AN IT PROJECT INVESTMENT EVALUATION FRAMEWORK BASED ON SPHERICAL FUZZY TOPSIS METHODOLOGY FROM A SUSTAINABILITY PERSPECTIVE

(SÜRDÜRÜLEBİLİRLİK PERSPEKTİFİNDEN KÜRESEL BULANIK TOPSIS METODOLOJİSİNE DAYALI BT PROJE YATIRIM DEĞERLENDİRME ÇERÇEVESİ)

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LIST OF SYMBOLS

AHP	**:**	Analytic Hierarchy Process
ANP	**:**	Analytic Network Process
ANP	**:**	Analytic Network Process
BSC	**:**	Balanced Scorecard
DEA	**:**	Data Envelopment Analysis
DEMATEL	**:**	Decision MAking Trial and Evaluation Laboratory
ELECTRE	**:**	ELimination Et Choix Traduisant la REalité
IFS	**:**	Intuitionistic Fuzzy Sets
IFS2	**:**	Type-2 Intuitionistic Fuzzy Sets
IS	**:**	Information Systems
IT	**:**	Information Technology
MCDM	**:**	Multi-Criteria Decision-Making
NS	**:**	Neutrosophic Fuzzy Sets
PESM	**:**	Project Evaluation and Selection Methods
SFS	**:**	Spherical Fuzzy Sets SFS
SWAM	**:**	Spherical Weighted Arithmetic Mean
TOPSIS	**:**	Technique for Order Preference by Similarity to Ideal Solution
ZOGP	**:**	Zero-One Goal Programming

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ABSTRACT

IT project investmen decision is a challenging process in the current technological dynamic environment because of the multiple criteria and requirements that need to be taken into account. The purpose of this paper is to design a suitable decision model to assess the IT projects, with a unique emphasis on the sustainability context.

This study uses the MCDM technique with criteria selected and weighted according to sustainability aspects, including economic, environmental, social, and cultural. Consequently, the Spherical Fuzzy TOPSIS approach is applied to prioritize the IT projects based on their correspondence to the sustainability criteria. A theoretical background of Spherical Fuzzy TOPSIS is introduced to evaluate the sustainability effect of different undertakings.

Reviewers of this study identified that Optimization on Flight Planning System as the most sustainable IT project among all the projects in this study and closely followed by the Carbon Offset Project. Based on these findings, this study concludes that projects that are most sustainable are those that directly influence the operational efficiency and resource usage within highly technological industries like the aviation industry especially if one considers long term gains such as; fuel conservation, integration, and effective information processing. To sum up, the conclusions give a clear signal that even though the high-cost projects imply a high level of risk, the achievement of sustainability concerns in many organizations' strategic objectives like operating efficiency, environmental sensitivity, and customer experiences would be enormously beneficial.

Currently, there is a lack of information about sustainability analysis of IT projects in the existing literature. This study fills that void by considering sustainability issues in the assessment process and urging decision-makers to approach projects from this perspective. The proposed framework enables organizations to evaluate and select IT projects that best align with their sustainability strategies and operational constraints. Unlike previous studies, which often rely on traditional project evaluation criteria, this research introduces novel criteria such as Impact on Customer Experience, Flexibility, and Compatibility with Existing Systems, offering a more holistic approach to IT project evaluation.

Keywords: Spherical TOPSIS, Fuzzy Sets, IT Projects, Sustainability, MCDM, Decision-Making

ÖZET

Günümüzün hızla değişen teknolojik ortamında, organizasyonların hangi BT projelerine yatırım yapması gerektiğine karar vermek, çeşitli gereksinimler ve kriterler nedeniyle karmaşık bir sorun olarak durmaktadır. Bu makale, yatırım gerektiren BT projelerinin sürdürülebilirlik perspektifinden değerlendirilmesi için kapsamlı bir karar alma çerçevesi sunmayı amaçlamaktadır.

Bu çalışma, ekonomik, çevresel, sosyal ve kültürel sürdürülebilirlik boyutları temel alınarak belirlenen kriterlerin seçimi ve ağırlıklandırılması ile çok kriterli karar verme (ÇKKV) yaklaşımını benimsemektedir. BT projelerinin sürdürülebilirlik hedefleriyle uyumuna göre sıralanmasında Küresel Bulanık TOPSIS yöntemi kullanılmıştır. Çeşitli projelerin sürdürülebilirlik etkilerini değerlendirmek için Küresel Bulanık TOPSIS uygulaması için teorik bir çerçeve geliştirilmiştir.

Sonuçlar, yüksek maliyet ve uygulama riski taşımasına rağmen, Uçuş Planlama Sisteminin Optimizasyonu projesinin en sürdürülebilir BT projesi olarak öne çıktığını, onu Karbon Offset projesinin izlediğini göstermektedir. Bu bulgular, havacılık endüstrisi gibi karmaşık teknolojik ortamlarda, operasyonel verimlilik ve kaynak optimizasyonu üzerinde doğrudan etkisi olan projelerin, özellikle uzun vadeli faydalar (yakıt tasarrufu, artan bağlantı kapasitesi ve iyileştirilmiş karar verme gibi) dikkate alındığında, sürdürülebilirlik değerlendirmelerinde daha yüksek puan aldığını ortaya koymaktadır. Genel olarak, bulgular, yüksek maliyetli projelerin önemli riskler taşımasına rağmen, operasyonel verimlilik, çevresel etki azaltma ve müşteri deneyimini geliştirme gibi stratejik önceliklerle uyumlu olduğunda önemli sürdürülebilirlik avantajları sunabileceğine dair güçlü bir gösterge sunmaktadır.

Mevcut literatürde, BT projelerinin sürdürülebilirlik analizinde belirgin bir eksiklik bulunmaktadır. Bu çalışma, sürdürülebilirlik perspektiflerini değerlendirme sürecine dahil ederek ve karar vericileri projeleri bu bakış açısıyla değerlendirmeye teşvik ederek bu eksikliği ele almaktadır. Önerilen çerçeve organizasyonların ; sürdürülebilirlik stratejileri ve operasyonel kısıtlamalarıyla en iyi şekilde uyumlu olan BT projelerini değerlendirmesine ve seçmesine olanak tanımaktadır. Ayrıca, çoğu çalışmanın geleneksel proje değerlendirme kriterlerine dayanmasına karşın, bu araştırma Müşteri Deneyimine Etki, Esneklik ve Mevcut Sistemlerle Uyum gibi yeni kriterler sunarak, BT proje değerlendirmesine daha bütüncül bir yaklaşım getirmektedir.

Anahtar Kelimeler – Küresel TOPSIS, Bulanık Kümeler, BT Projeleri, Sürdürülebilirlik, ÇKKV. Karar Verme

1. INTRODUCTION

1.1. Strategic IT Project Selection

In today's dynamic technological landscape, the strategic selection and prioritization of IT projects are crucial for organizations aiming to maintain a competitive edge and optimize operational efficiency. IT has turned into the primary support of enterprises in the modern world and is a part of each enterprise, starting with customer relationship management and ending with logistics. However, due to the rising complexity of IT environments, strategic choices of which IT projects the organization should embark on has not been easy. Every organization is not only expected to address technological needs, but also bear economic, social, environmental, and cultural accountability. Silvius (2017) notes that projects play a central role in achieving more sustainable business practices and highlights the growing focus in project management research on the relationship between projects and sustainability (G. Silvius, 2017). This has culminated into a shift the way in which measurement of IT projects executed with sustainability being a key factor.

Sustainability, which was tangential in the past, has become the central, defining issue in managing organizations and their IT projects. This paper posits that the concept of sustainability applicable to IT extends beyond the narrow scope of environmental sustainability associated with the physical environment to encompass the broader dimensions of financial, social, and cultural sustainability. Therefore, an integrated approach offered by the model that strikes to assess an IT project from sustainability perspective is crucial for organizations willing to advance numerous global objectives within their organizational contexts. This shift in thinking requires the development of robust decision models to support decision-makers in considering a myriad of sustainability factors in decision-making processes, based on the understanding that projects deemed worthy of selection should not only provide short-term organizational benefits but also contribute to sustainable development in the long term. The European

Union defines sustainable development as *"progress that integrates immediate and longer-term needs, local and global needs, and regards social, economic and environmental needs as inseparable and interdependent components of human progress"*(European Commission, 2007).

Economic and financial performance assessment possesses an important role for efficient usage of available resources(Karsak & Goker, 2019). The most conventional methods of project assessment often have regard to the financial assessment where the ROI or the cost/benefit ratio is taken into consideration. Although these measures are useful, they are not sufficient to assess the effects of IT projects on the environment, society and culture. Due to these limitations, multi criteria decision making models are increasingly being applied to overcome the limitations of a narrow set of criteria in the evaluation process. MCDM enables decision makers to manage conflicting objectives such as economic and financial gains, environmental effects, and social impacts. However, especially when it comes to IT projects, current MCDM models frequently fall short of properly integrating the subtleties of sustainability. This gap in the literature emphasizes the need for a more customized strategy that blends cutting-edge decision-making methods with sustainability principles.

The purpose of this paper is therefore to develop a decision model geared towards the evaluation of IT projects considering the sustainability perspective. As this research aims at offering a set of guidelines to help organizations select potential IT projects, the framework developed herein is built around sustainability dimensions that include economic, environmental, social, and cultural. The model proposed in this study will be using the Spherical Fuzzy TOPSIS, as the evaluation method will be able to capture the fuzziness of decision making, thus can provide a more precise and accurate evaluation. The use of fuzzy sets, and especially spherical ones, can be useful in this case as they help to model the information that can be imprecise when evaluating the sustainability factors.

This research does not restrict itself to appraising IT projects in terms of their financial success only. It comes up with new and fresh factors like Impact on Customer Experience, Company's Flexibility, and Compatibility of the proposed system with the preexisting systems, which are missing in the conventional IT project selection processes(A. J. G. Silvius & Schipper, 2014). These criteria mirror the changing needs and demands of organizations as the need to incorporate customer satisfaction, functions flexibility and technology as a way of life. Also, the framework developed in this thesis highlights the value of the long view with regard to the strategic impact of IT investments and recommends that decision-makers focus on the long-term outlook when assessing IT projects.

Sustainability is one of the most critical criteria when selecting IT projects. With global problems like climate change, depletion of resources, and social inequality growing bigger, organizations are experiencing growing pressure to adapt to sustainable development goals. In this alignment the enabler is IT projects as the innovation and transformation agenda often hinges on it. In this case, an evaluation of these projects from the sustainability perspective will enable the organizations to improve on their operations while fulfilling the objectives of other members of society. This thesis aims to fill the gap in the literature by offering a novel decision-making model that integrates sustainability into the core of IT project evaluation.

In conclusion, this thesis contributes a decision model that integrates MCDM and sustainability criteria to facilitate a holistic evaluation of IT projects. The model will then be tested utilizing case studies in the aviation industry given that they incorporate intricate IT systems and sustainability concerns. The conclusion of this study will provide insights to organizations that can be used in prioritizing IT projects that should enhance organizations' strategic plans and sustainability initiatives, hence resulting in a sustainable approach to the implementation of IT projects.

1.2. IT Projects and Their Relations with Sustainability

In the current world of business, sustainable development and its incorporation into organizational management processes is very crucial. IT is central to this change process because it improves organizational effectiveness and has a direct impact on sustainable development objectives. The management of IT projects can shift from being a negative influence on the environment, social relations as well as economic rationality into a positive force that enhances environmental sustainability, fairness and profitability. Such projects are agents of change that help organizations to solve multifaceted global problems, like climate change, scarcity of resources, and social injustice (Piotrowicz & Cuthbertson, 2009).

There are numerous aspects of IT and sustainability. On one hand, the implementation of IT systems can bring benefits such as efficiency gains, optimal utilization, and minimizing of waste. For example, cloud computing, big data analytics, and automation technologies enable organizations to reduce their brick infrastructure while enhancing utilization. However, in IT projects concerning the development of various solutions, social and cultural sustainable aspects need to be incorporated to ensure technology is useful to all the stakeholders, promotes equality, and does not disrespect different cultures. Furthermore, successful integration of sustainability initiatives to IT projects enhances an organization’s capacity to manage change by addressing dynamic regulatory standards and consumer expectations.

In the context of the airline industry, where environmental pressures and operational costs are considerably salient factors, IT projects present profound instruments for managing sustainability issues. From avoiding carbon emissions by implementing better flight management techniques to improving customer satisfaction with advanced digital solutions, that is exactly what IT projects offer airlines to achieve their sustainability goals(Parsa et al., 2019). While companies endeavored to find ways to make profits while also being socially and environmentally responsible, the position of IT in supporting sustainability efforts is more important. As a result, project sustainability assessment is critical for IT projects within organizations that seek to be relevant in a competitive environment that prioritizes sustainability.

In this context, we will examine both innovative and non-innovative projects to be implemented in an airline company (Turkish Airlines) with a high passenger capacity and a large software workload in terms of sustainability. The problems faced by this company are generally the same as those faced by many institutions. In addition, these problems can be solved by implementing challenging projects in various areas on a large, medium and small scale. These solutions may not have an impact on the ground aspect of sustainability, although they are rarely effective; for example, even if a project is beneficial in terms of economic sustainability, it may not contribute to social sustainability at all. In summary, the IT projects of an airline company are discussed below. Although the project examples given include IT projects in different areas of an airline company, they can be adapted to many companies. The reader of this thesis should consider the projects and their sustainability reviews in this section together with the explanations mentioned in the criteria section Key Criteria for Sustainable Project Selection.

2. LITERATURE REVIEW

This literature review is structured into two key sections to comprehensively examine the existing body of knowledge on IT Project Selection topic. The first section, 'Sustainable IT Innovation and Importance of Sustainability in IT' explores the significance of IT sustainability. The second section, 'Decision-Making Frameworks in IT Project Selection' delves into the contemporary methodologies employed in assessing IT projects. By elaborating on both the importance and the methodologies, this review aims to provide a holistic understanding of the current practices and emerging trends in IT project evaluation and selection.

The aim of this literature review is to reveal previous studies with regards to Project Evaluation and Selection Methods (PESM) on IT, and its relations to Innovation and Sustainability notions. A search has been handled the keywords of ("Project Evaluation") OR ("Information Technology" and "Project Selection") OR ("Information Technology " and ["Project Evaluation" or "Sustainable" or "Innovation"]) as title. Then, the abstract or keyword parts are reviewed in EBSCO and Google Scholar databases. The articles that are out of scope were eliminated, a thorough analysis was conducted on the remaining articles.

2.1. Sustainable IT Innovation and Importance of Sustainability in IT

Sustainable IT innovation is a collaborative management approach which involves the support of ecological and social factors into technological development. It aims to develope information technology solutions that favour conservation of the environment, along with economical feasibilty. Sustainable innovation enhances the process of change in technology, products, and marketing opportunities that are compatible with entrepreneurship (Larson, 2000) . It also refers to the creation of sustainable business models that are useful in guaranteeing the sustainable impacts in the long-run

(Geissdoerfer et al., 2018). Thirdly, sustainable IT innovation requires a balanced and systematic approach to quality as well as innovation to improve the quality of society.

IT departments help the core business by facilitating the processes or augmenting with tools such as ERP systems, useful API services and opsimization projects to enable data driven decision making. They streamline processes like supply chain operations whilst also ensuring data security and regulatory compliance. It also creates innovation, enabling new products and services to be developed that generate business growth or even take off by launching innovative products.

Through digital solutions such as cloud computing and paperless operation, IT departments improve resource efficiency and decrease environmental impacts, and contribute to the sustainability, too. They are in support of social sustainability through their transparency, equitable information access and remote work opportunities. IT departments support green initiatives and help organizations align their operations with the environmental regulations to achieve long term sustainability goals.

As discussed in Paul's book(Weaver et al., 2017), wealthier nations should aim for at least a tenfold increase in the efficiency of natural resource and environmental service utilization by 2050, while simultaneously developing sustainable resources to expand the resource base and replace unsustainable alternatives. Sustainability in IT is a key necessity for companies and goverments to respond to global challenges in the modern world like climate change, resource scarcity or social injustice. Sustainable IT innovations or projects are desirable components for achieving sustainable development agendas, as they make provision of solutions that are both economically vibrant and environmentally sustainable. In addition, sustainable IT innovations assist in creating environmentally friendly technologies and procedures that help in reducing emissions and are socially responsible (Pandya et al., 2024). Sustainable innovation enhances the process of change in technology, products, and marketing opportunities that are compatible with entrepreneurship (Larson, 2000) .

2.2. Decision-Making Frameworks in IT Project Selection

2.2.1. Traditional vs. Sustainable Approaches

Existing methodologies for IT project selection, selection criteria, and project prioritization mainly focus on technical and cost-based criteria, which do not consider environmental and social considerations. On the other hand, sustainable aspects capture more parameters, such as economic, environmental and social aspects to provide a balanced solution (Vollenbroek, 2002). Sustainable innovation is about creating new forms of constructing and bringing new values to the market that fit within the sustainability paradigm(Seebode et al., 2012). This transition from the conventional approach to the sustainable framework is imperative given the nature of the contemporary IT projects.

2.2.2. MCDM Techniques for Project Evaluation and Selection

Lee used Analytic Network Process (ANP) within a Zero-One Goal Programming (ZOGP) model for Information Systems (IS) project selection, focusing on recognizing and modeling project interdependencies (Lee, 2000). Orlowski proposed a mixed-methods approach that uses both qualitative and quantitative techniques, with an emphasis on employing fuzzy logic principles to express various project description aspects (Orlowski, 2002). The methods used are defuzzification of the output data, inference using the rule description, and fuzzification of the project conditions using the membership function. (Thomaidis, 2006) was created for project evaluation and used a fuzzy set-based approach to evaluate IT projects within a multi-criteria decision-making framework. It includes synthesizing evaluation teams, ranking the criteria, evaluating alternative performance, and ranking projects by combining fuzzy sets theory with classical multi-criteria decision analysis. (Rosacker, 2008) examined the use of financial and qualitative project selection and evaluation methodologies in state government IT project selection. Asosheh implemented a combination of the Balanced Scorecard (BSC) and Data Envelopment Analysis (DEA) methodologies to propose a new approach for IT project selection (Abbas Asosheh, 2010). According to Asosheh the optimal selection procedure is a crucial strategic resource allocation resolution that can engage an organization in considerable long-term commitments.

After 2010, studies on IT Project selection have reduced, but studies on common project selection problem has maintained. In order to evaluate and improve Six Sigma initiatives, (F. K. Wang et al., 2014) applied a hybrid MCDM model that combined the Decision MAking Trial and Evaluation Laboratory (DEMATEL), ANP, and VIKOR methodologies. This model handled inner and outer dependencies, ranked alternatives according to performance and ambition levels, and identified influential relationships. (Pangsri, 2015) used the methodical approach to group decision-making by implementing Delphi method, AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Expert opinions determine selection criteria, AHP assigns criteria weights, and TOPSIS evaluates alternatives. (Mohamed Abdel-Basset, 2019) integrated TOPSIS into DEMATEL within a neutrosophic environment, and handling ambiguity with neutrosophic set theory. In the work, weighted criteria executed by DEMATEL and chose the best project alternative with TOPSIS. Mohammed (2023) used Fuzzy AHP to determine the criteria's preference weights. In the study, the portfolio approach implemented by fuzzy TOPSIS to enhance project alternatives to meet organizational strategy and project interactions (Mohammed, 2023) .

Multi-Criteria Decision-Making (MCDM) methods such as the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Analytic Network Process (ANP), and ELimination Et Choix Traduisant la REalité (ELECTRE) are prominent in the evaluation and selection of IT projects. These methodoglies assist in systematized evaluating comlicated decisions that involve diverse and even conflicting criteria. The implementation of these methodologies provides more concrete and stable solutions to decision-makers, also enhances holistic efficiency of project selection.

AHP is a method to analyze complicated decisions. The main superiority of AHP is that decision-makers who have a low mathematical background may take advantage of it because of its lucidity and simple usage. On the other hand, the subjectiveness involved in weight assignment can generate bias, and its dependence on pairwise check can endanger the consumption of time, especially for large decision matrices (Saaty, 1990) .

AHP enables decision-makers to miniature a complicated problem in a hierarchical structure, along with breaking it down into smaller, more manageable parts. Each level of the hierarchy can be regarded as decision criteria, which can be evaluated alone. AHP is especially efficient in IT project selection because of its ability to handle both qualitative and quantitative input. For example, Amiri (2010) utilized AHP to select and prioritize criteria for oil-field projects, demonstrating its effectiveness in complex, multi-criteria environments(Amiri, 2010).

ANP enhances AHP via taking into account the dependencies between decision attributes and substitutes. This is an advantage of ANP for a little bit more complicated decision problems than the completely independent criteria. Biagi et al. (2021), ANP was used for ranking IT projects to take the dependencies between the different project criteria and the strategic objectives of the organization in account (Biagi et al., 2021). ANP is characterized by its unique ability to model complex interrelationships among the decision factors. However, inherent to the strength of the model also lay its weakness; the model is quite complex that often took a considerable amount of time and expertise to design the network and compute the calculations(Abildtrup et al., 2006).

The use of the Analytic Hierarchy Process (AHP) in IT/ project selection provides a structured and multi-criteria approach to decision-making, addressing both objective and subjective factors. In sustainable project selection, FAHP (Fuzzy AHP) extends AHP by incorporating fuzzy logic to manage the ambiguity inherent in expert judgments, ensuring criteria such as project cost, novelty, and uncertainty are evaluated with precision (Alyamani et al., 2021). Traditional AHP methods, as demonstrated by Muralidhar et al. (1990), align project objectives with organizational goals by prioritizing competing projects through pairwise comparisons, offering a clear framework for decision-makers (Muralidhar et al., 1990) . Additionally, Kulak and Kahraman integrate fuzzy axiomatic design with multi-criteria decision-making to refine IT project evaluations, particularly when data is vague or uncertain, enhancing the decision-making framework. These studies demonstrate AHP’s flexibility and effectiveness in IT/IS project selection, whether through direct application or integration with fuzzy logic, allowing organizations to make informed, structured, and goal-aligned project decisions under varying levels of complexity(Kulak et al., 2005).

The application of these MCDM methods in sustainable IT project selection presents powerful tools for evaluating projects based on numerous factors concerning sustainability. Likewise, TOPSIS was used by Frini and Benamor (2015) to select sustainable development projects emphasizing different time horizons and balancing economic, environmental and social criteria(Frini & Benamor, 2015).

A broad approach is necessary to embrace sustainability into the selection of IT projects, taking into account not just the financial earn but also the effects on the environment and social fairness. The resources required to manage these sophisticated evaluations are provided by MCDM techniques. The context and needs of the decision issue appoint which approach is the most preferable and logical; as mentioned above, every method has its own set of advantages and pitfalls.

As for TOPSIS, it is a methodology which is relies on the notion that the selected alternative should be the closest to the optimal solution and the farthest from the non-optimal solution. This method is specifically helpful in rating and selecting amongst limited alternatives. TOPSIS is useful as it is easy to understand, and it can easily prove to provide a clear ranking of alternatives. However, this method assumes that criteria are usually increasing or decreasing, which may not always be. Moreover, the method treats the criterion as independent, which might lead to missing out on some complex interaction amongst the criteria (Hwang & Yoon, 1981).

A robust framework for MCDM based on TOPSIS is extensively applied in IT and sustainability contexts. With TOPSIS, alternatives are ranked based on their distance to an ideal positive solution and ideal negative solution in order to rank alternatives based on objective and data driven basis.

