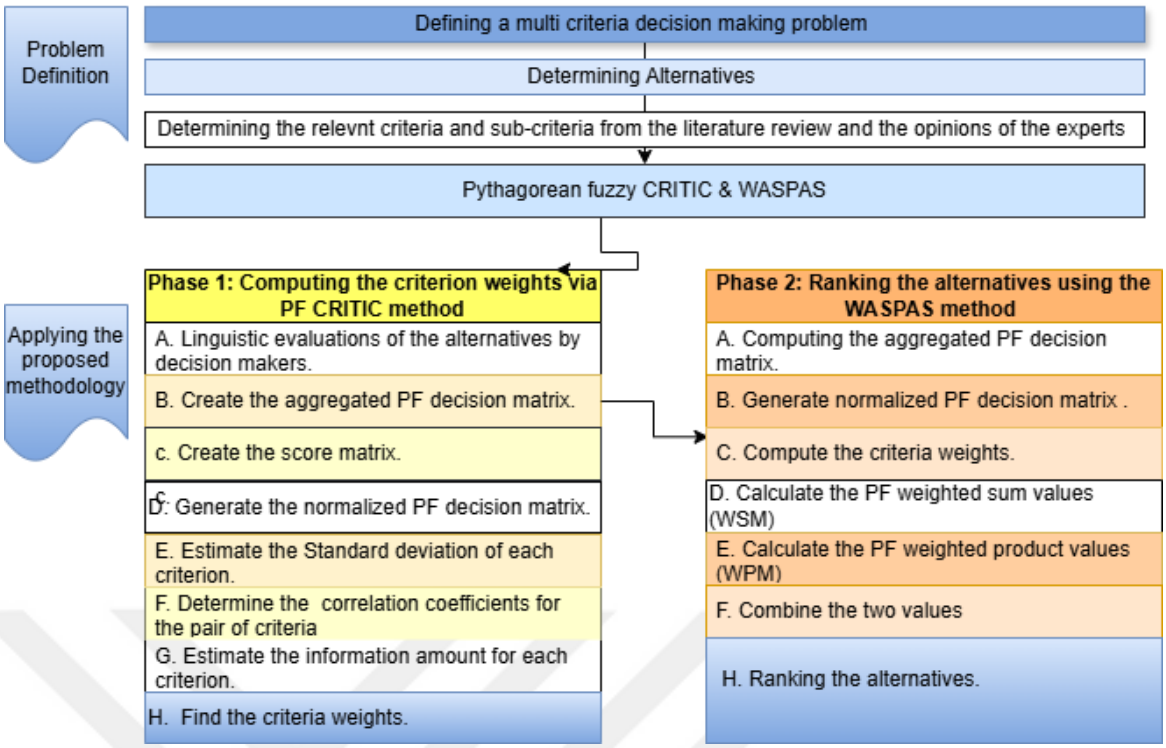


Figure 3.1. Proposed Methodology Framework: Pythagorean Fuzzy CRITIC-WASPAS Methodology

3.3.1. Preliminaries of Pythagorean Fuzzy Sets

Pythagorean fuzzy sets generalize intuitionistic fuzzy sets by loosening the restriction on the sum of membership and non-membership degrees, allowing their squares' sum to be ≤1 (Atanassov, 1994; Zeng et al., 2016). This extension provides greater modeling flexibility, making PFS ideal for multi-criteria decision-making problems involving significant ambiguity (Zhu & Li, 2018; Ilbahar et al., 2018). Researchers such as Yucesan and Gul, (2020) have successfully applied PFSs to healthcare service evaluations, demonstrating their practical effectiveness. Thus, Pythagorean fuzzy logic forms a foundational component of the methodology developed herein as service sector as well.

Definition 1: Take X as a fixed set. A Pythagorean fuzzy set P is an object having the form (Yager, 2016):

$$\tilde{P} \equiv \{\langle x, \mu_{\tilde{P}}(x), \nu_{\tilde{P}}(x)\rangle; x \in X\} \quad (1)$$

Where the degree of membership is defined by the function $\mu\tilde{p}(x)$:$X \mapsto [0,1]$ and $v\tilde{p}(x)$:$X \mapsto [0,1]$ presents the degree of non-membership of the element $x \in X$ to P, respectively and for every $x \in X$, it holds:

$$0 \leq \mu\tilde{A}(x)^2 + v\tilde{A}(x)^2 \leq 1 \quad (2)$$

Here, also the degree of hesitancy condition is as follows:

$$\pi\tilde{p}(x) = \sqrt{1-\mu\tilde{p}(x)2-v\tilde{p}(x)2} \quad (3)$$

Definition 2: Let = $\tilde{A} = \langle \mu_1 v_1 \rangle$, $\tilde{B} = \langle \mu_2 v_2 \rangle$ be two PFNs, and $\lambda > 0$, then the definitions of the operations on these two PFNs are below (Zhang, 2014)

$$\tilde{A} \otimes \tilde{B} = (\sqrt{\mu 1 \ + \ \mu 2 - \mu 1 \mu 2, v 1 v 2} \ ) \quad (4)$$

$$\tilde{A} \otimes \tilde{B} = \left(\mu_1\mu_2, \sqrt{v_1 + v_2 - v_1 v_2}\right) \quad (5)$$

$$\lambda\tilde{A} = \left(\sqrt{1-(1-\mu^2)^\lambda}, v^\lambda\right) \quad (6)$$

$$\tilde{A}^\lambda = \left(\mu^\lambda, \sqrt{1-(1-v^2)^\lambda}\right) \quad (7)$$

Definition 3: Let $\tilde{A}_i = \langle \mu i, vi \rangle$, $i = (1,2\ldots,n)$ be a collection of PFNs and $w = (w1,w2\ldots,wn)^T$ be the weight vector of $\tilde{A}_i, i = (1,2\ldots,n)$ with $\sum_{\mathrm{i}}^{\mathrm{n}} = {}_1 \, w_i = 1$, then the Pythagorean fuzzy weighted power geometric (PFWPG) operator is (Yager, 2013):

$$\mathrm{PFWPG}\left(\widetilde{A_1}, \widetilde{A_2}, \ldots, \widetilde{A_n}\right) = \left(\left(1 - \prod_{i=1}^{n}(1-\mu_i^2)^{w_i}\right)^{1/2}, \left(1 - \prod_{i=1}^{n}(1-v_i^2)^{w_i}\right)^{1/2}\right) \quad (8)$$

Definition 4. The Pythagorean fuzzy weighted averaging operator ($PFWA$) with respect to $w = (w_1, w_2, \ldots, w_n)$; $\sum_{i:1}^{n} Wi = 1$, is defined as follows (Yager, 2013):

$$\mathrm{PFWA}_w\left(\widetilde{A_{s1}}, \widetilde{A_{s2}}, \ldots, \widetilde{A_{sn}}\right) = w_1\widetilde{A_{s1}} + w_2\widetilde{A_{s2}} + \cdots + w_n\widetilde{A_{sn}} = \left((1\prod_{i=1}^{n}(1\,\mu_i^2)^{w_i})^{1/2}, \prod_{i=1}^{n}(v_i)^{w_i}\right) \quad (9)$$

3.3.2. Pythagorean Fuzzy CRITIC Method

The CRITIC method, originally developed by Diakoulaki et al. (1995), calculates the objective importance of criteria by considering the contrast intensity and conflict among them. In this study, CRITIC is adapted within a Pythagorean fuzzy environment to capture the uncertainty in linguistic expert evaluations. This approach quantifies each criterion's importance based on its variability and inter-criterion correlation, without relying on subjective preference extraction. The application of the PF-CRITIC process is summarized in the following (Ertemel, 2023; Menekse, 2023; Han, 2022):

Step 1. Establish the problem hierarchical structure.

Step 2. The alternatives are evaluated by the decision makers with respect to the criteria by employing the Pythagorean fuzzy linguistic terms as given in Table 3.1.

$$\begin{array}{c} \text{C1 C2 Cm} \\ A_1 \\ \tilde{D}_p = \begin{matrix} A_2 \\ \vdots \\ A_n \end{matrix} \end{array} \begin{bmatrix} \tilde{r}_{11}^P & \tilde{r}_{12}^P & & \tilde{r}_{1m}^P \\ \tilde{r}_{21}^P & \tilde{r}_{22}^P & \dots & \tilde{r}_{2m}^P \\ \vdots & & \ddots & \vdots \\ \tilde{r}_{n1}^P & \tilde{r}_{n2}^P & \dots & \tilde{r}_{nm}^P \end{bmatrix} \quad (1)$$

$$\textit{,and}$$

$$\widetilde{W}_p = \tilde{w}_1^p, \tilde{w}_2^p, \dots, \widetilde{W}_m^p$$

where $\widetilde{\Upsilon}_{ij}^{p} = (\mu_r, v_r)$ is the rating of i[th] alternative, $i = \{1,..,N\}$, for the j[th] criterion, $j = \{1,..,M\}$, as evaluated by the p[th] DM, p = {1,..,P}. Additionally, $wP\ j = (\mu_w, v_w)$ is the weight of j[th] criterion assigned by the p[th] DM. μ_r and v_r are the membership and non-membership degrees for the i[th] alternative and j[th] criterion, respectively.

Table 3.1. Linguistic Scale for PFSs for Criteria (Linguistic Terms)

Linguistic Terms	**(μ,v)**
Very Low (VL)	(0.15,0.85)
Low (L)	(0.25,0.75)
Medium Low (ML)	(0.35,0.65)
Medium (M)	(0.50,0.45)
Medium High (MH)	(0.65,0.35)
High (H)	(0.75,0.25)
Very High (VH)	(0.85,0.15)

Reference: Cui, 2018

Step 3. Create the aggregated PF decision matrix by deploying $PFWA$ operator in Equations:

$$\text{PFWA}_w(\widetilde{A_{s1}}, \widetilde{A_{s2}}, \dots, \widetilde{A_{sn}}) = \left(\left(1 - \prod_{i=1}^{n}(1-\mu_i^2)^{w_i}\right)^{1/2}, \prod_{i=1}^{n}(\nu_i)^{w_i}\right) \quad (11)$$

Step 4. Create score matrix $S = (x_{ij})_{mxn}$ with the below mentioned Eq.:

$$x_{ij} = \mu_{ij}^2 - \nu_{ij}^2 \quad (12)$$

Step 5. Generate the normalized PF decision matrix $\tilde{S} = (\tilde{x}_{ij})_{mxn}$ where

$$\tilde{x}_{ij}^{-} = \frac{x_{ij} - x_j^-}{x_j^+ - x_j^-}, \text{ j } \epsilon \text{ benefit} \quad (13)$$

$$\tilde{x}_{ij}^{-} = \frac{x_j^+ - x_{ij}}{x_j^+ - x_j^-}, \text{ j } \epsilon \text{ cost} \quad (14)$$

where in $x_j^+ = \max_i x_{ij}$ and $x_j^- = \min_i x_{ij}$

Step 6. The standard deviation σ_j of each criterion is estimated as given in Eq.:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\widetilde{x_{ij}} - \bar{x_j}\right)^2}{m}}, \quad \text{where } \bar{x_j} = \sum_{i=1}^{m} \tilde{x}_{ij}/m \quad (15)$$

Step 7. Determine the correlation coefficients for the pairs of criteria by using Eq.:

$$r_{jt} = \frac{\sum_{i=1}^{m}\left(\widetilde{x_{ij}} - \bar{x_j}\right)\left(\widetilde{x_{it}} - \bar{x_t}\right)}{\sqrt{\sum_{i=1}^{m}\left(\widetilde{x_{ij}} - \bar{x_j}\right)^2 \sum_{i=1}^{m}\left(\widetilde{x_{it}} - \bar{x_t}\right)^2}} \tag{16}$$

Step 8. Estimate the information amount (c_j) for each criterion with Eq.:

$$c_j = \sigma_j \sum_{i=1}^{n}\left(1 - r_{jt}\right) \tag{17}$$

Step 9. Find the criteria weights using Eq.

$$W_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{18}$$

3.3.3. Pythagorean Fuzzy WASPAS Method

WASPAS, developed by Zavadskas et al. (2012), combines the benefits of the WSM and WPM. It calculates final scores using a threshold parameter (λ), enabling it to behave dynamically between additive and multiplicative models. Its robustness against the rank reversal phenomenon (Chakraborty, 2014) and high reliability (Zolfani et al., 2013) make it a suitable ranking technique for this study. Embedding WASPAS into a Pythagorean fuzzy environment further enhances its ability to model complex uncertainties. Decision-makers evaluate alternatives in terms of several criteria via the linguistic scale. The steps of the WASPAS framework are presented as below (Madić & Lashgari, 2014).

Step 10. Creating the decision matrix.

