BARRIERS TO PUBLIC-PRIVATE PARTNERSHIP (PPP) IMPLEMENTATION IN SMART URBAN SERVICES

by

Baran Erdoğan

B.S., Civil Engineering, Yıldız Technical University, 2019

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Civil Engineering

Boğaziçi University

2023

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude to all people, who in one way or another contributed to the development of this research. I would like to express my sincere gratitude to my thesis advisor Assist. Prof. Semra Çomu, for her valuable help, guidance, and support throughout this thesis.

I also would like to thank all the experts who participated in the interview stages of this thesis for their valuable comments and suggestions.

Additionally, I would like to extend my appreciation to the members of my thesis examination committee for their comments and advice.

Through the streams of oceans, as we are floating in the blue, seasons came and changed the time. While overcoming challenges in the storm, having friends to support me was very valuable. Therefore, I would like to thank my dear friends Ediz Uzun, Elif Kayaaslan, and İsmail Çalışkan for encouraging me and believing in me throughout the "Reconstruction Plan 2022". After all this time, this spring breeze will be always remembered.

Finally, I would like to thank my family members for their continual support and encouragement in all stages of my life.

ABSTRACT

BARRIERS TO PUBLIC-PRIVATE PARTNERSHIP (PPP) IMPLEMENTATION IN SMART URBAN SERVICES

Urbanization has become an important issue in the world. Cities will be hosting more than 68% of the world's population in the following fifty years. This fast urbanization might cause excessive use of sources and the current infrastructure will not be enough.Organizations try to find a new urban solution concept to these problems. This concept is called smart urban service which is a conceptual development model that raises the standards of living spaces. Although they enhance our living standards, they are challenging projects in terms of financing and project delivery. At this point, cities are enlisting the support of private partners to advance these services. Public–Private Partnership is a collaborative model in the public and private sectors working as partners to drive a project. Even though the adoption of PPPs improving, many developing countries are still having difficulties against its implementation. The PPP model is not commonly used for smart urban services in Turkey, a developing country, due to macroenvironmental barriers. In this regard, this study aims to evaluate the barriers to PPP implementation in smart urban servicesin Turkey to fill the gap in the literature. The barriers are given based on an extensive literature survey. Then, interrelations, and relative importance rates are calculated. Fuzzy Analytic Network Process method is applied, and the Super Decisions is used to calculate the importance weights. "Political, Governmental and Legal Barriers" is observed as the most important main cluster and "Political instability" is calculated as the most important sub-barrier. Consequently, organizations should assess the barriers and shape their policies todevelop smart urban projects. This study provides information to help remove or limit these barriers for governments, investors, and other authorities.

ÖZET

AKILLI KENT SERVİSLERİNDE KAMU-ÖZEL İŞBİRLİĞİ(KÖİ) UYGULAMASININ ÖNÜNDEKİ ENGELLER

Kentleşme dünyada önemli bir sorun haline gelmiştir. Önümüzdeki elli yıl içinde şehirlerin dünya nüfusunun %68'inden fazlasına ev sahipliği yapacağı öngörülmekedir. Bu hızlı kentleşme kaynaklarımızın aşırı kullanımına neden olacaktır. Birçok kuruluş, bu sorunlara karşı yeni bir kentsel çözüm konsepti bulmaya çalışmaktadır. Bu konsept, yaşamalanlarımızın standartlarını yükselten bir model olan akıllı kent servisleri olarak adlandırılmaktadır. Yaşam standartlarımızı yükseltseler de finansman ve proje teslimi açısından zorlu projelerdir. Bu noktada şehirler, bu servisleri geliştirebilmek için özel ortakların desteğini almaktadır. Kamu-Özel İşbirliği(KÖİ), bir projeyi yürütmek için ortak olarak çalışan kamu ve özel sector de işbirliğine dayalı bir modeldir. KÖİ'lerin artan oranda benimsenmesine rağmen, birçok gelişmekte olan ülke başarılı şekilde uygulanmasının önünde engellerle karşılaşmaktadır. PPP modeli, gelişmekte olan bir ülke olan Türkiye'de akıllı kent servisleri için kullanılmamaktadır. Bu bağlamda, bu çalışma literatürdeki boşluğu doldurmak için Türkiye'deki akıllı kent servislerinde KÖİ uygulamasının önündeki engelleri değerlendirmeyi amaçlamaktadır. Bariyerler kapsamlı bir literatür araştırmasına dayalı olarak verilmiş ve aralarındaki ilişki gösterilmiştir. Bulanık Analitik Ağ Süreç yöntemi uygulanmış ve önem ağırlıklarını hesaplamak için Super Decisions yazılımı kullanılmıştır. "Siyasi, İdari ve Hukuki" en önemli ana bariyer, "Siyasi İstikrarsızlık" ise en önemli alt bariyer olarak hesaplanmıştır. Sonuç olarak, kuruluşlar akıllı kent servislerini geliştirmek için engelleri değerlendirmeli ve politikalarını şekillendirmelidir. Bu çalışma, engellerin kaldırılmasına ve yasınırlandırılmasına yardımcı olacak bilgiler sağlamaktadır.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii
ABSTRACT iv
ÖZET v
LIST OF FIGURES ix
LIST OF TABLES xii
LIST OF ACRONYMS/ABBREVIATIONS xx
1. INTRODUCTION 1
1.1. Background of the Research 2
1.2. Problem Definition 5
1.3. Aim and Objectives 6
1.4. Research Methodology 6
1.5. Scope and Limitations 7
1.6. Organization of the Study 8
2. LITERATURE REVIEW 10
2.1. Smart Urban Services Concept 10
2.2. Dimensions of Smart Urban Services 11
2.3. Global Applications of Smart Urban Services 15
2.3.1. Barcelona 15
2.3.2. Tokyo 16
2.3.3. Singapore 18
2.3.4. Gujarat 19
2.4. Smart Urban Services in Turkey 20
2.4.1. Istanbul 21
2.4.2. Ankara 23
2.4.3. Izmir 23
2.4.4. Bursa 24
2.4.5. Kayseri 25
2.4.6. Gaziantep 26

2.5. Necessity and Challenges of Smart Urban Services 26
2.6. Financing Models 29
2.6.1. Government-Based Financing 29
2.6.2. Debt Financing 30
2.6.3. Project Finance 31
2.6.4. Multilateral Finance 32
2.6.5. Crowd Funding 33
2.7. Project Delivery Methods 33
2.7.1. Design-Bid-Build (DBB) 34
2.7.2. Design-Build (DB) 35
2.7.3. Construction Management (CM) 36
2.7.4. Public-Private Partnership (PPP) 37
2.7.5. Build-Operate-Transfer (BOT) 40
2.7.6. Build–Own–Operate–Transfer (BOOT) 41
2.7.7. Build–Own–Operate (BOO) 42
2.7.8. Design–Build–Finance–Maintain (DBFM) 43
2.8. Public-Private Partnership (PPP) Application in Smart Urban Services 48
3. RESEARCH METHODOLOGY 54
3.1. Identification of Barriers for Smart Urban Services Implementation . . 56
3.1.1. Foreign Investors' Perception of a Country as High Risk (EF.1) 61
3.1.2. Interest and Inflation Rate and Currency Fluctuation (EF.2) . . 62
3.1.3. Limited Capital Availability (EF.3) 62
3.1.4. High Costs (EF.4) 63
3.1.5. High Length of Payback Period (EF.5) 63
3.1.6. Problems of Delays in Receiving Payments (EF.6) 63
3.1.7. Absence of Personal Data Security Protection (TT.1) 64
3.1.8. Weakness of Broadband Network Infrastructure (TT.2) 64
3.1.9. Lack of Knowledge and Expertise of the Parties (TT.3) 64
3.1.10. Resistance to Change and Unawareness of the Public (SCE.1) . 65
3.1.11. Poor Interaction between Local Governments and Citizens (SCE.2) 66
3.1.12. Inadequate Preliminary Environmental Assessment (SCE.3) . . 66

3.1.13. Politicalinstability (PGL.1) 66
3.1.14. Inefficiency and Long Delays Due to Bureaucratic Procedures (PGL.2) 67
3.1.15. Insufficient Government Guarantee (PGL.3) 67
3.1.16. Lack of Transparency (PGL.4) 68
3.1.17. Insufficient Legal and Regulatory Framework (PGL.5) 68
3.2. Theoretical Background 69
3.2.1. Analytic Hierarchy Process (AHP) 70
3.2.2. Analytic Network Process (ANP) 72
3.2.3. Fuzzy ANP and Chang's Extent Analysis Method 73
3.3. Interrelation Matrix 78
3.4. Model Formation 79
3.4.1. Pairwise Comparisons 81
3.5. Questionnaire Design and Gathering Data 86
3.6. Super Decision Software 89
4. FINDINGS 91
5. DISCUSSION 96
6. CONCLUSION 104
REFERENCES 110
APPENDIX A: THE FINAL BARRIERS LIST 126
APPENDIX B: QUESTIONNAIRE BASED ON THE INTERVIEWS 130
APPENDIX C: PAIRWISE COMPARISONS MATRICES AND ANALYSIS RESULTS 144

LIST OF FIGURES

Figure 2.1. Global smart urban market (US$bn), 2018-2025 (PwC, 2019). . . . 28

Figure 2.2. Traditional public funding (Flynn *et al.*, 2018). 30

Figure 2.3. Project finance (Flynn *et al.*, 2018). 32

Figure 2.4. The model of design-bid-build (Pakkala, 2002). 35

Figure 2.5. The model of design-build (Pakkala, 2002). 36

Figure 2.6. The model of construction management (Pakkala, 2002). 37

Figure 2.7. Phases of a typical BOT project (Tiong and Alum, 1997). 41

Figure 2.8. Typical structure of BOOT project (McCarthy and Tiong, 1991). . 42

Figure 2.9. Schematic scale of the public procurement classification (European Commission, 2003). 43

Figure 2.10. Private and public ownership of the projects (McKinsey, 2018). . . 48

Figure 3.1. General framework of the study. 55

Figure 3.2. Generic framework of AHP (Gkountis and Zayed, 2015). 70

Figure 3.3. Generic framework of ANP (Gkountis and Zayed, 2015). 73

Figure 3.4. A triangular fuzzy number (Kahraman *et al.*, 2004). 74

Figure 3.5. Intersection between M_1 and M_2 (Kahraman *et al.*, 2004). 76

Figure 3.6. Interrelation matrix. 79

Figure 3.7. View of the network model. 81

Figure 3.8. View of the network model in super decisions. 90

Figure 3.9. Questionnaire entry sample in super decisions. 90

Figure 3.10. Direct data entry sample in super decisions. 90

Figure C.1. Comparison matrix of the economic and financial barriers. 145

Figure C.2. The degree of possibility of pairwise comparisons for the economic and financial barriers. 146

Figure C.3. Comparison matrix of the political. Governmental and legal barriers. 148

Figure C.4. Comparison matrix of the political. Governmental and legal barriersac cording to the "Foreign investors' perception of a country as high risk due to economic instability. 150

Figure C.5. Sample table comparison matrix of the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation". 151

Figure C.6. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the "Limited capital availability". 152

Figure C.7. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the “High costs”. 154

Figure C.8. Comparison matrix of the Political. Governmental and Legal Barriers (PGL) according to the “High lenght of payback period”. . . 155

Figure C.9. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the “Problems of delays in receiving payments”. 156

LIST OF TABLES

Table 2.1. Components of a smart urban and related aspects 12

Table 2.2. Key dimensions of a smart urban (Albino *et al.*, 2015). 13

Table 2.3. Dimensions of example smart urban projects 20

Table 2.4. Key quality of life parameters 27

Table 2.5. Main steps of a PPP project (EIB, 2022). 44

Table 2.6. Stakeholders classifications (Selim and Elgohary, 2020) 49

Table 3.1. List of the barriers and sources. 58

Table 3.2. The model scale (Saaty, 2008) 71

Table 3.3. Triangular fuzzy scale. 77

Table 3.4. Comparison matrix 82

Table 3.5. Comparison matrix of the main barriers 83

Table 3.6. Comparison matrix of the economic and financial barriers 83

Table 3.7. Comparison matrix of the technology and technical barriers 83

Table 3.8. Comparison matrix of the sociocultural and environmental barriers 84

Table 3.9. Comparison matrix of the political, governmental and legal barriers 84

Table 3.10. Comparison matrix of the political, governmental and legal barriers according to the "Foreign investors"' perception of a country as high risk due to economic instability 84

Table 3.11. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation" 85

Table 3.12. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "Limited capital availability" 85

Table 3.13. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High costs" 85

Table 3.14. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High lenght of payback period" 86

Table 3.15. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments" 86

Table 3.16. Number of participants in reviewed papers 87

Table 3.17. Information of the respondents 88

Table 4.1. Priorities of the clusters and sub-barriers. 91

Table 4.2. Limiting importance weights of the sub-barriers. 93

Table A.1. The final barriers list after literature review. 126

Table B.1. Information about expert 130

Table B.2. Linguistic variables 130

Table B.3. Example selection for barriers 131

Table B.4. Compare the main barriers to public-private partnership (PPP) implementation in smart urban services by importance 132

Table B.5. Pairwise comparison with respect. 133

Table B.6. Pairwise comparison with respect to technology and technical barriers (TT) 135

Table B.7. Pair wise comparison with respect to sociocultural and environmental barriers (SCE) 136

Table B.8. Pair wise comparison with respect to political. Governmental and legal barriers (PGL) 137