In IT project selection, a study integrated entropy weight methods with TOPSIS to strengthen the reliability of rankings under conditions of uncertainty. A hybrid approach with weights assigned objectively for different criteria based on information entropy reduces subjective bias in selecting information systems (Huang, 2008) . In addition, the method has been applied to sustainability related MCDM problems. For instance, Ma et al. (2020) used fuzzy topology to develop fuzzy TOPSIS which takes fuzzy logic to process the inherent vagueness in linguistic assessments. The study illustrates how this approach can more accurately model complex decision situations involving environmental and operational sustainability (Ma et al., 2020).

Fuzzy–TOPIS has been used in yet another study of the domain of industrial applications as a tool for evaluating system reliability by transforming qualitative data into quantitative insights and one more time showing the flexibility of the method (Taylan et al., 2014). The study by Damghani & Nezhad (2013) presents a sophisticated integration of fuzzy TOPSIS with DEA to enhance decision-making in project selection. Their approach aims to address both qualitative and quantitative aspects of project evaluation, transforming linguistic judgments (such as "high risk" or "moderate quality") into numerical values through fuzzy logic. By combining these two methods, the study leverages the strengths of DEA in evaluating efficiency while using TOPSIS to rank projects based on proximity to an ideal solution

TOPSIS and its fuzzy extensions are very flexible, these studies show applicability across several decision-making landscapes, applications where they are especially useful in improving decision consistency and taking uncertainties associated with complex evaluations into account through the lens of IT management and sustainability.

3. THE IT PROJECTS AND SUSTAINABILITY CRITERIA

3.1. The Details of Evaluated Projects

In this study, different projects are carried out using information technologies on the agenda of an airline company were examined and their contribution to sustainability was taken into account. In this context, decision makers evaluated the contribution of each project to sustainability when evaluated from an economic, environmental, social and cultural perspective.

3.1.1. Expand the Use of Cloud Technology (Project 1) (P_1)

Cloud technology which replaced the conventional physical data centers is a concept in addressing IT infrastructure for the airlines. Earlier, airlines employed physical data centers that demanded capital expenditure in hardware infrastructure such as servers or storage peripherals as well as operating expenditure in terms of power, cooling, and protection. These systems were not very flexible hence could not be adjusted to suit the changing operational requirements, thus leading to inefficiencies and high operation costs. On the other hand, cloud technology is more flexible, scalable, and comparatively cheaper as compared to the tradition technology. It allows businesses to add or reduce resources based on demand, which means it is easy to expand or even reduce the resources used depending on business operations. Cloud manufacturing increases sustainability through collaborative design, greater automation, improved process resilience, and enhanced waste reduction, reuse, and recovery(Fisher et al., 2018).

It is also evident that cloud systems offer a number of advantages as it relates to cost control. There is always capital expenditure involved when adopting cloud solutions, but the overall costs in the long run will be less than the initial investment. Cloud providers more often than not, provide the pay per use styles where users are charged based on resource use. This helps to minimize the costs involved in maintaining and enhancing fixed structures like data centers. Also, energy costs for usage, security, and maintenance of physical hardware are lower considerably. Another important financial advantage is the possibility to grow the infrastructure and not overpay for it. Due to cloud solutions, airlines can handle higher workloads during the high demand season, while avoiding overloading of resources during low demand. Lastly, cloud-based technology has positive effect on supply chain integration, and the cloud-enabled supply chain integration is positively related to supply chain performance which eventually influenced firm sustainability (Shee et al., 2018).

However, migration to cloud technology is not without its risks. The first of them is related to data security issues. It is also important for companies to adopt strict security measures and ensure that the cloud systems they are subscribing to have adequate security measures against cyber terrorism and data theft. Another issue that is of concern is the issue of dependence, where relying on one cloud service provider might prove costly in case of service interruptions or changes in the terms and conditions of service provision by the provider. There are also legal and regulatory hazards in highly regulated businesses like aviation, especially reporting data privacy and protection legislation. It is, therefore, important to develop proper strategies and choose the right vendor in order to minimize these risks.

The cloud systems also play their part in enabling innovation in the IT departments in terms of the computing power and the storage architecture for emerging technologies like big data analytics and AI. These systems enable the formulation of relevant solutions, for instance, airline companies can utilize these systems to work on predictive models, real-time data aggregation and automation in an effort to increase their operational efficiency and customer satisfaction. Cloud technology integrates well with the concept of digital transformation plans that are critical in keeping the airlines relevant in the global market. Moreover, the use of cloud infrastructure provides a platform for future related technologies since it provides the flexibility to meet emerging market and technological requirements.

3.1.1.1. Sustainability Role of Cloud Technology

Cloud technology adoption corresponds well with some of the sustainability goals as outlined below. From the economic sustainability point of view, cloud systems are cost-effective means of business since they do not require the construction of physical structures and energy for their use. It becomes easy for airlines to manage their IT needs in a scalable manner, without having to incur the costs of having several servers that are not used during some time of the year. Such cost efficiencies contribute to financial viability and enable the funding of other areas of development and service enhancement.

Regarding the sustainability of the environment, cloud systems minimize the amount of energy used by physical data centers which require cooling and power to operate. Sustainability goals can be met by shifting to cloud solutions since it helps airline companies to reduce their carbon footprint. Another aspect of cloud computing is that cloud providers manage data centers with improved energy efficiency, which reduces the environmental footprint of IT infrastructures even more. In the same respect, since airlines do not need to purchase new physical hardware, there is less electronic waste produced by old hardware(Chang et al., 2010).

An improvement in social sustainability can also be observed due to the benefits that cloud systems bring to both the company's staff and customers. The flexibility and effectiveness in managing cloud-based IT make it easier for the employees to work and less stressful and more enjoyable to work. In addition, through cloud systems, one can establish service inclusion features, including real-time access to the passengers with disabilities, thus enhancing social inclusion and equality.

As for the cultural sustainability; cloud systems are often integrated with automated data backup and disaster recovery solutions. This can reduce the risk of data loss and ensure business continuity. However, the security of cloud systems depends entirely on the configuration of users and the security policies implemented. Misconfigurations, inadequate access control, and weak encryption policies can lead to security vulnerabilities in cloud systems. Therefore, as it can be considered more reliable and have positive impact on cultural sustainability.

3.1.1.2. Evaluation of Project 1 According to Specified Criteria

From a perspective of technical feasibility, cloud systems have numerous benefits over the conventional data centers. Many solutions run on the cloud, and the management of resources and performance of the program or system is relatively easy in this case. However, there are always some difficulties which might appear during the migration process, for example, data transfer problem, or compatibility problem with other systems. Solving these issues needs a lot of planning, and the collaboration of professional IT personnel to accomplish the changes with minimal disruption of operations (Kumar & Vidhyalakshmi, 2012).

From the resource point of view, cloud systems provide less concentration of actual resources like servers and energy, which makes them environmentally non-harmful. Also, another advantage of cloud platforms is that technical requires less on-site IT staff for maintenance, thus freeing up the human capital to undertake more fruitful tasks. But, efficient human resources are still required to monitor cloud systems and all the processes that occur in them to meet security requirements. The benefits of cloud technology can only be fully realized if there is a proper training of employees and offering of training programs for up skilling of the employees.

Cloud technology has a huge influence to the internal users as well as the external users. While for the employees, the facility of working under cloud platforms that has provided them efficient and fast access to different systems and data has proved to be beneficial to their work satisfaction.

3.1.2. Strengthening Cybersecurity Infrastructure (Project 2) (P_2)

In the current world where airlines have adopted the use of digital systems in almost all aspects of their operations ranging from booking systems to the flying operations, having a secure system free from hackers is very important to secure information and to avoid disruptions in operations. The "Strengthening Cybersecurity Infrastructure" project to enhance the airline's protection against cyber threats through the use of best encryption methods, threat monitoring, multi-factor authentication and intrusion detection methods. These are measures that aim at safeguarding not only the passengers' information but also other important operational systems that are vital for the proper running of the airline.

Alternative to the Project: Before implementing this complex cybersecurity system, most airline companies used conventional systems that provided only firewalls and simple antivirus programs, as well as the reactive security measures. Although the systems provided this basic security, they were incapable of handling today's complex cyber threats to aviation. The conventional cybersecurity approach was a reactive one that was based on responding to incidents after they happened, and this came with many drawbacks such as longer recovery time, loss of data, and fines. However, the revised structure of cybersecurity focuses on the identification of threats and their immediate prevention, rather than reacting to threats as they occur.

Cost Comparison: In the context of costs, legacy systems were cheaper in the beginning because they incurred less expenses and did not need advanced tools. But it increased long-term costs because of security threats, regulatory penalties, and business disruptions. The new cybersecurity system requires higher initial investment in technology and personnel training, but the potential losses from cyber-attacks, including data leaks, downtime, and potential legal and reputational repercussions, outweigh the initial costs. Also, procuring advanced cybersecurity technology aids in the protection of consumer data from hackers' attacks, which is mandated by the contemporary data protection law that has severe implications for organizations that fail to adhere to its provisions.

Risks Associated with Implementation: Despite the positive effects that the project has in achieving the vision and mission of the organization, it is important to state that it has its own disadvantages. This, for instance, raises the issue of compatibility of new security measures with the current IT platforms. Difficulties with compatibility may arise during implementation, sometimes resulting in data loss or brief system breakdowns. Another difficulty is making sure that all staff members have received the necessary training to utilize the new security technologies and adhere to updated protocols, which calls for a dedication to thorough training initiatives. Finally, in order to prevent being exposed to service interruptions or modifications in vendor terms, the airline must employ caution while managing its reliance on outside cybersecurity suppliers.

3.1.2.1. Sustainability Role of Cybersecurity

Economical Sustainability: Cybersecurity issues constitute a key concern of today's technology-based economies. Cybersecurity has become a core need for providing a sustainable and safe society to online users in cyberspace (Sadik et al., 2020). Enhancing cyber security framework is directly linked with economic viability considering the fact that the airline will not lose any amount of money from the attacks of hackers and system crashes. Such incidences can lead to considerable expenses; penalties from failure to observe data protection laws, attorney fees, and reimbursement of the customers. Furthermore, there are intangible losses that may occur as a result of cybercrimes such as losses due to reputational damage that may take time to recover since customers may shift to the competitors. Apart from avoiding such costs, the airline also gains on efficiency by proactively addressing security issues in the use of IT systems.

Environmental Sustainability: Safeguarding of IT systems assist to prevent the operations disruption that may cause high utilization of resources. For instance, if the airline's flight management systems are hacked then rerouting of flights can be negative impacting fuel efficiency and thereby emissions. In this sense, through its digitized network security, the airline makes a contribution to its other environmental initiatives, for instance, in terms of optimal use of its flights and resources for the least environmental impact possible.

Social Sustainability: The digitalization of society has brought about various occasions for sustainable development. However, it has also introduced a diverse challenges, particularly in the realm of cybersecurity(Adebimpe Bolatito Ige et al., 2024). From social perspective, cybersecurity is important to prevent the vulnerability of the passengers' and employees' personal and financial data. Airlines process a lot of information and if it leaks, it can cause a lot of problems such as identity theft, fraud, and loss of confidence. Effective implementation of infrastructure for cybersecurity protection guarantees that the customer data are well protected thereby improving on customer satisfaction and customer loyalty. As is the obligation of any industry, the aviation sector continues to strive to improve the quality of services provided and enhance customer experience (Ukwandu et al., 2022). Cybersecurity also protects the privacy of the employees as well as their information, thus promoting a safer and more secure working environment and in turn, social sustainability since customer and workers are assured of their safety.

Cultural Sustainability: In terms of culture, the preservation of data is considered as the human right and this project reflects the ethical and legal responsibilities of the airlines in the different parts of the world. Through bolstering cybersecurity, the airline guarantees adherence to international data protection standards, including the General Data Protection Regulation (GDPR) in Europe and other regional privacy statutes. In an increasingly culturally varied global market, the airline's reputation as a responsible and ethical entity is enhanced by its observance of local laws and cultural norms around privacy.

3.1.2.2. Evaluation of Project 2 According to Specified Criteria

In a dynamic new world where new technologies produce portable devices that are seamlessly connected to well-established, on-line systems, cybersecurity solutions need to be able to be swiftly updated and re-calibrated, so that new cyber threats can be effectively detected and mitigated(Koroniotis et al., 2020). The Strengthening Cybersecurity Infrastructure project is also compatible with the airline’s strategic goals of carrying out operations with adequate protection and meeting legal requirements. Despite the high costs that are usually incurred during the initial stages of establishing an effective cybersecurity system, the benefits in the long run are numerous. Reducing the risks of data leakage, system failures, and fines protects financial stability, maintaining constant revenue, and stabilizing the airline’s dignity. As well, it is crucial to ensure customer data security to retain customer confidence and, in turn, affect customer retention and revenues.

From the risk management point of view, this project is critical for minimizing the increasing risks of cybercrimes in the context of digitalized aviation business. Another obvious benefit is the constant reduction of operational and financial risks associated with the timely introduction of threat detection and encryption systems, which allows the airline to remain in compliance with increasingly stringent data protection legislation. In addition, the project involves implementing new security features, namely artificial intelligence-based security and surveillance, which place the airline on the cutting edge of cybersecurity technology. All in all, it is not just a technical project but a strategic one that is vital for the airline’s sustainable and competitive future.

3.1.3. Optimization on Flight Planning System (Project 3) (P_3)

With increasing air traffic, rising fuel costs and tighter environmental targets, efficient airport ground operations are one of the key aspects towards sustainable air transportation

(Weiszer et al., 2015). The emphasis of the Optimization on Flight Planning System project is on improving both the efficiency and profitability of the airline's scheduling of flights and distribution of its fleet. There is an increasing demand for air transportation, not only in terms of passengers but also in terms of logistics, creating a competitive environment in the industry (Demircan & Kaplan, 2023). Airline flag carriers, such as Turkish Airlines, deal with complicated challenges related to fleet planning, aircraft routing, and maintaining robust connectivity in their network. The aim of this project is to meet these challenges by refining the airline’s flight schedule and improving how it manages its fleet and routes. Improving passenger connectivity, raising profitability by better fleet allocation, and minimizing costs associated with inadequate slot usage and excess capacity are the main objectives for generating a competitive advantage. The model that will be established reoptimizes departure times to take into account the sequences of activities that have to be carried out within all aircraft routes and crew rotations. Fixed rotations allow complicated resource constraints to become simple backward arcs in the proposed network(Stojković et al., 2002).

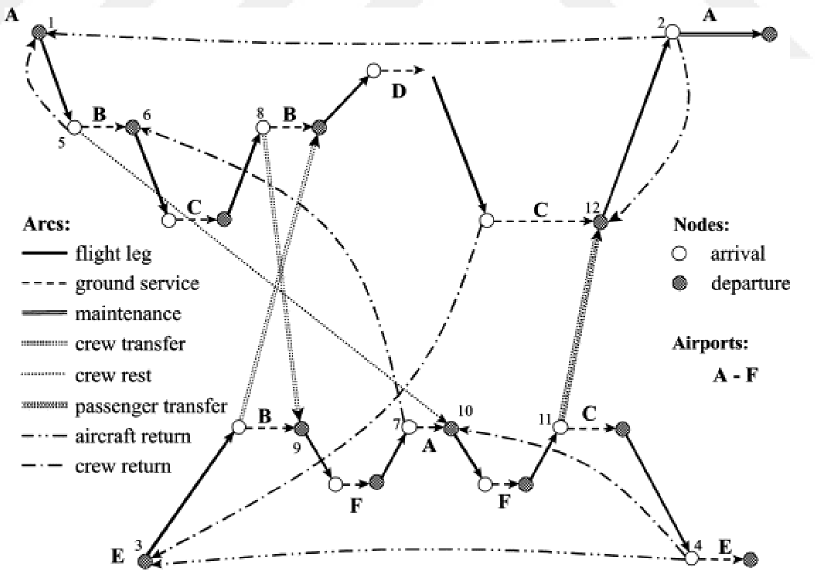

Figure 3.1 A network with two aircraft and five crew itin. (Stojković et al., 2002)

The intention of the project is to find the best fleet composition necessary to cover all scheduled flights, so as to maximize connectivity within the airline's network. The objective function used in this optimization process takes into account several key factors: the general profitability of fleet allocation for every flight, the value of linking passengers, the profitability of individual routes, and the costs incurred as penalties for exceeding allocated airport slots. The use of data drives approach ensures flight planning is both more efficient and in harmony with operating and profitability goals.

Alternative to the Project: In advance of the optimization initiative, the flight planning system of the airline was based on a more standard and less unified approach for fleet and route management. Such an approach commonly entailed handmade changes to flight schedules informed by historical data, accompanied by little real-time optimization or predictive analytics. As a consequence, the airline encountered a number of inefficiencies, such as inadequate fleet allocation, unutilized aircraft on certain routes, and fails to capture opportunities for enhancing passenger connections. In contrast, the novel optimization model embeds real-time data and sophisticated analytics, permitting more dynamic scheduling and improved fit with market demands and operational objectives.

Cost Comparison: The project for optimization involves a major initial outlay for the development or upgrade of software systems, the training of personnel, and the procurement of advanced analytical tools, but the enduring cost benefits are considerable. The previous system operated well, but it did lead to inefficiencies including the overuse of pricey airport slots, fleet capacity underutilization, and lost opportunities for enhancing route profitability. The inefficiencies lead to direct financial costs (because of penalties for exceeding slot usage) and also indirect costs (including lost revenue from suboptimal passenger connections). Differently, the optimized flight planning system lessens these costs by bettering fleet allocation, increasing aircraft utilization levels, and optimizing route profitability.

Risks Associated with Implementation: A principal threat to the project is the possible disruption that may occur during the changeover from the old system to the optimized planning system. Embedding newly developed optimization algorithms into existing infrastructure may result in transient delays or problems concerning system compatibility. Furthermore, there exists a risk that staff resistance will occur due to their familiarity with the usual methods of flight planning. In addition, an additional risk is the precision of the input data in the optimization models; if the data is lacking or incorrect, the model might generate suboptimal results. In order to lessen these risks, the airline has to run extensive tests on the system prior to full implementation, ensure that staff receives sufficient training, and confirm that the data in the model is accurate and current.

3.1.3.1. Sustainability Function of Optimization on Flight Planning System

Economic Sustainability: The primary economic advantage of the project is the serious increase in operational efficiency and profitability. Optimizing fleet allocation and flight schedules allows the airline to get the most out of its aircraft and cut down on the frequency of empty flights. This has a direct impact on profitability for routes and helps to reduce the expense of preserving excess capacity. The flight planning transformation is closely related to the concept of economic sustainability because it increases fuel efficiency and minimizes operating expenses. Fuel is one of the largest expenses for airlines, and even minor route optimizations can translate into significant cost savings. The efficiency is the result of integration of flight planning systems driven by artificial intelligence that allow to decrease fuel consumption, choose the best flight route, avoid delays and, in this way, implement essential cost-saving measures. Apart from the effect on fuel consumption, the automation of scheduling and routing also eliminates the requirement for human effort, thereby lowering operational costs.

Environmental Sustainability: From an environmental perspective, the flight planning transformation constitutes a significant and an important component in the impact of the airline's carbon footprint. Through more efficient flight planning and real-time rerouting based on current weather conditions, traffic density, and airspace restrictions, the new system is estimated to produce minimum 20% less fuel burn and CO_2 emissions. This also benefits the airline in its environmental management agenda because emissions of greenhouse gases are reduced while resource utilization is optimally done. The project contributes towards the reduction of aviation's negative effects on the environment, as a result, it enhances the airline's sustainability plan.

Social Sustainability: As for social sustainability, the project helps to enhance the quality of service for passengers and working conditions for employees. For passengers, improved flight routes reduce cases of delays and cancellations hence enhancing satisfaction. Also, service scheduling and route planning cause less pressure on employees, especially pilots and ground staff, who can plan their work with greater reliability. This makes the environment safer and less gendered, which benefits the employees' health and increases the company's recognition as the socially-oriented employer.

Cultural Sustainability: The project also contributes to cultural sustainability by increasing services that are more consistent and culturally appropriate. Through effective flight planning and the integration of real-time information, the airline can provide accurate and timely services to passengers of different cultural backgrounds. For instance, flexibility in the sense that the airline can easily modify schedules to attend to cultural/religious travel demands enhances its inclusiveness. Furthermore, the project enhances the flight route planning and reduces the delays, and this means that those individuals who are flying to attend important cultural or family occasions will not be inconvenienced.

3.1.3.2. Evaluation of Project 3 According to Specified Criteria

The Flight Planning Structure Transformation Project directly supports the airline's strategic goals concerning operational effectiveness, cost optimization, and long-term viability. Despite the fact that the implementation of advanced flight planning systems may involve high initial costs, the savings in terms of fuel, time and customer satisfaction ultimately justify the investment. From the risk management point of view, the project relates to the significant problems like poor fuel consumption, timetable management, and operational disruptions which are potentially dangerous for the financial and image security of the airline. On the same note, the project is about cutting fuel usage and emissions to help the airline meet its environmental objectives and contribute to sustainability endeavors in the aviation sector.

As for innovation, it is possible to examine the transition to the use of AI in processing real-time data as a major advancement for the airline. These innovations do not only enhance service delivery but also enhance the image of the airline in terms of environmentally friendly practices in aviation. It can be implemented with low risk of disruption by stabilizing it in phases; the stages will enable the phasing of the new systems while minimizing disruption. Furthermore, the skilled human resources available to oversee and support the new systems and infrastructures guarantee that the project can be carried out to its fruition and then continued in the long run.

Based on the above findings, the client and other stakeholders will significantly benefit from the project. From the standpoint of passengers, the application of the better flight planning system has an added benefit of cutting down on the number of delays and cancellations. In employees' perspective, automated schedule and route offer easy working plans to manage workload and enhance job satisfaction. In conclusion, the Flight Planning Structure Transformation Project they have undertaken is a strategic business investment that would enable the airline to sustain its operations and competitiveness in the future years through efficient and responsible operation in light of the increasing stringency of the rules and regulation of the airline operations.

3.1.4. ERP Transformation Project (Project 4) (P_4)

The ERP (Enterprise Resource Planning) Transformation Project is a project that was designed to upgrade the existing ERP system of the airline to a better version. Although the current ERP system has been helpful in facilitating many business processes, such as financial, procurement, and human resource management, it is no longer adequate to suit the increasing needs of the airline. Air transportation not only provides both employment and earnings but also acts as the backbone for mobility and supply chains(Büyüközkan et al., 2021). The new ERP system is expected to address these issues by integrating systems, increasing data accuracy, and supporting real-time decision making across functional areas. This transformation is crucial for the improvement of processes, better usage of resources, and the ability to manage growth in an industry that can change at any given time. Organizations still have problems in collecting, integrating and reporting sustainability information. The lack of integration affects the sustainability productivity and effectiveness. To solve this problem, the organizations need to have an integrated information system, such as S-ERP (Sustainable Enterprise Resource Planning) system(Chofreh et al., 2014).

Challenges with the Current ERP System: The current ERP system in place is adequate but it has several drawbacks which restrict airline operations. One major problem is the absence of guaranteed time-integrated data. Currently, there is a need to transfer the information manually from one department to the other, which may lead to delays in decision-making processes, as well as errors. Another problem is the weak capacity of the old system to accommodate the growing number of transactions and data in light of the airline’s expansion. Also, the current ERP has a poor and complex user interface, leading to low usage and increased training expenses. The previous ERP system does not come equipped with some of these features such as artificial intelligence in analyzing data and providing insights for better resource utilization or demand forecasting.