The decision matrix (x) is created as Eq.(11) by determining the alternatives and criteria.

$$X = \left[x_{ij}\right]_{mxn} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} i = 1,2,\ldots,mj = 1,2,\ldots,n \tag{19}$$

Table 3.2. An IVPFN Scale to Rate Alternatives with Respect to Criteria

Linguistic Terms	**Interval- valued fuzzy numbers**			
	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
Very very bad (VVB)	0.03	0.18	0.75	0.90
Very bad (VB)	0.12	0.27	0.66	0.81
Bad (B)	0.21	0.36	0.57	0.72
Medium bad (MB)	0.30	0.45	0.48	0.63
Fair (F)	0.39	0.54	0.39	0.54
Medium good (MG)	0.48	0.63	0.30	0.45
Good (G)	0.57	0.72	0.21	0.35
Very good (VG)	0.66	0.81	0.12	0.27
Very very good (VVG)	0.75	0.90	0.03	0.18

Rference: Aktas, 2022

Step 11: Defuzzification and normalization of the decision matrix Eq.(20) and (21) are used for normalization separately for the benefit and cost criteria.

$$\text{For } benefit\ criteria\text{: } x^{*}_{ij} = \frac{x_{ij}}{maksx_{ij}} \tag{20}$$

$$\text{For cost criteria: x} * \text{ij} = \frac{minx_{ij}}{x_{ij}} \tag{21}$$

Step 12: Maximum defuzzified values are obtained through Eq.(22). Using the maximum defuzzified values, a normalized decision matrix is created in the form of Pythagorean fuzzy numbers with Eq.(23).

$$p = \frac{\lambda_L + \lambda_U + \sqrt{1 - v_L^2} + \sqrt{1 - v_U^2} + \lambda_L\lambda_U - \sqrt{\sqrt{1 - v_L^2}\sqrt{1 - v_U^2}}}{4} \tag{22}$$

$$\lambda\tilde{p} = \left(\left[\sqrt{1 - (1 - \mu_L^2)^{\lambda}}, \sqrt{1 - (1 - \mu_U^2)^{\lambda}}\right], \left[v_L^{\lambda}, v_U^{\lambda}\right]\right) \tag{23}$$

Step 13: Linguistic evaluations about the importance levels of the criteria are converted into Pythagorean fuzzy numbers through the comparison scale given in Table 3.3.

Table 3.3. Linguistic Scale for Weighting of Subdimensions

Linguistic terms	**Interval- valued fuzzy numbers**			
	$\boldsymbol{\mu\iota}$	$\boldsymbol{\mu\upsilon}$	$\boldsymbol{\nu\iota}$	$\boldsymbol{\nu\upsilon}$
Extremely Important (EI)	0.70	0.90	0.06	0.26
Important (I)	0.54	0.74	0.22	0.42
Medium (M)	0.38	0.58	0.38	0.58
Medium Low (ML)	0.22	0.42	0.54	0.74
Low (L)	0.06	0.26	0.70	0.90

Step 14: The values in the normalized decision matrix are producted by the weights of the criteria using Eq.(24). These values are then added together through Eq. (25) and Pythagorean fuzzy weighted sum values are obtained through Eq. (26).

$$p_1 \otimes p_2 = \left([\mu_L\mu_L^*, \mu_U\mu_U^*], \left[\sqrt{(v_L)^2 + (v_L^*)^2 - (v_L)^2(v_L^*)^2}, \sqrt{(v_U)^2 + (v_U^*)^2 - (v_U)^2(v_U^*)^2}\right]\right) \quad (24)$$

$$p_1 \otimes p_2 = \left(\left[\sqrt{(\mu_L)^2 + (\mu_L^*)^2 - (\mu_L)^2(\mu_L^*)^2}, \sqrt{(\mu_U)^2 + (\mu_U^*)^2 - (\mu_U)^2(\mu_U^*)^2}\right], [v_L\mu_L^*, v_U v_U^*]\right) \quad (25)$$

According to WSM, total relative importance of the i. alternative:

$$\tilde{Q}_i^{(1)} = \sum_{j=1}^{n} \tilde{x}\ ij \quad \tilde{w}\ ij \quad (26)$$

Step 15: Eq.(28) is applied by using the values in the normalized decision matrix and the criterion weights and the weighted normalized decision matrix is obtained. Then, these values are multiplied with each other via Eq.(24). Thus, the Pythagorean fuzzy weighted product values are calculated by Eq. (27)

$$\tilde{Q}_{\text{i}}^{(2)} = \prod_j^n = 1\, \tilde{x}_{\text{ij}}^{wj} \quad (27)$$

$$p^{\lambda} = \left(\left[\mu_L^{\lambda}, \mu_U^{\lambda}\right], \left[\sqrt{1 - (1 - v_L^2)^{\lambda}}, \sqrt{1 - (1 - v_U^2)^{\lambda}}\right]\right) \quad (28)$$

Step 16: Calculation and ranking of the combined optimal value (Q_i)

The calculation of the combined optimal value is given in Eq. (29).

$$Qi = \lambda Q_i^{(1)} + (1-\lambda)\, Q_i^{(2)} \tag{29}$$

λ: the combined optimality coefficient is generally 0,5 ve $0 \leq \lambda \leq 1$.

If $\lambda = 0$, WASPAS method turns into WPM,

If $\lambda = 1$, WASPAS method turns into WSM.

In terms of ranking, the alternative with the largest Q_i values is selected as the best alternative.

CHAPTER IV

PROPOSED NGO DIGITAL MATURITY MODEL FRAMEWORK

4.1. Introduction to the Framework

The study is divided into 3 phases. Firstly, it identifies the main problem by surfing academic papers and constructing the expectations and barriers to digital transformation. Consequently, the problem statement according to MCDM logic is " NGOS lack a dedicated framework to evaluate their digital readiness. Thus, it is essential to propose a digital maturity model that can be tailored to the NGO sector ", by selecting the most important criteria for developing a DMM for the NGO sector. The DMM criteria are structured by considering the nature of the problem and the appropriate MCDM techniques, which are CRITIC and WASPAS in a Pythagorean fuzzy environment. Secondly, A new DMM depends on the existing models applied in the previous research papers. By thorough review, the model of this study is selected to include 5 main dimensions and 16 sub-dimensions. Critic technique is applied to determine the weights of the dimensions and sub-dimensions through 3 alternatives. Additionally, WASPAS techniques are used to rank those alternatives and the sub-dimensions. To assess their weights and rank, a pairwise questionnaire consisting of 127 questions is designed and distributed to the decision makers in the sector, (AppendixA1,2 and 3). Thirdly, the weights of the dimensions in the model are calculated to determine their importance and rank the alternatives and the subdimensions among themselves. As a result, we offer the NGO sector a ready model that they can personalize to their organisation and design a robust digital roadmap accordingly.

4.2. Proposed DMM

The proposed Model is contrasted after reviewing the academic research papers on DT and discussing with the decision makers considering the Unique NGO environment and challenges. The model consists of 5 main dimensions and 16 sub-dimensions as illustrated in the figure below.

4.2.1. Stakeholder

Stakeholder dimension is vital for NDMM as it includes leaders, employees, associates, volunteers, donors, service recipients and society at large, playing an integral role in achieving its mission and services (Gooyabadi et al., 2023). DT enhances the stakeholder communication with organisation by leveraging digital platforms. Active stakeholder interaction improves the service delivery and increases the stakeholder trust in the organisation, strengthening the organisation's societal impact.

This Dimension is divided to 3 sub-dimensions:

i. **Stakeholder Engagement**: The involvement of beneficiaries, donors, and other stakeholders in shaping services, providing feedback, and advocating for the NGO (Kumar and Pansari,2016; Harmeling et al., 2017). It assesses to which extent an NGO uses digital tools to engage with stakeholders, including beneficiaries, donors, employees, and broder community (Gooyabadi et al., 2023) .

ii. **Stakeholder experience**: Enhancing stakeholder interactions through digital tools like AI, chatbots, and analytics to better understand and meet their needs. it represents use of technological tools to increase understanding of and engagement with customers which is crucial for driving digital change (CGI Report, 2016),(MEHTAP ÖZŞAHİN, 2023).

iii. **Stakeholder insights and behavior**: To which extent stakeholders (internal and external) are digitally literate and ready to level up their digital

skills, including education and training, data management, individual competence, technology usage of tools (Duncan et al., 2022).

4.2.2. Strategy

Strategy is the long term perspective, therefore, DT is a matter of strategy, by adopting processes supported by IT. Strategy is more than a mere plan of goals, it guides the NGOs their digital transformation journey and serves as a roadmap (Gooyabadi et al., 2023). The nature of NGO sector requires strategy to be flexible and aligned with stakeholders' needs. A transparent digital strategy with measurable performance metrics is crucial to ensure successful digital transformation for an organisation (Grimm et al., 2006). In 2021 TEKsystems conducted a survey with 500 technology and business decision-makers, it shows that 89% of digital leaders chose a DT strategy as a core pillar of their business strategy (State of digital transformation strategy: building a framework for digital success, 2022).

This Dimension is divided to 4 sub-dimensions:

i. **Ecosystem management:** This sub-dimension refers to the partner ecosystem development and the results of the digital conectivity with external actors in the DT context. For example: digital partnerships with external actors, managing relationships via online channels, trust and transparency in relationships with partners, and fast reaction to ecosystem dynamics (Fujitsu, 2016; PwC, 2016; Accenture, 2017; EY, 2016).

ii. **Sustainable funding strategies:** The ability of the organisation to utilize technology and digital platforms to boost fundraising and engage stakeholders. To what extent NGOs use crowdfunding platforms to acquire funding from a diverse array of donors, including individuals and corporations (Michael, 2023).

iii. **Stakeholder relationship management:** It reflects to which extent the organisation use digital technology to effectively engage and communicate

with stakeholders, including employees, donors, beneficiaries, and the broader society (Gooyabadi et al., 2023).

iv. **Strategic planning and execution:** it represents the level, to which extent the digital strategy is well governed by digitalization standards and supported by the bord members. This sub-dimension is to guide decisions related to long-term progress and digital technology adoption (Gooyabadi et al., 2023).

4.2.3. Technology

Due to the rapid advancement in technology, digital transformation emerged to embrace this change. High technology adaptation inside an organisation indicates the level of digital maturity (Zillmann, 2016). NGO sector need to invest in suitable digital technology otherwise they will confront a decrease in performance due to lack of innovation against the rapid technological changes adjustments (Laporte et al. 2018). This rapid advancements in technology including, Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) revolutionize the growth of businesses and organisations (Gooyabadi et al., 2023).
This Dimension is divided to 3 sub-dimensions:

i. **Digital Applications:** This sub-dimension refers to the specific tools, platforms or software that NGO use for service delivery, communication or planning for their missions. It considers the level of digital applications integrated in their processes. Digital tools and platforms present for NGOs an environment where they acquire more supporters, interact with stakeholders, facilitate operations, and intensify voices to advocate for their cause (Gooyabadi et al., 2023).

ii. **Connected Community Platforms:** The ability of NGO to integrate digital platforms, tools and networks in for service delivery, operations management, and stakeholder connection. It shows how an NGO is prepared concerning digital infrastructure (Gooyabadi et al., 2023).

iii. **Data Security & Privacy:** the measure taken by NGO to protect their digital assets including data, infrastructure, and services, from threats and un-authorized access. It also includes stakeholder privacy protection(Gooyabadi et al., 2023).

4.2.4. Operation

The embracement of digital tools whether foundational, structural, or engagement-centric, promises is mainly to facilitate the operation of NGOs tasks, making operations more efficient, achieving their tangible and intangible missions (Gooyabadi et al., 2023). This dimension mainly concentrates on the execution of an organistions' tasks and services. To ensure more efficiency autonomous processes should be established instead of manual digital (Zillmann, 2016). This enables NGOs to receive a broad assessment of current practices, identifying areas for improvement, and finding digital solutions that align with organisational strategic objectives. Such ongoing development and improvement enables organisations to sustain in such rapid digital growth world (Gooyabadi et al., 2023).

This Dimension is divided to 3 sub-dimensions:

i. **Volunteer and resource management:** This sub-dimension refers to the use digital tools to ensure effective allocation of human and material resources, in order to enhance operational efficiency. This involves recruiting, training, and managing volunteers while integrating suitable technologies to support sustainable resource deployment (Nikita et al., 2024).

ii. **Integrated service delivery:** This sub-dimension involves program strategy and management, including dynamic promotion, social media marketing integration (Sina et al., 2023).

iii. **Adaptive processes for mission delivery:** This sub-dimension refers to the adapted NGO's strategy to create, deliver, and capture value, including incorporating digital technologies into operations and services (Gooyabadi et al., 2023).

4.2.5. Culture & Organisation

This dimension encompasses the values, beliefs and practices in an NGO that directs the organisation through its DT journey. Basically, a culture that encourages change and values learning within an organisation leads the success of DT through supporting teamwork, innovation, transparency and attitude of giving. When executing DT, this existing culture becomes the backbone of the strategy (Gooyabadi et al., 2023). Previous studies prove that when digital culture is embraced inside an organisation this ensure attaining innovative performance than those neglecting such a culture (BCG, 2022). Developing a digital organisational culture, encompassing flexibility, stakeholder engagements, structural agility, digital awareness and skills, knowledge sharing, and innovation (Kiefer et al., 2021) facilitates DT. The leadership ability to inspire, guide and create an environment for digital change is critical for the success of DT. Leadership is responsible for encouraging innovation, alleviating fears, clarifying the benefits of DT and ensuring that the DT aligns with the organisations' missions and values (Gooyabadi et al., 2023).