Table B.9. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “Foreign investors’ perception of a country as high risk due to economic in stability” 138

Table B.10. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “High interest and inflation rate and currency fluctuation”. 139

Table B.11. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “Limited capital availability” 140

Table B.12. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “High costs” 141

Table B.13. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “High length of payback period” 142

Table B.14. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the “Problems of delays in receiving payments” 143

Table C.1. Comparison matrix of the main barriers 144

Table C.2. Value of fuzzy synthetic extent of pairwise comparisons for the main barriers 144

Table C.3. Degree of possibility of pairwise comparisons for the main barriers 144

Table C.4. The minimum degree of possibility of pairwise comparisons for the main barriers 145

Table C.5. Value of fuzzy synthetic extent of pairwise comparisons for the economic and financial barriers 145

Table C.6. The minimum degree of possibility of pairwise comparisons for the economic and financial barriers 146

Table C.7. Comparison matrix of the technology and technical barriers 146

Table C.8. Value of fuzzy synthetic extent of pairwise comparisons for the technology and technical barriers 146

Table C.9. The degree of possibility of pairwise comparisons for the technology and technical barriers 147

Table C.10. The minimum degree of possibility of pairwise comparisons for the technology and technical bBarriers 147

Table C.11. Comparison matrix of the sociocultural and environmental barriers 147

Table C.12. Value of fuzzy synthetic extent of pairwise comparisons for the main barriers 147

Table C.13. The degree of possibility of pairwise comparisons for the sociocultural and environmental barriers 148

Table C.14. The minimum degree of possibility of pairwise comparisons for the sociocultural and environmental barriers 148

Table C.15. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers 149

Table C.16. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers 149

Table C.17. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers 149

Table C.18. Value of fuzzy synthetic extent of pairwise comparisons for the Political. Governmental and legal barriers according to the "Foreign investors'" perception of a country as high risk due to economic instability 150

Table C.19. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers according to the “Foreign investors’ perception of a country as high risk due to economic instability . . 150

Table C.20. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers according to the ”Foreign investors”’ perception of a country as high risk due to economic instability 151

Table C.21. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the “High interest and inflation rate and currency fluctuation” 151

Table C.22. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the “High interest and inflation rate and currency fluctuation” 152

Table C.23. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the “High interest and inflation rate and currency fluctuation” 152

Table C.24. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the “”Limited capital availability” 153

Table C.25. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the “Limited capital availability” 153

Table C.26. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Limited capital availability" 153

Table C.27. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs" 154

Table C.28. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs" 154

Table C.29. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs" 155

Table C.30. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period" 155

Table C.31. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period" 156

Table C.32. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period" 156

Table C.33. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments" 157

Table C.34. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments" 157

Table C.35. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments" 157

LIST OF ACRONYMS/ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
ELECTRE	Elimination and Choice Translating Reality English
ICT	Information and Communications Technology
MCDM	Multi-Criteria Decision Method
PPP	Public–Private Partnership
TFN	Triangular Fuzzy Numbers
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

1. INTRODUCTION

Smart urban services are conceptual urban development models that combine human, collective, and technological capital (Angelidou, 2015). The main aim of these services is to provide a sustainable future for people with high-quality technologies. Although these smart urban services enhance the quality-of-life standards (Yang and You, 2019), they are challenging projects for local governments in terms of financing, project delivery, and size. Thus, cities need the support of external partnerships with private and non-profit organizations. At this point, PPPs enable a collaborative project delivery model for the public and private sectors to work together to generate smart urban services (Liu *et al.*, 2021). Although the adoption of PPPs improving in smart urban services, many developing countries still have barriers against its successful implementation (Leiringer, 2003 – Yang and You, 2019). Considering the advantages of the PPP model in smart urban services, the application challenges of these development projects should be investigated. This thesis aims to evaluate the barriers to Public-Private Partnership (PPP) implementation in smart urban services in Turkey, a developing country. After a comprehensive literature review, the barriers were identified. As a multiple-criteria decision method, the Fuzzy Analytical Network Process (FANP) was selected to analyze the barriers. Then, the model was created, and an online questionnaire survey was designed for smart urban experts. The collected data was analyzed by using Super Decision, a decision-making software, to find the priorities and importance weights of the barriers. The study is expected to make both theoretical and practical contributions by exploring the smart urban services concept, defining project delivery methods, and evaluating the barriers to PPP implementation in smart urban services. The following parts explain the background of the research, the problem and gap in the literature, the aim and objectives of this thesis, the research methodology, scope and limitations, and the organization of the study respectively.

1.1. Background of the Research

Urbanization has become a critical issue for the governments in developing countries recent years. According to statistics, the percentage of urbanization has significantly increased globally. It is also seen that citizens choose to live in cities rather than back countries due to enhanced living standards. The recent report of United Nations claimed that metropolitan areas will be hosting more than 68% of the world's total population by the next fifty years. For example, it is already known that 75% of the total European population lives in city centers and this volume is expected to raise 80% in 2020s (Albino *et al.*, 2015).Naturally, this rapid and uncontrolled urbanization will lead to excessive use of our sources like food and water. Moreover, current infrastructure services will not be sufficient due to high number of migrations in this situation such as increase in traffic problems. Subsequently, people will face with low living conditions in following years (Liu *et al.*, 2021).

In this sense, people, governments, and various organizations should seek solutions to overcome these challenges. Lately, some local governments have started to implement urban service solution technologies to enhance the standards of living spaces. They aim to provide sustainable future for the citizens with high-quality urban services. In literature, these types of solutions are identified as "smart urban services" which is a conceptual urban development model that combines human, collective, and technological capital (Angelidou, 2015). Smart urban concept applies all the feasible technology and resources in a coordinated way to increase sustainable, integrated, habitable living spaces according to Barrionuevo *et al.* (2012).

Some studies have showed that smart urban applications develop important quality-of-life parameters between 10-30% which are safety, time, health, environment, social connected ness, jobs, and cost of living (McKinsey, 2018). In the light of many research and practical examples, governments have recognized the benefits and necessity of the smart urban service projects. The demand and popularity of smart urbans continues to expand worldwide. Also, it is declared that the global smart urban market

estimated to outpace US$1 trillion by 2020 and US$2.5 trillion by 2025 which shows the rapid growth in smart urban development projects (PwC, 2019).

Local governments in many different parts of the world have implemented various smart city services due to urban needs and increasing trend. For example, a smart water project was implemented with to control of the irrigation system of Polenou Park in Barcelona (Libelium, 2016). Also, Autonomous taxis have been developed in Tokyo in order to provide comfortable transportation between the airport and sports venues for the visitors coming to the city during the Olympics (Weforum, 2019). In Singapore, Hiring Robotic Police Project was applied to prevent, deter, and detect crime to keep country safe (MHA, 2019). Moreover, the Solid Waste Management system was installed by the government in Gujarat to provide organic fertilizer to nearby rural farmland and water for irrigation purposes with products from waste recycling (GIFT Gujarat, 2022).

Although smart urban services raise quality of life standards (Yang and You, 2019); they are very challenging projects in terms of financing, project delivery, and size. According to recent study, only 16% of city governments are able to self-fund in the world (Flynn *et al.*, 2018). As stated in the article, in order for cities to move forward with providing smart urban services, they need to be supported by external partnerships such as private companies or nonprofit organizations. By reducing costs with new technological solutions and bringing key stakeholders together, local governments may overcome numerous challenges in funding and administering smart urban development initiatives (Cruz and Sarmento, 2017).

At this point, PPPs enable a collaborative project delivery model for the public and private sectors working together to create smart urban service projects (Liu *et al.*, 2021). This PPP project delivery model enhances the efficiency and sustainable availability of resources (Babatunde *et al.*, 2015). Municipalities can prefer this model due to many benefits such as access to private capital, technology, people, skills, saving resources (Cumming, 2007) and transfer of risk (Liu *et al.*, 2021). With participation

of the private parties, the assets, data, and intellectual property of the government can be utilized more effectively, which leads to important enhancement in the quality of urban services (Edkins and Smyth, 2006). Furthermore, this agreement type naturally enhances the collaboration between the public sector and the private sector in positive way (Erridge and Greer, 2002; Zhang and Kunaraswamy, 2001; Zhang, 2004). Considering these advantages of PPP, the application of this project delivery method in smart urban services should be more wide spread approach in the world. In recent years, some successful examples have been applied, especially in developed countries.

For example, LinkNYC was installed with the PPP model in New York City as smart urban service. The city faced an aging network problem of 8.400 public phones that the services attracted fewer users in modern technology era (Fishman and Flynn, 2018). The city government deal ed with City Bridge Consortium, a partnership that includes Qualcomm, Titan, and Control Group, for replacing its old payphones in 2014. With this effective partnership, they replaced the obsolete payphones with smart kiosks that provide free Wi-Fi, maps, transportation updates, video calls, device charging, and more (LinkNYC, 2022). In addition to this advantage, LinkNYC is expected to generate around 100–150 full-time jobs and 650 support jobs. In this business model, City Bridge Consortium pays for and operates all LinkNYC system at no cost to the New York City and offers many services to users free of charge, directly funded with the support from advertising revenues (Fishman and Flynn, 2018). Similar to previous example, another kiosk system was implemented in Kansas City Local government, Cisco and Sprint tech companies made a partnership and private parties had installed 25 kiosks that provide a free public Wi-Fi and many other features (Fishman and Flynn, 2018). As a major difference, the annual budget of the local government was not used, and Cisco and Sprint companies spent $12.3 million to cover hardware and maintenance costs but they will not receive any direct monetary return on investment. Instead of the money, they will get exclusive access to usage data from the smart kiosks (Start land news, 2022). Nowadays, many organizations seek ways to get access to data beyond their customer bases because of numerous benefits. Data effectively helps companies make better decisions with a sustainable format that clarifies the importance of this

partnership. Therefore, considering the importance of PPP model implementation in smart urban services, focusing on expanding the use of this application is an important step for both local governments and the private sector parties.

1.2. Problem Definition

In developed markets, there are some application examples of smart urban services with the PPP model. The use of PPPs in smart urban services is increasing, yet many developing countries still struggle to successfully implement them (Leiringer, 2003 – Yang and You, 2019). Their complex structure and a lack of infrastructure are the reasons for the developing countries having difficulties in the application (Lam and Yang, 2020; Liu *et al.*, 2021). As a developing country example, these barriers can be clearly seen in Turkey. Although Turkey has some application examples of PPP in transportation projects, there are still various macro environmental constraints that prevent the widespread adoption of PPP in smart urban services.

To provide sustainable living spaces for citizens, the PPP model should be correctly utilized in Turkey's smart urban services which brings the necessity of identifying the barriers as a first step. Despite the fact that many articles looked into the difficulties in applying PPPs, their focus was mainly on infrastructure projects. A thorough literature search showed that PPP topics and smart urban services were studied independently. For example, Babatunde *et al.* (2015) conducted a literature review to identify and classify the selected barriers to PPP project application in the country of Nigeria. Pezzutto *et al.* (2016) only searched the barriers and drivers for smart city project application within a European scope. As stated in the examples, the barriers to PPP implementation in smart urban services have not been studied which indicates that there is a gap in the literature in this area. In this sense, these components should be merged and investigated together, taking into account the numerous benefits of PPP as an efficient project delivery method in smart urban services.

1.3. Aim and Objectives

The challenges in infrastructure projects are commonly studied by many academics; however, there is a gap in the literature regarding the application of Public-Private Partnership (PPP) in the smart urban services as a combination. To fill this gap, this thesis aims to evaluate the barriers to Public-Private Partnership (PPP) implementation in smart urban services in Turkey.

To fulfil the main aim of this thesis, the objectives are as the following:

- Identifying the main barrier clusters and sub-barriers of PPP implementation in smart urban services in Turkey.
- Obtaining the inter dependencies between these clusters.
- Determining the priorities and importance weights of these barriers with the Fuzzy Analytic Network Process method.
- Deciding on the most important barriers in flouncing smart urban services in Turkey.

1.4. Research Methodology

Initially, a literature review was conducted to in order to understand the challenges in the smart urban services development projects. This research provided two essential outcomes separately. Firstly, it provided an opportunity to know the general barriers to PPP implementation in smart urban services. Also, various multiple criteria decision methods were reviewed that provided a general overview to determine the importance rates of the barriers as a second step.

After a comprehensive literature review, the phase of determining the barriers was started. More than 30 articles were analyzed and the most relevant 16 current studies were selected that were published after 2010. Then, these studies were carefully evaluated, and 252 barriers were identified. Repetitive and less relevant barriers were

eliminated with expert comments. Finally, 17 sub-barriers were selected. These barriers were grouped under 4 main clusters that are "Economic and Financial Barriers", "Technology and Technical Barriers", "Sociocultural and Environmental Barriers", and "Political, Governmental and Legal Barriers".

It is seen that Analytic Hierarchy Process (AHP) is very popular multiple criteria decision method in the literature. Considering the inter dependency factor among the barriers, ANP (Analytic Network Process) was selected which is also an extended model of AHP. ANP structure contains dependence's and feed backs among factors and clusters which is not considered in the AHP (Saaty, 2008). It is also observed that factors are generally dependent on each other in real-life decision-making problems. In this sense, ANP is preferred to make more accurate determination in analysis phase while considering the inter dependencies of selected barriers. Then, fuzzy set theory and ANP were combined to deal with the imprecise judgments in multi-criteria decision-making problem in this thesis. Because the data was collected from the experts in the industry regarding the comparison of barriers and their comments were quite subjective. In the pairwise comparison section, Fuzzy ANP applies a range of values that into account the decision makers' uncertain judgements contrary to the exact values. Hence, Fuzzy Analytical Network Process is selected as the most appropriate methodology to apply for this thesis.