Cost Comparison: In moving to a new ERP system, firms incur a fair amount of cost in the form of license fees for the software, costs of implementation, and staff training costs among others, nevertheless, the later costs outweigh the former. The flaws in the legacy ERP system entail expenses that are not immediately apparent, such as duplicated effort in managing data, time consumption in manually altering data, and additional costs from system constraints. For example, delays in financial reporting, inventory management, and procurement are caused by the antiquated system's incapacity to handle real-time data flow. These delays might result in fines or missed income opportunities. Long-term cost reductions are substantial due to the new ERP system's capacity to automate several operations and deliver real-time insights, as well as its potential to increase efficiency and decrease manual involvement.

Risks Associated with Implementation: There are risks involved in moving from one ERP system to another; specifically, there may be data conversion problems, system outages, and some level of disruption in business operations during the switch. Another significant threat is that which arises from a new system and the time it takes for the employees to learn and adapt to it. Those who have previously used the old version of the ERP are likely to learn new interface and features, which will take some time hence slowing down the operations. This is because compatibility concerns may emerge with regard to the integration of the new ERP with other legacy systems in use by the airline.

Nevertheless, these risks can be managed by proper planning and staged implementation as well as extensive training in the use of the technology.

3.1.4.1. Sustainability Role of ERP Transformation

Economic Sustainability: The new ERP system affects the economic sustainability by now having efficient business processes and less costs. This is because, when manual tasks such as the processing of payroll, procurement, and financial reporting are automated, the airline is able to reduce its labor costs and also reduce the likelihood of errors. Further, the new ERP system offer real-time data that enhances on the resource utilization, budgetary control, and decision-making processes. This increased efficiency translates directly to the airline's bottom line and also enables it to grow its operations at a much faster rate than the corresponding increase in the overall administration costs. However, by incorporating AI analytics in the operation of the airline, more efficient decisions can be made regarding the use of resources which will in turn eliminate wastage.

Environmental Sustainability:It was found that the new ERP system enhances sustainable development by increasing the efficiency of resources used by the airline. For instance, enhanced management of inventory and procurement to minimize wastage and increase the effective utilization of resources like fuel, parts, and materials. Moreover, with the help of the ERP system, it is easier for the airline to track sustainability metrics and, specifically, their carbon footprint in areas such as fleet and fuel management. The automation of reporting and data consolidation also eliminates the use of papers and paperwork, which in turn helps the airline save on papers and hence support its environmental goals.

Social Sustainability: From the social aspect, the new ERP system increases employee satisfaction by minimizing the paperwork and making processes clearer. By having an easy to use interface, the new system allows the employees to easily find the information they need without much trouble and hence improving their job satisfaction. It also improves the visibility of the HR practices like payroll, performance appraisal, and benefits administration; thus, creating a more responsible organizational culture. Furthermore, by eliminating repetitive work, the idea of automation results in increased interest and productivity of the workforce, thus contributing to the airline's social sustainability.

Cultural Sustainability: The change made through the implementation of ERP also fosters cultural sustainability because it enhances the interaction among the employees as well as the organization. The fact that the new system can manage operations in a number of regions, languages, and regulations is a perfect fit for the airline and its employees and customers. For instance, the system can address local legal requirements in different countries and can accommodate multiple languages and money types. This enables the airline to work in a culturally sensitive environment in the international market without violating the laws and regulations of the various countries. Also, due to the enhanced access and friendly interface of the ERP system, employees with disabilities are embraced, and the system enhances cultural fit within the organization.

3.1.4.2. Evaluation of Project 4 According to Specified Criteria

As for the systematic context, the ERP Transformation Project is strategically aligned with the proposed goals of the airline to employ more efficient, scalable, and accurate operation. The costs of implementing a new ERP system are in this case offset by the benefits accrued from longer and efficient use, better decision making, and scalability. Since the ERP system integrates and automates many of the key business processes of the airline, there is less chance of errors and delays, which lead to financial and image stability.

In risk management aspect, the new ERP system can mitigate several significant operational risks related to the airline's outdated legacy systems. It eliminates data silos that in the past have been a source of reporting issues, compliance issues, and bad decision-making. Also, the real-time report creates a way of ensuring the airline complies with regulatory rules and regulations, thus avoiding fines and penalties.

It also can also be considered as a major innovational effort as the airline incorporates new technologies, including predictive analytics and AI-based forecasting, into the project. The following trends facilitate enhanced sales forecasting, more efficient inventory control and management, and effective fiscal planning. Technical viability of the proposed project is another factor that can be achieved through phased implementation of the new system, which can be gradually introduced to the organization’s operations without disrupting its normal functionality.

Last of all, the user and stakeholder impact of the ERP transformation is positive. Employees stand to gain from a system that is easy to use and one that minimizes hassles in their work hence providing them with job satisfaction. In the case of customers, better operation efficiency and real time information management mean that service delivery is faster and information provided to the customers during their travelling is more accurate. In summary, the ERP Transformation Project is a strategic venture that provides the airline with a competitive edge, operational agility, and economic viability in an ever-evolving industry.

3.1.5. Carbon Offset Project (Project 5) (P_5)

Aviation accounts for 2% of global human-induced greenhouse gas emissions. Carbon offsetting enables passengers to balance out their carbon footprint by paying towards environmental projects. (BBC, 2019). The Carbon Offset Project is an initiative that seeks to offer passengers a chance to reduce their carbon footprint by acquiring carbon credits on the ticket’s purchase. This approach enables the passenger to directly finance the reduction of CO_2 emissions in areas like renewable energy or carbon dioxide capture. For instance, if a passenger’s flight generates 2 tons of CO_2, they can opt for a project that will eliminate the same amount of CO_2 in another region. However, as an incentive to make people engage in the program, the airline will bear part of the cost of the offsets which will be split between the airline and the passengers. This project not only establishes a more efficient and less carbon polluting way of flying but also contributes to the other sustainability objectives by financing projects in developing states that have the potential to deliver both economical and social returns.

Alternative to the Project: Prior to the Carbon Offset Project, the airline had few opportunities to directly involve the passengers in the sustainability initiatives beyond improving the internal fuel efficiency and purchasing new fleets. Although these measures helped to decrease emissions, they did not engage the passengers in any way or provide them with an opportunity to offset their carbon emissions resulting from their travels. The other course of action would be to persist with such internal initiatives only, which lessens the scope for customer engagement in sustainability efforts at the airline. With this project, the airline can expand customer engagement and promote carbon conservation, which will help advance the airline's objectives and worldwide sustainability goals.

Cost Comparison: The costs are associated with creating an integrated system within the booking process to calculate and display carbon emissions, along with the expenses towards partners with verified offset providers. Even though it will cover a portion of the offsets to ensure that they are bought into by the airline, the expense is not very significant in relation to other general expenses of an airline. However, there are a number of possible advantages as well, including the airline being able to strengthen its reputation in the environmental space, increase customer loyalty, and conform to new market and regulatory trends that are centered on cutting carbon emissions. Customers usually incur few costs (the offset cost per tonne of CO_2 may vary depending on the flight), therefore a broad spectrum of travelers can take use of this option.

Risks Associated with Implementation: The primary threat that lurks in implementing the Carbon Offset Project is customer acceptance. Some passengers may be willing to share their personal data to help the firm and reduce their carbon footprint, but others may not if they do not understand the advantages or if the costs of contributing are too high. There is also reputational risk within the project if the offset programs are not well scrutinized or if clients feel the airline is using offsets to avoid more concrete measures to lower the emissions. To counter these risks, the airline needs to explain the offset program's legitimacy and the company's larger, more comprehensive environmental agenda. Another is the ability to guarantee the quality of the purchased offsets, as buyers will seek to know that their money is being well spent.

3.1.5.1. Sustainability Role of the Carbon Offset Project

Economic Sustainability: The Carbon Offset Project also supports the airline's economic sustainability by improving its image and promoting the company as an industry leader in sustainability. Allowing passengers to buy carbon offsets provides a new revenue stream that can be re-invested in sustainability initiatives within or outside the company.

The project also enables the airline to timely counteract the changing legislation, as more and more governments set rules that oblige airlines to cap emissions or buy carbon credits. To some extent, this strategy allows the airline to limit the costs of future regulations and avoid penalties or extra taxes regarding emissions.

Environmental Sustainability: Thus, the focus of the Carbon Offset Project is to help make the world a greener place from an environmental perspective. CO_2 emissions through air travel is another area that the offset program clearly focuses on because the company directly compensates for the carbon footprint through verified projects. Many of these projects involve the creation of renewable energy sources, tree planting, and even carbon sequestration, all of which decrease overall CO_2 emissions. Furthermore, most of the offset projects funded under this scheme are in the developing countries and therefore, have a positive impact on the sustainability of the global environment by encouraging the use of renewable energy and environmental protection. Partial sponsorship of these offsets by the airline enhances its stance in meeting its remaining environmental stride towards the global environmental standards like the Paris Agreement.

Social Sustainability: The Carbon Offset Project also has a social aspect in the sense that; it has positive impacts especially for the following social factors; The following are the social impacts of carbon offset projects. Apart from lowering the carbon emissions, through investment in renewable energy projects, reforestation, and sustainable development projects, the airline is also fostering economic growth and the welfare of the affected communities. These project tend to generate employment and grant access to electricity and enhanced facilities that are instrumental in the social sustainability of these areas. In addition, it also makes the passengers more aware of the social responsibility and environmental consequences of traveling through an airline, making them more conscious about their choices and impacts on the environment.

Cultural Sustainability: In this regard, the Carbon Offset Project can be considered as the cultural effect due to the fact that it emphasizes the idea of community responsibility for the environment. This way, the airline ensures that passengers of different cultural backgrounds are equally interested in preserving the environment. There is a great concern in many cultures for environmental conservation and the use of ethical products.

Thus, by providing the possibility for passengers to compensate for emissions per flight, the airline complies with such cultural values and strengthens its position as an international, environmentally friendly brand. It also promotes cultural sustainability in the developing world by financing projects that protect natural resources, and ecosystems, which are in most cases, heritage to cultures and communities.

3.1.5.2. Evaluation of Project 5 According to Specified Criteria

From the above explanation, it is clear that the Carbon Offset Project supports the airline's strategic aims and objectives of combating environmental degradation, customer involvement in environmental conservation, and compliance with regulatory standards regarding environmental degradation. Even though the initial investment in programme setup and offsets may be low, the overall benefits of brand enhancement and customer loyalty are likely to be high. Further, the project gives the airline an opportunity to respond to the increasing concerns of the public in relation to environmental conservation and sustainability of travel in the market.

Evaluating in the context of risk management, the project tackles major environmental risks by actually cutting down on the airline's emissions. There is always the possibility that some of the customers will not agree to be part of the program but the partial sponsorship by the airline reduces the chances of this occurrences by a huge margin. Thus, working with reliable vendors and being as open and clear as possible helps the airline avoid reputational risks that may be associated with carbon offset programs.

From an innovation standpoint, the Carbon Offset Project is an innovation that is not strictly operational but rather engages the passengers themselves in terms of sustainability. This project is able to determine emissions in real time and it is able to provide passengers with a clear avenue through which they are able to contribute towards sustainability of the world at large. The assessment of the project's technical feasibility is positive since it is easy to incorporate the carbon offset options into the ticket and booking systems now in use.

Lastly, the user and stakeholder impact of the Carbon Offset Project can be considered as the positive side. It provides passengers with a purposeful approach to managing their impact on the environment, which may lead to increased brand loyalty and satisfaction with the airline. The target audience, comprising of environmental agencies and regulatory authorities, are also likely to perceive it as a positive effort towards enhancing sustainability in the aviation sector. In conclusion, the Carbon Offset Project can help consumers recognize the airline as an environmentally friendly company that provides passengers and society with meaningful value.

3.1.6. Minimizing Paper Consumption Project (Project 6) (P_6)

The elimination of paper usage in the company's operations is one of the main goals that the Project aims to achieve. This is an industry that has used paper in many ways, for example in ticketing, in-flight service, documentation of cargos, and other administrative operations, there is a shift to more extensive use of digitization. The objectives of this project shall therefore be to introduce digital solutions wherever possible like e-ticketing, electronic boarding passes, digital flight manuals, and electronic document management for administrative use. Through these solutions, the airline will not only be able to decrease its negative effects on the environment but also enhance operations and the efficiency and cost of using paper in the organization.

Cost Comparison: The change from traditional solutions to digital solutions was initially characterized by investments in software, infrastructures, and human resources. Nonetheless, such costs are compensated by the long-term benefits of saving paper, associated printing costs, and physical storage space. Further, the use of the digital solution minimizes costs of labor in managing, storing, and accessing paperwork. On the other hand, if they continue with paper-based systems, they will be incurring costs such as the costs of paper, managing the printers, and accommodating large piles of papers. The financial advantage of digitization therefore lies in the speed of operations, improved access and minimization of wastage.

Risks Associated with Implementation: Change resistance is also a risk that can be associated with this project due to the possible objections from the employees or customers who may prefer traditional paper-based approaches. To address this, the airline needs to manage the change effectively and make sure that all the interested parties embrace the changes and offer proper training to help them adapt to the new changes. The first is the risks associated with the implementation of digital systems that are often complex to integrate with existing systems and the security, access management, and compliance of digital documents. To this end, the airline needs to incorporate best practices when it comes to digitization of documents, and also meet the data protection laws.

3.1.6.1. Sustainability Role of the Minimizing Paper Consumption Project

Economic Sustainability: The adaptation of more digital solutions within the operation of the airline has a positive impact as it creates economic sustainability because of the overall reduction of costs. It is a well-established fact that paper costs are enormous in terms of buying, printing, archiving, and handling in various organizational units like ticketing, cargo, and administrative offices. With every of these costs going down by a notch when the airline introduces its digital options, it will also attain efficiency in its operations. Less paper usage also leads to less storage of the paperwork, which in turn cuts down the cost incurred in the storing of physical documents. Furthermore, higher efficiency in processing and storing the digital documents enhances productivity and yields increased economic returns in the long-run.

Environmental Sustainability: The main environmental advantage derived from the project is a tremendous decrease in the airline’s use of paper and, therefore, a decreased need for paper manufacturing, which is a highly invasive activity in terms of environmental resources and has been cited for being a leading cause of deforestation. Integrated digital methods of conduct at the airline also help in reduction of environmental impact as the global concept of waste management and conservation of resources is upheld. Likewise, saving on paper storage and cutting down the number of deliveries also helps conserve energy and decrease emissions, supporting the airline’s environmental impact reduction plan. Taking this within a broader context of environmental concerns, such as waste minimisation and more sustainable ways of operating the project aids in supporting wider environmental goals.

Social Sustainability: The impact of the project on social sustainability is characterized by the enhancement of working conditions for employees and the provision of better services to passengers. The switch to digital solutions means that the employees are able to do away with the physical paperwork and documentation processes that would prove cumbersome in their work. It enables efficient execution of tasks, empowers employees to do more relevant work while minimizing stress resulting from paperwork. From the perspective of passengers, the adoption of e-tickets and electronic boarding passes is more convenient and integrated, where passengers can organize the documents on travel through mobile terminals. Also, the use of digital solutions preferred by the passengers increases customer satisfaction and portrays the airline as one that adopts green means of conducting its business.

Cultural Sustainability: The goal of cultural sustainability is achieved through the promotion of innovative and innovative strategies for the functioning of the airline. As such, the digital transformation of the airline's services allows making them more accessible and inclusive, especially in the regions where people are increasingly connected to the Internet and learn how to use the digital technologies. Technology also aids in the adoption of a sustainable culture around the world, as passengers and employees demand that organizations embrace sustainable practices in their operations. Furthermore, with the decrease in the usage of paper, the airline supports the cultural trends, which call for the optimization of the use of resources, thus making it a responsible corporate entity.

3.1.6.2. Evaluation of Project 6 According to Specified Criteria

The Minimizing Paper Consumption project is highly correlated with the airline's strategic objectives in terms of operational effectiveness, environmental conservation, and financial savings. The setup cost for digital operations and staff training is high, yet the advantages regarding revenue and saving in the long run cannot be refuted. Cutting down paper use results in direct cost savings on paper, space, and personnel time, as well as enhancing internal operations' speed. It also changes the positioning of the airline as a socially responsible company of the new century, providing customers with a progressive and eco-friendly service.

From a risk management standpoint, the project reduces operational risks that are inherent in paper-based processes, including document loss, delays in accessing information, and increased error rates. The adoption of safe computer systems makes sure that the airline is in line with data protection laws and prevents leakage of information. In addition, the airline also minimizes the operational disruptions that may be accompanied by supply chain issues or resource shortages because document management is also streamlined to reduce the use of physical resources.

As for innovation, the project uses current digital solutions to update all the airline's processes, thus reducing the negative impact on the environment and improving the efficiency of its activities. The technical practicality of the project can be further justified by the fact that there are numerous mobile applications and APIs available for integration with the airline's systems ranging from electronic ticketing solutions to document management systems.

The effects of the project based on the users and stakeholders are outstandingly positive. Customers get a more comfortable and environmentally friendly means of transport while employees enjoy better working conditions with less paperwork. By adopting modern digital practices, the airline builds a good image in the eyes of the customer, the employees, and the regulating agencies as a company that is embracing change and is willing to take advantage of the technological advancement in its operations. In conclusion, the Minimizing Paper Consumption Project is a value proposition that aligns with the airline's sustainability strategy and contributes to sustainable development by enhancing the company's internal operations and reducing expenses.

3.2. Key Criteria for Sustainable Project Selection

The success of a project is contingent upon multiple factors that must be considered to ensure sustainable performance. Both the project manager and team members should identify these factors and actively work towards their realization to achieve a successful project outcome. (Goker & Dursun, 2022). In the case of deciding on the sustainable IT project evaluation, the proper assessment tool is crucial in order to choose not only the projects being profitable and sustainable but also the ones that can contribute the revenue. The ever changing nature of information technology has the potential of offering many opportunities to organizations in their bid to achieve competitive advantage.

Nevertheless, innovation should be sustainable, which means that the goals and objectives set to achieve innovation should be in line with sustainable development goals, where innovation should be financially sustainable but at the same time socially and environmentally responsible. When these criteria are incorporated into the decision-making process, then an organization is more likely to select those projects which are most likely to have sustainable value in the long run, foster technological development, and support the creation of a sustainable environment. These sub-criteria, as outlined in the numerical example section, provided a more granular understanding of the sustainability impacts of the evaluated projects. Decision-makers were guided to assess IT projects by these sub-criteria, ensuring a comprehensive and precise evaluation aligned with the sustainable goal. In conclusion, in this section, the criteria on sustainable project selection will be discussed and elaborated in detail. In our numerical example, we operate on diverse attributes, the main criteria and sub-criteria are elucidated with the details below.

Table E.1 presents a structured evaluation of sustainable IT projects in the airline industry, outlining key criteria, their explanations, and real-world examples. The table highlights how each criterion contributes to sustainability from economic, environmental, social, and cultural perspectives. By providing concrete examples, it demonstrates the practical implications of these criteria in IT project selection, offering a comprehensive framework for decision-makers aiming to integrate sustainability into their IT strategies.

3.2.1. Cost and Financial Revenue Criteria (C_1 and C_2)

Economic sustainability in the selection of IT projects mainly focuses on the potential financial profitability, cost-benefit analysis, and potential long-term economic effects on the environment. Sustainable projects should be economically beneficial and support economic stability and growth, while not negatively impacting the natural environment and social structures. Considering of economic criteria provides a assurance that projects can be funded and will be able to generate economic returns throughout their lifecycle.

The subcriteria of Cost or Financial Revenue criteria are explained as follows:

3.2.1.1. Investment and Maintenance Costs ($C_{1.1}$, $C_{1.2}$)

The first capital that required for the initial acquisition, development, and implementation of the IT project. This includes hardware, software, and any other resources essential to launch the project. On the other hand, maintenance Costs is the ongoing expenses associated with the welfare of the IT system. This includes costs for updates, repairs, and support services to ensure the system remains operational and efficient.

3.2.1.2. Expected Financial Revenue and Reduction in Op. Costs ($C_{2.1}$, $C_{2.2}$)

The projected financial gains from the IT project; this includes any direct income generated, such as increased sales or services provided, as well as indirect financial benefits. In other respects, the Expected Reduction in Operational Costs is anticipated decrease in costs resulting from the implementation of the IT project. This can include savings from improved efficiencies, reduced labor costs, or lower resource consumption.

The sustainability point of view of Cost or Financial Revenue Criteria is mentioned below.

3.2.1.3. Economic Sust. Perspective of Cost and Financial Revenue Criteria

Cost-Benefit Analysis: Proposed projects should be accompanied by a proper cost benefit analysis in order to justify the cost of the investment. For example, ERP system requires significant amount of resources to be invested, but as a result of integration it leads to efficient operations and better control over data.

Scalability: Application of capital cannot afford future costs of accommodating expansion hence the importance of scalability. For example, choosing the right cloud infrastructure for a business means that it is possible to avoid spending on upgrades due to business growth.

Maintenance Efficiency: The choice of right maintenance process can have a huge impact on the future expenses. For instance, while carrying out routine check-ups and servicing of the information technology infrastructure, it is possible to reduce system down time as well as the costs of repairs.

3.2.1.4. Environmental Sust. Perspective of Cost and Fin. Revenue Criteria

Energy Efficiency: A priority to energy efficiency should be afforded to technologies that will minimize the effects on the environment and costs. For instance, replacing old servers and cooling facilities with the new energy-efficient ones in data centers drastically reduces the amount of electricity consumed and subsequent greenhouse gas emission.

Sustainable Materials: This is another area which has a direct impact on the selection of environmentally-friendly materials for the IT infrastructure. For example, the use of recycled products in hardware parts may decrease the impact of IT ventures in the environment.

Lifecycle Management: Proper and efficient management of it assets is also crucial in the reduction of waste and the ability to recycle it assets. For instance, the take-back program for old hardware guarantees that the hardware is recycled or disposed of in an appropriate manner hence reducing e-waste.

3.2.1.5. Social Sust. Perspective of Cost and Fin. Revenue Criteria

Job Creation: In this view, there is the ability to create employment leading to economic development through undertaking of new projects. For example, starting a new IT support center means that there will be employment for people in the particular region.

Training and Development: Funding towards employee training is crucial in order to guarantee that the employees can use and manage new systems. For example, training them on new software systems in the organization can improve on their skills and levels of productivity.

Equitable Access: Investment has to ensure appropriate use of technology in the interest of all the stakeholders. For example, investing in affordable internet infrastructure in underserved areas fosters digital inclusion and access to information.

Cultural Sensitivity: It has been stated that there is a need for any investment initiative to be sensitive to cultural realities and settings in order for them to be embraced and prove effective. For example, the creation of culturally appropriate material for use in learning processes can raise participation levels and effectiveness.

Preservation of Cultural Heritage: In this case, technological implementations can be used to support the preservation and development of cultural identity. For instance, financing digital archiving projects can help in the preservation of records and artifacts of past events.

3.2.1.6. Cultural Sust. Perspective of Cost and Financial Revenue Criteria

Corporate Cultural Values: Corporations can improve the effectiveness of employee and community engagement by investing in accordance with cultural norms. For example, supporting the community programs that are in line with the company culture can enhance image and create goodwill with stakeholders.

Table 3.1 Summarized concept table on Expected Revenue and Reduction in Operational Costs Criteria (C_1 and C_2)

Economic Sustainability Perspective Cost-Benefit Analysis Scalability Maintenance Efficiency	**Environmental Sustainability Perspective** Energy Efficiency Sustainable Materials Lifecycle Management
Social Sustainability Perspective Job Creation Training and Development Equitable Access	**Cultural Sustainability Perspective** Cultural Sensitivity Preservation of Cultural Heritage Corporate Cultural Values

3.2.2. Strategic Alignment Criteria (C_3)

The subcriteria of Strategic Alignment criteria are explained as follows:

3.2.2.1. Alignment with Business Goals ($C_{3.1}$)

The extent to which the IT project enhances the achievement of organizational strategic vision and mission. This helps to ascertain that the project serves to support the goals and objectives of the institution in the long-run.