This Dimension is divided to 3 sub-dimensions:

i. **Culture:** This sub-dimension involves the NGO's collective embrace of digital technologies, promoting a culture of innovation grounded in ethical digital use (Gooyabadi et al., 2023).

ii. **Leadership & Board Governance:** Managers lead the digital transformation within the NGO. Digital vision, providing motivation, openness to new innovative ideas (Nebati et al., 2023).

iii. **Volunteer and Workforce Enablement:** The ease of adaptation of the organisation to various changes is supported by continuous learning activities and change management. In addition, the willingness to learn allows for a better process of organisational adaptation, awareness, skills, and continuous learning (Al Najjar et al., 2023), (Haryanti et al., 2024).

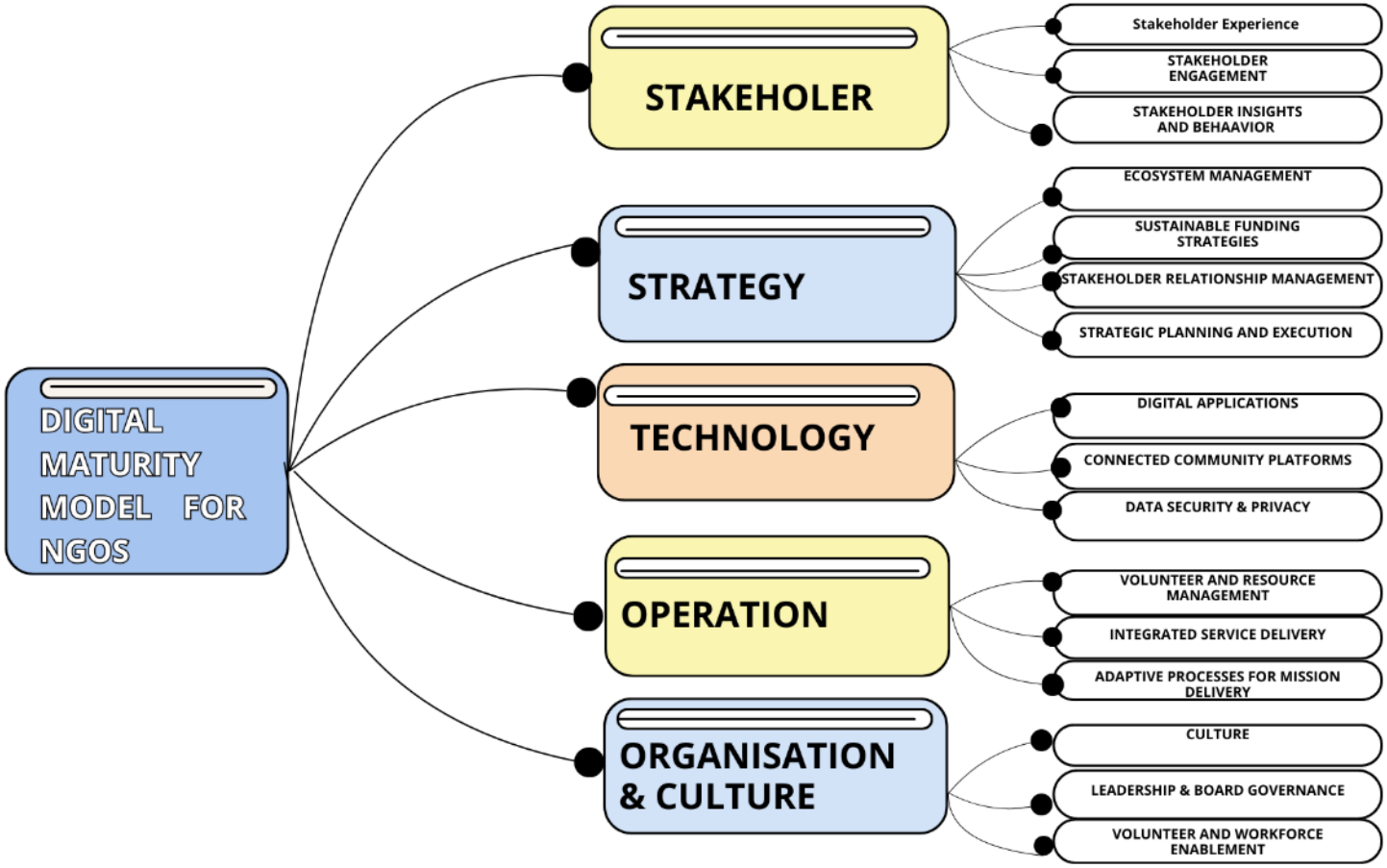


Figure 4.1. A Flowchart Illustrates the Proposed Digital Maturity Model

CHAPTER V

APPLICATION IN TÜRKİYE FOR DEVELOPING NDMM

5.1. Overview of the Application Sector: Brief Context of the NGO Sector as a Case

Civil society plays a critical role in addressing the social, economic, and developmental needs the government cannot meet. Non-governmental organisations (NGOs), as key actors in civil society, operate across diverse domains such as health, education, and social services, often filling gaps left by public and private sectors. Despite not constituting a formal industry, the nonprofit sector commands a workforce that rivals some of the largest global industries. For instance, as of 2017, U.S. nonprofits employed 12.5 million paid workers—exceeding the employment levels of construction, finance, and even manufacturing industries and nearly matching those of the retail and hospitality sectors. This scale sheds light on the strategic significance of NGOs in national and global systems.

For this reason,DT enables NGOs to enhance the effectiveness and sustainability of NGOs. It allows organisations to operate more efficiently, reach broader audiences, and better fulfill their missions. However, digital transformation in NGOs is not merely about acquiring new technologies; it involves strategic foresight, data-driven planning, and cultural shifts within organisations. According to Al Shobaki et al. (2020, 2021, 2022), NGOs must develop structured digital strategies that account for their current state of digitization, future aspirations, and the pathways to bridge that gap—all while safeguarding against disruption and technological obsolescence.

Despite its growing importance, the nonprofit sector demonstrates considerable variance in digital maturity. A Salesforce report surveying 867 nonprofit professionals across North America and Europe revealed that only 16% of organisations had

achieved high levels of digital maturity. Organisations classified as digitally mature achieved higher success rates in fundraising outcomes and grant acquisition, with leading nonprofits outperforming peers by 27% in fundraising and increasing foundation grants by 48% during the pandemic. These findings emphasize that digital maturity directly impacts operational and financial performance. Similarly, in Türkiye, The Türkiye Civil Society Index (2023) reports that approximately 70% of NGOs still need to enhance their technical knowledge and digital competencies, with only 31% considering themselves adequate in this domain.

Furthermore, the communication strategies of NGOs remain narrow and heavily reliant on social media, with minimal use of traditional or diversified digital platforms. Over half of the organisations use only one communication channel, and fewer than 10% utilize a multichannel approach. These limitations further make the need for a structured, evidence-based digital maturity model explicitly tailored to the unique characteristics and constraints of NGOs more crucial.

Given NGOs' societal importance and operational diversity, assessing their digital maturity in a methodologically sound and contextually relevant way is essential. This study addresses that need by applying a hybrid Pythagorean Fuzzy CRITIC–WASPAS model to evaluate and rank NGO digital readiness, offering both a decision-support framework and an empirical lens on digital maturity in the nonprofit context.

5.2. Decision Problem Setup

This section presents the application steps of the research methodology. In the evaluation phases of the methods, the data is collected from 14 DMs. DMs are experts, working in NGOs sector in different departments and they have knowledge about DT.

Table 5.1. DMs' Roles and Years of Experience

DMs	Role	Years of Experience
DM1	Assistant-external coordinator	**5**
DM2	Deputy Chairman / Coordinator of Foreign Relations	**11**
DM3	Project expert	**7**
DM4	International projects coordinator	**9**

Table 5.1. (cont.)

DM5	Student unit coordinator	**15**
DM6	General Coordinator	**10**
DM7	General manager of robotic education center	**8**
DM8	Assistant general manager	**10**
DM9	Human resouces coordinator	**20**
DM10	Women social activity resposibile	**12**
DM11	Board member	**5**
DM12	Assistant general manager	**14**
DM13	Cash based interventions technical advisor	**11**
DM14	Director general- governance office	**19**

For this reason, the questionnaire about identifying the importance of digital maturity dimensions and ranking the alternatives in Appendix (A) summarizes the digital maturity dimensions and subdimensions with their abbreviations and definitions. To determine the digital maturity model's dimensions of NGOs, a comprehensive literature review and expert input from practitioners in the nonprofit and digital transformation sectors. The proposed model is structured around five main dimensions, each containing relevant sub-dimensions demonstrated in Table *5.2.* with abbreviations, definitions, and references. Additionally, alternatives have been chosen according to the Turkiye civil society index, (2023) for the three most populated cities of NGOs: 22.7% of associations are located in Istanbul, 10.5% are in Ankara, and 5.6% are in Izmir. Those alternatives have also been discussed with DM1 and DM2.

Table 5.2. Digital Maturity Model with Definitions and References

Dimension & Sub- dimension	Definition	References
Stakeholder (C1)	(Zhu et al., 2025), (Kalender & Žilka, 2024), (Utama et al., 2024), (Merdin et al., 2023)**,** (Haryanti et al., 2023)**,** (Goumeh & Barforoush, 2021)**.**	
Stakeholder Engagement (C1.1)	The involvement of beneficiaries, donors, and stakeholders in shaping services, providing feedback, and advocating for the NGO.	Kumar and Pansari (2016) , (Harmeling et al., 2017).
Stakeholder Experience (C1.2)	Enhancing stakeholder interactions through digital tools like AI, chatbots, and analytics to better understand and meet their needs	(CGI Report, 2016), (MEHTAP ÖZŞAHİN, 2023).
Stakeholder Insights & Behavior (C1.3)	Understanding stakeholders' digital literacy, motivation, and ability to use technology for engagement and service improvement.	(Duncan et al., 2022).
Strategy (C2)	(Zhu et al., 2025)**,**(Kalender & Žilka, 2024)**,** (Utama et al., 2024)**,**(Al Najjar et al., 2023)**,** (Merdin et al., 2023)**,** (Haryanti et al., 2023)**,** (Goumeh & Barforoush, 2021)**.**	

Table 5.2. (cont.)

Ecosystem Management (C2.1)	Ensures effective digital collaboration with external partners by fostering trust, managing online relationships, and adapting quickly to ecosystem changes.	(Fujitsu, 2016), (PwC, 2016), (Accenture, 2017), (EY, 2016).
Sustainable Funding Strategies (C2.3)	Leveraging digital platforms and technology to enhance fundraising efforts, engage stakeholders, and secure diverse funding sources, including crowdfunding and corporate donations.	(Michael, 2023).
Stakeholder Relationship Management (C2.3)	The use of digital technology to effectively engage and communicate with stakeholders, including staff, donors, beneficiaries, and the broader community.	(Gooyabadi et al., 2023).
Strategic Planning and Execution (C2.4)	The extent to which an organisation integrates digital technology through structured strategic planning.	(Gooyabadi et al., 2023).
Technology (C3)	(Utama et al., 2024)**,**(Al Najjar et al., 2023)**,** (Merdin et al., 2023)**.**	
Digital Applications (C3.1)	Integrating digital tools effectively across organisational processes.	(Gooyabadi et al., 2023).
Connected Community Platforms (C3.2)	The digital tools, networks, and platforms an organisation uses to manage operations, deliver services, and engage stakeholders.	(Gooyabadi et al., 2023).

Table 5.2. (cont.)

Data Security & Privacy (C3.3)	Measures taken to protect an organisation's digital assets, infrastructure, and stakeholder data from threats, unauthorized access, and privacy breaches.	(Gooyabadi et al., 2023).
Operation (C4)	(Utama et al., 2024)**,**(Al Najjar et al., 2023) (Newman, 2020).	
Volunteer and Resource Management (C4.1)	Managing effective allocation of resources, training, and digital tools to enhance operational efficiency and sustainable resource deployment.	(Nikita et al., 2024).
Integrated Service Delivery (C4.2)	Coordinating program strategy with social media and marketing to enhance service reach and impact.	(Sina et al., 2023).
Adaptive Processes for Mission Delivery (C4.3)	The strategic adaptation of operations and services through digital technologies to enhance value creation and delivery.	(Gooyabadi et al., 2023).
Organisation & Culture (C5)	(Utama et al., 2024)**,**(Al Najjar et al., 2023)**,** (Merdin et al., 2023)**,** (Bandara et al., 2019)**.**	
Culture (C5.1)	The organisation's collective adoption of digital technologies, fostering innovation while ensuring ethical digital use.	(Gooyabadi et al., 2023).
Leadership & Board Governance (C5.2)	Guiding digital transformation through vision, motivation, and openness to innovation within the organisation.	(Nebati et al., 2023).
Volunteer and Workforce Enablement (C5.3)	Enhancing adaptability through learning, skill development, and change management.	(Al Najjar et al., 2023), (Haryanti et al., 2024).