After identifying the barriers and selecting suitable analysis method, the interrelation of the barriers was classified and pairwise comparisons were generated. Then, reviews of participants on each pairwise comparison matrices were obtained. Lastly, "Super Decision" decision-making software was used to calculate the priorities and importance weights.

1.5. Scope and Limitations

This thesis investigates the evaluation of the barriers to Public-Private Partnership (PPP) implementation in smart urban services with a Turkey scope while ob-

taining the importance weights of these barriers. While focusing on many points, this study also has limitations that can be addressed in future academic research.

Firstly, the scope of this thesis can be shown as the most significant limitation that focuses on only Turkey. Developed, developing, and underdeveloped markets have various macro-environment factors that can lead to important differences in participants' assessments. In this regard, academics can focus on these scopes separately and compare with each other in the future. Also, 15 participants are selected from technology and telecommunication industries generally. The number of participants in the survey can be increased. The answers obtained from different sectors can be analyzed separately and compared with each other to gain more specific results. The last limitation is related to comparison of the theory and practice of the result. Current smart urban services can be defined that have different scopes. Afterwards, the barriers of these real current smart urban service sand the results of this study can be compared.

1.6. Organization of the Study

The structure of the thesis is as follows:

- Literature review chapter firstly presents the smart urban concept in terms of history, definition, and dimensions. Next, it shows the current necessity and challenges of smart urban services. Then, it provides information about Public-Private Partnership (PPP) model as an efficient agreement to implement smart urban services. In the final part, the gap in the literature is reviewed in regard of the PPP application in urban services development projects.
- Research methodology chapter explains the identification of the barriers, theoretical background of the model, model formation, and gathering data steps.
- Findings chapter demonstrates the results of the analysis. It out lines the priorities of the main and sub-barriers while mentioning the related reasons.
- Discussion chapter compares the results of this thesis and related studies in the literature and consists of three main phases. Firstly, it focuses on analysis methods

while showing various multi criteria decision making methods in similar studies. Then, it provides a scope of main clusters comparison between different papers. Lastly, the prioritization of the selected barriers is discussed with the related articles.

- Conclusion chapter gives a summary of the study as final part of this thesis. It also outlines the contributions and limitations and of this thesis and gives advice for future research.

2. LITERATURE REVIEW

2.1. Smart Urban Services Concept

The concept of smart urban services has become more popular in the literature and global policies recent years. Various organizations agree that smart urban concept is an effective approach to improve urban management and development. Although there are many smart urban definitions in the literature, it essentially represents a well-planned urban that is surrounded by various technologies to make the environment more efficient. According to the definition of Mahesa *et al.* (2021), smart urban services are an essential function in sustainable development based on the concept of smart city development for developing countries. These services aim to ensure that the lives of its citizens are safe, comfortable, and prosperous perpetually.In urban services, resources are used effectively, and any kind of data is saved for further improvements. Besides the efficient use of technology, these cities distinguish with an eco-friendly environment. In a nutshell, with an innovator perspective, useful and sustainable living spaces are offered by smart urban services.

The term first introduced in the 1990s while focusing on the importance of new Information Communication Technologies (ICT) with modernized infrastructure in cities (Albino *et al.*, 2015). The California Institute for Smart Communities was the first organization who investigated to implement these information technologies to become a smart urban(Alawadhi *et al.*, 2012). A few years later, the Center of Governance at the University of Ottawa criticized the smart urban concept as being too technically oriented. The importance of the governance-oriented approach was clarified with the studies carried out and the researchers also focused on social capital and urban development topics in following years (Albino *et al.*, 2015). Overall, the main objective of smart urban services is to make the city intelligent with technological transformations.

Although there is ongoing discussion in recent years, there is no agreed and exact definition of a smart urban concept (Angelidou, 2015). There are many studies in the literature that smart urban concept has identified with different focuses and aspects. Angelidou (2015) identified as a conceptual urban development model that combines human, collective, and technological capital. The concept represents a multidisciplinary area, generally shaped by growth in technology and urban development. Bakıcı *et al.* (2013) also investigated the concept of smart urban. Their definitions emphasis that it connects people, information, and city components with advanced technology to generate sustainable place while providing a quality life for the citizens. Harrison *et al.* (2010) discussed the smart concept and identified as a city connecting the IT infrastructure, the social infrastructure, and the business infrastructure to use the united intelligence of the city. Smart urban concepts apply all the available technology and resources in a coordinated way to enhance sustainable, integrated, habitable living spaces according to Barrionuevo *et al.* (2012). Marsal-Llacuna *et al.* (2014) clarified that smart urban concepts try to enhance urban performance with analyzed data, information, and technology to provide efficient services to the people. Additionally, it improves the cooperation between different financial institutions from private and public sectors to generate innovative business models.

2.2. Dimensions of Smart Urban Services

Smart urban services have various dimensions. According to the research of Giffinger *et al.* (2007), there are four main components of a smart urban service development projects which are industry, education, participation, and technical infrastructure. Then, they expanded these dimensions with extra components in the following research (Giffinger and Gudrun, 2010). These are smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. In addition to that Lombardi *et al.* (2012) generated the six related elements with different aspects of urban life which can be seen in Table 2.1. The smart economy refers to ICT industries and production. Smart mobility also indicates the usage of intelligent transport technologies to optimize urban traffic (Albino *et al.*, 2015).

Table 2.1. Components of a smart urban and related aspects (Lombardi*et al.*, 2012).

Components of a Smart Urban	**Related Aspect of Urban Life**
Smart Economy	Industry
Smart People	Education
Smart Governance	E-Democracy
Smart Mobility	Logistics & Infrastructures
Smart Environment	Efficiency & Sustainability
Smart Living	Security & Quality

Smart environment dimension refers to control and monitoring of environmental factors such as pollution, waste, planning of green areas, and energy. The services in this dimension provide increase the efficiency in citizen's lives by creating more sustainable habitats. Intelligent Recycling, Intelligent Waste Collection, Electric Energy Tracking Intelligent Lighting, and Automatic Air Quality systems can be shown as examples of this dimension.

Smart mobility and transportation is a new concept of thinking about how we get around-one that is cleaner, safer, and more efficient. These services focus to reduce traffic congestion and its related side effects, pollution, fatalities rate, and wasted time. There are many examples of this dimension such as Intelligent Park Management, Autonomous Driving, Cycling Evaluation System, and Electric Vehicles.

Smart living is a dimension encompassing advancements that give people the opportunity to benefit from new ways of living. It involves innovative services aimed at making life more efficient, more controllable, safer, productive, integrated and sustainable. Intelligent health system, informative kiosks can be illustrated as examples of this dimension.

Smart economy adopts innovative solutions, new entrepreneurial initiatives, increases productivity and competitiveness in industries. Also, smart people dimension

refers to intelligent education system with the overall goal of enhancing the quality of life of all citizens.

Smart governance urban services provide simple, moral, accountable, responsive, and transparent governance. These solutions include simplification of rules, regulations, and processes of government through the use of ICTs and thereby providing for a user-friendly government. The service of e-devlet in Turkey is an example for this dimension.

Furthermore, the following table is created by Albino *et al.* (2015) as a summary and it shows the dimensions of "smart urban" as advanced by different researchers.

Table 2.2. Key dimensions of a smart urban (Albino *et al.*, 2015).

Key Dimensions of a Smart Urban	**Source**
IT Education IT Infrastructure IT Economy Quality of Life	Mahizhnan (1999)
Economy Mobility Environment People Governance	Giffinger *et al.* (2007)
Technology Economic Development Job Growth Increased Quality of Life	Eger (2009)
Quality of Life Sustainable Economic Development Management of Natural Resources through Participatory Policies Convergence of Economic, Social, and Environmental Goals	Thuzar (2011)

Table 2.2. Key dimensions of a smart urban. (cont.)

Key dimensions of a smart urban	**Source**
Economic Socio-Political Issues of the City Economic-Technical- Social Issues of the Environment Interconnection Instrumentation Integration Applications Innovations	Nam and Pardo (2011)
Economic (GDP, Sector Strength, International Transactions, Foreign Investment) Human (Talent, Innovation, Creativity, Education) Social (Traditions, Habits, Religions, Families) Environmental (Energy Policies, Waste and Water Management, Landscape) Institutional (Civic Engagement, Administrative Authority, Elections)	Barrionuevo *et al.* (2012)
Human Capital (e.g. Skilled Labor Force) Infrastructural Capital (e.g. High- Tech Communication Facilities) Social Capital (e.g. Intense and Open Network Linkages) Entrepreneurial Capital (e.g. Creative and Risk-Taking Business Activities)	Kourtit and Nijkamp(2012)
Management and Organizations Technology Governance Policy Context People and Communities Economy Built Infrastructure Natural Environment	Chourabi *et al.* (2012)

2.3. Global Applications of Smart Urban Services

Many city governments have focused on smart urban services due to the urban needs and increasing trend. In this section, various application examples such as smart security, smart transportation, smart living, and smart environment in some selected cities are given.

2.3.1. Barcelona

The local government of Barcelona offers smart urban services such as access to livable housing, employment, security, and air pollution. Many energy, climate change, and water reserve projects have been realized in the city. According to IREC (2022) news, one of the projects in the energy sector is the construction of an integration and storage platform for renewable energy. It was aimed to establish an industrial energy transfer center in the Besos region with this project. The main purpose of the project is to increase the competitiveness of the energy sector through R and D and innovation within the scope of the new green agreement. The project is directly related to three goals. These targets can be listed as investing in affordable energy sources, supporting industry and innovation, and infrastructure, and incorporating urgent measures to combat climate change and its effects (IREC, 2022).

Also, according to the statement in Info Barcelona (2020), one of the projects for clean energy and more green space is the urban remodeling project on the section of the Ronda de Dalt ring road between the neighborhoods of Sant Genísdels Agudells and La Teixonera. It includes spaces for relaxation, children's playgrounds, and multi-purpose areas for residents. After the first phase has been completed, three smart pergolas will be built with solar panels to generate energy. The solar panels will have a power potential of 50 kW producing approximately 75,600 kWh equivalent to the energy consumption of 33 households, and the energy produced will be connected to the electricity grid to help the latter be greener (Info Barcelona, 2020). Cleaner energy will be produced by reducing greenhouse gas emissions with this project. With the

clean energy coming from this production facility, 27,540 kg of CO2 will not be released into the atmosphere. Moreover, since clean energy production is important against the climate crisis, the city council uses various materials with the aim of sustainability. For example, many solar panels were implemented in public buildings (Info Barcelona, 2020).

Moreover, a smart water project was implemented with the partnership of the Barcelona City Council, Starlab, and Libelium for the control of the irrigation system of Polenou Park (Libelium, 2016). According to the information in Libelium website (2016), the system installed in this project optimizes water consumption by considering the weather conditions and the water needs of the plants. Before starting the project, the water requirement of the park was analyzed. In this way, the sensors are placed in the ground with waterproof boxes. Data from these sensors is sent to the cloud data storage system via a network. This information is visualized and presented to the end user. This mechanism can be controlled with smartphones or tablets. This irrigation management system allows automatic control of electronic valves that turn the water flow on and off. It is additionally outlined that 58 million dollars are saved annually by using this smart water technology (Libelium, 2016).

2.3.2. Tokyo

Tokyo Metropolis is the capital and largest city of Japan. The city has a population of more than 37 million people (Macrotrends, 2022). The city government focused on smart urban services to increase the effectiveness of living conditions. The prominent indicators regarding smart urban services are health services, access to livable housing, and traffic density. According to the article of World Economic Forum (Weforum, 2019), autonomous taxis have been developed in Tokyo in order to provide comfortable transportation between the airport and sports venues for the visitors coming to the city during the Olympics. Tokyo-based firm NEC has developed facial recognition technology that takes just 0.3 seconds to complete to help speed up security screenings of over 300,000 athletes and staff. With facial recognition service, it is aimed

to speed up security scans for hundreds of thousands of athletes and personnel. On the other hand, Japanese technology giant Panasonic has reduced the language barrier experienced by many tourists by developing a live translation device that allows people to instantly communicate face-to-face to break down language barriers (Weforum, 2019). Tokyo Government invested approximately $51.4 billion in Tokyo's re-developing areas and special technologies between 2017 and 2020. These smart urban services, which began to be implemented in Tokyo, are seen as a tool to create a smart city that can serve the world as an international financial center even after the Olympics are over (Weforum, 2019).

Also, a news of CNN (2022) declared that Tokyo Green Building Program was implemented which is a mandatory rating and disclosure program on environmental performance for buildings (buildings over 5000 square meters). All newly constructed large-scale buildings in Tokyo are subject to the Tokyo Green Building Program, and the relevant buildings are required to publish their building environmental plans on the Tokyo Metropolitan website as per the program's obligation. This program, which started in 2002, has been applied to 1307 buildings in total (CNN, 2022).