3.2.2.2. Contribution to the Prestige of the Institution ($C_{3.2}$)

The potential organizational consequences of the completed IT project in terms of the organization’s reputation and public image. A successful project can increase the recognition level and reputation of the institution in the society.

3.2.2.3. Compatibility with the Country's Technology Policies ($C_{3.3}$)

The extent to which the particular IT project supports the national standards and policies of technology. This guarantees adherence and contributes to more extensive government and industry goals.

For example, the projects that are related to Turkey’s digital transformation initiatives, including the establishment of domestic cybersecurity products or fintech startups may benefit from state incentives and can lead to economic growth and sustainability in the long run.

Development of IT projects that are consistent with country’s technnology policies can also support the small and midsize enterprises (SMEs) economy and encourage employment and innovation. For instance, the software development projects supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK) promote indigenous development of software tech-based startups, which in turn supports the country’s economy and contributes to sustainable economic development.

The projects that are implemented in a manner that is consistent with the country’s technology policies may be entitled to economic and culturally effective. For example, the new inhouse development project of a new and sophisticated passenger service system (PSS) in a flag carrier airline can contribute not only in the financial way but also in the cultural way. Because, the passengers’ confidential data stays in the airline database and also in the country.

For instance, a new carbon offset system that would be incorporated into the airline’s reservation system, through which passengers can easily offset their carbon footprints during the ticketing process. This increases awareness of environmental issues and makes airlines a responsible airline company in the field of aviation. Obviously, it augments the sustainability in an environmental and social perspectives.

3.2.2.4. Market Potential ($C_{3.4}$)

The capacity of the IT project to generate or exploit fresh market spaces. This involves evaluating the market demand for the project's outcomes, size of the targeted market, and market competition. Higher market potential increases the prospects of the project to contribute towards sustainable revenue generation and growth of the market. In global competitive markets, organizations should keep up with the new trends and changing technologies while conducting their projects(Goker & Dursun, 2022).

The sustainability point of view of Strategic Alignment Criteria is mentioned below.

3.2.2.5. Economic Sustainability Perspective of Strategic Alignement Criteria

Strategic Investment: Business focused IT projects means that proper investments are made in IT technologies that are aligned to business strategy and vision so as to support business growth in the long run. For instance, designing a special CRM system that improves the clients' relations and their further loyalty plays a crucial role in business expansion and revenue increase.

Cost Efficiency: The IT projects when planned and executed in a proper manner are known to reduce cost and bring in innovation that aligns with business goals and objectives. For instance, utilizing the Robotic Process Automation (RPA) to enable the automation of operations will change the operational costs and enhance efficiency.

Market Positioning: Every business pursuit has the potential to enhance the company's standings in the market and make it more competitive. For instance, a company may decide to launch a data analytics platform that will help it come up with proper recommendations on how to undertake its business.

3.2.2.6. Environmental Sust. Perspective of Strategic Alignement Criteria

Eco-Friendly Innovations: Meaningful IT projects, which are in sync with organizational objectives can lead to the development of sustainable solutions that help the environment. For instance, creating an application in new intelligent structures that enables the regulation of energy usage may limit the usage of energy thus having a decreased negative effect on the environment.

Sustainable Practices: There is evidence that indicates that IT projects which are strategic to the business can encourage sustainability within the organization. For example, digital document management is a common example where the use of paperless process can greatly help in reduction of wastage.

Resource Management: Projects related to resource management are capable of achieving organizational objectives and objectives related to environmental conservation at the same time. For instance, developing resources management software for resource use in production processes that will reduce wastage will both pursue the goals.

3.2.2.7. Social Sust. Perspective of Strategic Alignement Criteria

Employee Engagement: Accomplished IT projects can further the organization's strategic objectives, and increase the degree of employee motivation. For instance, creating an internal collaboration platform that enhances the flow of information and projects increases the employees' morale and productivity.

Community Development: It is therefore clear that projects that are in harmony with the business objectives may help in improving the standards of community and social welfare. For instance, the development of an e-learning program where people can acquire education and receive training in certain skills to improve their standard of living will be considered as having a positive social impact.

Inclusive Growth: Effective IT projects that spur inclusive growth mean that the benefits are availed to all the parties. For example, development of software with capabilities that enhance its usability by disabled persons is a good example of making technology available to all, regardless of their disability.

3.2.2.8. Cultural Sustainability Perspective of Strategic Alignement Criteria

Cultural Integration: In this sense, understanding IT projects that are in line with business objectives can promote the organizational culture of integration and respect for diversity. For instance, creating programing that can support multiple languages improves on cultural diversity.

Cultural Preservation: Cultural sustainability is also met in projects that are aimed at the preservation of cultural heritage which are business goals. For example, initiation of a website for the purpose of preserving cultural items and events is a way of conserving culture.

Corporate Culture: In its simplest form, identity can be defined as the characteristics that make one organization's IT projects different from those of another organization. For example, implementing an employee recognition system that aligns with company values fosters a positive corporate culture.

Table 3.2 Summarized concept table on Strategic Alignment Criteria (C_3)

Economic Sustainability Perspective Strategic Investment Cost Efficiency Market Positioning	**Environmental Sustainability Perspective** Eco-Friendly Innovations Sustainable Practices Resource Management
Social Sustainability Perspective Employee Engagement Community Development Inclusive Growth	**Cultural Sustainability Perspective** Cultural Integration Cultural Preservation Corporate Culture

3.2.3. Risk Assessment Criteria (C_4)

3.2.3.1. Technical Failure Risk ($C_{4.1}$)

This criterion evaluates the probability of technical hitches or system flaws in the IT projects and their ramifications on the success of the project. From a sustainability standpoint, it is crucial to reduce economic costs and avoid environmental or operational breakdowns that may be caused by technical failures.

3.2.3.2. Exceeding Planned Cost Risk ($C_{4.2}$)

This criterion assesses the likelihood of going over the planned budget, and the consequences that come with such overruns on the economic feasibility of the project. Inability to manage cost can be risky to the financial viability of the project and may lead to directing the resources towards environmental or social objectives.

3.2.3.3. Operational Risk ($C_{4.3}$)

Operational risks include all the difficulties and interruptions that are likely to happen in the course of performing project operations. These risks can influence sustainability in terms of environmental efficiency, the social aspect, and the chance of success at the project.

These criteria are important for making certain that the IT projects will be managed in a way that will sustain their long term and harnessing the effect of risk management for the protection of economic, environment, and social resources.

The sustainability point of view of Risk Assessment Criteria is mentioned below.

3.2.3.4. Economic Sustainability Perspective of Risk Assessment Criteria

Malfunctioning in crucial IT systems can result in major monetary repercussions, such as revenue loss due to system inaccessibility, decreased revenues, and additional expenses. For example, in a reservation system of a Turkish Airlines, a technical failure can cause unavailability of taking a flight and thus, directly affecting the airline’s revenues besides compromising the trust of its clients. Reducing technical failure risk by investing in secure IT as well as constant system upgrades can improve the economic sustainability as operations are maintained and revenues protected.

Failing to achieve the planned costs set for an airline can be a detriment to the company’s financial health as it may affect other key projects and economic performance. For example, if a Turkish Airlines decides to acquire a new IT system for its operation and then realizes that it has spent much more than initially planned, it will have to cut costs in other areas like maintaining its fleet of planes or improving the staff’s customer relations. Of significant importance is cost control and the realistic setting of cost estimates that the airline has to meet in order to be economically sustainable.

Contingency risks which include IT system failure pose a threat to the commercial airlines’ operations and can result in large monetary losses due to competition. For instance, a breakdown in the airline’s scheduling system means that some flights are delayed or cancelled and this will have financial implications on the company as it incurs losses as well as pays customers compensation. In addition to controlling operating risks through strong IT supports and risk management plans, the sustainable economic running could be achieved by the airline company.

3.2.3.5. Environmental Sust. Perspective of Risk Assessment Criteria

Malfunctions in the IT systems decrease the efficiency of the business processes that can negatively affect the environment. For instance, a failure in a flight management system could mean that the planes are routed in a way that consumes more fuel, thus emitting more carbon dioxide. Airline firms are in a position of performing environmental sustainability through embedding energy efficient technologies for use in their operations and guaranteeing the efficiency of information technologies.

Cost overruns impact the success of environmental efforts as well. For instance, if money is redirected from a project that seeks to lower emissions of CO_2 due to certain expenses that are encountered in another IT project, then environmental enhancements may be halted or slowed down. When IT projects are aligned with budget and environmental objectives, the projects do not detract from the goals of environmental sustainability for the airline.

It is also important to note that operational risks can also point to environmental impacts. For instance, delay in the IT system can lead to time wastage hence more fuel consumption, increased emissions and wastage of resources. Adopting accurate IT systems of operations can save the airline’s resource by incorporating the fuel management software, therefore support the airline’s environmental responsibility.

3.2.3.6. Social Sustainability Perspective of Risk Assessment Criteria

A technical breakdown of customer-facing systems including mobile apps and check-in kiosks can be detrimental to passenger experience. For instance, if a Turkish Airlineshas a mobile application that has issues of frequently crashing, it will become unpoepaЬle for passengers, especially those with accessibility needs, which will lead to a decrease in the aspect of social inclusion. Mitigating technical failure risks with respect to the usability and reliability of the systems can improve social sustainability by ensuring that customers are satisfied and accommodated.

When IT projects are over budget, there could be cuts to other areas that improve societal value, including training for employees or the improvement of services for customers. For instance, where a Turkish Airlineshas had to reduce training programmes because of cost escalations in an IT project, it could lead to demoralisation and poor standards of service delivery. It is critical to note that cost control is an important factor in the preservation of investment in social pursuits, which supports social sustainability of the airline.

The operational risks within the IT systems that are employed in the management of the airline maybe a threat to the provision of services that would be of importance to the passengers hence would be causing an impairment of social sustainability. For instance, a breakdown in the airline's customer support system means that passengers' enquiries especially in cases of emergency may not be handled as and when they are supposed to be, thus resulting in customer dissatisfaction and possibly unsafe situations. Mentioned above, the operational reliability that comes with efficient IT systems work towards social sustainability as it delivers standard and dependable services to the passengers.

3.2.3.7. Cultural Sustainability Perspective of Risk Assessment Criteria

Malfunctions in service delivery can be disastrous to services that are intended to uphold cultural differences and sensitivity. For example, a failure in a multilingual support system may mean that passengers do not get service in their preferred language, thus, they will be dissatisfied. Cultural sustainability is also achieved by guaranteeing that the IT systems are culturally sensitive and accurate in order to avoid discriminating against or disrespecting other cultures.

Fiscal overruns can potentially result in the downsizing of culturally relevant projects. For example, in an IT project that aims at providing cultural sensitive services where the budget has been exceeded by the IT project team, the airline may cut down on the services to be offered in order to fit the bill but in the process may end up offending a certain cultural group. To maintain cultural sustainability, appropriate measures are taken by managing projects' costs and resources.

Operational risks can affect cultural sensitive services that the airline undertake for its clients. For example, if there is a problem with the system that deals with special meal requests for instance halal or kosher diets then the airline will be unable to cater for the social and eating requirements of its users. Mitigating operational risks in the IT systems keeps culture sustainable since everyone's cultural needs are considered.

Table 3.3 Summarized concept table on Risk Assessment Criteria (C_4)

Economic Sustainability Perspective Cost Management Revenue Stability Risk Mitigation Investments	**Environmental Sustainability Perspective** Environmental Compliance Resource Efficiency Sustainability of Operations
Social Sustainability Perspective Service Reliability Community Impact Stakeholder Trust	**Cultural Sustainability Perspective** Cultural Sensitivity Preservation of Cultural Practices Alignment with Cultural Values

3.2.4. Innovational Contribution Criteria (C_5)

Innovation Contribution (C_5) targets the changes that a project brings, including the novelty of the output, enhancements made to process or technology, and contribution to science and society.

3.2.4.1. Novelty of the Project Output ($C_{5.1}$)

In this criterion, the extent of novelty of the project outcomes to existing solutions is considered. It determines how well the project is able to bring in novelty in the form of ideas, equipment, processes, and tools that offer improvements. Thus, new outputs can provide better, more cost-effective, less resource-intensive or more socially responsible solutions within the framework of sustainability. For instance, an IT department of an airline company can build a new AI-assisted system for real-time passenger sentiment analysis to better understand passengers' needs and expectations to improve services thereby increasing customers' satisfaction and loyalty.

3.2.4.2. Process or Technological Improvements ($C_{5.2}$)

This criterion deals with the changes made to the previously known processes or creation of new technologies providing higher efficiency, lower costs or increased effectiveness.

These are considerations that are important for the sustainability of the project in the future. For example, an IT project that uses business intelligence and analytics to schedule aircraft maintenance can help in cutting down the costs of maintenance while providing safer and eco-friendly services by maximizing utilization of resources.

3.2.4.3. Contribution to Science and Society($C_{5.3}$)

This criterion evaluates how the project advances science and benefits the welfare of society at large. Such projects are perceived as more sustainable because they create more value than just pursuing a business case. An example could be the IT department of an airline company creating an open-source platform to share flight data analytics with research institutions and other stakeholders to enhance the advancement of aviation technology and knowledge throughout the world.

The sustainability point of view of Innovational Contribution Criteria is detailed below.

3.2.4.4. Economic Sust. Perspective of Innovational Contribution Criteria

Novelty of the Project Output: Strategic IT projects that present innovative solutions can add value to an companie’s strategic positioning hence increase the market share and revenue. For instance, a new innovative passenger service with blockchain for a secure and efficient loyalty program can create more traffic and hence, contribute to the economic sustainability.

Process or Technological Improvements: The second type of sustainability is economic, meaning that advanced processes or technologies are cost effective, allowing for more efficient use of resources. For instance, enhanced baggage tracking can be used to enhance some operational efficiencies, which in turn improves profitability.

Contribution to Science and Society: Measures that contribute to the enhancement of scientific research and improvement of society’s well-being can create new economic opportunities or improve brand image, thus providing indirect support to the economic sustainability. For instance, working with universities on researches in the area of aviation safety might result in improvement of the reliability of air transport and, therefore, reputation of the airline.

3.2.4.5. Environmental Sust. Perspective of Innovational Cont. Criteria

Novelty of the Project Output: New IT solutions that integrate procedures for the minimization of CO2 emissions can help an airline to decrease its environmental impact. For instance, a new flight planning software that can plan a flight to consume the least amount of fuel will help the airline meet the sustainability objective of emitting less greenhouse gases.

Process or Technological Improvements: Technological advancements that increase efficiency of energy or decrease the amount of waste produced are crucial for the environment. An IT project that entails the adoption of paperless cockpit system that eliminated printed manuals and logs equally helps in environmental conservation.

Contribution to Science and Society: Any project that would help in the advancement of knowledge of the environment or the improvement of sustainable processes on the earth is a positive impact on the society. For instance, the creation of a system that can record and provide updates of an airline's environmental footprint can have a positive impact on the industry by encouraging environmentally friendly measures.

3.2.4.6. Social Sust. Perspective of Innovational Contribution Criteria

Novelty of the Project Output: Projects that introduce new tools or services that enhance passengers' experience or accessibility enhance social sustainability. For instance, creating an IT system that offers accessibility preferences to disabled passengers would make air travel more accommodating.

Process or Technological Improvements: Social sustainability improvements are those that improve employee working conditions or directly affect service to the customers. For example, the use of an IT system that addresses repetitive tasks can ease the burden on the employees resulting in increased satisfaction hence improving the services being offered.

Contribution to Science and Society: Measures that have a positive impact on society, for instance, the implementation of IT systems in the sphere of aviation emergency preparedness enhances social sustainability. An example could be a platform that coordinates interaction between the airlines and the emergency services during emergencies.

3.2.4.7. Cultural Sustainability Perspective of Innovational Cont. Criteria

Novelty of the Project Output: Intercultural initiatives that preserve and enhance cultural differences play a role in cultural sustainability. For instance, an IT project of an airline that entails designing of in-flight entertainment with multi-lingual support helps accommodate clients from different cultures.

Process or Technological Improvements: Any improvements that support or maintain cultural practices are in line with cultural sustainability. For example, the booking system that caters for the conventional travel habits or organizing group bookings for cultural events fosters cultural integrity.

Contribution to Science and Society: Cultural sustainability is supported by projects that promote cultural exchange or outlooks. An example could be an IT platform that focused on making passengers more culturally sensitive through sharing stories of global cultures.

Table 3.4 Summarized concept table on Innovational Contribution Criteria(C_5)

Economic Sustainability Perspective Competitive Advantage Cost Efficiency Market Expansion	**Environmental Sustainability Perspective** Carbon Footprint Reduction Energy Efficiency Waste Reduction
Social Sustainability Perspective Accessibility Employee Satisfaction Social Welfare	**Cultural Sustainability Perspective** Cultural Inclusivity Preservation of Cultural Norms Cultural Exchange

3.2.5. Technical Feasibility Criteria (C_6)

Technical Feasibility focuses on the feasibility and flexibility of a project given the existing technology, integration with other systems and the project's ability to be flexible and scalable. Such criteria make sure that the IT projects can indeed be implemented, supported and changed for the future requirements.

3.2.5.1. Availability of Technological Infrastructure ($C_{6.1}$)

This criterion evaluates whether the technological resources including hardware, software and networking necessary for implementing the project is in place. For example, it is important to have high-speed internet and cloud storage in an airline's IT department so that such systems as a real-time flight tracking system can be put in place and implemented.

3.2.5.2. Compatibility with Existing Systems ($C_{6.2}$)

This criterion looks at the compatibility of the new IT solution with the existing systems in the airline setting. Failure in this area may result in poor interoperability that raises cost and inefficiency as well as disruption of operations. For instance, if an airline's new PSS is not integrated with the loyalty management system, it results in disparate data and inefficient operation.

3.2.5.3. Flexibility ($C_{6.3}$)

It means that the system is able to change with the requirements or the changes without needing to be replaced completely. This is especially important in the today's dynamic aviation industry whereby changes in regulations, the market, or customers can be addressed in an IT solution. For example, a flexible booking platform that can easily incorporate changes in travel policies, such as health regulations, ensures that the airline can respond quickly to external factors. The Covid pandemic was one of the events that showed how vital flexibility is for companies and which companies are flexible.

3.2.5.4. Scalability ($C_{6.4}$)

This criterion measures the scalability of the system, its ability to accommodate additional users, more extensive data, or greater system complexity. Another strength of the system is that the firm can expand the airline without having to put in more resources to upgrade the system. For example, the IT infrastructure that facilitates routes and a customer based expansion helps in operations as the airline expands.

The sustainability point of view of Technical Feasibility Criteria is detailed below.

3.2.5.5. Economic Sust. Perspective of Technical Feasibility Criteria

Availability of Technological Infrastructure: It is a common business adage that it is much cheaper to invest in a sound and cutting edge technological platform in the long run. For instance, strong cloud storage services enable Turkish Airlines to manage huge amounts of flight and passenger data to avoid constant upgrades that can disrupt operations.

Compatibility with Existing Systems: Solving compatibility issues lowers the price of integration and decreases unfavorable incidences, which in turn promote economic sustainability. For instance, the new cargo management system is integrated with the existing fleet management system to avoid creating additional work and reducing risks and cost in the process.

Flexibility: Out of the two, flexible systems allow for quick changes and more control by the airline since expensive overhauls are not necessary. For instance, an adaptable crew scheduling system that can be adjusted to disruptors or last-minute changes significantly reduces operation costs and delays.

Scalability: A scalable system means that the expansion of a business is possible without the need to invest in new resources and technologies, thereby making it economically efficient. For instance, when a large airline like the Turkish Airlines decides to incorporate a scalable CRM system, they can accommodate many clients without requiring additional investment in structures.

3.2.5.6. Environmental Sust. Perspective of Technical Feasibility Criteria

Availability of Technological Infrastructure: Technological solutions can be used to improve energy efficiency and minimize energy waste, thus contributing to the overall environmental protection. For instance, adopting energy-efficient data centers for flight operations management will help the airline to minimize its impact on the environment.

Compatibility with Existing Systems: Compatibility with already installed systems can help minimise the number of new systems that are bought, which in turn, can have a positive impact on the environment. For example, using a new fuel optimization system alongside other navigation systems avoids the need for extra devices, thus decreasing e-waste.

Flexibility: They can also be easily modified to address the requirements of environmental laws, making them sustainable without much redesign. For instance, suppose there is a flight management system that integrates the ability to accommodate new changes in regulatory procedures meant to curb emissions.

Scalability: Scalable systems help optimize resource use by adjusting energy and resource consumption according to demand. For instance, a scalable cloud infrastructure allows firms to manage the data efficiently without using extra energy during low-demand periods, thus this method reduces the environmental impact.

3.2.5.7. Social Sustainability Perspective of Technical Feasibility Criteria

Availability of Technological Infrastructure: Appropriate technological development is an important component of social sustainability to improve passengers' satisfaction and employees' efficiency. For instance, offering effective and high-speed wireless internet connection in airports and on airplanes enhances passengers' journey.

Compatibility with Existing Systems: The integration with existing systems enhances the efficiency of its operations and minimizes dissatisfaction among the employees and clients, contributing to social sustainability. For instance, when the internal communication platform of Turkish Airlines is linked to the existing HR systems for the organization, staff can easily access such updates and this improves satisfaction at the workplace hence delivering better customer service.

Flexibility: This kind of IT flexibility as an ability to accommodate the needs of different passenger and employee profiles enhances inclusiveness and accessibility. For example, an adaptable mobile app allows passengers with diverse language preferences and accessibility requirements to have a better experience in public transportation.

Scalability: Services can be taken to more people without compromising on quality, which is one aspect of social sustainability. For example, a scalable passenger service system enables Turkish Airlines to provide high levels of service despite the increasing numbers of passengers.

3.2.5.8. Cultural Sustainability Perspective of Technical Feasibility Criteria

Availability of Technological Infrastructure: There is significant technological development that can help in the preservation and dissemination of cultural content, thus improving cultural sustainability. For instance, Turkish Airlines could harness its IT systems to offer entertainment content with a focus on Turkish culture to audiences across the world. Compatibility with Existing Systems: Incorporation of culturally sensitive system that can work alongside mainstream services can go along way in enhancing cultural practices. For instance, one may want to ensure that a booking system allows group travel for cultural festivals, and this will enhance cultural sustainability since it will encourage passengers to attend major cultural events.

Flexibility: This way, flexible systems can be used to adjust services to the specific culture. For instance, a ticketing system that is capable of accommodating holidays and culturally sensitive dates increases the relevance of Turkish Airlines in the culturally diverse market.

Scalability: Scalable systems can promote cultural exchanges by accommodating a growing number of culturally diverse passengers. For instance, a scalable translation service embedded in the customer service system can ensure that passengers from various cultural backgrounds can easily access information in their preferred language as the airline expands.

Table 3.5 Summarized concept table on Technical Feasibility Criteria (C_6)

Economic Sustainability Perspective Cost Efficiency Seamless Integration Growth Support	**Environmental Sustainability Perspective** Energy Efficiency Reduction of E-Waste Resource Optimization
Social Sustainability Perspective Passenger Satisfaction Employee Productivity Inclusivity	**Cultural Sustainability Perspective** Cultural Promotion Support for Cultural Practices Cultural Adaptability

3.2.6. Resource Availability Criteria (C_7)

Resource Availability (C_7) aims at assessing the availability and appropriateness of resources including manpower, facilities and project management expertise for the delivery of IT projects. They are crucial for the assessment of the project's practicality and viability since the organizational readiness measures the ability of the organization to efficiently allocate and manage resources.