5.3. Data Collection

Firstly, the dimensions and sub-dimensions listed in Table 5.2, along with the alternatives mentioned above, are subjected to pair-wise comparison by nine expert decision-makers. The decision-makers used the linguistic terms in Table 3.1 to express their weighting value of criteria compared to the alternatives chosen. The pair-wise comparison was conducted via a questionnaire, as shown in Appendix (A). The linguistic terms of the pair-wise comparison matrices, which express the evaluation of decision-makers, are transferred into interval-valued PFNs.

5.4. Estimation of Criterion Weights via PF-CRITIC

Step 1: The pairwise comparisons of criteria, that are transferred into interval-valued PFNs, are presented Table 5.4.

Table 5.3. Evaluation of Decision-Makers for the 5 Main Dimensions

DM	A	C1	C2	C3	C4	C5
DM1	A1	**VH**	**VH**	**VH**	**H**	**VH**
	A2	**H**	**H**	**MH**	**MH**	**VH**
	A3	**VH**	**VL**	**VL**	**MH**	**H**
DM2	A1	**VH**	**VH**	**VH**	**VH**	**VH**
	A2	**VH**	**VH**	**VH**	**H**	**VH**
	A3	**VH**	**H**	**L**	**VH**	**H**
DM3	A1	**H**	**VH**	**VH**	**MH**	**VH**
	A2	**MH**	**H**	**ML**	**M**	**MH**
	A3	**MH**	**H**	**VL**	**ML**	**ML**
DM4	A1	**H**	**MH**	**VH**	**H**	**MH**
	A2	**H**	**MH**	**MH**	**H**	**VH**
	A3	**M**	**MH**	**M**	**H**	**H**

Table 5.3. (cont.)

DM5	A1	**VH**	**VH**	**VH**	**VH**	**VH**
	A2	**VH**	**VH**	**H**	**H**	**VH**
	A3	**MH**	**H**	**L**	**H**	**MH**
DM6	A1	**VH**	**VH**	**VH**	**VH**	**VH**
	A2	**VH**	**VH**	**H**	**H**	**VH**
	A3	**MH**	**VH**	**L**	**VH**	**H**
DM7	A1	**VH**	**VH**	**VH**	**VH**	**VH**
	A2	**VH**	**VH**	**M**	**H**	**VH**
	A3	**VH**	**H**	**VL**	**H**	**H**
DM8	A1	**H**	**VH**	**H**	**H**	**H**
	A2	**H**	**VH**	**M**	**H**	**H**
	A3	**H**	**M**	**VL**	**H**	**MH**
DM9	A1	**VH**	**MH**	**VH**	**H**	**VH**
	A2	**VH**	**MH**	**M**	**H**	**VH**
	A3	**VH**	**MH**	**VL**	**H**	**H**
DM10	A1	**VH**	**H**	**VH**	**VH**	**VH**
	A2	**VH**	**H**	**ML**	**H**	**VH**
	A3	**VH**	**MH**	**VL**	**H**	**MH**
DM11	A1	**VH**	**H**	**VH**	**VH**	**H**
	A2	**VH**	**H**	**L**	**MH**	**H**
	A3	**VH**	**H**	**VL**	**MH**	**H**
DM12	A1	**M**	**VH**	**VH**	**H**	**VH**
	A2	**H**	**VH**	**M**	**MH**	**VH**
	A3	**M**	**H**	**L**	**MH**	**MH**

Table 5.3. (cont.)

DM13	A1	**VH**	**MH**	**H**	**H**	**MH**
	A2	**VH**	**MH**	**L**	**M**	**MH**
	A3	**VH**	**MH**	**L**	**MH**	**M**
DM14	A1	**VH**	**VH**	**H**	**VH**	**VH**
	A2	**VH**	**VH**	**L**	**M**	**MH**
	A3	**MH**	**MH**	**VL**	**ML**	**ML**

Table 5.4. Linguistic Terms of the Main Dimensions Transferred into Interval-Valued PFNs

DM	A	C1		C2		C3		C4		C5	
DM1	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**
	A2	**0.75**	**0.25**	**0.75**	**0.25**	**0.65**	**0.35**	**0.65**	**0.35**	**0.85**	**0.15**
	A3	**0.85**	**0.15**	**0.15**	**0.85**	**0.15**	**0.85**	**0.65**	**0.35**	**0.75**	**0.25**
DM2	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.85**	**0.15**	**0.75**	**0.25**	**0.25**	**0.75**	**0.85**	**0.15**	**0.75**	**0.25**
DM3	A1	**0.75**	**0.25**	**0.85**	**0.15**	**0.85**	**0.15**	**0.65**	**0.35**	**0.85**	**0.15**
	A2	**0.65**	**0.35**	**0.75**	**0.25**	**0.35**	**0.65**	**0.5**	**0.45**	**0.65**	**0.35**
	A3	**0.65**	**0.35**	**0.75**	**0.25**	**0.15**	**0.85**	**0.35**	**0.65**	**0.35**	**0.65**
DM4	A1	**0.75**	**0.25**	**0.65**	**0.35**	**0.85**	**0.15**	**0.75**	**0.25**	**0.65**	**0.35**
	A2	**0.75**	**0.25**	**0.65**	**0.35**	**0.65**	**0.35**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.5**	**0.45**	**0.65**	**0.35**	**0.5**	**0.45**	**0.75**	**0.25**	**0.75**	**0.25**
DM5	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.65**	**0.35**	**0.75**	**0.25**	**0.25**	**0.75**	**0.75**	**0.25**	**0.65**	**0.35**
DM6	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.65**	**0.35**	**0.85**	**0.15**	**0.25**	**0.75**	**0.85**	**0.15**	**0.75**	**0.25**

Table 5.4. (cont.)

DM7	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.85**	**0.15**	**0.5**	**0.45**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.85**	**0.15**	**0.75**	**0.25**	**0.15**	**0.85**	**0.75**	**0.25**	**0.75**	**0.25**
DM8	A1	**0.75**	**0.25**	**0.85**	**0.15**	**0.75**	**0.25**	**0.75**	**0.25**	**0.75**	**0.25**
	A2	**0.75**	**0.25**	**0.85**	**0.15**	**0.5**	**0.45**	**0.75**	**0.25**	**0.75**	**0.25**
	A3	**0.75**	**0.25**	**0.5**	**0.45**	**0.15**	**0.85**	**0.75**	**0.25**	**0.65**	**0.35**
DM9	A1	**0.85**	**0.15**	**0.65**	**0.35**	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.65**	**0.35**	**0.5**	**0.45**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.85**	**0.15**	**0.65**	**0.35**	**0.15**	**0.85**	**0.75**	**0.25**	**0.75**	**0.25**
DM10	A1	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.75**	**0.25**	**0.35**	**0.65**	**0.75**	**0.25**	**0.85**	**0.15**
	A3	**0.85**	**0.15**	**0.65**	**0.35**	**0.15**	**0.85**	**0.75**	**0.25**	**0.65**	**0.35**
DM11	A1	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**
	A2	**0.85**	**0.15**	**0.75**	**0.25**	**0.25**	**0.75**	**0.65**	**0.35**	**0.75**	**0.25**
	A3	**0.85**	**0.15**	**0.75**	**0.25**	**0.15**	**0.85**	**0.65**	**0.35**	**0.75**	**0.25**
DM12	A1	**0.5**	**0.45**	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**
	A2	**0.75**	**0.25**	**0.85**	**0.15**	**0.5**	**0.45**	**0.65**	**0.35**	**0.85**	**0.15**
	A3	**0.5**	**0.45**	**0.75**	**0.25**	**0.25**	**0.75**	**0.65**	**0.35**	**0.65**	**0.35**
DM13	A1	**0.85**	**0.15**	**0.65**	**0.35**	**0.75**	**0.25**	**0.75**	**0.25**	**0.65**	**0.35**
	A2	**0.85**	**0.15**	**0.65**	**0.35**	**0.25**	**0.75**	**0.5**	**0.45**	**0.65**	**0.35**
	A3	**0.85**	**0.15**	**0.65**	**0.35**	**0.25**	**0.75**	**0.65**	**0.35**	**0.5**	**0.45**
DM14	A1	**0.85**	**0.15**	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**	**0.85**	**0.15**
	A2	**0.85**	**0.15**	**0.85**	**0.15**	**0.25**	**0.75**	**0.5**	**0.45**	**0.65**	**0.35**
	A3	**0.65**	**0.35**	**0.65**	**0.35**	**0.15**	**0.85**	**0.35**	**0.65**	**0.35**	**0.65**

Step 2. We obtain the aggregated PF decision matrix by utilizing $PFWA$ operator in Eq. (11) as given in Table 5.5.

Table 5.5. Pythagorean Fuzzy Number Correspondence of Multi Attribute Fuzzy Decision Matrix

	C1		C2		C3		C4		C5	
A1	**0.85**	**0.15**	**0.75**	**0.25**	**0.85**	**0.15**	**0.65**	**0.35**	**0.85**	**0.15**
A2	**0.85**	**0.15**	**0.75**	**0.25**	**0.5**	**0.45**	**0.5**	**0.45**	**0.75**	**0.25**
A3	**0.75**	**0.25**	**0.65**	**0.35**	**0.25**	**0.75**	**0.5**	**0.45**	**0.65**	**0.35**

Step 3. The Score matrix and standard decision matrix are calculated with using Eq. (12) and Eq. (13), (14) as shown in Table 5.6.

Table 5.6. The Score Matrix and Standard Decision Matrix

	C1	C2	C3	C4	C5
A1	**0.4729**	**-0.0750**	**0.4729**	**0.1815**	**0.4729**
A2	**0.4729**	**-0.3891**	**-0.3891**	**0.1815**	**0.1815**
A3	**0.1815**	**-0.3891**	**-0.8185**	**-0.0750**	**-0.0750**
MaX	0.4729	-0.0750	0.4729	0.1815	0.4729
Min	0.1815	-0.3891	-0.8185	-0.0750	-0.0750
	C1	**C2**	**C3**	**C4**	**C5**
A1	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**
A2	**0.0000**	**1.0000**	**0.6675**	**0.0000**	**0.5317**
A3	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**

Step 4. Furthermore, using equations (15)-(17), the SD, CRC and amount of information of each challenge are estimated. Lastly, criteria weights are calculated using Eq. (18) and shown in Table 5.7.

Table 5.7. SD, CRC and Amount of Information then the Given Weights

	C1	C2	C3	C4	C5
σj	0.4714	0.4714	0.4158	0.4714	0.4085
CRC	C1	C2	C3	C4	C5
C1	1.00000	0.50000	0.75529	1.00000	0.84714
C2	0.50000	1.00000	0.94523	0.50000	0.88375
C3	0.75529	0.94523	1.00000	0.75529	0.98809
C4	1.00000	0.50000	0.75529	1.00000	0.84714
C5	0.84714	0.88375	0.98809	0.84714	1.00000
	C1	C2	C3	C4	C5
Cj	0.4231	0.5520	0.2312	0.4231	0.1772
	C1	C2	C3	C4	C5
Wj	0.2342	0.3055	0.1280	0.2342	0.0981

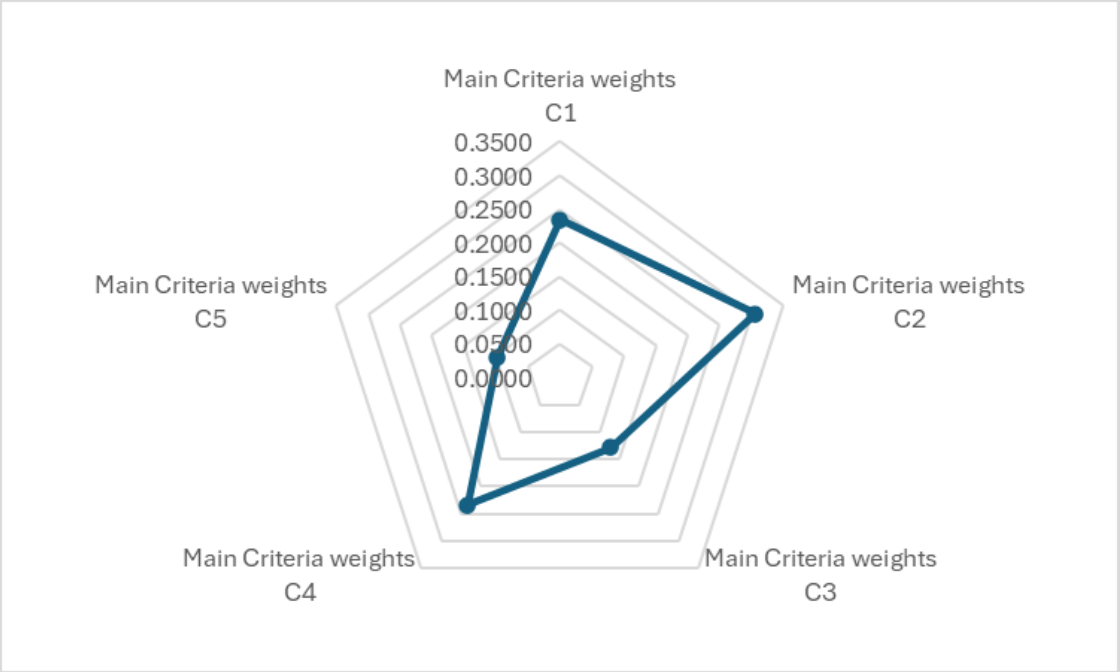


Figure 5.1. Weights of Main Dimensions Using PF-CRITIC Technique

As shown in Table 5.7 and Figure 5.1, the PF-CRITIC method results indicate that the strategy dimension holds the highest importance among the five main criteria, with a weight of .3055. At the same time, the dimensions of stakeholder and operation obtain an equal weight of .2342. In contrast, we find that the Technology dimension is less important, holding a weight of .1280. The remaining Organisation & Culture dimension has the least weight of .0981, indicating a balanced but obviously lower influence on the overall maturity assessment. The same PF- CRITIC steps were systematically applied to the sub-criteria under each primary dimension, as detailed in the subsequent Tables 5.8, 5.9, 5.10, 5.11 and 5.12 and Figures 5.2, 5.3, 5.4, 5.6, and 5.7, to derive the weights for deeper-level analysis.