Furthermore, a report was published about Tokyo smart city development in perspective of 2020 olympics opportunities (EU-Japan, 2015). According to the report, the city generated The Smart Energy City strategy that is based on the measures taken after the Fukushima disaster and the resulting inability of manufacturing facilities to supply Tokyo at the same level as before. The Tokyo Emergency Power Saving Program was prepared in May 2011 and entered into force in the summer of the same year. The program includes lowering the brightness standard, switching to LED, and keeping devices in energy-saving mode to enhance energy efficiency. Large facilities, small and medium facilities, and households are targeted. The program aims to maintain work and basic daily activities even in the event of a power outage with distributed power generation and energy savings (EU-Japan, 2015).

2.3.3. Singapore

Singapore is ranked 1st according to the IMD (World Competiness Center)Smart City Index (IMD, 2021). They focused on various smart urban services such as access to livable housing, unemployment, health care, and public transportation. According to the news in MHA (2019), Hiring Robotic Police Project was implemented by the government. Although the crime rate in Singapore is currently the lowest in the world, this practice is used to minimize the crime level. The aim is to prevent, deter and detect crime to keep Singapore safe. Last year, the SPF (Singapore Police Force) began using specialized drones to conduct aerial searches. The robotic helicopter can reach heights of up to 60 meters. Engineers have equipped them with powerful sirens and floodlights. In addition, it is now patrolled by bots during special public events. These drones use pre-planned routes to navigate. As the bots are equipped with cameras, they provide facilities for remote surveillance (MHA, 2019).

Additionally, The Guardian (2015) stated in the news that Robots Among Us Project has been applied recently. Students and staff from Ngee Ann Polytechnic have developed a "RoboCoach" that can provide physical education for elderly people. The robot is part of Singapore's Smart Nation plan to apply cutting-edge technology to nearly every aspect of operations in the country. Robocach works with Singapore's elderly citizens to help them stay healthy by exercising regularly. It enables the elderly to do their exercise routines correctly with motion sensor technology. According to The Infocomm Development Authority of Singapore (IDA), the feedback from people has been positive (The Guardian,2015).

Furthermore, the government implemented Autonomous Vehicles Project with participants from private industry according to the information in Consultancy.asia (2020). They allocated a budget of 6 million dollars to support the autonomous vehicle project. Also, annual road taxes for electric vehicles were reduced along with the budget. The test area for autonomous driving has expanded to cover all public roads (approximately 1,000 kilometers). In addition, it is aimed to serve three new towns with

driverless buses in 2022. The partnership between Volvo and Nanyang Technological University has launched a 12-meter autonomous vehicle electric bus that can be used to serve these areas in Singapore (Consultancy.asia, 2020).

2.3.4. Gujarat

Gujarat is the fifth-largest Indian state by area (covering 196,024 km2) and the ninth-most populous state with more than 60 million population. The Gujarat Government has established the Gujarat Urban Development Mission to develop smart urban services. With the focus created, it is one of the 20 cities selected for development within the scope of smart cities. Projects in the city are an important example of developing countries' aspects (GUDCLTD, 2022).

According to the information in GIFT Gujarat (2022), the Solid Waste Management system was installed by the government to cover approximately 38% of the state population and generate approximately 7000 tons of waste per day. Conversion of solid wastes into compost and reuse of such productions for industrial or agricultural purposes are emphasized. This project mainly focuses on the concept of Waste Reuse. This project is proposed to provide organic fertilizer to nearby rural farmland and water for irrigation purposes with products from waste recycling. It balances water demand by reusing waste for different purposes. In this way, there is an increasing demand for organic food in the affordable market. It is aimed to reduce the demand for chemical fertilizers by providing organic fertilizer/compost to the farmers (GIFT Gujarat, 2022).

The government also started the construction of Gujarat International Finance Tech City (GIFT Gujarat, 2022). Approximately 67% of the total area is reserved for commercial uses, 22 percent is reserved for residential use, and the remaining parts are reserved for social reinforcement areas. It is aimed to have an international education district, integrated districts, an entertainment district, hotels, a congress center, and an international techno park in this special region. GIFT is seen as a global financial

and technology services hub for the first time in India, designed to be on par with globally bench marked financial centers such as Shinjuku, Tokyo, Lujiazui, Shanghai, La Defense, Paris, and London Shipyards. The government has created this mega-city project with smart urban services. Thus, it aims to become a financial services center in the world (GIFT Gujarat, 2022).

2.4. Smart Urban Services in Turkey

Turkey is a speedily developing country, and some cities of the country are comparable with the highly developed cities all around the world. Although it has a large surface area, the population is not evenly distributed. The population of over 85 million is generally dispersed in major cities. This causes overpopulation and irregular migration problems variously especially in cities. Although the smart urban services have not yet fully settled in Turkey, initiatives are gradually spreading. Some smart urban service sin vestments are started to be implemented by metropolitan municipalities such as Istanbul, Izmir, Ankara, Bursa, Gaziantep, and Kayseri. The successful examples of smart urban services are grouped according to Akıllı Şehirler (2022a) website by dimensions in Table 2.3 as a brief summary. After that, these examples are explained in the following sections respectively.

Table 2.3. Dimensions of example smart urban projects.

Dimension	**Urban Projects**
Smart Environment	Smart Recycling Container, Istanbul Automatic Meteorology System, Istanbul Intelligent Waste Collection System, Ankara Electric Energy Tracking System, Ankara Intelligent Lighting, Kayseri Solid Waste Management, Kayseri Air Quality Station, Kayseri

Table 2.3. Dimensions of example smart urban projects. (cont.)

Dimension	**Urban Projects**
Smart Living	Fire Detection System, Izmir Love Chip, Bursa Intelligent Mobility Service, Bursa Charge Units for the Disabled, Kayseri City Square Energy Pipeline, Kayseri Smart Library, Kayseri Informative Kiosks, Kayseri
Smart Mobility and	Intelligent Park Management, Istanbul Fleet Trackingand Management, Kayseri Smart Parking Project, Kayseri Rail Control Center, Kayseri Autonomous Driving, Kayseri Electric Bus, Kayseri Green Wave System, Gaziantep Cycling Evaluation System, Gaziantep
Smart Economy	Agricultural Forecasting and Early Warning System, Izmir Fleet Trackingand Management, Kayseri Smart Parking Project, Kayseri Rail Control Center, Kayseri Autonomous Driving, Kayseri Electric Bus, Kayseri Green Wave System, Gaziantep Cycling Evaluation System, Gaziantep
Smart Economy Transportation	Agricultural Forecasting and Early Warning System, Izmir Smart Station, Kayseri

2.4.1. Istanbul

Istanbul is the largest city in Turkey and has a population of over 15 million residents, comprising 19% of the population of Turkey. Also, it is the most populous European city (Statista, 2022). For example, the population is two times more than Austria. City capacity and resources are being challenged by the impact of irregular

migration. Thus, some intelligent urban solutions have been implemented recently. According to the Akıllı Şehirler (2022b), a website about successful implementations of smart urban services in Istanbul, Intelligent Park Management System was applied by the municipality that saves the time and fuel for the effective and efficient use of indoor, outdoor, and roadside parking lots in the city. It contributes to the country's economy by aiming to reduce carbon emissions. Open and closed park entrances and exits are managed with license plate recognition system. Also, drivers can use Istanbul public transportation card during the payments to be made quickly and practically. Furthermore, variable message signs on the road, traffic density map web page, mobile traffic applications and the occupancy information of the parks are shared with the drivers (Akıllı Şehirler, 2022b).

Also, Smart Recycling Container was developed by the municipality in order to prevent environmental pollution (Akıllı Şehirler, 2022c). It is currently available at some metro stations. With the application, it is aimed to develop the culture of recycling and to bring social responsibility and environmental awareness especially to primary school children. Containers can recognize the pet bottles (0.5 to 1.5 liters) and metal cans (200 to 500 milliliters) with image processing algorithm and barcode scanning system. The machine also recognizes and gives back the full bottle and different materials. The amount of waste discarded with the sensor is determined and the reward is loaded into Istanbul transportation card. With the remote monitoring system, the number of wastes in the station, the approximate percent occupancy rate, error codes, location and working time can be monitored instantly over the internet network (Akıllı Şehirler, 2022c).

Moreover, Dener (2018) mentioned that hidden ice in roads, bridges, and tunnels causes some traffic accidents during cold weather conditions. In this regard, an automatic meteorology surveillance, analysis, and anti-ice system were installed on roads to prevent these damaging situations. Thus, the negative impact of winter months on urban life is decreased with the help of the icing detection and prevention system. In this service, the water formed on the road remains as a liquid without freezing, and

precautions can be taken in areas where there is a risk of icing (Dener, 2018).

2.4.2. Ankara

Ankara is the capital and the second-largest city in Turkey. According to the Akıllı Şehirler (2022d), a website about successful implementations of smart urban services in Ankara, the municipality focused on smart environment projects and an "Intelligent Waste Collection System" was implemented. They aimed to reduce carbon emissions and prevent garbage overflows that may threaten public health for a more livable environment. Additionally, this system provides savings in fuel and operation costs. With this Intelligent Waste Collection System, the occupancy rates, temperature conditions, and positions of all waste containers integrated into the system can be monitored remotely. Thus, waste will be collected on time, and it will contribute to preventing problems in terms of public health and hygiene (Akıllı Şehirler, 2022d)

Also, Dener (2018) declared that every year 35% of electric energy is wasted in Turkey. In this regard, the "Electric Energy Tracking System" was taken into consideration by the municipality buildings for energy savings. An energy management system was implemented by monitoring the energy quality, active-reactive power monitoring, fault conditions, and instantaneous voltage-current values at the municipal facilities. Thus, an energy saving of up to 75% is foreseen in municipal facilities (Dener, 2018).

2.4.3. Izmir

Izmir is the third biggest city in Turkey. According to the Akıllı Şehirler (2022e), a website about successful implementations of smart urban services in Izmir, the municipality has created the Sustainable Urban Mobility Plan (SUMPIZMIR) to provide a safer, cleaner, accessible, durable, and sustainable living area for the citizens of İzmir. Compared to other provinces, İzmir is located in the south of the country and faces the forest fires problem, especially in the summer season. In this sense, a fire detection system was applied to quickly detect and respond to fires that may occur in forest

areas. Inputs are analyzed with the help of artificial intelligence. Up to this time, 45 artificial intelligence camera systems have been installed at 12 radio stations and an intelligent fire alarm system has been installed in forest areas within the scope of the project (Akıllı Şehirler, 2022e).

It was stated on the website (Akıllı Şehirler, 2022f) that the municipality also implemented an agricultural forecasting and early warning system to inform the people who are in agricultural business regarding the meteorological conditions and precautionary measures against irrigation (Akıllı Şehirler, 2022f). Producers can get information about temperature, air humidity, precipitation amount, wind speed and direction, soil temperature, sunshine, soil moisture etc. for their lands. It is aimed to increase the quality of the product and to prevent waste by taking frost and storm warnings, early warnings against climate, irrigation suggestions for the producers. This system produces its own energy needs with solar energy panels on it and records the data with the sensors. Then, these data are processed by the agricultural engineers who appointed for this job and converted into SMS messages as simple data. These sms messages are also sent to registered producers as notification messages. Producers who receive these messages can protect their products by being directed correctly (Akıllı Şehirler, 2022f).

2.4.4. Bursa

Bursa is the fourth-most populous city in Turkey, and it is one of the industrial centers of the country. The local government has started to seek smart urban solutions with the effect of increasing immigration recently. According to the information in Akıllı Şehirler (2022g) website, Bursa Metropolitan Municipality was involved in the Global Future Cities Programme Turkey that is funded by the UK Foreign, Commonwealth and Development Office. The program aims to improve inclusive economic growth, reduce poverty, and enhance gender equality, inclusion in the areas of mobility, resilience, transport. The municipality received 3.2 million pounds grant for urban service projects with the theme of urban transformation (Akıllı Şehirler, 2022g).

In the regard of intelligent mobility dimension, the municipality offered free, secure, and high-quality internet service for the citizens in the long-distance buses. Moreover, the traffic data is collected in one specific center from 20 different vehicle follow-up firms to create intelligent infrastructure system which provides users tracking and reporting facilities in public transport. In addition to that wireless internet services are implemented in public service buildings for the needs of domestic and foreign guests under the smart environment component (Akıllı Şehirler, 2022g).

Differently, with the smart living and health concept, "Love Chip" is applied by the municipality that offers to connect easily with the relatives ofAlzheimer's and mentally ill citizens (Akıllı Şehirler, 2022h). While the patient, who carries the smart device on, is out of the house, the relatives can instantly monitor the patient on the internet, 24 hours a day, in Turkey and all over the world. 117 smart chips were distributed in the first stage of the project (Akıllı Şehirler, 2022h).

2.4.5. Kayseri

The city attaches great importance to smart urban services. They focused on many different dimensions in the regard of such projects. According to the study of Dener (2018), Intelligent Lighting, Solid Waste Management, and Air Quality Stations were implemented within the scope of intelligent environment. They also concentrated on smart community urban services such as Navigation Implementation for the Disabled,Charge Units for the Disabled, City Square Energy Pipeline, Smart Library Construction, and Informative Kiosk. Furthermore, smart transportation dimension was taken into consideration. Smart Station, Rail Control Center, Ambulance Transit Elevation, Autonomous Driving, Electric Bus, Fleet Tracking and Management for Municipal Vehicles, and Smart Parking projects were applied by the municipality (Dener, 2018).