3.2.6.1. Availability of Human Resources ($C_{7.1}$)

This criterion evaluates whether the organization has adequate human capital to implement the project. Firstly, talent and team size are crucial in an airline's IT department. For instance, obtaining skilled software engineers and data analysts is crucial to creating an AI-based flight delay prediction system for maximizing operation effectiveness.

3.2.6.2. Architectural Suitability ($C_{7.2}$)

Architectural suitability seeks to determine if the current IT architecture is capable of supporting the new system or project. For example, if an airline company is planning to implement a new real-time luggage tracking system then it has to be assessed whether the existing IT structure including database management systems and server storage and capacity can accommodate the new technology without causing any interference to the current operations.

3.2.6.3. Project Planning and Scheduling ($C_{7.3}$)

Project planning and scheduling are critical to ensure all the activities in the project are well coordinated, timely and cost efficient. For instance, when developing an automated check-in system, timeframes for software rollout, testing, and integration must be well defined to ensure that customer service is not compromised or operations are not left unprepared.

The sustainability point of view of Resource Availability Criteria is detailed below.

3.2.6.4. Economic Sustainability Perspective of Resource Availability Criteria

Availability of Human Resources: This is made possible through the availability of qualified human resources which guarantee timely delivery of projects hence minimizing on time wastage. For example, the effective implementation of a new cybersecurity system in Turkish Airlines would require a well-trained IT team, which can prevent the company from experiencing significant financial losses due to cyber threats.

Architectural Suitability: That way, new projects do not require expensive rework or infrastructure investments, thereby promoting IT economic sustainability. For instance, if the current cloud environment can support another passenger data analytics platform, then additional costs will not be incurred.

Project Planning and Scheduling: Budgeting and scheduling also assist in controlling project costs because unnecessary delays and misallocation of resources are eliminated by planning and scheduling. For instance, the implementation of a new customer relationship management (CRM) system in an airline company can be well coordinated without interrupting business operations and still be implemented at an affordable cost.

3.2.6.5. Environmental Sust. Perspective of Resource Availability Criteria

Availability of Human Resources: It is also important for IT projects to be staffed by employees knowledgeable in sustainable business practices to minimize the airline's environmental footprint. For instance, the IT department may employ personnel who have adequate information regarding energy efficient coding that enhances the energy efficiency of the airline's data centres.

Architectural Suitability: Proper compatibility in architecture can conserve resource wastage and other redundancies such as hardware replacements or energy wastage. For example, if the current IT systems can accommodate the implementation of the fuel efficiency monitoring system, this means that they do not have to invest in extra systems that may be detrimental to the environment.

Project Planning and Scheduling: It is important to note that environmentally sustainable practices can be integrated into the IT project plan. For example, an airline could consider the green IT practices as a goal, including for the use of energy-efficient servers, that can be incorporated at some level of the project life cycle.

3.2.6.6. Social Sustainability Perspective of Resource Availability Criteria

Availability of Human Resources: It is crucial to ensure there are sufficient numbers of IT professionals capable of meeting the demand for projects so that the workforce is happy and has room for growth. For example, implementing upskilling for the IT team designing a new mobile booking app increases morale and career progression, which is socially sustainable.

Architectural Suitability: Another aspect that can be affected by architectural suitability is the quality of user experience, which is beneficial for social sustainability. For instance, an effective and manageable IT design that helps deliver excellent digital services improves the passenger experience while guaranteeing that customer satisfaction remains optimal.

Project Planning and Scheduling: Appropriate timing ensures that it projects are accomplished without exerting pressure and excess force on the work force hence ensuring social sustainability. For instance, a strategic and well-executed new employee scheduling system project at the Turkish Airlines can ensure that the staff was not overwhelmed when adopting the new system.

3.2.6.7. Cultural Sustainability Perspective of Resource Availability Criteria

Availability of Human Resources: The issue of diversity within an IT team means that cultural sensitivity is understood and incorporated into any project undertaken. For instance, making sure that developers are aware of the cultural attributes that may impact on features such as language in the new customer service chatbot will improve passenger experience and diversity.

Architectural Suitability: The IT architecture that is able to adapt to the culture within a learning institution and other organizations will help in providing services to meet cultural needs in order to enhance cultural sustainability. For instance, the capability of a booking system to integrate and offer culturally relevant travel products or locally preferred payment methods enhances the customer experience in different markets.

Project Planning and Scheduling: The consideration of culturally relevant time, including religious holidays or national celebrations, in the planning of projects is another way that the airline avoids offending the cultural perspectives. For instance, the IT upgrades can be programmed during low seasons such as during cultural holidays to ensure that the system is always available when people are most likely to travel for cultural or religious purposes.

Table 3.6 Summarized concept table on Resource Availability (C_7)

Economic Sustainability Perspective Cost Control through Skilled Resources Infrastructure Cost Efficiency Prevention of Delays	**Environmental Sustainability Perspective** Energy-Efficient Practices Minimized Environmental Impact Resource Optimization
Social Sustainability Perspective Job Satisfaction Employee Development Work-Life Balance	**Cultural Sustainability Perspective** Cultural Inclusivity in Systems Cultural Sensitivity in Design Scheduling Around Cultural Needs

3.2.7. User and Stakeholder Impact (C_8)

User and Stakeholder Impact (C_8) focuses on how a project or system impacts the organization's employees and its customers and partners. These criteria are important to guarantee that not only the IT system is working efficiently but also positively contributing to the stakeholders' experience. Decisions to improve an airline's operational and financial performance regardless of customer satisfaction may result in internal and external factors that can cause a number of negative reactions

3.2.7.1. User Satisfaction ($C_{8.1}$)

This criterion assesses the extent to which a system satisfies the requirements of the people who use it, for instance, staff or commuters. For instance when designing IT for an airline to make changes that make the employee scheduling more efficient, and reduce miscalculations, then employees will be happy to work and be more productive.

3.2.7.2. Impact on Customer Experience ($C_{8.2}$)

This criterion essentially looks at the impact of an IT system on how customers engage with the company's services. For instance, for an airline company, implementing of an application where passengers will receive immediate notifications on the status of their flight, when there was a delay or when the gate has been changed can enhance the overall passengers' experience hence reducing stress levels and enhancing satisfaction levels.

The sustainability point of view of User and Stakeholder Impact Criteria is detailed below.

3.2.7.3. Economic Sustainability Perspective of User and Stakeholder Impact

User Satisfaction: Lack of effective internal communication systems can lead to dissatisfaction among the employees and cause high turnover which can be costly for the organization. For instance, if an airline has a reporting system for the flight crew, then the procedure will be more efficient and cost-effective, which will enhance economic sustainability.

Impact on Customer Experience: Improving the customer experience via IT projects can help to grow customer base and ultimately, revenues. For example, implementing an advanced booking platform that includes passengers' preferences, for instance, seat selection or meal preferences, would increase the rate of passengers' return travels and overall long-term business revenues.

3.2.7.4. Environmental Sust. Perspective of User and Stakeholder Impact

User Satisfaction: Employees who are satisfied with their jobs are likely to ensure sustainable practices with items like energy systems or wastes. For instance, when an interface for environmental metrics, like fuel or energy usage, is simplified, employees are more likely to participate in the airline's sustainability initiatives.

Impact on Customer Experience: As a result, IT systems that make the customer experience better while at the same time advancing environmental sustainability are also effective for environmental sustainability. For instance, an automated e-ticketing system that does away with paper tickets is an environmentally friendly solution that enhances customer satisfaction.

3.2.7.5. Social Sustainability Perspective of User and Stakeholder Impact

User Satisfaction: Increased user satisfaction within people at the workplace enhances employee motivation, leading to increased workplace productivity, positive organizational culture, and social sustainability. For instance, an efficient intranet that connects employees from different departments can enhance team dynamics and staff happiness.

Impact on Customer Experience: If implemented in IT projects, the customer experience enhancement can help in improving social sustainability by including accessibility for the disabled individuals. For instance, an application that is used to help passengers with disabilities or persons with mobility limitations means that all customers have equal access to the necessary services, which enhances the inclusion of the disabled in air transport.

3.2.7.6. Cultural Sustainability Perspective of User and Stakeholder Impact

User Satisfaction: It is thus obvious that a culturally sensitive system can enhance user satisfaction in a multinational workforce. For instance, a Turkish Airlines company has an internal platform that enables multilingual communication among employees of different cultures; therefore, increasing their job satisfaction.

Impact on Customer Experience: Introducing culturally sensitive IT systems can also improve the customer experience since they have to address a demographically diverse set of passengers. For example, an in-flight entertainment system that provides content in multiple languages and focuses on cultural events will be useful for the customer and contribute to cultural sustainability.

Table 3.7 Summarized concept table on User and Stakeholder Impact (C_8)

Economic Sustainability Perspective Productivity & Cost Efficiency Revenue Growth through Loyalty	**Environmental Sustainability Perspective** Sustainable Practices via IT Waste Reduction
Social Sustainability Perspective Improved Work Culture Waste Reduction	**Cultural Sustainability Perspective** Multilingual & Inclusive Systems Promotion of Cultural Events

The criteria discussed in this study have been previously utilized in academic research models. Table 8 provides an overview of the criteria employed in a study conducted by specific academic researchers. Please note that, these studies not directly written about sustainability or IT Project selection, they might be on different topics but basically consider the specified criteria in their selection or evaluation processes.

Table 3.8 The list of references for used criteria

#	Criteria	#	Sub-criteria	Covered By
C_1	Cost	$C_{1.1}$	Investment Costs	(Nowak, 2005) , (Zarjou & Khalilzadeh, 2022)
		$C_{1.2}$	Maintenance Costs	(AHMADI et al., 2010) (Ighravwe & Oke, 2019) (Chan & Prakash, 2012)
C_2	Financial Revenue	$C_{2.1}$	Expected Revenue/Income	(Wen et al., 2003)
		$C_{2.2}$	Expected Reduction in Operational Costs	this study
C_3	Strategic Alignment	$C_{3.1}$	Alignment with Business Goals	(Asosheh et al., 2010),(Dickinson et al., 2001), (Eilat et al., 2008) (Franco & Lord, 2011)
		$C_{3.2}$	Contribution to the Prestige of the Instution	(Billaut et al., 2010), (Topaler & Ayvaz-Çavdaroğlu, 2022 (NGUYEN et al., 2020)
		$C_{3.3}$	Compatibility with the country's technology policies	(Hsu et al., 2003)
		$C_{3.4}$	Market Potential	(Halouani et al., 2009)
C_4	Risk Assessment	$C_{4.1}$	Technical Failure Risk	(Tüysüz & Kahraman, 2006) (Knight & Robinson Fayek, 2002)
		$C_{4.2}$	Exceeding planned cost risk	(Raz et al., 2002) (Bonet et al., 2021)
		$C_{4.3}$	Operational Risk	(Xu et al., 2003)
C_5	Innovationional Contribution	$C_{5.1}$	Novelty of the Project Output	(Karasakal & Aker, 2017)
		$C_{5.2}$	Process or Technological Improvements	(Pietraszek & Skrzypczak-Pietraszek, 2014) (Serrano García et al., 2017) (Hosseini Ezzabadi et al., 2015) (Xu et al., 2003)
		$C_{5.3}$	Contribution to the science and society	(Karasakal & Aker, 2017)
C_6	Technical Feasibility	$C_{6.1}$	Availability of Technological Infrastructure	this study
		$C_{6.2}$	Compatibility with Existing Systems	this study

		$C_{6.3}$	Flexibility	this study
		$C_{6.4}$	Scalability	this study
C_7	Resource Availability	$C_{7.1}$	Availability of Human Resources	(Certa et al., 2009)
		$C_{7.2}$	Architectural Suitability	(Cabello-Briones et al., 2021) (Moaven & Habibi, 2020)
		$C_{7.3}$	Project Planning and Sc	(Laslo, 2010)
C_8	User and Stakeholder Impact	$C_{8.1}$	User Satisfaction	(Yusuf Durachman, 2016) (Williams et al., 2015)
		$C_{8.2}$	Impact on Customer Experience	this study

4. METHODOLOGY

4.1. Methodology Selection

Decision-making problems in daily and work life are often of a nature that cannot be solved by considering a single criterion. Evaluating such choices by considering a single criterion may lead to unrealistic decisions due to the nature of the work. Therefore, evaluating all criteria together is a more effective method. In this section, the details of the reason of why a Fuzzy TOPSIS is selected instead of classical MCDM methods will be explained in detail. After that, Developments of Fuzzy Sets will be explained chronologically, and then Theoretical Framework of Spherical TOPSIS will be explained in detail.

4.2. The Reason of Selecting Fuzzy System Method

Fuzzy logic, unlike the classical logic system, is a framework that assigns membership degrees to verbal expressions used in daily life. Its basis is relied on fuzzy sets. In the classical logic approach, an element is either a member of a set or not. However, in the fuzzy logic approach, it belongs or not according to the membership degree determined. Thus, it can be said that fuzzy logic gives the rate of occurrence of events. It has advantages over classical logic in terms of being flexible, established in the natural language order and being able to express uncertainty. Linguistic or verbal expressions constitute an important part of fuzzy logic and its applications. The proposal of fuzzy logic for decision-making in uncertain and uncertain situations inherent in systems involving human decision-making was first introduced to the literature with an article written by Zadeh in 1965(Zadeh, 1965). According to Zadeh, the status of an element belonging to a set takes a value between 0 and 1.

The main difference between fuzzy multi-criteria decision-making (Fuzzy MCDM) methods and classical multi-criteria decision-making (MCDM) methods stands for their ability to tackle uncertainty and vagueness in decision-making processes. Classical MCDM methods require precise and deterministic data like two sides priority comparison on AHP, which fact make classical MCDM less suitable for real-world scenarios where data might be imprecise or subjective. On the other hand, Fuzzy MCDM methods use fuzzy logic to manage uncertainty which feature allows for more realistic modeling of decision-making scenarios. This is especially functional when dealing with linguistic assessments or when the criteria are not properly measurable. This attribute makes Fuzzy MCDM more preferable option in complex and uncertain environments(Kulak et al., 2005).

Since precise figures may not always be accessible in real-world situations and decision-makers' preferences are sometimes arbitrary and vague, fuzzy approaches are frequently used. Fuzzy sets, for instances, provide an additional dimension to decisions by allowing criteria significance to be expressed in terms of linguistic variables (e.g., "extreme," "average," "modest") instead of exact value in numbers (Y.-J. Wang, 2011).By considering these circumstances and pros, a fuzzy methodology is selected for the real life problem illustration and the application.

4.3. The Reason of Selecting TOPSIS Method

There are several reasons for selecting the TOPSIS method. Those are; simplicity and computational ease, practical applicability, comparison with ideal and anti-ideal solutions:

Due to its simplicity on calculation, Fuzzy TOPSIS is more popular in cases of MCDM because of its simplicity and less difficulty. Unlike other decision-making techniques where one might have to solve complicated matrices or computationally intensive functions, Fuzzy TOPSIS reduces the effort by ranking the decision alternatives based on the distances between the other options and the ideal solution. It is helpful especially when working with a large number of criteria and alternatives, which reduces the computational complexity greatly. Fuzzy TOPSIS is not only faster at providing results compared to the conventional approach but it also reduces the possibility of arriving at wrong computations. Making it even more beneficial for managers and decision-makers, who require processing large volumes of data to arrive at actionable conclusions in short time periods (Vahdani & Hadipour, 2011)

The other spefic advantage of TOPSIS is practical applicability. It is useful to point out here that Fuzzy TOPSIS is quite useful in dealing with uncertainties that are inevitable in real life decisions. Thus, using the fuzzy numbers in defining the weights of criteria and in the evaluation of the alternatives offers a more accurate representation of imprecise and subjective information. This capability is most useful when data is missing, vague, or difficult to put into exact figures as may be the case in most real life situations. Therefore, Fuzzy TOPSIS is considered as superior to other approaches to the decision-making process in conditions where it is challenging to consider all the existing discrepancies and fluctuations in the available data. (Osiro et al., 2014)

The last reason of picking up TOPSIS is its comparison opportunity with ideal and anti-ideal solutions: Fuzzy TOPSIS is used to arrange the alternatives depending on the relative distance of the analytical fuzzy sets with respect to an ideal solution and an anti-ideal solution. This makes it easier for decision makers to assess any given choice and make an informed decision on the most effective one. Hence, Fuzzy TOPSIS offers a definitive way of ranking options by determining the extent to which each of the given alternatives is close to the ideal solution and far from the anti-ideal solution. This clarity and effectiveness make Fuzzy TOPSIS a powerful tool in scenarios where multiple competing criteria must be considered (T.-C. Wang & Chang, 2007)

4.4. The Reason of Selecting Spherical Fuzzy TOPSIS Method

When compared the Spherical Fuzzy TOPSIS approach to other fuzzy methods such as IFS (Intuitionistic Fuzzy Sets), IFS2 (Type-2 Intuitionistic Fuzzy Sets), and NS (Neutrosophic Fuzzy Sets), there are a number of distinctions and benefits.

Below is a comprehensive overview of its pros and differences:

Three-Dimensional Membership Functions:

In Spherical Fuzzy Sets (SFS) there are three aspects involved like in IFS and NS membership level and non-membership level along with degrees of hesitancy. Unlike IFS and NS where these degrees have specific limitations such as the sum of squares being equal or less, in SFS these degrees are allowed within a spherical volume. This presents a less rigid model where the levels of inclusion and exclusion and uncertainty can vary independently but are limited by a spherical boundary.

Spherical Distance Measurement:

The Spherical Fuzzy TOPSIS approach uses distance to measure the closeness between decision points and ideal solutions instead of the typical Euclidean distance in other techniques. This spherical distance captures the linear shifts in membership degrees more effectively than traditional methods. This non linear aspect enhances the suitability of distance for fuzzy spaces, in three dimensions and enhances the precision and utility of distance measurements in decision making scenarios.

Aggregation and Arithmetic Operations:

Arithmetic functions developed for SFS include operations such as addition, subtraction, and multiplication, and these operations are performed within the global space defined by SFSs. These arithmetic operations ensure that the results are in the appropriate range while remaining within the structural boundaries of SFSs. This is important considering that SFSs are a geometrically based representation. After all, the arithmetic operations of SFSs take into account the geometric constraints of the global representation and are performed in accordance with these constraints.

Generalization of Existing Fuzzy Models:

IFS, IFS2, and NS are all included in and enhanced by SFS, which functions as a generic model. SFS can simulate a wider array of uncertainty and decision-making scenarios than its predecessors, providing a more complete framework. This is made possible by establishing membership functions on a spherical surface and permitting individual attribution of parameters within a bigger domain.

Advantages of Spherical Fuzzy TOPSIS:

Enhanced Flexibility in Decision Making: More freedom to express choices and uncertainties is made available to decision-makers by the independence of membership, non-membership, and resistance degrees. When complicated decisions are involved in MCDM procedures, this flexibility is very helpful.

Improved Accuracy of Distance Measurements: In comparison with linear distances, Spherical Fuzzy TOPSIS employs spherical distances for more precise evaluation of the proximity between the alternatives and ideal solutions. This results in the increase of the accuracy of the ranking and higher quality of the decisions made.

Adaptability to Complex Decision Environments: As other Fuzzy Set operations, due to the fact that the spherical framework is more capable of dealing with different type of uncertainties compared to the linear, it is more applicable in decision-making process that includes multiple criteria which may have conflict, such as the supplier selection decision, the risk evaluation decision, and the resource allocation decision. The summary features and benefits of the Sphercal Fuzzy TOPSIS methodology is presented on Table 4.1.

Table 4.1 Features and benefits of the Sphercal Fuzzy TOPSIS

Feature	Benefit
Three-Dimensional Membership Functions	Greater flexibility in representing uncertainty and hesitancy.
Improved Distance Measurement	More accurate proximity calculations, leading to better alternative rankings.
Adaptability	Applicability across diverse, complex decision-making scenarios.
Enhanced Accuracy	Superior ranking of alternatives by capturing subtle differences in membership and hesitancy.
Simplified Arithmetic and Aggregation	Efficient and robust computations using the SWAM operator.
Representation of Hesitancy	Allows modeling of real-world uncertainty in a more precise manner.
Suitability for Sustainability	Effectively balances conflicting criteria in sustainability-oriented decision problems.

Therefore, the Spherical Fuzzy TOPSIS method has many advantages over the other methods in terms of flexibility, accuracy and applicability to the complex environment.

Its introduction marks an important advancement in the field of fuzzy set theory and multi-criteria decision-making.

4.5. Developments of Fuzzy Sets

Zadeh's groundbreaking work (Zadeh, 1965)revolutionized the way we approach uncertainty in models with the introduction of fuzzy set theory in his acclaimed publication "Fuzzy Sets". This innovative framework expanded upon classical set theory by incorporating the concept of membership within sets. A significant departure from conventional binary logic methods and crucial, for handling imprecise or uncertain data accurately. The basic concepts of fuzzy set theory have been widely utilized in fields such as artificial intelligence and decision-making processes and have had a substantial impact, on the advancement of these work of fields.

Expanding upon the idea of fuzzy sets, Zadeh brought in Type 2 fuzzy sets (Zadeh, 1965)This expansion was created to handle cases where the membership function itself is unclear. The hypotesis was enabling a variety of membership values rather than just one point. Type-2 fuzzy sets have shown to be particularly useful in situations with levels of data uncertainty by offering an adaptable and detailed method, for execution on some circumstances. The advancement has greatly influenced the progress of logic systems specifically in fields that demand sophisticated control methods and pattern recognition abilities.

In 1975, Zadeh introduced the concept of interval valued sets as a means to expand on existing theory. This modification enabled the representation of an elements membership degree as an interval range of a specific value. It facilitated an extensive consideration of uncertainty. Interval-valued fuzzy sets have been particularly useful in decision-making processes where it is difficult to determine exact membership values, offering a more robust framework for modeling imprecise or incomplete information.

Atanassov brought about a concept in 1986 with intuitionistic fuzzy sets that included non-membership and hesitation degrees alongside the traditional fuzzy set model components to better capture uncertainty and indecision in complex decision making scenarios where these aspects are crucially important to consider definitively. The integration of fuzzy sets has greatly expanded the adaptability of fuzzy set theory by enabling advanced applications in diverse areas like medical diagnosis techniques and pattern identification as well, as multi criteria decision making analysis. After that, Yager introduced multisets which broadened the scope of fuzzy set theory by permitting the incorporation of elements appearing multiple times and having their own respective membership degrees attached to them individually. This development has particularly been efficient in data analysis and pattern recognition domains where the frequency of elements plays a important role. By addressing to multi fuzzy sets, it has widened the spectrum of issues that can be tackled using logic thereby boosting the theories flexibility.

In 2010, Torra brought in the theory of fuzzy sets by introducing hesitant fuzzy sets which let the one depict numerous potential membership values for one specific element (Torra, 2010) . This development proves a beneficial role when decision makers make decision under uncertain environments as it allows them to model scenarios with no agreement. Hesitant fuzzy sets have gained popularity in decision making processes involving criteria and social network analysis where the capacity to grasp and portray hesitation is vital.

The next important development in the theory of fuzzy sets is the picture fuzzy sets which was proposed by Cuong in 2015(Cuong & Kreinovich, 2013)). The picture fuzzy sets consist of a third element of refusal in addition to the conventional degrees of membership and non-membership. This extension permits the depiction of neutrality/indecisiveness. Thus, picture fuzzy sets are useful in cases where decision makers required to make a decision as yes, abstain, no, refusal. To sum up, the introduction of this concept has made developments in fields like decision theory, and computational intelligence possible.