Table 5.8. Weights of Subdimension of C1

	C1.1	C1.2	C1.3
Wj	**0.2690**	**0.4303**	**0.3007**

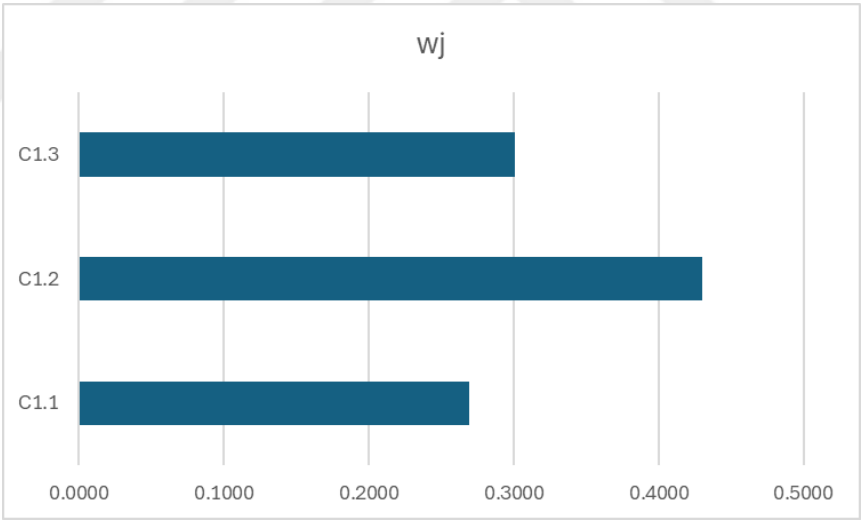


Figure 5.2. Weights of Subdimension of C1

Table 5.9. Weights of Subdimension of C2

	C2.1	C2.2	C2.3	C2.4
Wj	**0.3742**	**0.2281**	**0.1695**	**0.2281**

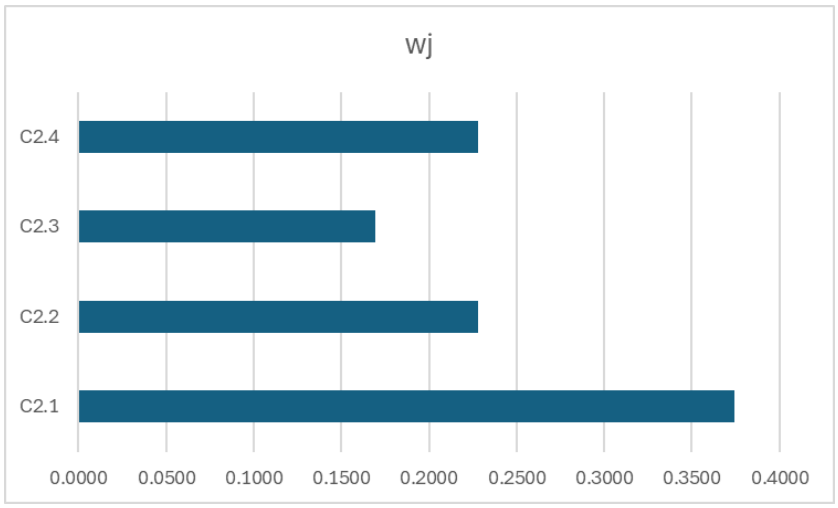


Figure 5.3. Weights of Subdimension of C2

Table 5.10. Weights of Subdimension of C3

	C3.1	C3.2	C3.3
Wj	**0.2500**	**0.5000**	**0.2500**

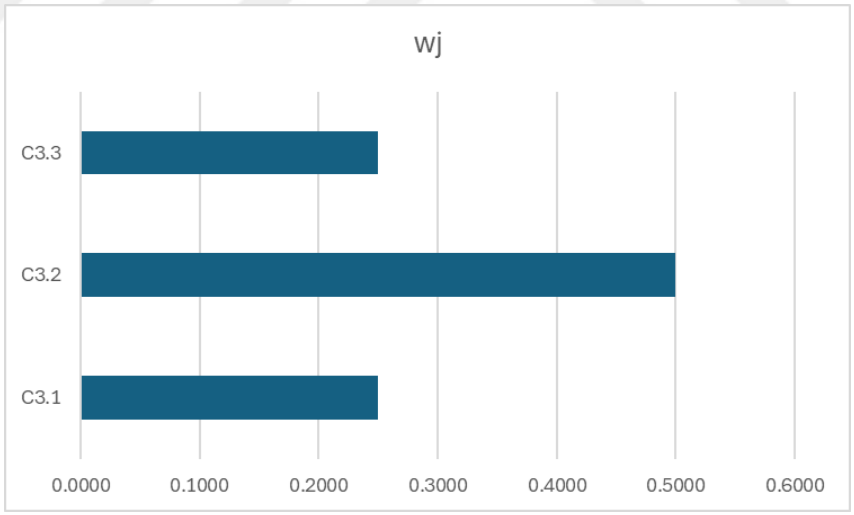


Figure 5.4. Weights of Subdimension of C3

Table 5.11. Weights of Subdimension of C4

	C4.1	C4.2	C4.3
Wj	**0.2773**	**0.1956**	**0.5271**

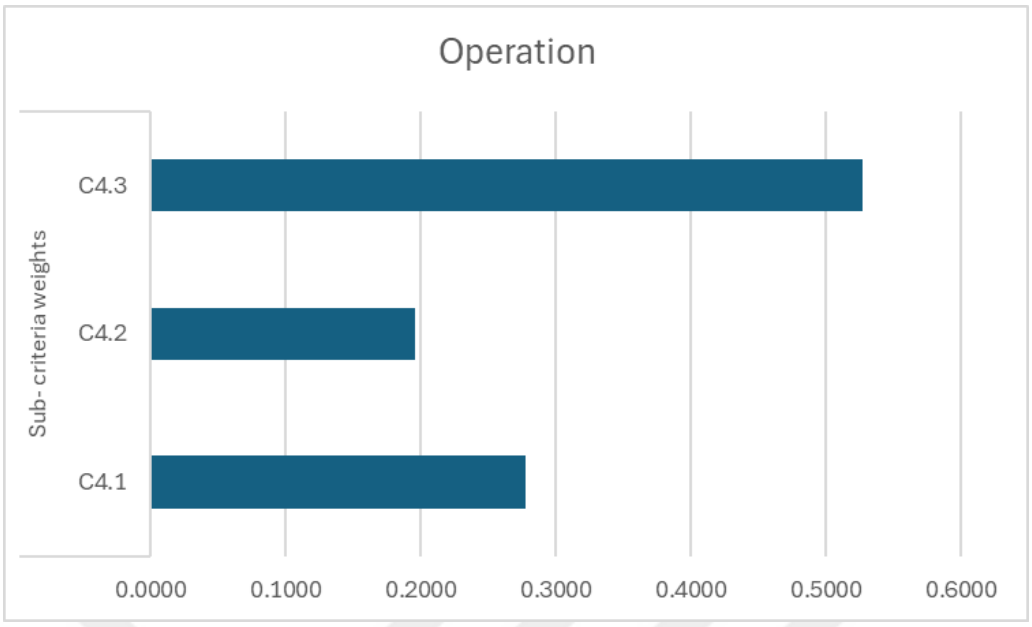


Figure 5.5. Weights of Subdimension of C4

Table 5.12. Weights of Subdimension of C5

	C5.1	C5.2	C5.3
Wj	0.1956	0.5271	0.2773

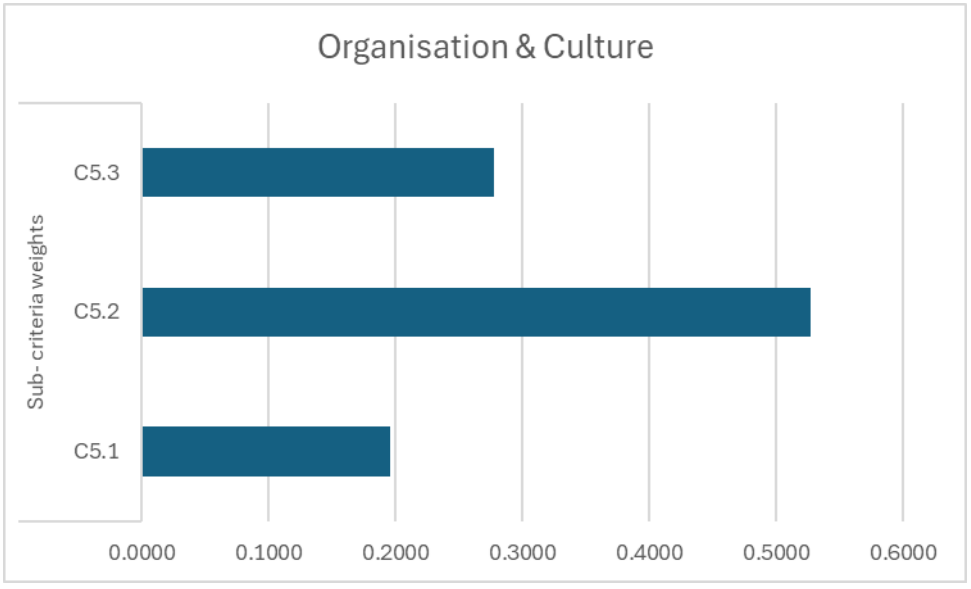


Figure 5.6. Weights of Subdimension of C5

As presented in the tables and figures above, which display the calculated weights of each sub-dimension by the PF-CRITIC technique, the results indicate the relative importance of components within each main digital maturity dimension. Within the Stakeholder category, Stakeholder Experience holds the highest importance with a weight of 0.4303, followed by Stakeholder Insights and Behavior at 0.3007, and finally Stakeholder Engagement at 0.2690. For the Strategy dimension, Ecosystem Management ranks as the most important sub-dimension with a weight of 0.3742. At the same time, both Sustainable Funding Strategies and Strategic Planning and Execution share the second level of importance, each with a weight of 0.2281. The lowest weight in this category is assigned to Stakeholder Relationship Management, at 0.1695.

Regarding the Technology dimension, the Connected Community Platform is identified as the most important sub-dimension, with a weight of 0.5000, while Digital Applications and Data Security and Privacy are ranked equally in second place, each with a weight of 0.2500. In the Operation category, the highest important subdimesnsion is adaptive process for mission delivery, computing the weight of .5271 while Volunteer and resource management is the second, holding the weight of .2773. Integrated and service delivery is the least important, with a weight of .1956. Similarly, the Organisation and Culture dimension, where Leadership and Board Governance computes the highest importance with the weight of .5271, while Volunteer and Workforce Enablement computes the weight of .2773. The least important is culture, with the weight of .1956.

To ensure consistency across the hierarchical structure of the model, Table 5.13 and Figure 5.7 show the global weights of the sub-dimensions as they are calculated by multiplying each sub-criterion's local weight by the weight of its corresponding main criterion. This step allows for a unified comparison of all sub-criteria, reflecting their overall influence within the decision-making process. Additionally, it shows the highest importance among the subdimensions according to their computed global weights, which is where the adaptive process for mission delivery comes from. First, ecosystem management comes second, and stakeholder experience comes third.