2.4.6. Gaziantep

The municipality of Gaziantep city also made investments in smart urban services. According to national smart cities strategic plan in Akıllı Şehirler (2022i) website, more than 37 different projects have been implemented. For instance, the green wave system operates in 15 main roads and 51 signalized junctions connected to it throughout the city. This system provides a series of traffic lights are coordinated to allow continuous traffic flow over multiple intersections in one main direction (Akıllı Şehirler, 2022i). Besides, it has been determined that the rate of bicycle use for transportation is 1% in the city that is very low between middle-sized cities generally. Within the scope of smart transportation, the city generated Cycling Potential Measurement and Evaluation System. The project aims to increase the use of bicycles by expanding bicycle routes and to collect information about bicycle activity and mobility behaviors through bicycle counter and analyzes for this purpose (Akıllı Şehirler, 2022j).

2.5. Necessity and Challenges of Smart Urban Services

Urbanization has become an important trend for developing countries with social and economic aspects. It is observed that the global urbanization percentage has dramatically raised in the last years. Nowadays, many people prefer to live in cities rather than rural areas because of better living conditions. According to United Nations' statistical data, the cities will be hosting more than 68% of the world's total population by the next fifty years. More specifically, 75% of the total European population already lives in urban areas and the amount is expected to grow 80%in 2020s (Albino *et al.*, 2015). In worldwide, urban areas consume most of the energy which is between 60 %-80% and they are responsible for large shares of greenhouse gas emissions.

Naturally, this fast urbanization will cause excessive use of sources such as food and water with an increased number of migrations. Additionally, in this scenario, existing infrastructure services will not be enough, and traffic problems will arise. As a result, citizens will come up with decreased living standards (Liu *et al.*, 2021). In this

respect, cities and governments must find new ways to deal with these challenges in the current situation.Recently, cities have started to seek solutions that enable transport links, mixed land use, and high-quality urban services with long-term positive economic outcomes. These new technologies based urban solutions are called as "smart urban services" for the sustainable future of our living spaces (Albino *et al.*, 2015). Nowadays, many local governments are getting aware of the necessity and advantages of the smart urban services.

According to the recent McKinsey Global Institute Analysis (2018), smart urban service applications can enhance some key quality-of-life parameters by 10-30% positively such as safety, time, health, environment, social connectedness, jobs, and cost of living. These key indicators can be seen below.

Table 2.4. Key quality of life parameters (McKinsey, 2018).

Main Group	**Key Quality-of-Life Indicators**	**Improvement Percentage**
Safety	Fatalities averted (homicides, road deaths, fire deaths)	8 - 10%
	Crime incidents prevented (assaults, robberies, burglaries, auto thefts)	30 - 40%
	Emergency response time reduced	20 - 35%
Time and convenience	Commute time saved	15 - 20%
	Time saved in interactions with government and the heal thcaresystem	45 - 65%
Health	Disease burden reduced	8 - 15%
Environmental quality	GHG emission saver ted	10 - 15%
	Recycled waste reduced	10 - 20%
	Water consumption reduced	20 - 30%
Social connected nessand civic participation	Share of residents who feel connected to the local community	15 - 20%
	Share of residents who feel connected to the local government	20 - 30%
Jobs	Formal employment increased	1 - 3%
Cost of living	Average annual expenditures reduced	1 - 2%

In this regard, the popularity of smart urban service development projects is increasing worldwide, and many organizations invest in these projects. The Creating the Smart Cities of the Future report of PwC (2019) illustrated that the development of smart urban services around the world is growing rapidly, with the total value of the global smart urban market calculated to outpace US$1 trillion by 2020 and US$2.5 trillion by 2025. Figure 2.1 shows this increasing trend below

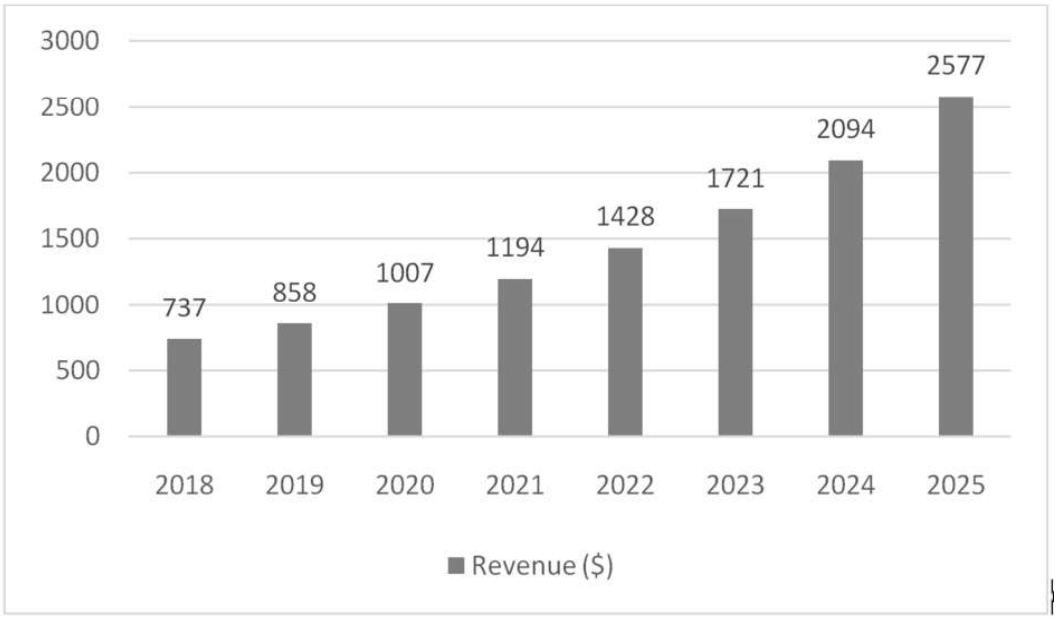

Figure 2.1. Global smart urban market (US$bn), 2018-2025 (PwC, 2019).

On the other hand, there are many challenges of the smart urban services development projects with different aspects. It is observed that governments have budgetary constraints especially the financing phase of these projects. Moreover, the technical infrastructure of the cities is getting ageing (Lam and Yang, 2020). Alim and Polak (2016) outlined those constraints on public financing cause a huge barrier to the development phase of smart urban services.

Additionally, smart urban service projects involve different stakeholders such as municipal authorities, citizens, and private and non-profit organizations. Naturally, this multi-stakeholder model increases the difficulty of doing business because of dif-

ferent needs, interests, and requirements (Liu *et al.*, 2021). Moreover, this type of development projects requires a high level of innovation and significant commercial view from service providers(Ojasalo and Kauppinen, 2016). Additionally, these projects generally have complex structure in regard of mega size, complicated systems. It can be another barrier for the project managers who led the development projects.

2.6. Financing Models

It is known that countries spend more than $2.5 trillion each year on building and repairing their infrastructure all around the world and $1.3 trillion of additional public infrastructure investment is required for developing countries. Unfortunately, these amounts are not close sufficient to meet the current demand for transportation, water, power, energy, telecommunications, and other infrastructure, especially in developing countries and this problem may continue in near future. Although centralized government budgets are the main source of infrastructure finance, they are not enough to finance public needs. In this regard, other financing options must be considered (Flynn *et al.*, 2018). Major financing types, Government-Based Financing, Debt Financing and Project Finance, in smart urban services are explained in this chapter. Then, Multilateral Finance and Crowd Funding were identified respectively as leading examples of alternative funding options.

2.6.1. Government-Based Financing

Public funding is the most common financing way for infrastructure projects for governments all around the world. Own-source revenues and equity are funds that centralized governments can collect themselves. Generally, property taxes, income taxes, retail taxes, and other taxes, along with fees for business licenses, and the use of public facilities are included in these revenue sources. Additionally, there are non-tax revenues that include proceeds from the lease or sale of public assets. After the collection of these revenues, centralized governments internally transfer to the city's local governments as a grant for a specific project or program to enhance public investment.

Whereas, own-source revenues of governments are very limited, especially in developing countries. For instance, big cities with high proportions of low-income residents generate little in the way of taxes and fees in some developing countries. Moreover, many governments find it very difficult to collect some taxes due to weakness of centralized system. It is very clear that many local city governments and municipalities prefer to get grants to deliver their smart urban services; however, limited budgets lead them to alternative funding methods (Flynn *et al.*, 2018).

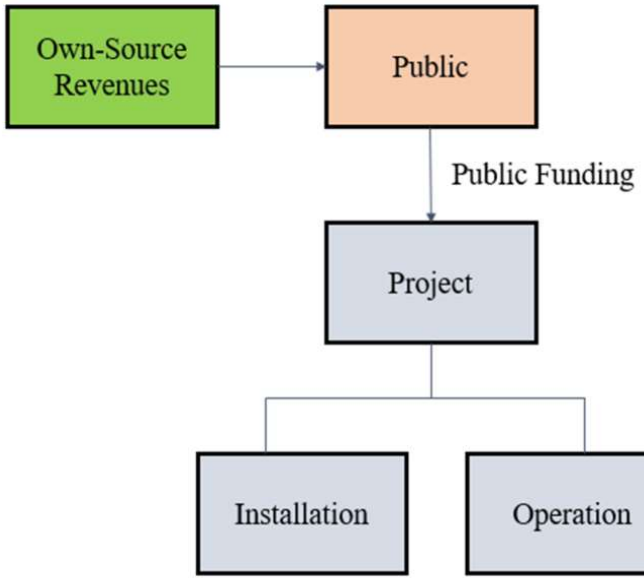

Figure 2.2. Traditional public funding (Flynn *et al.*, 2018).

2.6.2. Debt Financing

According to European Commission report (2018) debt financing is "an acquisition of funds by borrowing: a lender provides capital to a borrower for a defined purpose over a fixed period of time. These can be loans or bonds, structured as recourse or limited recourse debt with full or limited guarantees". When government agencies borrow to finance a project, the lender's return is limited to the interest earned on the principal and the repayment of the principal over time. The interest on the borrowing can be fixed or variable. One advantage of lenders over equity financing is that they

can claim income and assets first in the event of default (European Commission, 2018).

2.6.3. Project Finance

According to European Commission report (2018) project financing consists of "a financial transaction through which public administrations fund public works whose financial burden is partly or wholly borne by private capital, on the basis of a financial plan able to ensure a self-financing process of the operation itself. "The major guarantee for the repayment of this funding is represented by the cash flows of the project and by an effective management of risk, which gives the opportunity to limit the possibility of a reduction in the expected cash flows. This financing mechanism can be used for various projects; one of its main implementations is the financing of large-scale infrastructure related projects. In project financing, it is also seen that Special-Purpose Vehicles (SPV) are created which is a single-asset legal entity for the sole and exclusive purpose of acting as the project owner. SPVs are generally limited liability firms of some type or limited partnerships. They are generated by the project sponsor to shield the main firms from financial risks. When an SPV is built to serve as the project company, the main firm transfers only those assets to the SPV that are essential to capitalize the project and comply with the demands of the project financing documents. This is the extent of the main firm's investment in the project and thus the extent of their assets at risk. SPVs are also generally used in complex project financings to separate different layers of equity invested in the project, particularly if there are different levels of ownership or preferred returns (Sainati *et al.*, 2017).

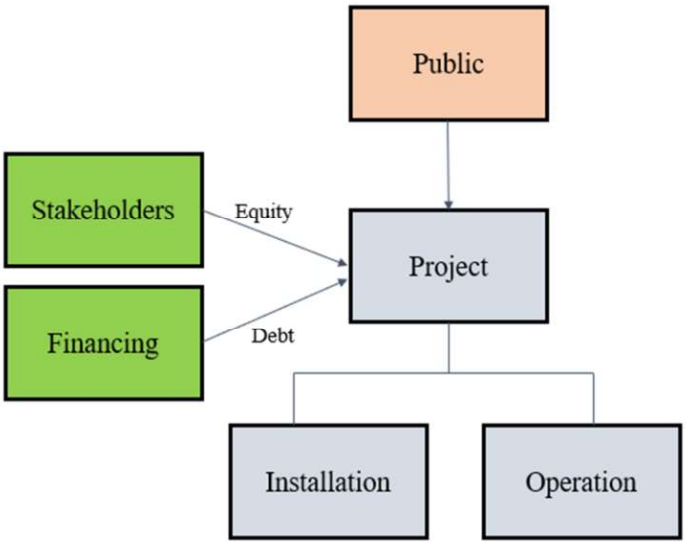

Figure 2.3. Project finance (Flynn *et al.*, 2018).

2.6.4. Multilateral Finance

International finance institutions provide investment loans, funds, and grants that finance infrastructure projects and services in support of economic development in numerous sectors such as transport, water, sanitation. These institutions provide resources to the developing countries to support restructuring efforts, to reduce global poverty and to improve living conditions. They focus on many subjects such as guaranteeing foreign investments, increasing private capital investments, developing international trade, reducing poverty, environmental sustainability, global cooperation for development, education, health, natural disasters (Flynn *et al.*, 2018). The World Bank, Asian Investment Infrastructure Bank, Japan International Cooperation Agency (JICA), The International Bank for Reconstruction and Development (IBRD), International Finance Corporation (IFC), International Development Association (IDA), and European Investment Bank (EIB) are some of these institutions.

2.6.5. Crowd Funding

Crowd funding is an alternative funding method that the people contribute voluntarily small amounts to a cause. It is defined as "the collective effort of individuals who network and pool their resources to support efforts initiated by other people or organizations" in the literature. In the practice of this funding type, money is collected from a large number of people via the internet. It is estimated that over $34 billion was collected in this way worldwide in 2015. It is seen that crowd funding carries a potential for supporting urban wide projects and overcoming challenges related to funding and other constraints. For example, local community members played an important role in the application of renewable energy projects through an alternative, community-based crowdfunding model in Chicago city(European Commission, 2018).