Spherical fuzzy sets, the methodology that is executed in this paper, is developed by Kahraman in 2019. Spherical fuzzy sets can be considered as one of the most advanced developments of the fuzzy set theory. These sets are defined by three independent of membership parameters that are membership, non-membership and hesitancy which considered to lie within a spherical region. It is more advanced in terms of capturing the uncertainty compared to other methodologies hence spherical fuzzy sets are particularly effective in decision making problems where uncertainty has to be modeled attentively.

Since the initial introduction of fuzzy set theory, there have been developments and improvements made to increase its dynamics and to use it in more complex, uncertain environments. These developments underscore the theory's versatility and its critical role in addressing real-world problems characterized by imprecision and ambiguity.

4.6. Fuzzy Sets and Spherical Fuzzy Set Operations

4.6.1. Fuzzy Logic and Fuzzy Sets

Fuzzy logic, unlike the classical logic system, is a logical system that assigns membership degrees to verbal expressions used in daily life. Its basis is based on fuzzy sets. In the classical logic approach, an element is either a member of a set or not. However, in the fuzzy logic approach, it belongs or not according to the membership degree determined. Thus, it can be said that fuzzy logic gives the rate of occurrence of events. It has advantages over classical logic in terms of being flexible, established in the natural language order and being able to express uncertainty. Linguistic or verbal expressions constitute an important part of fuzzy logic and its applications. The proposal of fuzzy logic for decision-making in uncertain and uncertain situations inherent in systems involving human decision-making was first introduced to the literature in an article written by Zadeh (Zadeh, 1965).

According to Zadeh, the status of an element belonging to a set takes a value between 0 and 1. Although the first presented model was very basic, various methods based on this logic were developed in later periods.

Fuzzy sets, rules, inputs and outputs form fuzzy systems when considered as a whole. Fuzzy systems can be expressed as basically converting the input into fuzzy data and processing it according to its own rules and then converting the resulting fuzzy output into a crisp output. Fuzzy logic has a wide range of applications because it can be used in situations where humans are involved or that involve uncertainty.

4.6.2. Fuzzy TOPSIS Method

Fuzzy TOPSIS extends the classical TOPSIS by incorporating fuzzy set theory to handle the uncertainty and vagueness inherent in human judgment and preferences. This method allows decision-makers to evaluate alternatives using linguistic variables represented by fuzzy numbers.

Steps of the Fuzzy TOPSIS Method are explained below;

Step 1: Construct the Fuzzy Decision Matrix and Determine Fuzzy Weights

Let $A = \{A_1, A_2, \dots, A_m\}$ be a set of m alternatives and $C = \{C_1, C_2, \dots, C_n\}$ be a set of n criteria.

1. Fuzzy Decision Matrix: Construct the fuzzy decision matrix $\widetilde{D} = \left[\tilde{x}_{ij}\right]_{m\times n}$ whew $\tilde{x}_{ij}$ is the performance rating of alternative A_i with respect to criterion C_j , expressed as a fuzzy number.

2.Fuzzy Weights Vector: Determine the fuzzy weights $\widetilde{W} = (\widetilde{w}_1, \widetilde{w}_2, \dots, \widetilde{w}_n)$ for the criteria, where $\widetilde{w}_j$, is a fuzzy number representing the importance of criterion C_j.

The weights should satisfy the normalization condition:

$$\sum_{j=1}^{n} m_{w_j} = 1 \tag{1}$$

where m_{w_j} is the most probable value of $\widetilde{w}_j$.

Step 2: Normalize the Fuzzy Decision Matrix

Normalization adjusts the scales of different criteria to make them comparable.

For Benefit Criteria (Higher Values Preferred) and Cost Criteria (Lower Values Preferred), respectively:

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^{max}}, \frac{m_{ij}}{m_j^{max}}, \frac{u_{ij}}{l_j^{max}}\right)$$

$$\tilde{r}_{ij} = \left(\frac{l_j^{min}}{u_{ij}}, \frac{m_j^{min}}{m_{ij}}, \frac{u_j^{min}}{l_{ij}}\right) \tag{2}$$

Where;

$$\begin{aligned} l_j^{max} &= max_i l_{ij} \\ m_j^{max} &= max_i m_{ij} \\ u_j^{max} &= max_i u_{ij} \\ l_j^{min} &= min_i l_{ij} \\ m_j^{min} &= min_i m_{ij} \\ u_j^{min} &= min_i u_{ij} \end{aligned} \tag{3}$$

Step 3: Calculate the Weighted Normalized Fuzzy Decision Matrix

Multiply each element of the normalized decision matrix by its corresponding fuzzy weight:

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \widetilde{w}_j \tag{4}$$

The multiplication of two TFNs $\tilde{A} = (l_A, m_A, u_A)$ and $\tilde{B} = (l_B, m_B, u_B)$ is defined as:

$$\tilde{A} \otimes \tilde{B} = (l_A \times l_B, m_A \times m_B, u_A \times u_B) \tag{5}$$

Step 4: Determine the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS):

FPIS $\widetilde{(A^*})$:

$$\tilde{A}^{*} = (\tilde{v}_1^{*}, \tilde{v}_2^{*}, \dots, \tilde{v}_n^{*}) \tag{6}$$

where $\tilde{v}_j^{*} = \left(u_j^{*}, u_j^{*}, u_j^{*}\right)$ and $u_j^{*} = max_i u_{ij}$

FNIS $(\widetilde{A^{-}})$:

$$\tilde{A}^{-} = (\tilde{v}_1^{-}, \tilde{v}_2^{-}, \dots, \tilde{v}_n^{-}) \tag{7}$$

where $\tilde{v}_j^{-} = \left(l_j^{*}, l_j^{*}, l_j^{*}\right)$ and $l_j^{*} = min_i l_{ij}$.

Step 5: Calculate the Distance of Each Alternative from FPIS and FNIS

Compute the distance between each alternative and the FPIS and FNIS using a suitable distance measure for fuzzy numbers, such as the vertex method.

Distance Between Two TFNs: Given two TFNs $\tilde{A} = (l_A, m_A, u_A)\ and\ \tilde{B} = (l_B, m_B, u_B)$, the distance is calculated as:

$$d\left(\tilde{A}, \tilde{B}\right) = \sqrt{\frac{1}{3}\left[(l_A - l_B)^2 + (m_A - m_B)^2 + (u_A - u_B)^2\right]} \tag{8}$$

Distance of Each Alternative from FPIS:

$$d_i^{*} = \sqrt{\sum_{j=1}^{n} \left[d\left(\tilde{v}_{ij}, \tilde{v}_j^{*}\right)\right]^2} \tag{9}$$

Distance from FNIS:

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} \left[d\left(\tilde{v}_{ij}, \tilde{v}_j^{-}\right)\right]^2} \tag{10}$$

Step 6: Calculate the Closeness Coefficient for Each Alternative

The closeness coefficient CC_i indicates how close an alternative is to the FPIS and is calculated as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{11}$$

where $0 \leq CC_i \leq 1$ and a higher CC_i value means the alternative is closer to the FPIS.

Step 7: Rank the Alternatives

Rank the alternatives in descending order based on their closeness coefficients CC_i . The alternative with the highest CC_i is considered the best choice.

In summary, Fuzzy TOPSIS effectively addresses the ambiguity and uncertainty in decision-making by incorporating fuzzy set theory into the TOPSIS framework. By representing subjective judgments with fuzzy numbers, it allows for a more nuanced evaluation of alternatives across multiple criteria.

After a brief introduction of Fuzzy TOPSIS, Spherical fuzzy sets (SFS) logic is explained. Spherical fuzzy sets (SFS) were introduced to the literature in 2019 by Kutlu and Kahraman as an extension of fuzzy sets. Before explaining spherical fuzzy sets, it is necessary to explain the concept of spherical distance. In the literature, there are studies in previous years that give geometric and stereometric representations of the distance between intuitive fuzzy sets. In these studies, it has been shown that spherical distance seems more appropriate than linear distances because it does not have a linear structure since the membership degrees change (Gündoğdu & Kahraman, 2019). However, these studies mostly remained in the form of using intuitive fuzzy sets on the sphere. In this context, the following expression is provided, where $\tilde{A} = \{\langle u, \mu_{\tilde{A}}(u), v_{\tilde{A}}(u)\rangle : u \in U\}$ is an intuitionistic fuzzy set on the surface of a sphere.

$$\mu_{\tilde{A}} + v_{\tilde{A}} + \pi_{\tilde{A}} = 1 \tag{12}$$

This equation can be commented as $x^2 + y^2 + z^2 = 1$, under the condititon of $x^2 = \mu_{\tilde{A}}(u), y^2 = v_{\tilde{A}}(u), z^2 = \pi_{\tilde{A}}(u)$. The proposed spherical fuzzy sets are based on the fact that the indecision of the basic decision maker can be defined independently of the membership values and the following condition is met.

$$0 \leq \mu_{\tilde{A}}^2 + v_{\tilde{A}}^2 + \pi_{\tilde{A}}^2 \leq 1 \qquad \forall u \in A \tag{13}$$

When this equation is used; on the surface of the sphere below equation is satisfied.

$$\mu_{\tilde{A}}^2 + v_{\tilde{A}}^2 + \pi_{\tilde{A}}^2 = 1 \qquad \forall u \in A \tag{14}$$

Figure 4.1 shows the Euclidean and spherical distances. Euclidean distance is the shortest distance between two points. In the spherical fuzzy set approach, the sphere is not a solid but a spherical volume. Therefore, the Euclidean distance measure is meaningful. This also means that any two points within the spherical volume are on the surface of another sphere.

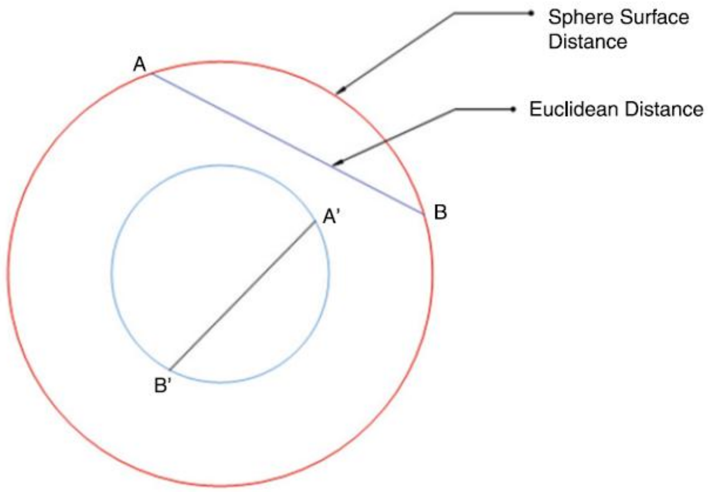

Figure 4.1 Euclidean distance and spherical distance on a spherical surface

In spherical fuzzy sets, the sum of squares of the membership, non-membership and indecision parameters can be between 0 and 1, while each of them can be defined independently between 0 and 1. Figure 4.2Figure 4.1 shows the differences in geometric representations of intuitionistic fuzzy sets (Type-1 and Type-2), neutrosophic fuzzy sets and spherical fuzzy sets, which are extensions of fuzzy sets.

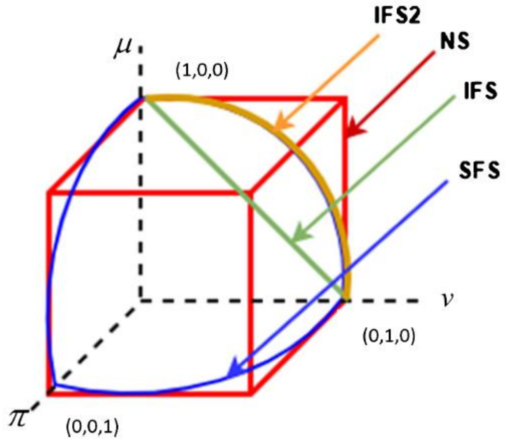

Figure 4.2 Geometric representation difference of fuzzy set extensions

Based on the Figure 4.2 , the spherical distance between two spherical clusters on the surface of the sphere shown geometrically is expressed by the equation below.

$$\operatorname{dis}(\tilde{A}_s, \tilde{B}_s) = \frac{2}{\pi}\sum_{i=1}^{n} \arccos\left\{1 - \frac{1}{2}\left(\left(\mu_{\tilde{A}_s} - \mu_{\tilde{B}_s}\right)^2 + \left(v_{\tilde{A}_s} - v_{\tilde{B}_s}\right)^2 + \left(\pi_{\tilde{A}_s} - \pi_{\tilde{B}_s}\right)^2\right)\right\} \quad (15)$$

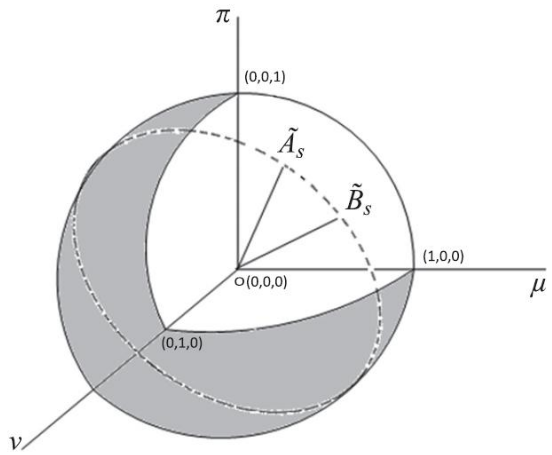

Figure 4.3 Geometric representation of spherical fuzzy sets.

Using the information of

$$\mu_{\tilde{A}}^2 + v_{\tilde{A}}^2 + \pi_{\tilde{A}}^2 = 1 \qquad \forall u \in A \tag{16}$$

the normalized spherical distance expression between $\tilde{A}$ and $\tilde{B}s$ on the surface of the sphere emerges as equation 17, if the equation is normalized to obtain a set of values in the range [0,1].

$$\begin{aligned} &\mathrm{dis}_n\left(\tilde{A}_s, \tilde{B}_s\right) = \\ &\frac{2}{n\pi}\sum_{i=1}^{n} \arccos\left(\mu_{\tilde{A}_s}(u_i) \cdot \mu_{\tilde{B}_s}(u_i) + v_{\tilde{A}_s}(u_i) \cdot v_{\tilde{B}_s}(u_i)\right. \\ &\left.+ \pi_{\tilde{A}_s}(u_i) \cdot \pi_{\tilde{B}_s}(u_i)\right) \end{aligned} \tag{17}$$

For reaching the result of decision-making process, Spherical Weighted Arithmetic Mean (SWAM) operator is used. For definition of SWAM, let $w = (w_1, w_2, \dots, w_n); w_i \in$ [0,1]; $\sum_{j=1}^{n} w_j = 1$, SWAM is calculated as

$$\begin{aligned} &\mathrm{SWAM}_w\left(A_{S_1}, \dots, A_{S_n}\right) = w_1 A_{S_1} + w_2 A_{S_2} + \dots + w_n A_{S_n} \\ &= \left\{\left[1 - \prod_{i=1}^{n}\left(1 - \mu_{A_{S_i}}^2\right)^{w_i}\right]^{\frac{1}{2}},\right. \\ &\left.\prod_{i=1}^{n} v_{A_{S_i}}^{w_i}, \left[\prod_{i=1}^{n}\left(1 - \mu_{A_{S_i}}^2\right)^{w_i} - \prod_{i=1}^{n}\left(1 - \mu_{A_{S_i}}^2 - \pi_{A_{S_i}}^2\right)^{w_i}\right]^{\frac{1}{2}}\right\} \end{aligned} \tag{18}$$

In addition, Score and Accuracy Functions is defined. Score and accuracy can be used to evaluate alternatives. With this process, a crisp number is obtained from a fuzzy number.

$$\text{Score}(A_s) = \left(\mu_{A_s} - \pi_{A_S}\right)^2 - \left(v_{A_s} - \pi_{A_S}\right)^2$$
$$\text{Accurancy}(A_s) = \mu_{A_s}^2 + v_{A_S}^2 + \pi_{A_S}^2 \tag{19}$$

Since fuzzy values are converted to crisp values, comparison of fuzzy numbers can be made. A_s<B_s is possible when the following conditions are met.

I. $\text{Score}(A_s) < \text{Score }(B_s)$ or

II. $\text{Score}(A_s) = \text{Score }(B_s)$ and $\text{Accurancy}(A_s) < \text{Accurancy }(B_s)$

4.7. Theoretical Framework of the Spherical Fuzzy Operations

The goal of all three-dimensional extensions of typical fuzzy sets, which include intuitionistic fuzzy sets (IFS), intuitionistic fuzzy sets of second type (IFS2), and neutrosophic fuzzy sets (NFS), is to present a more thorough explanation of the decisions made by experts. In this direction, this paper utilize generalized three-dimensional spherical fuzzy sets (SFS) and highlights several key distinctions from conventional fuzzy sets. The spherical fuzzy distances that have been proven in the literature serve as the foundation for the new class of fuzzy sets. The multi-criteria decision-making approach TOPSIS is expanded to spherical fuzzy TOPSIS. To sum up, fuzzy TOPSIS method, has been developed in the literature with different extensions of fuzzy sets. In this study, the spherical fuzzy TOPSIS method introduced to the literature by (Gündoğdu & Kahraman, 2019) selected as the methodology. The spherical fuzzy sets and TOPSIS method to be explained in this section.

In order to understand the notion, the relevant spherical fuzzy operations and the SF-TOPSIS approach will be explained step by step in relation to each other in this part.

This method is an MCDM method based on spherical fuzzy sets. In multi-criteria decision-making problems, which are also explained in the fuzzy TOPSIS method, decision matrices containing the evaluation values of the alternatives in terms of each criterion can also be created in the spherical fuzzy environment. In this problem, alternatives (projects) can be specified as $P = \{ p_1, \; p_2 \; , \dots , p_m \mid m \geq 2 \}$ and criteria as $C = \{c_1, c_2, \dots , c_n \}$,weight vector as $w_1, w_2, \dots , w_n, 0 \leq w_j \leq 1$ provides the equation of $\sum_{j=1}^{n} w_j = 1$. In addition, let two Spherical fuzzy sets be $\tilde{A}_S = (\mu_{\tilde{A}_S}, \; v_{\tilde{A}_S} \; , \; \pi_{\tilde{A}_S})$ and $\widetilde{B}_S = (\mu_{\tilde{B}_S}, \; v_{\tilde{B}_S} \; , \pi_{\tilde{B}_S})$.

Step 1: The evaluations of decision makers are listed based on linguistic terms.

Step 2: The decisions of the decision makers are combined using the Spherical Weighted Arithmetic Mean (SWAM) operator. With regards to SWAM operator, let $w = (w_1, w_2, \dots , w_n); w_i \in [0,1]; \;\; \sum_{j=1}^{n} w_j = 1$, SWAM will be calculated as

$$\begin{aligned} &\mathrm{SWAM}_w \left(A_{S_1}, \dots , A_{S_n}\right) = w_1 A_{S_1} + w_2 A_{S_2} + \dots + w_n A_{S_n} \\ &= \left\{ \left[1 - \prod_{i=1}^{n} \left(1 - \mu_{A_{S_i}}^2\right)^{w_i} \right]^{\frac{1}{2}}, \right. \\ &\left. \prod_{i=1}^{n} v_{A_{S_i}}^{w_i}, \left[\prod_{i=1}^{n} \left(1 - \mu_{A_{S_i}}^2\right)^{w_i} - \prod_{i=1}^{n} \left(1 - \mu_{A_{S_i}}^2 - \pi_{A_{S_i}}^2\right)^{w_i} \right]^{\frac{1}{2}} \right\} \end{aligned} \tag{20}$$

Step 2.1 Since all criteria do not have equal importance in real scenario situations, each decision maker's opinion of the importance of the criteria is combined. The weights of the decision makers are also taken into consideration and a weight matrix of the criteria is created.

Step 2.2 Spherical fuzzy decision matrix is established in line with the opinions of decision makers. According to the evaluations of the P_i th alternative in terms of the C_i th criterion, the values C_i (P)=(μ_{ij} , v_{ij}, π_{ij}) are filled in the matrix and the $D = \left(C_j(X_i)\right)_{m \times n}$ decision matrix is established as follows.

$$D = \left(C_j(P_i)\right)_{m\times n} = \begin{bmatrix} (\mu_{11}, v_{11}, \pi_{11}) & \cdots & (\mu_{1n}, v_{1n}, \pi_{1n}) \\ \vdots & \ddots & \vdots \\ (\mu_{\mathrm{m}1}, v_{m1}, \pi_{m1}) & \cdots & (\mu_{mn}, v_{mn}, \pi_{mn}) \end{bmatrix} \tag{21}$$

Step 3 After determining the weight of each criterion and the degree of the alternatives, the weighted spherical fuzzy matrix is established as follows, based on the matrix created in the previous step.

$$D = \left(C_j(P_{iw})\right)_{m\times n} = \begin{bmatrix} (\mu_{11w}, v_{11w}, \pi_{11w}) & \cdots & (\mu_{1nw}, v_{1nw}, \pi_{1nw}) \\ \vdots & \ddots & \vdots \\ (\mu_{\mathrm{m}1w}, v_{m1w}, \pi_{m1w}) & \cdots & (\mu_{mnw}, v_{mnw}, \pi_{mnw}) \end{bmatrix} \tag{22}$$

Below formula should be utilized while calculating the weighted spherical fuzzy matrix, multiplication of two Spherical Fuzzy Sets be:

$$\tilde{A}_S \otimes \tilde{B}_S = \left\{ \begin{matrix} \mu_{\tilde{A}_S}\mu_{\tilde{B}_S}\left(v_{\tilde{A}_S}^2 + v_{\tilde{B}_S}^2 - v_{\tilde{A}_S}^2 v_{\tilde{B}_S}^2\right)^{\frac{1}{2}}, \\ \left(\left(1 - v_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1 - v_{\tilde{A}_S}^2\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2\right)^{\frac{1}{2}} \end{matrix} \right\} \tag{23}$$

Step 4 The weighted spherical fuzzy matrix is clarified and score functions are written for each alternative-criteria pair. Ideal solutions will be obtained by using the score values calculated by converting fuzzy values to crisp values.

$$\text{Score}\left(C_j(P_{iw})\right) = \left(\mu_{ijw} - \pi_{ijw}\right)^2 - \left(v_{ijw} - \pi_{ijw}\right)^2 \tag{24}$$

Step 5 Using the score values, the spherical fuzzy positive ideal solution (SF-PIS) and the spherical fuzzy negative ideal solution (SF-NIS) are determined.

For the spherical fuzzy positive ideal solution (SF-PIS), the highest score value of each criterion is found on the decision matrix. Then, the weighted global fuzzy value of the criterion that gives the highest score value is written.

$$\begin{gathered} P^* = \left\{C_j, max_i \left\langle \text{Score}\left(C_j(P_{iw})\right)\right\rangle \mid j = 1,2 \ldots n\right\} \\ P^+ = \{\langle C_1, (\mu_1^+, v_1^+, \pi_1^+)\rangle, \langle C_2, (\mu_2^+, v_2^+, \pi_2^+)\rangle \ldots \ldots \langle C_n, (\mu_n^+, v_n^+, \pi_n^+)\rangle\} \end{gathered} \quad (25)$$

As for the spherical fuzzy negative ideal solution (SF-NIS), the lowest score value of each criterion is found on the decision matrix. Then, the weighted spherical fuzzy value of the criterion that gives the lowest score value is written.

$$\begin{gathered} P^* = \left\{C_j, min_i \left\langle \text{Score}\left(C_j(P_{iw})\right)\right\rangle \mid j = 1,2 \ldots n\right\} \\ P^- = \{\langle C_1, (\mu_1^-, v_1^-, \pi_1^-)\rangle, \langle C_2, (\mu_2^-, v_2^-, \pi_2^-)\rangle \ldots \ldots \langle C_n, (\mu_n^-, v_n^-, \pi_n^-)\rangle\} \end{gathered} \quad (26)$$

Step 6

For each P_i alternative, the distances to SF-PIS and SF-NIS are calculated. The Euclidean distance formula is used in the calculations.