Table 5.13. Local and Global Weights of Each Sub-Dimension

Main Criteria		Sub Criteria	Local Weight	Global Weight
Stakeholder			0.23420	
	C1.1	Stakeholder Engagement	0.26900	0.06300
	C1.2	Stakeholder Experience	0.43032	0.10078
	C1.3	Stakeholder insights & behavior	0.30068	0.07042
Strategy			0.30550	
	C2.1	Ecosystem Management	0.37424	0.11433
	C2.2	Sustainable funding strategies	0.22815	0.06970
	C2.3	Stakeholder relationship management	0.16946	0.05177
	C2.4	Strategic planning and execution	0.22815	0.06970
Technology			0.12800	
	C3.1	Digital Applications	0.25000	0.03200
	C3.2	connected community platforms	0.50000	0.06400
	C3.3	Data Security & Privacy	0.25000	0.03200
Operation			0.23420	
	C4.1	Volunteer and Resource Management	0.27730	0.06494
	C4.2	Integrated Service Delivery	0.19560	0.04581
	C4.3	Adaptive Processes for Mission Delivery	0.52710	0.12345
Organisation & Culture			0.09810	
	C5.1	Culture	0.19560	0.01919
	C5.2	Leadership & Board Governance	0.52710	0.05171
	C5.3	Volunteer and Workforce Enablement	0.27730	0.02720

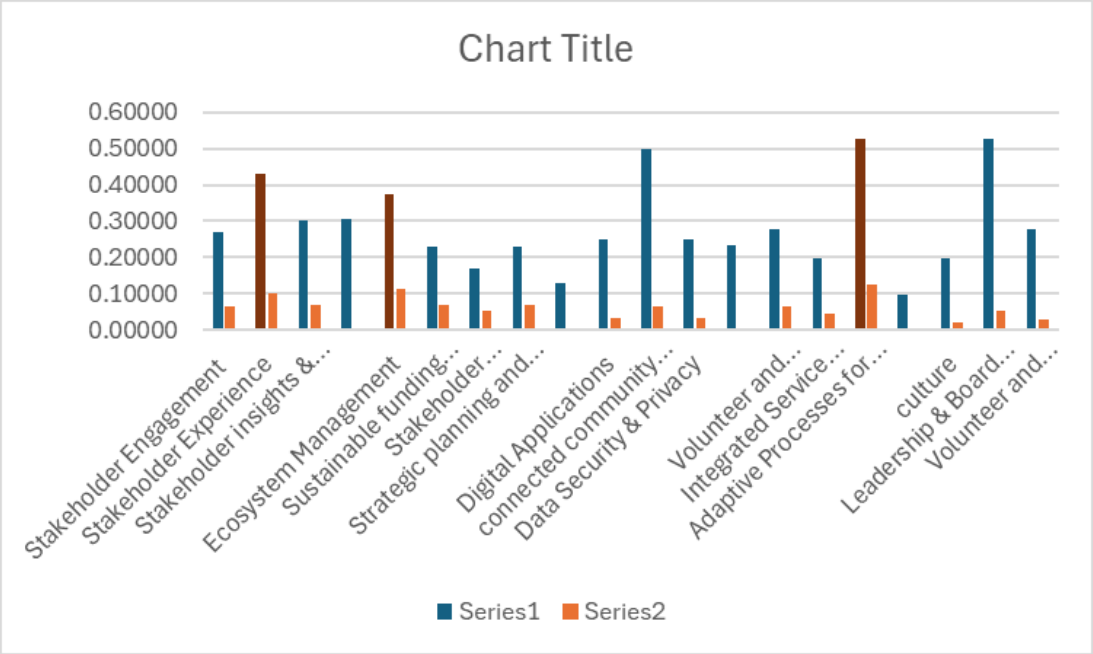


Figure 5.7. Local and Global Weights of Subdimensions Including the 3 Most Important Ones

5.5. The Evaluation of Alternatives Using PF-WASPAS

The decision-makers, who are experts in NGOs in Türkiye, were asked to evaluate the alternatives in terms of subdimensions' level of existence using the linguistic expressions specified in Table 3.2 and rating the importance of subdimensions using the linguistic terms in Table 3.3. Appendix (A.2) shows the questionnire answered by decision makers. After collecting evaluations made by decision-makers using linguistic expressions as shown in Appendix (B), the steps of PF-WASPAS were implemented sequentially.

Step 1: The aggregated fuzzy decision-making matrix was obtained using the PFWPGw operator in Definition 4, as given in Table 5.14.

Table 5.14. The Aggregated Fuzzy Decision-Making Matrix Obtained Using PFWPGW Operator

Criteria	C1.1				C1.2				C1.3			
Alternatives	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
A1	**0.660**	**0.810**	**0.120**	**0.270**	**0.570**	**0.720**	**0.210**	**0.350**	**0.660**	**0.810**	**0.120**	**0.270**
A2	**0.570**	**0.720**	**0.210**	**0.350**	**0.480**	**0.630**	**0.300**	**0.450**	**0.570**	**0.720**	**0.210**	**0.350**
A3	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**
	C2.1				**C2.2**				**C2.3**			
A1	**0.570**	**0.720**	**0.210**	**0.350**	**0.660**	**0.810**	**0.120**	**0.270**	**0.660**	**0.810**	**0.120**	**0.270**
A2	**0.570**	**0.720**	**0.210**	**0.350**	**0.660**	**0.810**	**0.120**	**0.270**	**0.660**	**0.810**	**0.120**	**0.270**
A3	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**
	C2.4				**C3.1**				**C3.2**			
A1	**0.570**	**0.720**	**0.210**	**0.350**	**0.660**	**0.810**	**0.120**	**0.270**	**0.660**	**0.810**	**0.120**	**0.270**
A2	**0.570**	**0.720**	**0.210**	**0.350**	**0.660**	**0.810**	**0.120**	**0.270**	**0.570**	**0.720**	**0.210**	**0.350**
A3	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**
	C3.3				**C4.1**				**C4.2**			
A1	**0.660**	**0.810**	**0.120**	**0.270**	**0.660**	**0.810**	**0.120**	**0.270**	**0.660**	**0.810**	**0.120**	**0.270**
A2	**0.660**	**0.810**	**0.120**	**0.270**	**0.570**	**0.720**	**0.210**	**0.350**	**0.570**	**0.720**	**0.210**	**0.350**
A3	**0.570**	**0.720**	**0.210**	**0.350**	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**
	C4.3				**C5.1**				**C5.2**			
A1	**0.660**	**0.810**	**0.120**	**0.270**	**0.570**	**0.720**	**0.210**	**0.350**	**0.570**	**0.720**	**0.210**	**0.350**
A2	**0.570**	**0.720**	**0.210**	**0.350**	**0.570**	**0.720**	**0.210**	**0.350**	**0.570**	**0.720**	**0.210**	**0.350**
A3	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**	**0.480**	**0.630**	**0.300**	**0.450**
	C5.3											
A1	**0.660**	**0.810**	**0.120**	**0.270**								
A2	**0.570**	**0.720**	**0.210**	**0.350**								
A3	**0.480**	**0.630**	**0.300**	**0.450**								

Table 5.15. Calculation of the Maximum Defuzzified Values

Finding Maximum Clarified Values																
Alts	**C1.1**	**C1.2**	**C1.3**	**C2.1**	**C2.2**	**C2.3**	**C2.4**	**C3.1**	**C3.2**	**C3.3**	**C4.1**	**C4.2**	**C4.3**	**C5.1**	**C5.2**	**C5.3**
A1	**0.746**	**0.664**	**0.746**	**0.664**	**0.746**	**0.746**	**0.664**	**0.746**	**0.746**	**0.632**	**0.632**	**0.632**	**0.632**	**0.598**	**0.598**	**0.632**
A2	**0.664**	**0.584**	**0.664**	**0.664**	**0.746**	**0.746**	**0.664**	**0.746**	**0.664**	**0.632**	**0.598**	**0.598**	**0.598**	**0.598**	**0.598**	**0.598**
A3	**0.584**	**0.584**	**0.584**	**0.584**	**0.584**	**0.584**	**0.584**	**0.584**	**0.584**	**0.598**	**0.561**	**0.561**	**0.561**	**0.561**	**0.561**	**0.561**
Maximum	**0.746**	**0.664**	**0.746**	**0.664**	**0.746**	**0.746**	**0.664**	**0.746**	**0.746**	**0.632**	**0.632**	**0.632**	**0.632**	**0.598**	**0.598**	**0.632**
(1/Maximum)	**1.341**	**1.505**	**1.341**	**1.505**	**1.341**	**1.341**	**1.505**	**1.341**	**1.341**	**1.582**	**1.582**	**1.582**	**1.582**	**1.672**	**1.672**	**1.582**

Step 2: Maximum defuzzified values are obtained in Table 5.15. Using the maximum defuzzified values, a normalized decision matrix is created in Table 5.16.

Table 5.16. The Normalized Decision Matrix Obtained

Criteria	C1.1				C1.2				C1.3			
Alternatives	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
A1	**0.732**	**0.872**	**0.058**	**0.173**	**0.668**	**0.817**	**0.095**	**0.206**	**0.732**	**0.872**	**0.058**	**0.173**
A2	**0.640**	**0.790**	**0.123**	**0.245**	**0.571**	**0.730**	**0.163**	**0.301**	**0.640**	**0.790**	**0.123**	**0.245**
A3	**0.544**	**0.702**	**0.199**	**0.343**	**0.571**	**0.730**	**0.163**	**0.301**	**0.544**	**0.702**	**0.199**	**0.343**
	C2.1				**C2.2**				**C2.3**			
A1	**0.668**	**0.817**	**0.095**	**0.206**	**0.732**	**0.872**	**0.058**	**0.173**	**0.732**	**0.872**	**0.058**	**0.173**
A2	**0.668**	**0.817**	**0.095**	**0.206**	**0.732**	**0.872**	**0.058**	**0.173**	**0.732**	**0.872**	**0.058**	**0.173**
A3	**0.571**	**0.730**	**0.163**	**0.301**	**0.544**	**0.702**	**0.199**	**0.343**	**0.544**	**0.702**	**0.199**	**0.343**
	C2.4				**C3.1**				**C3.2**			
A1	**0.668**	**0.817**	**0.095**	**0.206**	**0.732**	**0.872**	**0.058**	**0.173**	**0.732**	**0.872**	**0.058**	**0.173**
A2	**0.668**	**0.817**	**0.095**	**0.206**	**0.732**	**0.872**	**0.058**	**0.173**	**0.640**	**0.790**	**0.123**	**0.245**
A3	**0.571**	**0.730**	**0.163**	**0.301**	**0.544**	**0.702**	**0.199**	**0.343**	**0.544**	**0.702**	**0.199**	**0.343**
	C3.3				**C4.1**				**C4.2**			
A1	**0.772**	**0.903**	**0.151**	**0.336**	**0.772**	**0.903**	**0.151**	**0.336**	**0.772**	**0.903**	**0.151**	**0.336**
A2	**0.772**	**0.903**	**0.151**	**0.336**	**0.680**	**0.828**	**0.262**	**0.432**	**0.680**	**0.828**	**0.262**	**0.432**
A3	**0.680**	**0.828**	**0.262**	**0.432**	**0.582**	**0.742**	**0.372**	**0.549**	**0.582**	**0.742**	**0.372**	**0.549**
	C4.3				**C5.1**				**C5.2**			
A1	**0.772**	**0.903**	**0.151**	**0.336**	**0.694**	**0.840**	**0.270**	**0.443**	**0.694**	**0.840**	**0.270**	**0.443**
A2	**0.680**	**0.828**	**0.262**	**0.432**	**0.694**	**0.840**	**0.270**	**0.443**	**0.694**	**0.840**	**0.270**	**0.443**
A3	**0.582**	**0.742**	**0.372**	**0.549**	**0.595**	**0.755**	**0.382**	**0.561**	**0.595**	**0.755**	**0.382**	**0.561**
	C5.3											
A1	**0.772**	**0.903**	**0.151**	**0.336**								
A2	**0.680**	**0.828**	**0.262**	**0.432**								
A3	**0.582**	**0.742**	**0.372**	**0.549**								

Step 3: In table 5.17, Evaluations of the importance levels of the criteria are converted into Pythagorean fuzzy numbers.

Table 5.17. Evaluation of Subdimensions' Weights

Evaluation of Criteria Weights				
Criteria	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
C1.1	**0.70**	**0.90**	**0.06**	**0.26**
C1.2	**0.54**	**0.74**	**0.22**	**0.42**
C1.3	**0.54**	**0.74**	**0.22**	**0.42**
C2.1	**0.54**	**0.74**	**0.22**	**0.42**
C2.2	**0.70**	**0.90**	**0.06**	**0.26**
C2.3	**0.70**	**0.90**	**0.06**	**0.26**
C2.4	**0.54**	**0.74**	**0.22**	**0.42**
C3.1	**0.54**	**0.74**	**0.22**	**0.42**
C3.2	**0.54**	**0.74**	**0.22**	**0.42**
C3.3	**0.70**	**0.90**	**0.06**	**0.26**
C4.1	**0.54**	**0.74**	**0.22**	**0.42**
C4.2	**0.54**	**0.74**	**0.22**	**0.42**
C4.3	**0.54**	**0.74**	**0.22**	**0.42**
C5.1	**0.54**	**0.74**	**0.22**	**0.42**
C5.2	**0.70**	**0.90**	**0.06**	**0.26**
C5.3	**0.54**	**0.74**	**0.22**	**0.42**

Step 4: Pythagorean fuzzy weighted sum values are obtained as shown in Table 5.19.