2.7. Project Delivery Methods

Alternative financing models of smart urban services were explained in the previous section due to the limited budgets of centralized governments. However, it is known that financing is only one of the general challenges that organizations face with it during the lifecycle of the projects. Smart urban services are very complex and challenging solutions in regard of the nature of the dynamic characteristics. Briefly, the achievement of the projects is not a simple task. Therefore, appropriate project management is a significant factor for project success as well as completion with the planned schedule, costs, and quality (Çomu *et al.*, 2020).

There are many project delivery method definitions in the literature. According to Kenig (2011), a project delivery method is "the comprehensive process of assigning the contractual responsibilities for designing and constructing a project". This method clarifies the main participants taking contractual responsibility for the performance of the task. It is very important to the success of a project that all parties understand the main targets of the delivery method being implemented and how all stakeholders are related to each other contractually. Cost, quality, time, and safety are the main

elements of any project delivery method. However, the responsibilities for applying these components differ from method to method (Kenig, 2011).

In this chapter, Design-Bid-Build (DBB), Design-Build (DB), Construction Management (CM), and Public-Private Partnership (PPP) project delivery methods are explained respectively for smart urban services.

2.7.1. Design-Bid-Build (DBB)

Design-Bid-Build (DBB) is the most traditional and common method of project delivery process. In this method, the owner makes contracts with a designer and contractor separately as a first step. Then, the selected designer prepares a design package that includes contract documents. After the design phase, the owner submits the package for bidding and choose the most advantageous bidder to undertake the building of the project. Additionally, the owner has a right to monitor the activities of contractor to assure adherence to contract requirements (Al Khalil, 2002). Moreover, the method is known to foster adversarial relationships between the stakeholders involved in the project. Pakkala (2002) created the figure below that shows the relationships between organizations in this method.

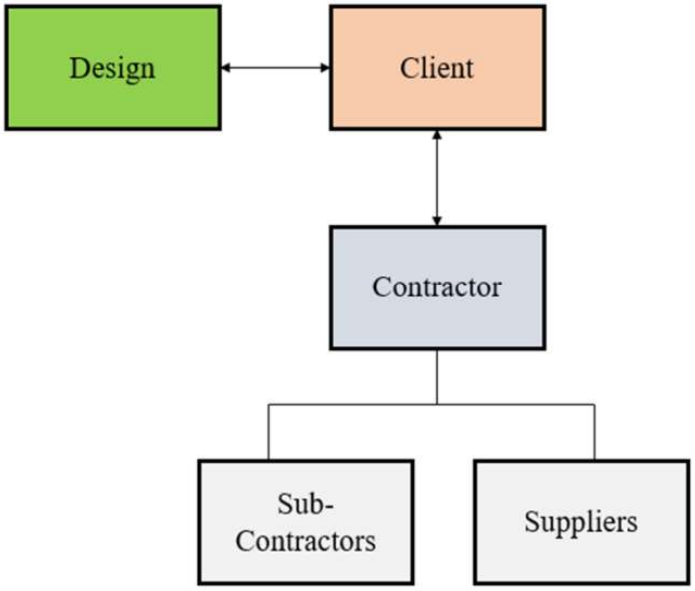

Figure 2.4. The model of design-bid-build (Pakkala, 2002).

2.7.2. Design-Build (DB)

Design-Build (DB) is another project delivery method that the owner makes a contract with only a single entity for the design and building phases. In contrast to the DBB, this method can reduce the impact of the adversarial relationship because only a single organization is responsible for both design and building. Furthermore, it can decrease the overall time of project completion as another advantage. However, quality assurance can be a problem for the owner's side due to the lack of checks and balances. The Design-Build method is particularly successful in cases where the scope is clearly defined, the design is standard, and the project time plan is tight (Al Khalil, 2002). Pakkala (2002) created the figure below that shows the relationships between organizations in this method.

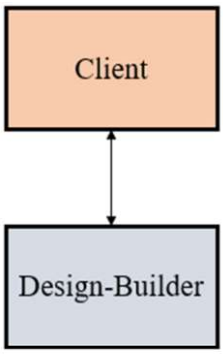

Figure 2.5. The model of design-build (Pakkala, 2002).

2.7.3. Construction Management (CM)

After the previous two traditional approaches, hiring a Construction Management agency is known as the third project delivery method in the literature. According to the Al Khalil (2002) the construction management agency is a consulting firm hired by the owner of the project to control on the owner's behalf, the process of project development. This approach is generally applied in the case of multiple main contractors. The Construction Management agency can fulfill different duties. They can offer implementation reviews, value engineering studies, project cost estimates, and contract packaging. The role of the Construction Management agency can be significant during the project application life cycle, especially in management-intensive situations which are required in fast track and cost-plus contracts (Al Khalil, 2002). Pakkala (2002) created the figure below that illustrates the relationships among the parties in this method.

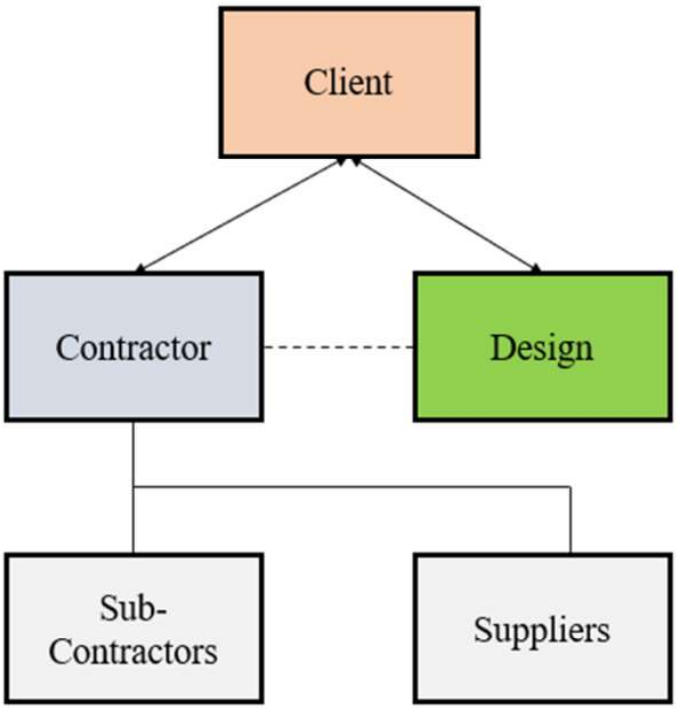

Figure 2.6. The model of construction management (Pakkala, 2002).

2.7.4. Public-Private Partnership (PPP)

Public-Private Partnership (PPP) is the is a cooperative project delivery method and there are numerous forms of PPPs definition in the literature. Although Li and Akintoye (2003) declared that there is no unified definition of PPPs, they also mentioned that all explanations have common aspects. According to Liu *et al.* (2021), PPPs are long-term agreement between the public and private sectors with common goals for the public infrastructure projects. Both private and public parties contribute to the services, projects with their skills and resources in PPPs (World Bank, 2019). In this project delivery method, risks and resources are shared for the common target of the urban services.

The concept of the PPP was also defined as a "cooperative venture between the public and private sectors, built on the expertise of each partner, which best meets clearly defined public needs through the appropriate allocation of resources, risks and

rewards" according to the The Canadian Council for Public Private Partnerships (Tang *et al.*, 2010). Hong Kong Efficiency Unit has developed another definition form for the PPP that is a "assist the government in meeting its priorities, building on the clear recognition that public funds are limited". They also declared as "the arrangements where the public and private sectors both bring their complementary skills to a project, with varying levels of involvement and responsibility, for the purpose of providing public services or projects" in the explanation which is referred to previous definitions (Tang *et al.*, 2010).

In history, private capital and assets have been used in many countries to provide public services and projects (Howes and Robinson, 2005). Although the PPP method was generally applied in the late 1990s, the investment trend of private parties in public infrastructure can be traced back to the 18th century in the European region (Tang *et al.*, 2010). The concession contract which supplied drinking water to the Paris region can be shown as an important example in history. Other countries also implemented some PPP projects such as the Suez Canal and Trans-Siberian Railway, as well as canals, turnpikes, and railroads in the 19th century (Kumaraswamy and Morris, 2002). The UK government has applied the PPP method in many projects since 1997 (Winch, 2000). Especially, private firms have been participated in the development of facilities, including designing, financing, construction, and operation phases of public sector services in recent years (Akintoye *et al.*, 2003). As a different aspect in China, international organizations or companies have participated rather than domestic firms in PPP projects (Luo *et al.*, 2001). For instance, the Guangxi Laibin B power station is the most successful and known PPP project in China that was implemented in 1997 (Tang *et al.*, 2010). Many countries have developed PPP projects for the prosperity of public infrastructure and services in recent years and there is a dramatic increase in the number and scope of PPPs implementation since the 1990s globally (Babatunde *et al.*, 2015). It is clear that the various advantages of this project delivery method contributed to increase its popularity worldwide.

Many organizations are aware of the PPPs advantages that is used as an effective tool for infrastructure development projects. Risk transfer is cited as one of the most important advantages of PPPs in the literature. Public sector can transfer or share the finance, design, and operation related risks to the private sector under these contracts (Liu *et al.*, 2021). Private industry participant brings the commercial disciplines into the PPP projects, and it contributes to decrease the risk of cost overruns and project delays(Li and Akintoye,2003). Some studies showed that better risk management in PPPs is the preference reason of authorities. (Grimsey and Lewis, 2002; Li *et al.*, 2005; Shen *et al.*, 2006; Tang *et al.*, 2010). Moreover, this type of agreements naturally enhances the collaboration between the public sector and the private sector in positive way (Erridge and Greer, 2002; Zhang and Kunaraswamy, 2001; Zhang, 2004).

Saving resources can also shown as main advantage of this project delivery method. The public side can focus on its core competencies and does not need to depend on its own resources for different and challenging projects (Cumming, 2007). With participation of the private parties, the assets, data, and intellectual property of the government can be utilized more effectively, which leads to important enhancement in the quality of urban services (Edkins and Smyth, 2006). Additionally, urban services can be delivered more productively through the proper use of the skills, experience, technology, and innovation of the private the private industry participant (Tang *et al.*, 2010). It is observed that PPPs harmonically enhance the service quality of the projects using by know-how of private parties (Lam and Yang, 2020).

On the other hand, the economic aspect can be enhanced by using the PPP delivery method Tang *et al.*, 2010).For instance, it has been illustrated that PPP contributes to decline the life cycle costs (Li and Akintoye, 2003), since these types of urban services spread public capital investment over the life of a project. This mainly guarantees the expected rate of return for the public investment (Tang *et al.*, 2010). Also, PPPs provide more appropriate and advanced financial analysis between the parties (Akintoye *et al.*, 2003; Norwood and Mansfield, 1999; Huang and Chou, 2006; Saunders, 1998). Last but not least, government policies are getting clearer and

transparent for the citizens (Ball and Maginn, 2005; Hart, 2003).

There are different delivery types of PPPs in the practice and literature. The main forms are explained briefly below.

2.7.5. Build-Operate-Transfer (BOT)

According to the definition of Özdogan and Birgönül (2000), it is "a private sector participation model in which a project company is established to finance, design, construct and operate a facility for a concession period before it is transferred to the government". The sponsors of the PPP projects organize the financing for the building of the project through equity contributions and loans. The BOT entity is in charge of the financing, design, construction, and operation phases. As a result, the client is taking no direct cost risk other than the possibility that the facility will not meet its requirements or that the concession agreement will be unsatisfactory (Smith *et al.*, 1994). When it is compared with traditional processes, the financing of BOT projects is quite different. Because the projects are financed on a project finance basis. In brief, "the parent companies of project company members do not incur liabilities on their balance sheets, and only the revenue generation capacity of the project serves as a guarantee for the lenders" (Akbıyıklı and Eaton, 2005). The company of the project is fully responsible for all main and subcontracts during the process. After the construction process is finished, the facility is operated by the project company. The services are either bought by the government side or sold to the public side. The operation phases must have enough time to cover debts, expenses, equity contributions, and a calculated profit through the collection of tolls or tariffs. After a certain period, the facility or services can be transferred to the government side from a private partner in well operating condition (Akbıyıklı and Eaton, 2005). In brief, it is well-known method that contains full integration of the project delivery.

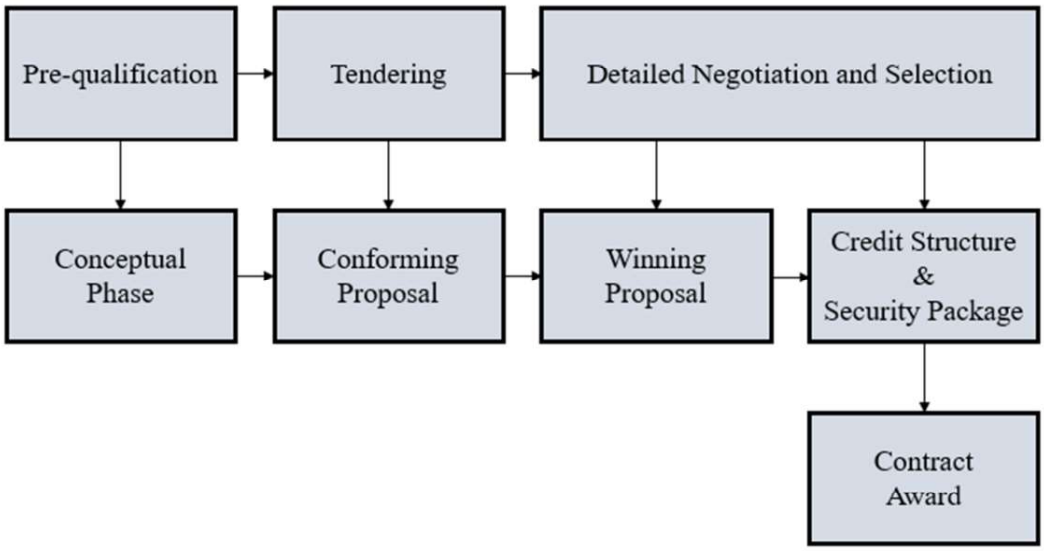

Figure 2.7. Phases of a typical BOT project (Tiong and Alum, 1997).