The following equation can be used for the spherical fuzzy negative ideal solution (SF-NIS). Thus, the distance of each criterion to the negative ideal solution is obtained. The greater this distance, the higher the probability of being selected.

$$D(P_i, P^-) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n} \left(\left(\mu_{p_i} - \mu_{p^-}\right)^2 + \left(v_{p_i} - v_{p^-}\right)^2 + \left(\pi_{p_i} - \pi_{p^-}\right)^2\right)} \quad (27)$$

The following equation can be used for the spherical fuzzy positive ideal solution (SF-PIS). Thus, the distance of each criterion to the positive ideal solution is obtained. The smaller this distance, the higher the probability of being selected.

$$D(P_i, P^+) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n} \left(\left(\mu_{p_i} - \mu_{p^+}\right)^2 + \left(v_{p_i} - v_{p^+}\right)^2 + \left(\pi_{p_i} - \pi_{p^+}\right)^2\right)} \tag{28}$$

Step 7 The minimum distance from the spherical fuzzy positive ideal solution and the maximum distance from the spherical fuzzy negative ideal solution are selected.

$$\begin{gathered} D_{\max}\,(P_i, P^-) = \max_{1 \le i \le m} D(P_i, P^-) \\ D_{\min}\,(P_i, P^+) = \max_{1 \le i \le m} D(P_i, P^+) \end{gathered} \tag{29}$$

Step 8

The modified closeness ratio is calculated using the values determined in Step 7. The modified closeness ratio formula proposed by Zhang & Xu, (2014)is as in below equation:

$$\xi(P_i) = \frac{D(P_i, P^-)}{D_{max}(P_i, P^-)} - \frac{D(P_i, P^+)}{D_{min}(P_i, P^+)} \tag{30}$$

In this equation, the second element will be at least equal to the first, so the equation returns a negative or zero result. To obtain positive or zero values, the equation is revised to calculate the closeness ratio as follows:

$$\xi(P_i) = \frac{D(P_i, P^+)}{D_{min}(P_i, P^+)} - \frac{D(P_i, P^-)}{D_{max}(P_i, P^-)} \tag{31}$$

Step 9 The alternatives are ranked according to their suitability and the most suitable alternative is determined according to this ranking. It can be applied by selecting one of the two calculations given in Step 8. If Equation 30 is used, the selection is made in decreasing order of closeness ratios. The alternative with the highest value is selected as the most suitable. If Equation 31 is used, the selection is made in increasing order of closeness ratios. It can be said that the alternative with the lowest value is the most suitable.

5. NUMERICAL EXAMPLE

5.1. Application and Numerical Analysis

Spherical Fuzzy TOPSIS methodology is executed to a project selection problem in an airline company.

The details of the projects are explained previously in detail. P_1, P_2, P_3, P_4, P_5, P_6 are assessed. Project evaluation decision criteria may differ depending on the number of qualitative and quantitative components. Numerous criteria and sub-criteria have been established based on an extensive assessment of the literature. 23 criteria are used in our execution. The details of these criteria are mentioned in section 3. Three decision makers are included who are working for IT departments. DM1 is the experienced IT Specialist, DM2 is the Head of Project Management Office and DM3 is the Head of IT Strategy Department. The weights of these decision makers have different which are 0.3, 0.2 and 0.5 respectively. Initially, decision makers' opinions are collected using the linguistic phrases listed in Table 5.1 for the criteria; and Table 5.2 for the projects in relation to the goal. Decision makers' opinions on projects are collected;

Linguistic Terms	(μ, v, π)
Superior(S)	(0.9, 0.1, 0.1)
Extremely Good(EG)	(0.8, 0.2, 0.2)
Very Good(VG)	(0.7, 0.3, 0.3)
Good(G)	(0.6, 0.4, 0.4)
Fair(F)	(0.5, 0.5, 0.5)
Poor(P)	(0.4, 0.6, 0.4)
Very Poor(VP)	(0.3, 0.7, 0.3)
Extremely Poor(EP)	(0.2, 0.8, 0.2)
Inferior(I)	(0.1, 0.9, 0.1)

Table 5.3, Table 5.4, Table 5.5 contain all of the linguistic judgments. The importance weights of the criteria determined by Decision Makers and they are represented by linguistic terms in Table 5.6.

Table 5.1 Linguistic terms and corresponding spherical fuzzy numbers (for criteria)

Linguistic Terms	(μ, v, π)
Absolutely more Importance (AMI)	(0.9, 0.1, 0.1)
Very High Importance (VHI)	(0.8, 0.2, 0.2)
High Importance (HI)	(0.7, 0.3, 0.3)
Slightly More Importance (SMI)	(0.6, 0.4, 0.4)
Equally Importance (EI)	(0.5, 0.5, 0.5)
Slightly Low Importance (SLI)	(0.4, 0.6, 0.4)
Low Importance (LI)	(0.3, 0.7, 0.3)
Very Low Importance (VLI)	(0.2, 0.8, 0.2)
Absolutely Low Importance (ALI)	(0.1, 0.9, 0.1)

Table 5.2 Linguistic terms and corresponding spherical fuzzy numbers (for projects)

Linguistic Terms	(μ, v, π)
Superior(S)	(0.9, 0.1, 0.1)
Extremely Good(EG)	(0.8, 0.2, 0.2)
Very Good(VG)	(0.7, 0.3, 0.3)
Good(G)	(0.6, 0.4, 0.4)
Fair(F)	(0.5, 0.5, 0.5)
Poor(P)	(0.4, 0.6, 0.4)
Very Poor(VP)	(0.3, 0.7, 0.3)
Extremely Poor(EP)	(0.2, 0.8, 0.2)
Inferior(I)	(0.1, 0.9, 0.1)

Table 5.3 Judgements of DM1

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	VP	P	G	EP	G	F	EP	G	P	P	F	F	F	P	VP	F	VG	G	VP	EP	P	F	G
P_2	P	P	VP	EP	VG	S	EG	VG	VP	VP	VP	P	P	EG	P	VG	F	F	EP	VP	G	S	VG
P_3	I	G	S	S	EG	G	F	S	EP	VP	F	VG	VG	VG	VP	G	VG	F	P	F	G	EG	VG
P_4	P	VP	VP	EP	F	EP	F	F	EP	P	P	F	EG	EG	VP	P	VP	F	VP	VP	VP	F	F
P_5	EG	EG	I	I	EP	G	G	I	F	EG	EG	F	F	VG	F	F	F	F	VG	F	EG	EG	VG
P_6	EG	EG	EP	VP	EP	F	F	EP	EG	EG	EG	F	F	EG	F	F	F	G	EG	F	G	G	VG

Table 5.4 Judgements of DM2

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	P	P	F	VP	F	F	EP	G	F	F	P	P	F	G	F	VP	G	F	G	VP	F	F	G
P_2	VP	P	F	EP	EG	S	EG	VG	P	VP	VP	P	P	S	VG	VG	G	F	F	VP	G	EG	S
P_3	EP	G	VG	VG	VG	G	G	EG	P	VP	P	G	VG	P	P	F	EG	G	G	F	G	VG	EG
P_4	P	VP	EP	EP	F	EP	F	F	P	P	P	F	EG	P	P	P	VP	F	VP	VP	VP	F	P
P_5	EG	S	I	I	I	G	G	EP	EG	EG	EG	P	F	F	F	VG	P	F	VG	G	EG	VG	G
P_6	S	S	EP	EP	EP	G	F	EP	EG	EG	EG	P	F	F	F	VG	F	G	S	F	G	VG	VG

Table 5.5 Judgements of DM3

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	P	F	F	EP	G	VP	VP	F	P	P	P	P	F	P	F	VP	G	EG	VG	VP	VP	G	F
P_2	P	F	EP	EP	VG	EG	S	EG	VP	VP	VP	VP	P	EG	P	P	F	VP	F	EP	G	S	S
P_3	VP	G	S	EG	S	VG	VG	VG	VP	VP	F	VG	VG	EG	F	VP	EG	F	G	G	G	EG	EG
P_4	F	VP	VG	VP	F	EP	F	F	P	EP	P	F	EG	EG	P	VP	VP	VP	VP	EP	VP	P	F
P_5	EG	EG	VG	I	I	P	G	I	EG	F	EG	P	VP	P	VG	F	F	P	VG	F	EG	G	EG
P_6	EG	S	EP	I	EP	P	VG	EP	EG	EG	EG	P	EP	P	VG	F	F	F	EG	G	G	VG	G

Table 5.6 The importance weights of the criteria

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
DM1	AMI	HI	AMI	SMI	SMI	EI	LI	VLI	VLI	HI	VLI	VLI	VLI	VLI	EI	EI	VLI	LI	EI	SMI	EI	HI	SMI
DM2	VHI	HI	VHI	VHI	VHI	SMI	SLI	LI	VLI	EI	SLI	ALI	ALI	ALI	SMI	HI	SLI	EI	EI	SMI	EI	HI	HI
DM3	VHI	VHI	AMI	HI	SMI	HI	HI	EI	LI	SLI	SLI	ALI	VLI	ALI	HI	HI	SLI	EI	HI	HI	EI	VHI	VHI

These judgments are aggregated using SWAM operator given in Equation (18) by considering the importance levels of decision makers. Decision matrix is obtained as in Table 5.7. As for the prioritization of criteria; also SWAM operator is used to aggregate these decisions while taking decision makers' levels of priority into account.

The opinions of the decision makers on the criteria aggregated by using the SWAM operator given in Equation (18) in order to determine the weight of each criterion which are presented in Table 5.7.

Table 5.7 Aggregation of criteria weights based on SWAM operator

Criteria	Weights of each criterion	Criteria	Weights of each criterion
$C_{1.1}$	(0.84,0.32,0.17)	$C_{5.1}$	(0.14,0.88,0.10)
$C_{1.2}$	(0.76,0.49,0.25)	$C_{5.2}$	(0.18,0.83,0.16)
$C_{2.1}$	(0.89,0.11,0.12)	$C_{5.3}$	(0.14,0.88,0.10)
$C_{2.2}$	(0.70,0.30,0.31)	$C_{6.1}$	(0.63,0.39,0.42)
$C_{3.1}$	(0.66,0.35,0.48)	$C_{6.2}$	(0.65,0.38,0.46)
$C_{3.2}$	(0.63,0.37,0.42)	$C_{6.3}$	(0.35,0.68,0.40)
$C_{3.3}$	(0.57,0.44,0.40)	$C_{6.4}$	(0.45,0.58,0.50)
$C_{3.4}$	(0.40,0.62,0.43)	$C_{7.1}$	(0.62,0.42,0.40)
$C_{4.1}$	(0.26,0.75,0.26)	$C_{7.2}$	(0.65,0.35,0.35)
$C_{4.2}$	(0.54,0.47,0.27)	$C_{7.3}$	(0.50,0.50,0.50)
$C_{4.3}$	(0.35,0.65,0.40)	$C_{8.1}$	(0.76,0.26,0.25)
		$C_{8.2}$	(0.74,0.30,0.33)

After prioritizing the alternatives, the aggregated weighted spherical fuzzy decision matrices are constructed by utilizing matrices multiplication.

Appendix A

as aggregation of decision matrices and; Table 5.7 as aggregation of criteria weights are used for matrices multiplication. As a result, weighted decision matrix is obtained as represented in **Hata! Başvuru kaynağı bulunamadı.**.

Score function values are shown in **Hata! Başvuru kaynağı bulunamadı.** which is based o n **Hata! Başvuru kaynağı bulunamadı.** and Equation (22), PIS (Positive Ideal Solution) is represented by the highest score values in each column, and NIS (Negative Ideal Solution) is represented by the lowest score values. The matching Spherical Fuzzy Positive Ideal Solution (SF-PIS) and Spherical Fuzzy Negative Ideal Solution (SF-NIS) are provided in **Hata! Başvuru kaynağı bulunamadı.**, based on the highest and lowest s cores. The distances between alternate P_i and the SF-PIS and SF-NIS, respectively, can be determined in the following step using Equations (27 and 28). The distances to positive and negative ideal solutions can be found Table 5.8.

Table 5.8 Distances to pos. and neg. ideal solutions based on SWAM operator

Project Alternatives	$D(P_i,P^*)$	$D(P_i,P\text{-})$
P_1	0.24	0.14
P_2	0.22	0.20
P_3	0.16	0.26
P_4	0.26	0.13
P_5	0.20	0.21
P_6	0.22	0.21

We calculate the minimum distance to the SF-PIS and the maximum distance to the SF-NIS using Table 5.8. Closeness ratios are computed and displayed in Table 5.9 using Equation (31).

Table 5.9 Closeness ratio of each alternative based on SWAM operator

Project Alternatives	Closeness Ratio	Rank
P_1	0.97	5
P_2	0.60	4
P_3	0.00	1
P_4	1.13	6
P_5	0.47	2
P_6	0.54	3

Closeness ratios based on the SWAM operator show that 'P_3' is the best option the top choice overall. The final selection ranking among the projects concluded as $P_3 > P_5 > P_6 > P_2 > P_1 > P_4$.

5.2. Sensitivity Analysis

5.2.1. Sensitivity Analysis of Decision Makers' Weight

A sensitivity analysis was conducted to observe the changes in the results obtained using the Spherical Fuzzy TOPSIS method in response to variations in the weights assigned by decision-makers. For analytical purposes, the weight of the second DM was adjusted both upward and downward, while the weights of the other decision-makers were modified such that their total remained 1 and their internal ratios were preserved. The steps of the Spherical Fuzzy TOPSIS method were applied for each weighting scenario, resulting in new rankings. Plase note that the Situation 1 (S_1) corresponds to the current situation (0.3,0.2,0,5 for DM1, DM2, DM3 respectively).

Table 5.10 The results of the sensitivity analysis in table format

Situation(S)	Decision Makers' Weights (DM-1-2-3)			Ranking of the Projects
S_1	0.35	0.10	0.55	P_3-P_5-P_6-P_2-P_1-P_4
S_2	0.30	0.20	0.50	P_3-P_5-P_6-P_2-P_1-P_4
S_3	0.25	0.30	0.45	P_3-P_5-P_6-P_2-P_1-P_4
S_4	0.20	0.40	0.40	P_3-P_5-P_6-P_2-P_1-P_4
S_5	0.15	0.50	0.35	P_3-P_6-P_2-P_5-P_1-P_4
S_6	0.10	0.60	0.30	P_3-P_6-P_2-P_5-P_1-P_4

To better interpret the obtained results, the rankings derived from the application are also presented in a graphical format, as shown in Figure 5.1. In the graphical representation, the results marked with S_2 indicate the current results obtained from the numerical example.

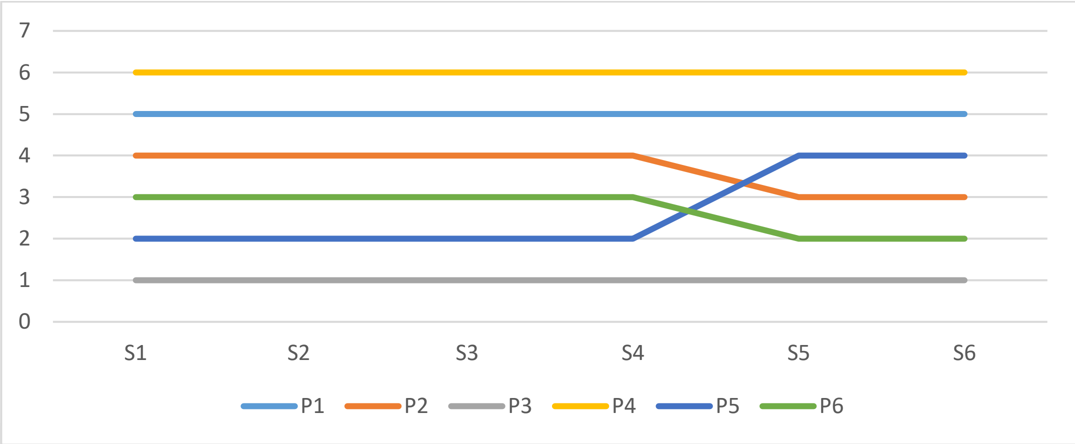

Figure 5.1 The results of the sens. analysis of Decision Makers' Weight in line chart

Looking at the results of the analysis, it can be observed that the rankings of the first and last alternatives remain unchanged regardless of the changes in decision-maker weights. This can be interpreted as all decision-makers aligning towards the same alternative. Additionally, there is a scenario where the P_5 initially ranked second, moved two positions lower when the decision-maker weights for the criteria were adjusted. Considering the overall results; since the rankings remain stable for weights close to the selected ones, the selection of P_3 as the preferred alternative appears strong.

5.2.2. Sensitivity Analysis of $C_{1.1}$ (Investment Costs)

To assess the impact of $C_{1.1}$ (Investment Costs) on the final ranking of IT projects, a sensitivity analysis was conducted by systematically reducing the weight assigned to $C_{1.1}$ across all decision-makers (DMs). Initially, the decision-makers assigned higher importance to $C_{1.1}$, as seen in the first set of weight values. Subsequently, a gradual reduction in $C_{1.1}$'s weight was implemented while maintaining the proportional distribution among other criteria.

As depicted in the ranking evolution in Figure 5.2, the ranking of certain projects exhibited noticeable changes in response to the adjusted weights. Specifically, P_2 and P_5, which initially held relatively stable positions, experienced shifts in their rankings as the weight of $C_{1.1}$ decreased. Conversely, P_3 remained the highest-ranked project across all scenarios, reinforcing its robustness against variations in investment cost considerations.

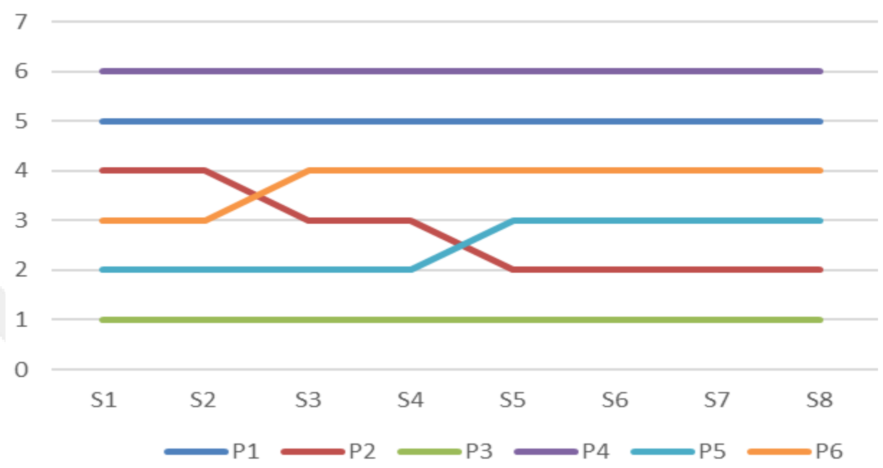

Figure 5.2 The results of the sensitivity analysis of $C_{1.1}$'s weight in line chart

The observed fluctuations indicate that $C_{1.1}$ plays a significant role in differentiating project rankings, particularly affecting mid-ranked alternatives. This finding highlights the importance of investment costs in decision-making processes while also suggesting that alternative rankings are influenced by the interplay between financial sustainability and other decision criteria.

Ultimately, this analysis confirms that while $C_{1.1}$'s influence is non-negligible, the overall ranking of the top-performing project (P_3) remains unchanged, demonstrating its resilience in diverse weighting scenarios. This insight underscores the robustness of the decision model and the stability of its recommendations under varying importance levels of investment costs.

5.2.3. Sensitivity Analysis of $C_{2.1}$ (Expected Revenue/Income)

To evaluate the impact of $C_{2.1}$ (Expected Revenue/Income) on the final project rankings, a sensitivity analysis was conducted by progressively reducing the weight assigned to this criterion across all decision-makers (DMs). Initially, the decision-makers assigned higher importance to $C_{2.1}$, as represented by the original weight values in Table 5.6. These values were subsequently adjusted downward to examine how the relative rankings of projects would respond to this change.

As depicted in Figure 5.3, the ranking of certain projects demonstrated noticeable variations as the weight of $C_{2.1}$ decreased. Notably, P_5 and P_6 exhibited shifts in their relative positions, indicating that the financial revenue potential of projects significantly influenced their rankings under the initial weight distribution. As $C_{2.1}$'s influence diminished, the ranking of P_6 improved, surpassing P5 at a certain threshold. This suggests that P_5's initial ranking was strongly dependent on its expected revenue impact, whereas P_6 demonstrated greater stability across varying weight scenarios.

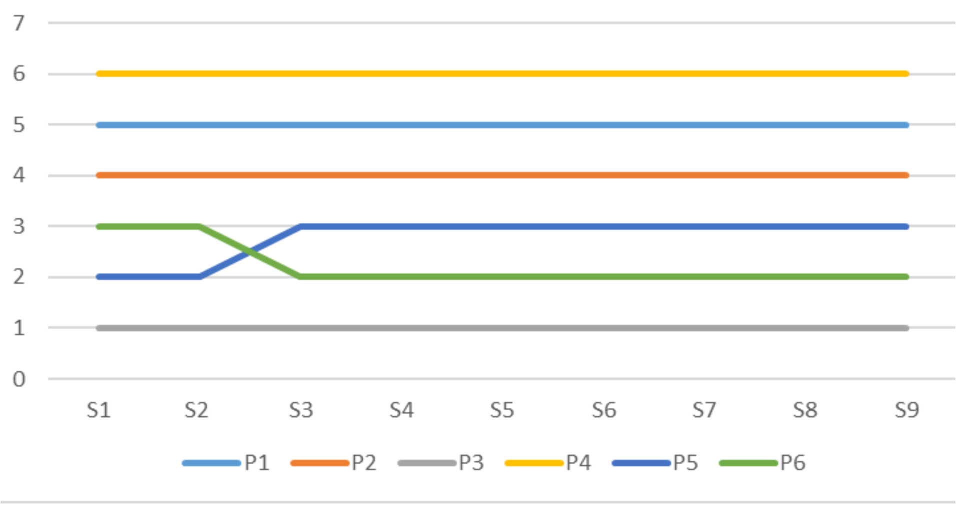

Figure 5.3 The results of the sensitivity analysis of $C_{2.1}$'s weight in line chart

Despite these shifts, P_3 (Optimization on Flight Planning System) remained the top-ranked project, reinforcing its robustness in the decision-making process, even with changes in financial revenue weighting. Furthermore, projects P_1, P_2, and P_4 maintained relatively stable rankings, indicating a lower sensitivity to variations in $C_{2.1}$'s weight.

These findings emphasize the importance of financial revenue considerations in project evaluation while also revealing the varying degrees of dependency each project has on this criterion. The results further confirm that while $C_{2.1}$ is influential in shaping the rankings, the overall decision framework remains stable, particularly for the highest-ranked alternative.