Table 5.18. Calculation of the Weighted Sum Values

Criteria	C1.1				C1.2				C1.3			
Alternatives	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
A1	**0.512**	**0.785**	**0.083**	**0.306**	**0.308**	**0.540**	**0.272**	**0.501**	**0.346**	**0.585**	**0.251**	**0.475**
A2	**0.346**	**0.632**	**0.207**	**0.421**	**0.308**	**0.540**	**0.272**	**0.501**	**0.294**	**0.519**	**0.293**	**0.523**
A3	**0.294**	**0.000**	**0.060**	**0.260**	**0.000**	**0.000**	**0.220**	**0.420**	**0.000**	**0.000**	**0.220**	**0.420**
	C2.1				**C2.2**				**C2.3**			
A1	**0.361**	**0.604**	**0.239**	**0.460**	**0.512**	**0.785**	**0.084**	**0.309**	**0.512**	**0.785**	**0.084**	**0.309**
A2	**0.308**	**0.540**	**0.272**	**0.501**	**0.381**	**0.632**	**0.207**	**0.421**	**0.381**	**0.632**	**0.207**	**0.421**
A3	**0.000**	**0.000**	**0.220**	**0.420**	**0.000**	**0.000**	**0.060**	**0.260**	**0.000**	**0.000**	**0.060**	**0.260**
	C2.4				**C3.1**				**C3.2**			
A1	**0.361**	**0.604**	**0.239**	**0.460**	**0.395**	**0.646**	**0.227**	**0.277**	**0.346**	**0.585**	**0.251**	**0.475**
A2	**0.308**	**0.540**	**0.272**	**0.501**	**0.294**	**0.519**	**0.293**	**0.400**	**0.294**	**0.519**	**0.293**	**0.523**
A3	**0.000**	**0.000**	**0.220**	**0.420**	**0.000**	**0.000**	**0.220**	**0.220**	**0.000**	**0.000**	**0.220**	**0.420**
	C3.3				**C4.1**				**C4.2**			
A1	**0.540**	**0.813**	**0.009**	**0.087**	**0.367**	**0.745**	**0.016**	**0.112**	**0.367**	**0.613**	**0.058**	**0.182**
A2	**0.476**	**0.745**	**0.016**	**0.112**	**0.314**	**0.668**	**0.022**	**0.143**	**0.314**	**0.549**	**0.082**	**0.230**
A3	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table 5.18. (cont.)

	C4.3				C5.1				C5.2			
A1	**0.367**	**0.613**	**0.058**	**0.182**	**0.375**	**0.621**	**0.059**	**0.186**	**0.486**	**0.756**	**0.016**	**0.115**
A2	**0.314**	**0.549**	**0.082**	**0.230**	**0.322**	**0.559**	**0.084**	**0.236**	**0.417**	**0.680**	**0.023**	**0.146**
A3	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
	C5.3											
A1	**0.367**	**0.613**	**0.058**	**0.182**								
A2	**0.314**	**0.549**	**0.082**	**0.230**								
A3	**0.000**	**0.000**	**0.000**	**0.000**								

Table 5.19. Pythagorean Fuzzy Weighted Sum Values

Pythaorean Fuzzy Weighted Sum Values				
Alternatives	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
A1	**1.657**	**2.696**	**0.000**	**0.000**
A2	**1.361**	**2.358**	**0.000**	**0.000**
A3	**0.294**	**0.000**	**0.000**	**0.000**

Step 5: The criterion weights and the weighted normalized decision matrix is obtained. Then, these values are multiplied with each other. Thus, the Pythagorean fuzzy weighted product values given in Table 5.20 are obtained.

Table 5.20. Pythagorean Fuzzy Weighted Product Values

Pythagorean Fuzzy Weighted Product Values				
Alternatives	$\mu\iota$	$\mu\upsilon$	$\nu\iota$	$\nu\upsilon$
A1	**0.049**	**0.165**	**0.094**	**0.340**
A2	**0.027**	**0.093**	**0.137**	**0.413**
A3	**0.005**	**0.018**	**0.227**	**0.605**

Step 6: Pythagorean fuzzy weighted sum values and Pythagorean fuzzy weighted product values are defuzzified in Table 5.21. Then, the two values are integrated in Table 26. At this stage, the $\boldsymbol{\lambda}$ value was accepted as 0.5, assuming that the results obtained from the two values are of equal importance.

Table 5.21. The Defuzzification of Pythagorean Fuzzy Weighted Sum Values and Pythagorean Fuzzy Weighted Product Values

Clarification of Sum Values	
Alternatives	
A1	**2.455**
A2	**1.982**
A3	**0.323**
Clarification of Product Values	
Alternatives	
A1	**0.298**
A2	**0.269**
A3	**0.228**

Table 5.22. The Total Relative Importance Values of the Alternatives

Total Relative Importance Values		
Alternatives		
A1	**1.377**	**0.496**
A2	**1.125**	**0.405**
A3	**0.276**	**0.099**

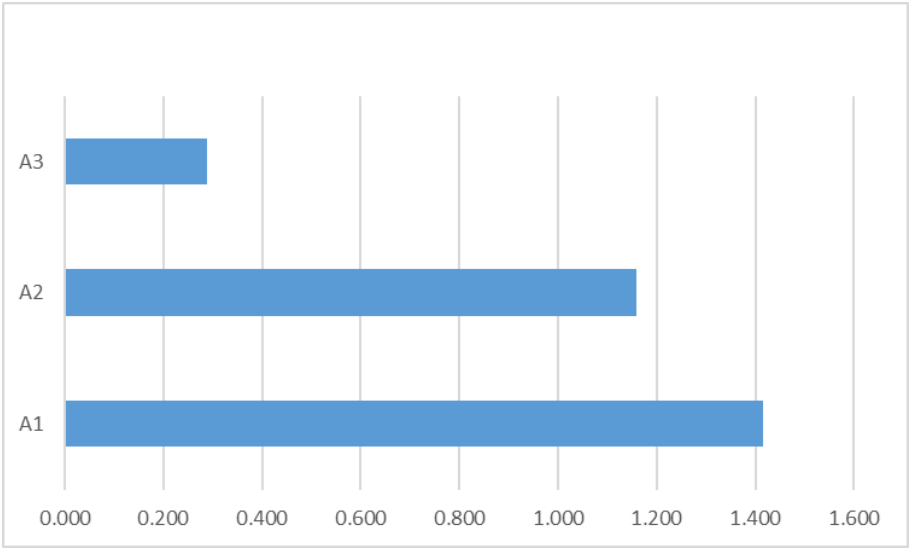


Figure 5.8. Final Ranking of the Alternatives

Step 7: The alternative with the highest total relative importance value is identified as the most digitally mature candidate. As shown in Table 5.22 and figure 5.8, the ranking of alternatives is as follows: A1 > A2 > A3. In the context of this study, this implies that NGOs operating in Istanbul exhibit the highest level of digital maturity, followed closely by those in Ankara, while NGOs in Izmir demonstrate comparatively lower levels of digital advancement.

5.6. Results Interpretation and Discussion

Digital Transformation is a series of activities that are interrelated with the goal of achieving organisational transformation toward digitalization. This study indicates that the most important dimension that supports the success of DT is strategy. This finding also confirms previous findings that successful digital transformation requires an alignment of strategy and governance (Merdin, 2023; Schumacher, 2018; Gökalp ,2021; Newman, 2020; Aslanova, 2022). These findings align with the current literature, where the strategy is also highly appreciated. Surprisingly, the results of this study indicate that technology is not the most important dimension in digital transformation. This is in line with the opinion of Tabrizi et al. and Nebati (2023) thatDTis not just about technology. The results of this study differ from several previous studies on technological advantages (Massimo 2022; Schumacher 2019; Shahiduzzaman, 2017), which are the main drivers of digital transformation. The dimensions of Stakeholder and Operation are the second most important dimensions that support the success of digital transformation. This aligns with the findings of previous studies indicating that the success of the transformation is determined by employees (Massimo, 2022; Bandara, 2019), customers (Aslanova, 2022; Schumacher, 2019), the transformation process (Gökalp, 2021; Mittal 2018; Mettler 2010; Gunsberg 2018), and the customer & operation (Kocaoglu & Kirmizi, 2024). In this case, Stakeholders, as transformation implementers, determine how the digital transformation implementation strategy is formulated.

The experts evaluated the organisation and culture dimension as the least in the model. On the contrary, Nebati, (2023) and Hanafiah, (2020) highlighted the importance of organisation and culture in achieving organisational transformation toward digitalization. We interpret this incompatibility with the existing literature in that it

reveals valuable insights for decision-makers into the DMMs explicitly designed for NGOs. The NDMM presented by (Gooyabadi, 2022) considered culture as the most essential factor for NGOs, while structure and leadership are the least important in the model. This finding aligns relatively with our study, and the difference in the result comes from considering organisation and culture as one dimension and also from using different data analysis methods, considering the hesitancy of the expert opinions by using PF CRITIC.

The WASPAS result ranks NGOs in Istanbul (A1) as the most digitally mature NGO environment, followed by Ankara (A2) and Izmir (A3). This finding aligns with the Türkiye Civil Society Development Index (2023), which identifies Istanbul as the province with the highest concentration of NGOs (22.7%) and the most national/international scale activities, likely contributing to greater digital infrastructure and maturity. Ankara, hosting 10.5% of NGOs, benefits from its status as the nation's capital and advocacy center, where NGOs are engaged in public policy making (YADA, 2023). Therefore, the strategic use of digital tools for policy engagement is common. Izmir, while active, ranks third both in NGO density and in digital maturity, reflecting a moderately strong but less resource-intensive civil society landscape. These regional disparities mirror broader trends in strategic, operational, and technological uptake, as well as institutional scale.

5.7. Managerial Implications

The novel NDMM proposed in this study, specifically tailored for the NGO sector, considers the unique objectives, challenges, and resources of these entities, distinct from their for-profit counterparts. The NDMM gives the highest importance to strategy as the main critical success factor in the transformation journey towards digitalization. Decision-makers need to construct a digital transformation strategy for the organisation, preparing a list of specific, clear actions needed to achieve a high level of digital maturity and, most importantly, ecosystem management. Decision makers and managers should also give high importance to stakeholders as NGO stakeholders are diverse, including beneficiaries, donors, and the wider community; therefore, considering stakeholder experience as an essential factor is justified. Hence, decision-makers and managers can actively engage stakeholders through transparent and

accessible channels, improving service delivery and fostering a sense of ownership. Enhancing stakeholder experiences via DT can bolster relationships and communities around the NGO's mission, encouraging advocacy and volunteerism and strengthening the organisation's societal impact. The model also revealed that operation is of equal importance to stakeholders as the unique challenges of NGOs involve more than simply integrating digital tools into existing workflows. It is about reimagining how the organisation operates to deliver its services most effectively and efficiently. Decision-makers should consider automating manual tasks, streamlining workflows, optimizing resource allocation, or implementing data-driven decision-making processes. This reengineering should also consider the various operational tasks of organisations in terms of their causes and mission. This is why the study proves that adaptive processes for mission delivery should be highly considered by managers' efforts toward enhancing productivity, reducing operational costs, and improving the quality and impact of the NPO's services, which contribute to its overall mission. Decision-makers may also draw specific attention to technological tools, organisation, and culture. Although they are not the highest in importance, The enhanced organisational culture and digital tools define an NGO's new and digitally updated roles and relationships and provide a framework for decision-making, accountability, and necessary changes for improvements. Therefore, the NDMM developed through this research enables NGOs to evaluate and enhance their digital capabilities in a manner that aligns with their unique objectives, resources, and community needs. Furthermore, it can provide practical, context-specific recommendations, aiding NGOs to more effectively fulfill their mission.

Based on the analysis above, this study is beneficial for:

- Consultants working in NGO sector: This study gives an overview about the sectors' unique challenges and characteristics which guides consultants step by step toward a successful DT journey.

- NGO managers: The study provides decision makers in NGOs with informed and wise choices that align technology with the heart and soul of the organisation's mission, achieving effectiveness and efficiency.

- NGO employees: It equips the workers of NGOs with the knowledge and courage to prioritize the digital tools that facilitate their mission and targeted goals.
- Researchers: It facilitates researchers' work to investigate the Digital journey of NGOs and assess their levels of maturity.

CHAPTER VI

CONCLUSION

The study proposes a hybrid MCDM model to provide a feasible NDMM that can assist decision-makers and managers in their transformation journey toward digitalization, a problem considered one of the essential decisions in NGO management. The first part is to compute the weights of the dimensions in the proposed model via PF-CRITIC. The second part ranks the alternatives using PF WASPAS to select the most mature alternative. To conclude, all the study's objectives and questions mentioned in Chapter One have been answered. Especially first, a new hybrid Interval-valued Pythagorean Fuzzy CRITIC and Pythagorean Fuzzy WASPAS model for the NDMM problem that is designed and applied to real-world case NGOs in Türkiye selecting regions as alternatives. Second, the model interprets the decision-makers' experience from the linguistic world to the numerical one with Pythagorean Fuzzy Numbers, which generate a data-driven result with applicable findings. Third, the importance of factors that affect the DT are determined after a detailed examination of the literature review, and they are evaluated with the help of Interval-valued Pythagorean Fuzzy CRITIC. Hence, the weights of the selected factors are determined. Lastly, the alternatives are ranked, and the most mature one is identified. The study results show that many factors affect the DT problem in the NGO sector and determine the importance of each factor, which usually varies, and few are computing the same weights. That organisation can apply this model and define the areas of improvement that facilitate their transformation toward digitalization.

6.1. Contribution

In conclusion, this study proposes a novel model for the NDMM problem. This is a novel study on designing DMM for NGO problems using MCDM methods. Considering the studies using MCDM methods for solving the research subject, the applied hybrid model is the main novelty of this study, in addition to the NDMM

problem. In terms of managerial implications, this research elaborates on a new method for NGO management to deal with network development decisions. This study provides three novel contributions:

Methodological: New hybrid fuzzy MCDM model, Pythagorean fuzzy CRITIC-WASPAS.