2.7.6. Build–Own–Operate–Transfer (BOOT)

The main vehicle for the BOOT project is the project company which is defined as a consortium. Contractual relationships are established by the project company in the process of the concession (Confoy *et al.*, 1999). According to the explanation of Barnett (1997), it is a model of the "government granting to a private sector organization a concession of a franchise to build a specific facility, to own it for a specified period, to operate it and to take the revenue from it, and ultimately to transfer it back to the government". The figure below illustrates the typical structure between the parties in a BOOT project (McCarthy and Tiong, 1991).

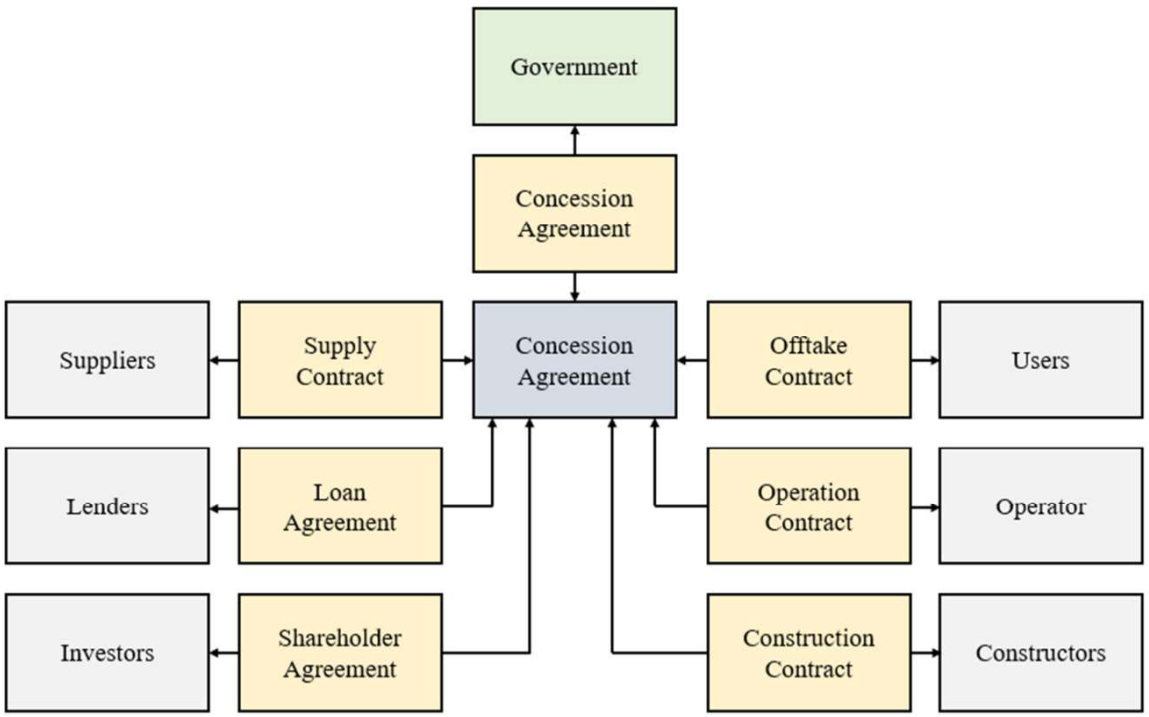

Figure 2.8. Typical structure of BOOT project (McCarthy and Tiong, 1991).

2.7.7. Build–Own–Operate (BOO)

BOOT and BOO are shown as similar delivery methods with the project ownership aspect. In general BOO, the concession arrangement ownership does not transfer back to the government side at the end of the concession agreement (Akbıyıklı and Eaton, 2005). The main difference between financing projects of BOOT and BOO types and the more traditional methods is that lenders have only the project's expected cash flows to indicate its viability (Woodward, 1995). The relation architecture of a BOO can be the same as the one shown in the BOOT figure above. The main difference is the offtake contract. In a BOO project, the private industry participant designs and builds the facility, finances its construction, and owns, operates, and maintains it during the concession period (Akbıyıklı and Eaton, 2005).

2.7.8. Design–Build–Finance–Maintain (DBFM)

It is another model in that the private party undertakes the responsibilities of design, construction, and finance. Then, private sector participant provides maintenance services under a long-term agreement. After the transfer, the owner of the project starts to operate the facility. This model includes. This model includes some involvement risks during the process (PPP Council, 2022).

Additionally, the Figure 2.9 (European Commission, 2003). Below shows the schematic scale of the public procurement classification. It is seen that the responsibilities of public side decrease from BOT model to BOO model while the responsibilities of private parties increase in contrast. Before the PPP project, experts on the local government side can decide on the most suitable model for the project by examining the responsibilities and working structure of the relevant models.

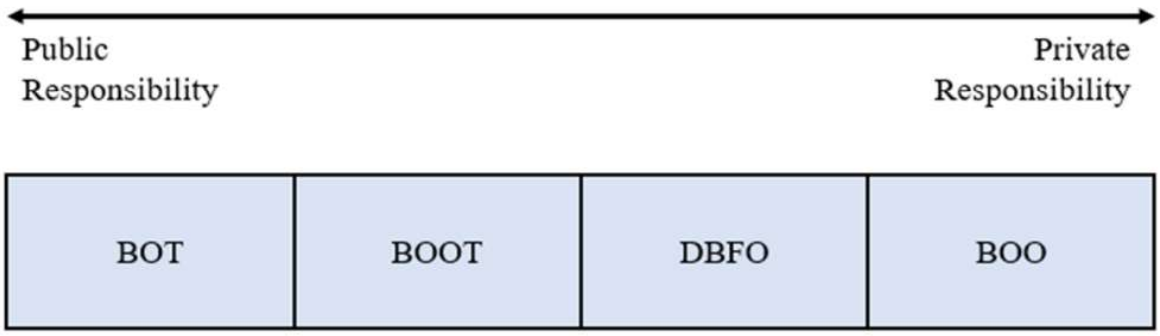

Figure 2.9. Schematic scale of the public procurement classification (European Commission, 2003).

There are many application steps for PPP projects. In 2008, the European PPP Expertise Centre (EPEC) was created by European Investment Bank for organizations to properly implement these steps. Their mission is to support the public sector in delivering better PPPs. In this regard, the EPEC has published a Guidebook and summarized the general PPP process in four main phases. The details of the related steps are listed in the figure below.

Table 2.5. Main steps of a PPP project (EIB, 2022).

Phase	**Stage**	**Step**
1 Project Identification	**1.1** Project Selection	• Investment assessment
		• Output specification
	1.2 Assestment of the PPP Opinion	• Affordability • Risk allocation • Bank ability • Value form oney analysis
2 Detailed Preparation	**2.1** Getting organised	• Set up project team and governance structure • Engage team of advisers • Develop project plan and timetable
	2.2 Before launching the tender	• Carryout further studies • Prepare detailed design of PPP arrangement • Select procurement method • Select bid evaluation criteria • Prepare draft PPP contract
3 Procument	**3.1** Bidding process	• Procurement notice, qualification, and shortlisting • Invitation to tender • Interaction with bidders • Evaluation of tender sand PPP contracta ward
	3.2 PPP Contract and financial close	• Finalise PPP contract • Conclu definancing agreements • Reach financial close

Table 2.5. Main steps of a PPP project (EIB, 2022). (cont.)

Phase	**Stage**	**Step**
4 Project Implementation	**4.1** Contract management	• Attribute management responsibilities • Monitor and manage project delivery and service outputs • Manages changes permitted in the PPP contract • Manages changes not Provided for in the PPP contract • Disputere solution
	4.2 Ex post evaluation	• When the contrac tends • Define institutional framework • Develop analytical framework

The first phase in the PPP project cycle is project identification. This part mainly focuses on identifying the needs, objectives, and outcomes of the project, and then shortlisting amount of project types that are consistent with these aims and outcomes. In this sense, the public side should be ensured that the proposed PPP project delivers the 'right' service (EIB, 2022). The authority and its advisers will investigate the alternative project options in the project selection process. They will undertake the responsibility of preliminary investigations, demand, and cost analysis. They should analyze the environmental impacts of the project. Additionally, the authority should assess the right PPP procurement option by studying the affordability, deciding risk allocation between the parties, and searching the bankability of the project (EIB, 2022).

Detailed preparation is described as a second step of the PPP project. The objective of the detailed preparation part is to explore the primary approval of the related public authorities in respect of the project procurement. This expected approval sup-

ports the improvement of the PPP project as an important prerequisite. The detailed preparation phase consists of two sub-parts which are getting organized and finalizing all preparation before launching the tender. In getting organized part, the authority sets up the responsible project team and creates the structure of the governance (EIB, 2022). Then, they develop the project plan and the timetable. Before launching the tender, the authority prepares detailed business cases and designs the arrangement of PPP. Then, a suitable procurement method should be selected. The role of the private partner in the PPP should be well-defined. After deciding on bid evaluation criteria, the draft contract of the PPP should be finalized. In this step, the authority should clearly define the required service standards (EIB, 2022).

The procurement part includes the procurement notice and ends with a financial close. There are two sub-stages which are the bidding process and the period from the selection of the preferred bidder to financial close. In the bidding process, the authority sends an invitation to the tender to the shortlisted firms (EIB, 2022). Then, they select the most advantageous and suitable bidder within the process. After that, the parties negotiate the contractual details of the PPP project. They conclude with financing agreements. Finally, the public side and private sector participant sign all PPP agreements and meet the conditions for the effectiveness of the agreements (EIB, 2022).

Project implementation is the final phase of the PPP project which has two sub-steps. They are contract management and ex-post evaluation parts. These steps address the most generic problems which responsible at the authority can have to face during the project life cycle. It is an important phase that the authority monitors the performance of the PPP project and takes related actions in accordance with the terms of the PPP contract. In some cases, a PPP project can require some changes to the contract such as restructuring the service specifications or the scope of the project (EIB, 2022). In the contract management part, the authority set up the project management team and defines a timeline and responsibilities for all tasks. Then, they monitor the operational phases and financial performance of the PPP project. They implement

some necessary changes with the private sector participant. When the contract ends, they the monitor residual value of the PPP assets and make compensation payments. In ex-post evaluation, the authority formalizes the evaluation objectives and criteria. Finally, they create an evaluation report (EIB, 2022).

It is important to clearly identify the stakeholders in the PPP according to the nature of the projects. In the literature, the project stakeholders are defined as an individual or a multidisciplinary team that involved in the to improve the quality of the project. Government (public side) and private sector participants such as contractor, lender, supplier, and consultants can shown as internal stakeholders (EIB, 2022). They have direct impact on the PPP project. Also, there are external stakeholders that are non-govermantal, environmental and social institutes and citizens. They do not have direct control over a resource; however, these stakeholders have an interest in the success of a process (Selim and Elgohary, 2020). Generally, private sector is responsible for financing, construction, operation, and service providing in the partnership. It is known that private partner can obtain payments from user fees or government as a return of investment. Additionally, recent McKinsey Global Institute analysis (2018) indicated that public industry could be the natural owner of the most projects, but the larger part of investment could come from private parties. Also, many public projects can generate returns.

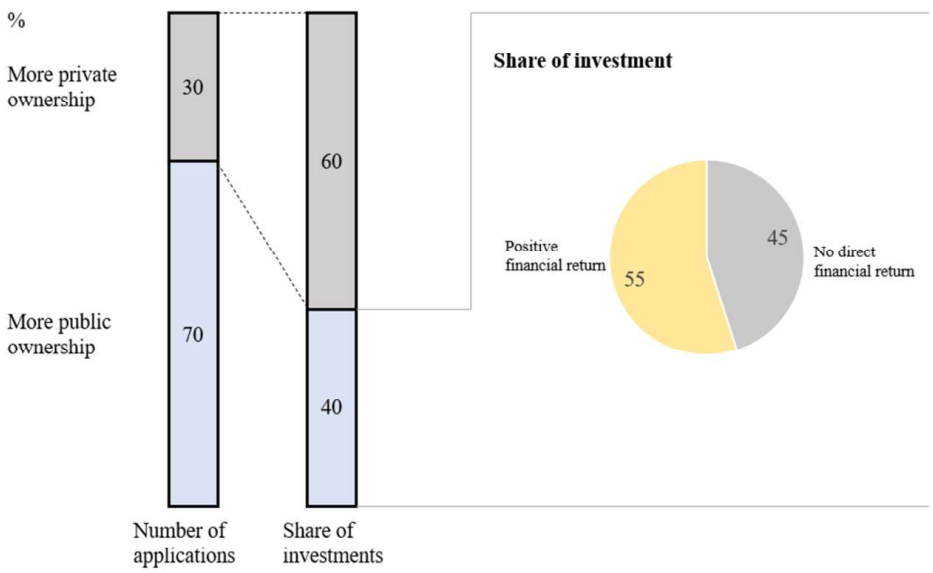

Figure 2.10. Private and public ownership of the projects (McKinsey, 2018).