6. CONCLUSION

This thesis aimed to address a critical gap in the evaluation and selection of IT projects by developing a decision-making framework grounded on sustainability principles. This research integrated economic, environmental, social, and cultural sustainability dimensions into a comprehensive model for the assessment of IT projects. Using a wide range of criteria, each project was evaluated and analyzed in terms of its sustainability roles. Spherical Fuzzy TOPSIS model is utilized for the solution the decision-making problem. Among the six projects, Optimization on Flight Planning System (P_3) achieved the highest score, reflecting its significant contributions to operational efficiency, cost optimization, and environmental sustainability. Results showed that considering sustainability criteria enables organizations to make decisions that align with broader societal and environmental imperatives.

Among the evaluated projects, Optimization on Flight Planning System (P_3) scored the highest, due to its balanced performance between sustainability dimensions. It was shown to be an exceptional alignment with key criteria, particularly in areas such as Strategic Alignment (C_3), Financial Revenue (C_2). The project optimizes flight routes and schedules to minimize operational inefficiencies and hence significant fuel and operational expense savings. By addressing environmental and operational challenges it contributes not only to immediate financial results but also to enhancing organization's market potential ($C_{3.4}$) and its prestige ($C_{3.2}$). Additionally, the higher efficiency of flight operations is expected to improve customer satisfaction ($C_{8.1}$) because delays and disruptions are reduced. In turn, this can boost the organization's reputation and attract new customers which, in turn, will drive growth in revenue. And on top of that, by optimizing flight paths, the project reduces carbon emissions and fuel consumption to critical levels of environmental sustainability. Although Carbon Offset Project (P_5) and Minimizing Paper Consumption Project (P_6) are close to the optimal solution and they bring particular contributions to environmental and social sustainability, P_3 stands out because of its wide and deep impact on financial, environmental and operational gains. The scoring also presents how decision makers' preferences and prioritization are shaped in the rankings, which may change if different criteria are given more or less importance.

To sum up; while financial metrics like Return on Investment or Cost-Benefit Analysis are commonly used in traditional IT project evaluation, these metrics often overlook the wider sustainability impact of projects on environmental and social wellbeing. The model captured the inherent uncertainty and complexity of sustainability related decisions by using the Spherical Fuzzy Sets, providing a more accurate evaluation process. In addition, new criteria regarding user satisfaction, system compatibility and operational flexibility were introduced by this research that reflect the changing demands of modern organizations and their stakeholders. The findings support a long-term view towards project selection in IT, helping organizations become more efficient and competitive while addressing global goals such as decreasing carbon footprints and achieving social equity. Overall, this paper offers a new decision-making framework that combines sustainability principles with sophisticated evaluation techniques, providing a useful tool to balance economical and operational success with societal and environmental duties.

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APPENDICES

Appendix A

Table A.1 Decision matrix by using SWAM operator

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	(0.37,0.63,0.38)	(0.45,0.55,0.46)	(0.53,0.47,0.47)	(0.22,0.78,0.23)	(0.58,0.42,0.42)	(0.42,0.59,0.43)	(0.26,0.75,0.26)	(0.55,0.45,0.45)	(0.42,0.58,0.43)	(0.42,0.58,0.43)	(0.43,0.57,0.44)	(0.43,0.57,0.44)	(0.50,0.50,0.50)	(0.45,0.55,0.40)	(0.45,0.55,0.46)	(0.38,0.63,0.39)	(0.63,0.37,0.37)	(0.71,0.30,0.32)	(0.60,0.41,0.33)	(0.27,0.73,0.28)	(0.38,0.62,0.39)	(0.55,0.45,0.45)	(0.55,0.45,0.45)
P_2	(0.38,0.62,0.38)	(0.45,0.55,0.46)	(0.32,0.70,0.34)	(0.20,0.80,0.20)	(0.72,0.28,0.28)	(0.86,0.14,0.15)	(0.86,0.14,0.15)	(0.76,0.24,0.25)	(0.32,0.68,0.33)	(0.30,0.70,0.30)	(0.30,0.70,0.30)	(0.35,0.65,0.36)	(0.40,0.60,0.40)	(0.83,0.17,0.18)	(0.49,0.52,0.38)	(0.59,0.42,0.35)	(0.52,0.48,0.48)	(0.42,0.59,0.43)	(0.44,0.58,0.46)	(0.26,0.75,0.26)	(0.60,0.40,0.40)	(0.89,0.11,0.12)	(0.86,0.14,0.15)
P_3	(0.24,0.78,0.24)	(0.60,0.40,0.40)	(0.88,0.12,0.14)	(0.83,0.18,0.19)	(0.85,0.15,0.16)	(0.65,0.35,0.35)	(0.63,0.37,0.38)	(0.80,0.20,0.21)	(0.30,0.71,0.30)	(0.30,0.70,0.30)	(0.48,0.52,0.49)	(0.68,0.32,0.32)	(0.70,0.30,0.30)	(0.73,0.28,0.26)	(0.43,0.57,0.44)	(0.46,0.55,0.39)	(0.77,0.23,0.23)	(0.52,0.48,0.48)	(0.55,0.45,0.42)	(0.55,0.45,0.47)	(0.60,0.40,0.40)	(0.78,0.22,0.22)	(0.77,0.23,0.23)
P_4	(0.45,0.55,0.46)	(0.30,0.70,0.30)	(0.56,0.47,0.30)	(0.26,0.75,0.26)	(0.50,0.50,0.50)	(0.20,0.80,0.20)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.35,0.65,0.36)	(0.32,0.69,0.33)	(0.40,0.60,0.40)	(0.50,0.50,0.50)	(0.80,0.20,0.20)	(0.76,0.25,0.23)	(0.37,0.63,0.38)	(0.35,0.65,0.36)	(0.30,0.70,0.30)	(0.42,0.59,0.43)	(0.30,0.70,0.30)	(0.26,0.75,0.26)	(0.30,0.70,0.30)	(0.45,0.55,0.46)	(0.48,0.52,0.49)
P_5	(0.80,0.20,0.20)	(0.83,0.17,0.18)	(0.54,0.52,0.26)	(0.10,0.90,0.10)	(0.14,0.87,0.14)	(0.52,0.49,0.40)	(0.60,0.40,0.40)	(0.13,0.88,0.13)	(0.74,0.26,0.29)	(0.69,0.32,0.35)	(0.80,0.20,0.20)	(0.43,0.57,0.44)	(0.42,0.59,0.43)	(0.54,0.47,0.39)	(0.62,0.39,0.40)	(0.55,0.45,0.46)	(0.48,0.52,0.49)	(0.45,0.55,0.46)	(0.70,0.30,0.30)	(0.52,0.48,0.49)	(0.80,0.20,0.20)	(0.70,0.31,0.45)	(0.74,0.26,0.33)
P_6	(0.83,0.17,0.18)	(0.88,0.12,0.13)	(0.20,0.80,0.20)	(0.20,0.82,0.21)	(0.20,0.80,0.20)	(0.48,0.52,0.44)	(0.62,0.39,0.40)	(0.20,0.80,0.20)	(0.80,0.20,0.20)	(0.80,0.20,0.20)	(0.80,0.20,0.20)	(0.43,0.57,0.44)	(0.39,0.63,0.41)	(0.60,0.42,0.36)	(0.62,0.39,0.40)	(0.55,0.45,0.46)	(0.50,0.50,0.50)	(0.55,0.45,0.46)	(0.83,0.17,0.18)	(0.55,0.45,0.47)	(0.60,0.40,0.40)	(0.67,0.33,0.33)	(0.65,0.35,0.35)

Appendix B

Table B.1 Weighted decision matrix based on SWAM operator

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	(0.31,0.68,0.37)	(0.34,0.68,0.44)	(0.47,0.48,0.48)	(0.16,0.80,0.28)	(0.38,0.52,0.55)	(0.26,0.66,0.49)	(0.15,0.80,0.66)	(0.22,0.71,0.49)	(0.11,0.84,0.33)	(0.23,0.69,0.42)	(0.15,0.78,0.66)	(0.06,0.92,0.22)	(0.09,0.87,0.30)	(0.06,0.92,0.21)	(0.29,0.64,0.52)	(0.25,0.70,0.47)	(0.22,0.73,0.44)	(0.32,0.62,0.52)	(0.37,0.56,0.45)	(0.18,0.77,0.34)	(0.19,0.74,0.48)	(0.42,0.50,0.48)	(0.41,0.52,0.50)
P_2	(0.32,0.67,0.38)	(0.34,0.68,0.46)	(0.28,0.70,0.34)	(0.14,0.82,0.26)	(0.47,0.43,0.51)	(0.54,0.39,0.43)	(0.49,0.46,0.64)	(0.30,0.65,0.45)	(0.08,0.87,0.27)	(0.16,0.78,0.32)	(0.11,0.84,0.64)	(0.05,0.93,0.18)	(0.07,0.89,0.25)	(0.11,0.88,0.13)	(0.31,0.62,0.47)	(0.38,0.54,0.50)	(0.19,0.76,0.46)	(0.19,0.75,0.49)	(0.27,0.67,0.50)	(0.17,0.78,0.32)	(0.30,0.61,0.54)	(0.67,0.28,0.27)	(0.63,0.32,0.36)
P_3	(0.20,0.80,0.25)	(0.45,0.60,0.41)	(0.78,0.17,0.18)	(0.58,0.35,0.35)	(0.56,0.38,0.49)	(0.41,0.49,0.49)	(0.36,0.55,0.47)	(0.32,0.64,0.45)	(0.08,0.88,0.26)	(0.16,0.78,0.32)	(0.17,0.76,0.47)	(0.09,0.89,0.18)	(0.13,0.84,0.22)	(0.10,0.89,0.16)	(0.27,0.66,0.50)	(0.30,0.64,0.50)	(0.27,0.70,0.41)	(0.24,0.70,0.54)	(0.34,0.59,0.50)	(0.36,0.55,0.51)	(0.30,0.61,0.54)	(0.59,0.33,0.32)	(0.57,0.37,0.38)
P_4	(0.38,0.61,0.45)	(0.23,0.78,0.31)	(0.49,0.48,0.31)	(0.18,0.77,0.31)	(0.33,0.58,0.58)	(0.13,0.83,0.30)	(0.29,0.63,0.66)	(0.20,0.73,0.50)	(0.09,0.87,0.29)	(0.17,0.77,0.34)	(0.14,0.80,0.66)	(0.07,0.91,0.25)	(0.15,0.83,0.19)	(0.10,0.89,0.15)	(0.24,0.70,0.45)	(0.23,0.71,0.45)	(0.11,0.85,0.34)	(0.19,0.75,0.49)	(0.19,0.76,0.38)	(0.17,0.78,0.32)	(0.15,0.79,0.42)	(0.34,0.59,0.48)	(0.35,0.58,0.52)
P_5	(0.67,0.38,0.25)	(0.62,0.51,0.24)	(0.48,0.53,0.28)	(0.07,0.91,0.16)	(0.09,0.89,0.26)	(0.33,0.59,0.50)	(0.34,0.57,0.64)	(0.05,0.93,0.22)	(0.19,0.77,0.30)	(0.38,0.55,0.39)	(0.28,0.67,0.64)	(0.06,0.92,0.22)	(0.08,0.89,0.27)	(0.07,0.91,0.20)	(0.39,0.53,0.51)	(0.36,0.56,0.55)	(0.17,0.78,0.45)	(0.21,0.73,0.51)	(0.43,0.50,0.45)	(0.34,0.57,0.52)	(0.40,0.53,0.51)	(0.53,0.39,0.48)	(0.55,0.39,0.44)
P_6	(0.69,0.36,0.23)	(0.66,0.50,0.21)	(0.18,0.80,0.21)	(0.14,0.83,0.26)	(0.13,0.83,0.33)	(0.30,0.61,0.51)	(0.35,0.56,0.47)	(0.08,0.88,0.29)	(0.20,0.76,0.28)	(0.43,0.50,0.31)	(0.28,0.67,0.47)	(0.06,0.92,0.22)	(0.07,0.90,0.25)	(0.08,0.90,0.19)	(0.39,0.53,0.51)	(0.36,0.56,0.55)	(0.18,0.77,0.46)	(0.25,0.68,0.54)	(0.51,0.45,0.42)	(0.36,0.55,0.51)	(0.30,0.61,0.54)	(0.51,0.41,0.39)	(0.48,0.44,0.44)

Appendix C

Table C.1 Score function values based on SWAM operator

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P_1	- 0.089	- 0.053	- 0.000	- 0.256	0.009	- 0.107	- 0.169	- 0.167	- 0.486	- 0.179	- 0.139	- 0.712	- 0.565	- 0.709	- 0.074	- 0.151	- 0.211	- 0.052	- 0.028	- 0.321	- 0.216	- 0.004	- 0.004
P_2	- 0.080	- 0.039	- 0.128	- 0.301	- 0.000	- 0.011	0.019	- 0.095	- 0.589	- 0.353	- 0.260	- 0.759	- 0.640	- 0.588	- 0.070	- 0.012	- 0.260	- 0.226	- 0.108	- 0.357	- 0.038	0.006	- 0.020
P_3	- 0.304	- 0.035	0.359	0.054	- 0.028	- 0.000	- 0.025	- 0.083	- 0.616	- 0.353	- 0.260	- 0.627	- 0.502	- 0.617	- 0.096	- 0.074	- 0.161	- 0.120	- 0.035	- 0.012	- 0.038	0.007	- 0.007
P_4	- 0.022	- 0.219	0.004	- 0.200	- 0.003	- 0.464	0.021	- 0.192	- 0.558	- 0.331	- 0.160	- 0.674	- 0.470	- 0.608	- 0.169	- 0.179	- 0.501	- 0.226	- 0.295	- 0.357	- 0.334	- 0.042	- 0.022
P_5	0.162	0.075	- 0.024	- 0.550	- 0.603	- 0.039	0.034	- 0.738	- 0.322	- 0.029	- 0.026	- 0.712	- 0.627	- 0.674	- 0.006	- 0.004	- 0.289	- 0.180	- 0.004	- 0.020	- 0.005	- 0.016	- 0.014
P_6	0.194	0.122	- 0.351	- 0.319	- 0.445	- 0.052	- 0.030	- 0.597	- 0.303	0.009	- 0.115	- 0.712	- 0.652	- 0.655	- 0.006	- 0.004	- 0.272	- 0.103	0.004	- 0.012	- 0.038	0.004	0.000

Appendix D

Table D.1 SF-PIS and SF-NIS based on SWAM operator

	$C_{1.1}$	$C_{1.2}$	$C_{2.1}$	$C_{2.2}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$	$C_{4.2}$	$C_{4.3}$	$C_{5.1}$	$C_{5.2}$	$C_{5.3}$	$C_{6.1}$	$C_{6.2}$	$C_{6.3}$	$C_{6.4}$	$C_{7.1}$	$C_{7.2}$	$C_{7.3}$	$C_{8.1}$	$C_{8.2}$
P^*(Best)	(0.69,0.36,0.23)	(0.66,0.50,0.21)	(0.78,0.17,0.18)	(0.58,0.35,0.16)	(0.56,0.38,0.26)	(0.54,0.39,0.30)	(0.49,0.46,0.47)	(0.32,0.64,0.22)	(0.20,0.76,0.26)	(0.43,0.50,0.31)	(0.28,0.67,0.47)	(0.09,0.89,0.18)	(0.15,0.83,0.19)	(0.11,0.88,0.13)	(0.39,0.53,0.45)	(0.38,0.54,0.45)	(0.27,0.70,0.34)	(0.32,0.62,0.49)	(0.51,0.45,0.38)	(0.36,0.55,0.32)	(0.40,0.53,0.42)	(0.67,0.28,0.27)	(0.63,0.32,0.36)
P^-(Worst)	(0.20,0.80,0.45)	(0.23,0.78,0.46)	(0.18,0.80,0.48)	(0.07,0.91,0.35)	(0.09,0.89,0.58)	(0.13,0.83,0.51)	(0.15,0.80,0.66)	(0.05,0.93,0.50)	(0.08,0.88,0.33)	(0.16,0.78,0.42)	(0.11,0.84,0.66)	(0.05,0.93,0.25)	(0.07,0.90,0.30)	(0.06,0.92,0.21)	(0.24,0.70,0.52)	(0.23,0.71,0.55)	(0.11,0.85,0.46)	(0.19,0.75,0.54)	(0.19,0.76,0.50)	(0.17,0.78,0.52)	(0.15,0.79,0.54)	(0.34,0.59,0.48)	(0.35,0.58,0.52)

Appendix E

Table E.1 Sust. IT Project Ev. in the Airline Ind. : Explanations, and Examples

#	Sub-criteria	Criteria Explanation	Example 1	Example 2	Key Sustainability Feature
$C_{1.1}$	Investment Costs	Represents the initial capital required to implement the IT project. High investment costs may limit feasibility but can lead to long-term sustainability benefits by reducing future expenses.	Cloud-based IT infrastructure to reduce initial capital expenses for airlines.	Smart energy management system to optimize electricity usage across terminals and reduce operational costs.	Economical, Environmental
$C_{1.2}$	Maintenance Costs	Covers the ongoing costs required to keep the project operational and efficient. Sustainable maintenance strategies help lower resource consumption and extend system lifespan.	Predictive maintenance system using IoT sensors to reduce unexpected aircraft downtime.	Automated aircraft component tracking system to reduce unnecessary part replacements.	Economical, Environmental
$C_{2.1}$	Expected Revenue/Income	Refers to the expected financial gains from implementing the IT project. Revenue-generating IT solutions contribute to economic sustainability by increasing profitability.	AI-driven seat pricing optimization to maximize airline revenue per seat.	AI-based ancillary service recommendations for upselling flight-related services.	Economical
$C_{2.2}$	Expected Reduction in Operational Costs	Addresses how much the project can reduce operational expenses in the long term. Cost reduction strategies improve financial stability and environmental sustainability.	Smart energy management system to optimize electricity consumption at airport terminals.	AI-based fleet fuel efficiency monitoring for sustainable aviation practices.	Economical, Environmental
$C_{3.1}$	Alignment with Business Goals	Ensures that the IT project aligns with the company’s strategic priorities. A well-aligned project improves long-term business sustainability.	AI-based customer preference analysis to tailor loyalty programs.	Data-driven dynamic scheduling for optimizing flight routes.	Economical, Social
$C_{3.2}$	Contribution to the Prestige of the Instution	Represents how the project contributes to the institution’s reputation and market positioning. Sustainable branding initiatives enhance corporate identity.	Introduction of a fully digitalized, paperless check-in experience.	AI-driven sustainability reporting platform for aviation emissions tracking.	Social, Environmental

Table 7.5 Sust. IT Project Ev. in the Airline Ind. : Explanations, and Examples (continue)

$C_{3.3}$	Compatibility with the country's technology policies	Examines whether the project complies with national technology policies and regulations. Compliance ensures smooth adoption and long-term feasibility.	National biometric verification system integration for seamless border control.	Implementation of blockchain-based passenger identity verification for security compliance.	Economical, Social
$C_{3.4}$	Market Potential	Evaluates the potential market size and growth opportunities associated with the project. High market potential ensures long-term financial viability.	Expansion of airline mobile applications with real-time personalized offers.	AI-driven multilingual support chatbots to expand accessibility for international travelers.	Economical
$C_{4.1}$	Technical Failure Risk	Assesses the risk of technical failures that could impact system reliability and performance. Failure management is essential for reducing downtime and financial losses.	AI-based predictive analytics for real-time aircraft system monitoring to prevent failures.	Automated baggage handling system monitoring to detect faults in advance.	Economical, Environmental
$C_{4.2}$	Exceeding planned cost risk	Measures the likelihood of the project exceeding its planned financial budget. Budget overruns impact economic sustainability and financial forecasting.	Blockchain-based financial management system to prevent budget overruns in IT projects.	AI-based expense prediction tool for managing IT investment risks.	Economical
$C_{4.3}$	Operational Risk	Identifies potential operational disruptions that may arise from implementing the project. Addressing operational risks ensures service reliability.	AI-powered decision support system to prevent air traffic congestion.	Machine learning-based crew scheduling to prevent flight delays.	Social, Economical
$C_{5.1}$	Novelty of the Project Output	Determines the degree of innovation introduced by the project in its field. Higher novelty increases competitive advantage and industry leadership.	Digital twin technology for real-time aircraft health simulation.	AI-based pilot training simulators using virtual reality.	Economical, Environmental
$C_{5.2}$	Process or Technological Improvements	Focuses on the process or technological advancements the project brings. Innovative improvements enhance sustainability by optimizing efficiency.	AI-assisted air traffic flow management for fuel efficiency.	Automated weather prediction system for more accurate flight planning.	Environmental, Economical

Table 7.5 Sust. IT Project Ev. in the Airline Ind. : Explanations, and Examples (continue)

$C_{5.3}$	Contribution to the science and society	Evaluates how the project contributes to scientific research and societal benefits. IT projects that support academic and social progress foster sustainable development.	Open-access airline sustainability data platform for researchers and policymakers.	AI-assisted aviation emission reduction analytics for regulatory compliance.	Social, Environmental
$C_{6.1}$	Availability of Technological Infrastructure	Assesses whether the necessary technological infrastructure is available for the project. Strong IT infrastructure ensures feasibility and scalability.	5G-enabled in-flight internet service for improved passenger experience.	Scalable translation services embedded in customer systems ensure accessibility for diverse passengers. (Not only Latin but also Arabic, Chinese alphabets.)	Cultural
$C_{6.2}$	Compatibility with Existing Systems	Checks if the project is compatible with existing technological systems within the organization. Compatibility reduces transition costs and operational disruptions.	AI-driven baggage tracking system integrated with legacy airport infrastructure.	Cloud-based maintenance tracking system linked to existing ERP solutions.	Environmental, Social
$C_{6.3}$	Flexibility	Measures the adaptability of the project to changes in business or technology needs. Flexible solutions future-proof investments and support sustainability.	Multi-platform airline reservation system that supports seamless API integrations.	AI-driven modular software architecture for airline IT infrastructure.	Economical
$C_{6.4}$	Scalability	Evaluates whether the project can be scaled efficiently as demand increases. Scalable solutions ensure long-term feasibility and cost-effectiveness.	Aircraft scheduling system that adapts to demand fluctuations.	Dynamic AI-based customer support scaling to manage seasonal ticket demand.	Economical, Social
$C_{7.1}$	Availability of Human Resources	Determines if there are sufficient human resources to successfully execute the project. Workforce availability is critical for operational continuity.	AI-driven crew scheduling and rostering optimization system.	Employee training chatbot to improve workforce preparedness for IT transformations.	Economical, Social

Table 7.5 Sust. IT Project Ev. in the Airline Ind. : Explanations, and Examples (continue)

$C_{7.2}$	Architectural Suitability	Analyzes whether the project fits within the existing architectural and operational structure. Suitable projects integrate seamlessly, reducing transition risks.	Cloud-based airline operational management platform that scales with demand.	IT architecture harmonization for integrating airline and airport systems.	Economical, Environmental
$C_{7.3}$	Project Planning and Scheduling	Ensures that the project follows structured planning and scheduling processes. Proper planning improves efficiency and resource allocation.	AI-assisted IT project planning tool to minimize delays in digital transformation projects.	Predictive analytics-based maintenance scheduling for airline operations.	Economical
$C_{8.1}$	User Satisfaction	Examines how the project improves user experience and satisfaction levels. Higher satisfaction leads to increased adoption and brand loyalty.	AI chatbot for real-time passenger inquiries and assistance.	Personalized in-flight entertainment recommendations based on past travel history.	Social, Economical
$C_{8.2}$	Impact on Customer Experience	Assesses how the project impacts customers and other stakeholders in the business. Enhancing customer experience improves retention and reputation.	Biometric boarding system to reduce queue times and improve security.	A system enabling Turkish Airlines employees to communicate in multiple languages fosters inclusivity.	Cultural, Economical