Practical: By identifying the importance of the criteria in the model, the study provides a decision support tool for resource allocation and roadmap design.

Sectoral: A new DMM Custom-tailored for NGOs, organisations can personalize it according to their needs.

In essence, this study is a mentor and an instructor to all who wish to harmonize the noble causes of NGOs with the dynamic world of digital transformation. It is about making technology a powerful tool to empower organisaions to achieve their missions and causes efficiently and effectively.

6.2. Limitations and Recommendations

This research was based on a questionnaire distributed among 14 decision-makers in the NGO sector. The limitation is that the decision-makers would have similar perspectives. Application of the model to different NGOs apart from Türkiye would confirm the validity of the model, which must be tested in different settings, such as varying Causes, regions, and sizes. Hybridizing other recent MCDM methods like AHP, VIKOR, or entropy may be one of the future research directions. The output of the proposed model can be used as input for some decisions on the strategic, operational, and organisational levels to assess NGOs' DM levels. Additionally, Personalizing the model to a specific NGO scope of work and designing an action plan or roadmap for improvements as a result.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

A.1. A pairwise questionnaire distributed to decision makers to determine the weights of criteria. The Question was asked is to rank the importance of criteria for each alternative from 1:7.

We thank you in advance for your contribution with your expertise in this study that we have carried out to select the important criteria that affects the digital maturity of an organisation. At this stage of the study, we asked for opinions to determine the importance degrees of the criteria. In the six pair-wise comparison tables given below according to your subjective evaluation in accordance with the coding in the given scale.

DM 1	Criteria				
Alts.	C1	C2	C3	C4	C5
A1					
A2					
A3					

C1. Stakeholder: Organisations' curtomers are Beneficiaries, Donors, and Stakeholders.

C2. Strategy: Focusing on Mission-Driven Goals

C3. Technology: Leveraging digital tools, and platforms to enhance service delivery.

C4. Operation: Enhancing efficiency and service delivery.

C5. Organisatiob and Culture: Structuring leadership, culture, and workforce adaptability

	C1.1	C1.2	C1.3		
A1					
A2					
A3					

C1.1. Stakeholder Engagement: The involvement of beneficiaries, donors, and stakeholders in shaping services, providing feedback, and advocating for the NGO

C1.2. Stakeholder Experience: Enhancing stakeholder interactions through digital tools like AI, chatbots, and analytics to better understand and meet their needs

C1.3. Stakeholder Insights and Behavior: Understanding stakeholders' digital literacy, motivation, and ability to use technology for engagement and service improvement.

	C2.1	C2.2	C2.3	C2.4		**C2.1. Ecosystem management**: Ensures effective digital collaboration with external partners by fostering trust, managing online relationships, and adapting quickly to ecosystem changes.
A1						**C2.2. Sustainable Funding Strategies:** Leveraging digital platforms and technology to enhance fundraising efforts, engage stakeholders, and secure diverse funding sources, including crowdfunding and corporate donations.
A2						**C2.3. Stakeholder Relationship Management:** The use of digital technology to effectively engage and communicate with stakeholders, including staff, donors, beneficiaries, and the broader community.
A3						**C2.4. Strategic Planning and Execution:** The extent to which an organisation integrates digital technology through structured strategic planning.
	C3.1	C3.2	C3.3			**C3.1. Digital Applications**: integrating digital tools effectively across organizational processes.
A1						**C3.2. Connected Community Platforms:** The digital tools, networks, and platforms an organisation uses to manage operations, deliver services, and engage stakeholders
A2						**C3.3. Data Security & Privacy:** Measures taken to protect an organisation's digital assets, infrastructure, and stakeholder data from threats, unauthorized access, and privacy breaches.
A3						
	C4.1	C4.2	C4.3			**C4.1. Volunteer and Resource Management:** through effective allocation, training, and digital tools to enhance operational efficiency and sustainable resource deployment.
A1						**C4.2. Integrated Service Delivery:** Coordinating program strategy with social media and marketing to enhance service reach and impact.
A2						**C4.3. Adaptive Processes for Mission Delivery:** The strategic adaptation of operations and services through digital technologies to enhance value creation and delivery.
A3						
	C5.1	C5.2	C5.3			**C5.1 .culture:** The organisation's collective adoption of digital technologies, fostering innovation while ensuring ethical digital use.
A1						**C5.2. Leadership & Board Governance:** Guiding digital transformation through vision, motivation, and openness to innovation within the organization
A2						**C5.3. Volunteer and Workforce Enablement:** Enhancing adaptability through learning, skill development, and change management.
A3						

A.2 Second part of questionnaire was to ask decision makers to rank the existence of criteria in the assigned alternatives from 1:9.

Dear participant, give this criterion a score between 1-9 point. According to whether it is present in your region or not. For example, if the Stakeholder Engagement criterion is good t in your region, give 7 points

DM1																
Alternatives/Criteria	**C1.1**	**C1.2**	**C1.3**	**C2.1**	**C2.2**	**C2.3**	**C2.4**	**C3.1**	**C3.2**	**C3.3**	**C4.1**	**C4.2**	**C4.2**	**C5.1**	**C5.2**	**C5.3**
A1																
A2																
A3																

A.3 Then, decision makers have to rank the importance of criteria from 1:5 for the WASPAS analysis.

we ask your opinions to determine the importance degrees of the sub-criteria (1-5).

Sub criteria	**point (1-5)**
C1.1	
C1.2	
C1.3	
C2.1	
C2.2	
C2.3	
C2.4	
C3.1	
C3.2	
C3.3	
C4.1	
C4.2	
C4.3	
C5.1	
C5.2	
C5.3	

APPENDIX B

WASPAS

Table B.1. Evaluation of Decision-makers for the Sub Dimensions

DMs	Alt.	C1.1	C1.2	C1.3	C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C3.3	C4.1	C4.2	C4.3	C5.1	C5.2	C5.3
DM 1	A1	VG	G	VG	G	VG	G	G	G	G	VG	G	G	VG	VG	VG	VG
	A2	G	G	VG	G	G	G	G	G	G	VG	G	G	VG	G	G	G
	A3	G	G	VG	G	VG	G	G	G	G	VG	G	G	VG	VG	G	VG
DM 2	A1	VG	VG	VG	VVG	VG	VG	VG	VVG	VG	VVG	VVG	VVG	VVG	VVG	VVG	VVG
	A2	VG	G	VG	VG	VG	VG	VG	VVG	VG	VVG	VVG	VVG	VVG	VVG	VVG	VVG
	A3	G	MG	G	G	G	VG	G	VG	G	VVG	VG	VVG	VVG	VVG	VVG	VVG
DM 3	A1	VG	VVG	VVG	VG	G	VVG	VVG	VVG	VVG	MG	VG	G	VVG	VVG	VG	VVG
	A2	MG	MG	VVG	MG	VG	VG	VVG	G	MG	MG	G	G	G	VG	G	MG
	A3	F	G	VG	F	F	MG	G	G	MB	F	MB	F	B	MG	F	MB
DM 4	A1	VG	VG	VVG	VG	VG	VG	MG	VG	VG	VG	VVG	VG	VG	G	G	VVG
	A2	VG	G	G	VG	MG	G	MG	VG	MG	VG	G	MG	G	G	VG	VG
	A3	VG	VG	VG	VVG	VVG	VG	G	VG	VG	VG	VVG	VG	VG	F	VG	VVG
DM 5	A1	VG	VG	G	G	VG	VG	MG	G	VG	G	G	VG	G	MB	MG	F
	A2	VG	VG	G	VG	VG	VG	MG	G	VG	VG	VG	VG	G	F	MG	F
	A3	G	G	G	G	G	VG	MG	MG	VG	MG	MG	VG	MG	F	F	MB
DM 6	A1	VVG	VVG	VVG	VG	VVG	VVG	VVG	VG	VVG	VVG	VVG	VVG	VG	VG	VVG	VVG
	A2	G	MG	F	G	VG	G	G	MG	G	VVG	VG	G	G	MG	VG	G
	A3	F	F	MG	F	MG	MG	MG	MB	MG	VVG	G	F	MG	F	G	F
DM 7	A1	VVG	G	VG	G	VG	G	G	VG	G	MG	VG	G	G	VG	G	G
	A2	VVG	G	VG	G	VG	G	G	VG	F	VG	VG	G	G	VG	G	G
	A3	MG	F	VG	F	VB	F	F	VG	F	VG	VG	VG	G	VG	F	F

Table B.1. (cont.)

DM 8	A1	VVG	VVG	G	VG	VG	VG	G	VG	VG	G	VG	VG	G	G	G	G
	A2	VG	VG	G	G	VG	G	MG	G	G	G	G	G	MG	MG	MG	MG
	A3	G	G	MG	MG	G	G	F	MG	G	MG	G	MG	MG	MG	MG	MG
DM 9	A1	VVG	VVG	VVG	VVG	VVG	VG	VVG	VVG	VVG	VG	VVG	VG	VG	VG	VVG	VVG
	A2	VG	G	VG	VVG	VVG	VVG	G	VG	VVG	G	VVG	G	VVG	VG	VVG	G
	A3	F	MG	MB	MB	F	MB	F	F	F	MB	MG	MB	MB	B	MB	MB
DM 10	A1	VVG	VVG	VVG	VVG	VVG	VVG	VVG	VVG	VVG	VVG	VVG	VG	VVG	VG	VVG	VVG
	A2	VG	VG	VG	VG	VG	VVG	VG	VVG	VVG	VG	VG	MG	VVG	VG	VVG	VG
	A3	F	MG	F	B	F	B	MB	MB	MB	MB	MB	F	B	F	B	F
DM 11	A1	VG	VVG	VVG	VVG	G	VG	G	VG	G	VVG	VG	VG	VG	VG	VG	VG
	A2	VG	VG	VG	VG	G	VG	G	VG	G	VVG	VG	VG	VG	VG	VG	VG
	A3	G	VG	VG	G	G	VG	G	VG	G	VVG	VG	G	VG	G	G	G
DM 12	A1	F	B	F	MG	VG	MG	MG	G	VG	MG	G	VG	MG	F	MG	G
	A2	F	B	F	MG	VG	MG	MG	G	VG	MG	G	VG	MG	F	MG	G
	A3	F	B	F	MG	VG	MG	MG	G	VG	MG	G	VG	MG	F	MG	G
DM 13	A1	F	F	MB	F	MB	F	F	G	MG	VG	MB	F	MG	MG	F	F
	A2	G	F	F	F	MG	G	MG	G	MG	VG	F	F	G	MG	MG	G
	A3	F	F	MB	F	MB	MB	MB	G	MG	VG	MB	F	MG	MG	F	F
DM 14	A1	VG	VG	G	G	VG	VG	G	G	G	G	VG	G	G	G	VG	VG
	A2	MG	F	F	G	G	VG	G	VG	G	VG	MG	MG	F	MG	G	MG
	A3	F	F	MB	MG	MG	G	G	G	G	G	MG	F	F	MG	G	MG

APPENDIX C

ETHICS COMMITTEE PERMISSION

Evrak Tarih ve Sayısı: 07.05.2025-56992

İBN HALDUN ÜNİVERSİTESİ

T.C.
İBN HALDUN ÜNİVERSİTESİ
Sosyal ve Beşeri Bilimler Bilimsel Araştırma ve Yayın Etiği
Kurulu Başkanlığı

2025 AİLE YILI

Sayı : E-71395021-050.04-56992 07.05.2025
Konu : Etik Kurul Kararı - Ayatullah MUSTAFA

İLGİLİ MAKAMA

Kurulumuza başvuran Ayatullah MUSTAFA'nın, "Enhancing NGO Digital Maturity: A Data-Driven Approach with Pythagorean Fuzzy and WASPAS Methods" isimli projesi; amaç, araştırma türü, veri toplama araçları, süreç ve işlemler, veri analizleri dikkate alınmak suretiyle 25.04.2025 tarihinde değerlendirilerek 2025/05-03 karar numarası ile etik açıdan uygun bulunmaktadır.

Bilgilerini ve gereğini arz/rica ederim.

Prof. Dr. Alev ERKİLET
Başkan

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Adres:Başak Mah. Ordu Cad. No:3 P.K. 34480 Başakşehir / İstanbul
Telefon:0212 692 0212 Faks0212 551 6464
e-Posta:info@ihu.edu.tr Elektronik Ağ:www.ihu.edu.tr

Bilgi için: Ümran HASANOĞLU
Unvanı: Sekreter
Tel No: 2505

Bu belge,güvenli elektronik imza ile imzalanmıştır.

CURRICULUM VITAE

Full Name:

Ayatullah Mustafa

Education:

2023 – 2025	MA in Management, Ibn Haldun University, Istanbul, Turkiye.
2018 – 2022	MA in Simultaneous interpretation, American University, Cairo.
2013 – 2018	BA English language, literature, and simultaneous interpretation, Al-Azhar University, Cairo.

Work Experience:

2022 – 2023	Youth worker at Telsiai Youth Center, Telsiai, Lithuania.
2020 – 2022	Senior compliance Associate at Amazon, Cairo, Egypt.