2.8. Public-Private Partnership (PPP) Application in Smart Urban Services

It is known that smart urban services improve quality of life standards (Yang and You, 2019); however, they are difficult projects in terms of financing, project delivery and size. According to recent research, just 16% of cities are able to self-fund in the world (Flynn *et al.*, 2018). This investigation shows that cities need the support of external partnerships with private and non-profit organizations to proceed smart urban services together. The local governments can overcome many difficulties to funding and managing smart urban development projects through reducing expenses with new technological solutions and bringing essential stakeholders together (Cruz and Sarmento, 2017).

At this point, PPPs enables a collaborative project delivery model for the public and private sectors working together to generate smart urban service projects (Liu *et al.*, 2021 and 2017).The modelin creases the efficiency and sustainable availability of the resources (Babatunde *et al.*, 2015). Municipalities can prefer this model due

to many advantages such as access to private capital, technology, people, skills, and transfer of risk.

Governments use different delivery methods of PPP which are generally Build-Operate-Transfer (BOT), and Design-Build-Finance-Operate (DBFO) approaches for the development of their public infrastructure with smart urban services. For instance, a local government appoints a private sector partner to apply the smart facilities and provide smart services in a certain period within BOT and DBFO models. The private sector is generally repaid depending on unitary charges, and after the agreed period, the facilities will be transferred back to the government side (Cruz and Sarmento, 2017). At this point, it is essential to classify the internal and external stakeholders for the success of the PPP project in smart urban services. Project developers should assess the needs, and priorities based on the city's scope to develop an organized action plan. Also, they should analyze the value proposals and requirements for the achievement of the project. Within a PPP project scope, Selim and Elgohary (2020) generated a stakeholder classification table for smart urban services that can be seen below.

Table 2.6. Stakeholders classifications (Selim and Elgohary, 2020).

Code	**Internal Stakeholder**	**Code**	**External Stakeholder**
In 1	Government (public sector)	Ex 1	Non Gov.-Environmental institutes
In 2	Lender & suppliers	Ex 2	Non Gov.-social institutes
In 3	Developer (private sector)	Ex 3	Non Gov.-political institutes
In 4	Contractor & ICT sectors	Ex 4	Citizens & Neighbors
In 5	Planners & Experts	Ex 5	Human rights organizations
In 6	Legalistic & Policy makers	Ex 6	Academia and research institutes
In 7	Financial consultant	Ex 7	Media

PPPs are being increasingly used to develop smart urban services around the world (Cruz and Sarmento, 2017). There are several types of PPPs applied in smart urban services due to different organizational dynamics and areas of services provided by the private sector (Liu *et al.*, 2021). Many public organizations have implemented PPPs to provide "soft systems" in their information, communications, and technology (ICT) network (Cruz and Sarmento, 2017). Additionally, private industries are interesting in the funding and development phases of these soft systems in public infrastructure. For instance, Connected Boulevard was set up by French local government and private partner as a PPP project to enhance the efficiency of transportation in the Nice city. Their first aim was to provide new and helpful services for the public. More than thousands of wireless sensors were installed in four years. These sensors were monitoring and sending traffic datawith real-time information (Grimaldi and Fernandez, 2019).

PPPs can be applied by governments for new perspectives and innovative ideas within smart urban services. It is known that private partners have unlimited resources and capabilities which allows cutting-edge ICT products (Ferraris *et al.*, 2020). In this respect, these international tech companies can play an essential role for smart urban initiatives. Although the exploratory projects involve a high level of uncertainty, more effective results can be obtained with help of dynamic structure of private industry (Lam and Yang, 2020). The State of Virginia generatedan innovative PPP project for researching and testing of autonomous vehicles. Their first goal was to test roadbed on a heavily used set of highways, integrating different technologies such as real-time traffic information and vehicle connectivity (Cruz and Sarmento, 2017). It is known that most of the traffic accidents are caused by the human factor. After applying these kind of advantageous projects, human factor will decrease due to autonomous driving and safety issue will increase significantly. Also, vehicle behavior will be more rational and the detection-response time with real-time traffic data. The electronic equipment and software will be faster than that of the human reactions during the driving. Legal speed limits can be increased to higher levels and traffic control becomes easier as the vehicle behavior in the traffic is more predictable.

Asset recycling New York City is another example of PPP application within the smart urban services concept. Thecity faced anaging network problem of 8.400 public phones that the services attracted fewer users in modern technology era. Although the usage of the pay phones has decreased, the phone booths still generated revenues for the municipality. Billboards of advertisers provided over $17 million revenue in 2013, wheares, there were other problems that caused by this network such as blocking pedestrian traffic and anachronistic appearance in the world of modern communications. In this regard, the IT department of the municipality requested proposals for replacing its old payphones in 2014 (Fishmanand and Flynn, 2018). After tender process, the city dealed with City Bridge Consortium which is a partnership that includes Qualcomm, Titan, and Control Group. With this effective partnership, they replaced the obsolete payphones with smart kiosks (Link System) that provide free Wi-Fi, maps, transportation updates, video calls, device charging, and more. City Bridge Consortium pays for and operates all LinkNYC system at no cost to the New York city and offers many services to users free of charge, directly funded with the support from advertising revenues. City Bridge incurred an estimated $200 million to install the links (LinkNYC, 2022). The consortium spent approximately $200 million for installing the Links. Each year, the city government receives 50 percent of the gross advertising revenue from the consortium. 7,500 Links were installed that made the infrastrucuture expansive system of Wi-Fi hotspots in the city. It is estimated that its share of advertising revenues will be $500 million over the initiative's first 12 years (LinkNYC, 2022). On the other hand, LinkNYC is expected to generate around 100–150 full-time jobs and 650 support jobs (Fishman and Flynn, 2018).

Unlocking data value in the Kansas City project is a similar example to Asset recycling in New York City. Cisco and Sprint tech companies proposed a free public Wi-Fi and interactive kiosk project to the local government in 2014. These private firms had installed 25 kiosk systems to decrease traffic congestion and encourage greater foot traffic. The citizens of Kansas City can easily use the kiosks to access the web through their connected devices free of charge. Moreover, people can also interact with kiosks to find information regarding city services, current events, transportation, local business

information, local history, and entertainment (Fishman and Flynn, 2018). Additionally, the kiosk system operates as an emergency alert system, enhancing public safety. The municipality provided $3.7 million towards the overall capital cost of $16 million for the project. The local government expects to recoup its share of the capital costs by collecting advertising revenue from the smart kiosks (Startlandnews, 2022). The city shares the revenue from advertising equally with its advertising management firm that is Smart City Media (Startlandnews, 2022). They expect to fully recoup its capital costs in four to five years. The model of revenue sharing will shift to give 25 percent to the city, while Smart City Media retains the rest. Additionally, Cisco and Sprint companies provided the remaining $12.3 million to cover hardware and maintenance costs. These private investors will not receive any direct monetary return on investment which is the major difference from the previous New York City kiosk project. Instead of the money, they will get exclusive access to usage data from the smart kiosks. Sprint used the collected Wi-Fi data to test the viability of expanding its Wi-Fi coverage to other areas of Kansas City. The city will benefit from the usage of data to make its operations more efficient and sustainable. The services of the city will be able to quickly respond to maintenance requests for streets, water lines, and other infrastructure. Big data also assist the live maps that will enable commuters to find free parking quickly and easily (Fishman and Flynn, 2018).

Various companies seek ways to get access to data beyond their customer bases because of numerous benefits. This situation explains the general expression of many investors. They believe that the data is the new oil for the new tech era. Moreover, even after being transformed, the data can be continuously reused to generate new information, whereas oil is discarded after its transformation. In short, data helps organizations make better decisions with a sustainable format that clarifies the importance of it.

As explained in the previous paragraphs, there are examples of PPP applications for smart urban services in some developed countries. Although the improving adoption of PPPs increases in smart urban services, many developing countries are still

having challenges against its successful implementation (Leiringer, 2003 – Yang and You, 2019). The complex structure and lack of infrastructure can be shown as some examples of challenges of PPP implementation in smart urban services. In market-specific focus, the PPP model is not preferred for smart urban services in Turkey, a developing country. Although some examples are seen in transportation projects in Turkey, there is no commonly known application in smart urban services due to many macroenvironmental barriers. As an initial step, given the many benefits of PPP as in smart urban services, these barriers should be clearly identified in Turkey. After determining the barriers and their effects, the PPP model should be properly implemented in smart urban services in Turkey to provide sustainable living spaces for the citizens.

Despite the fact many papers investigated the barriers to PPP application, their scope was limited to infrastructure projects. Only a few studies academics examined researched smart urban development projects as a focus of study. After a comprehensive literature review, it was observed that smart urban services and PPP subjects were studied separately. There is no study that focused on the barriers to PPP implementation in smart urban services. This indicates that there is a gap in the literature in this area. In this regard, considering the many advantages of PPP as an effective project delivery method in smart urban services, these elements should be combined and studied together to fill the gap in the literature. This thesis explores the barriers to Public-Private Partnership (PPP) implementation in smart urban services with a Turkey scope. This study provides information to help remove or limit these barriers for local governments, investors, and other authorities.

3. RESEARCH METHODOLOGY

The purpose of this thesis study is to identify and evaluate the barriers to Public-Private Partnership (PPP) implementation in smart urban serviceswith a Turkey scope and to obtain their importance weights.

In this chapter, the barriers are identified as a first step. Then, the theoretical background of multiple criteria decision methods isexplained. Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), and Fuzzy ANP methods are compared in regard of their advantages and disadvantages. The interrelation of the barriers is clarified and pairwise comparisons are illustrated. Questionnaire design, gathering data,and model construction are explained, respectively. Finally, "Super Decision" decision-making software and matrices examples are explained in detail. The general framework of the research study is shown below as a summary.

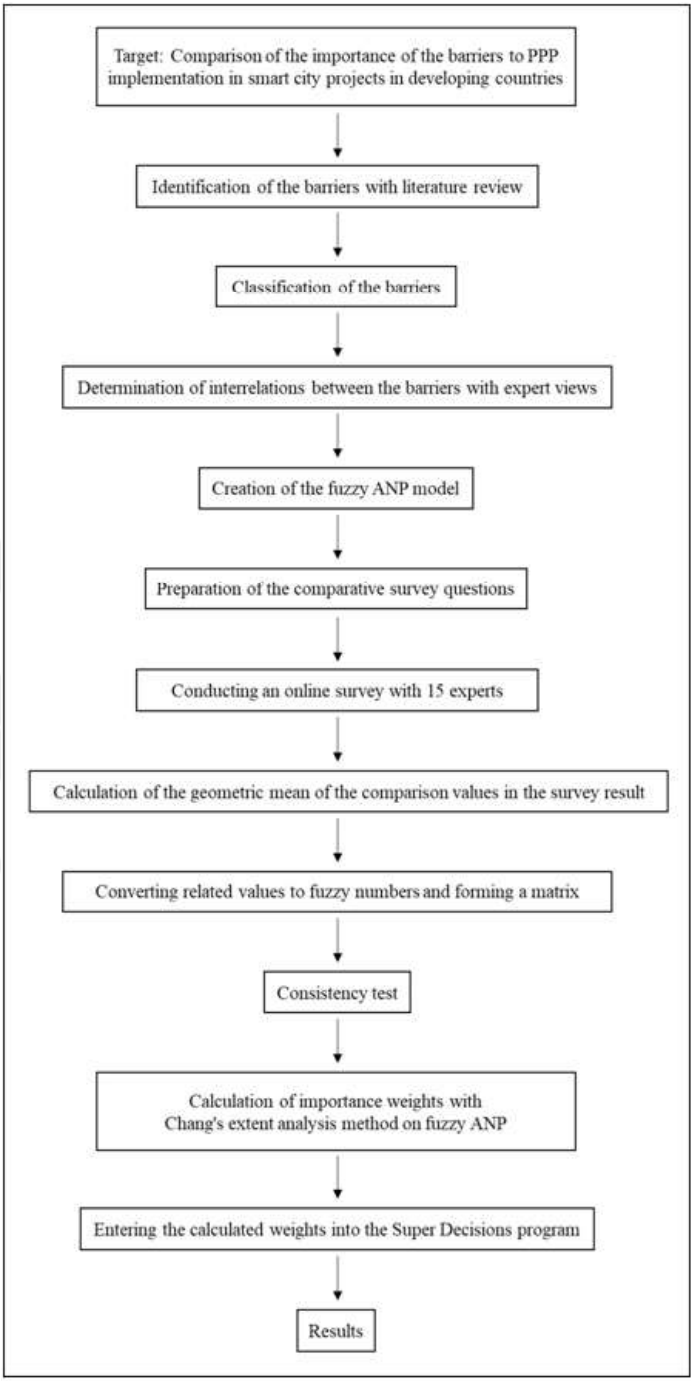

Figure 3.1. General framework of the study.

3.1. Identification of Barriers for Smart Urban Services Implementation

Barriers to PPP Implementation in infrastructure projects were investigated by numerous researchers in the literature with different scopes. Lam and Yang (2020) identified the factors influencing the consideration of PPP for smart city projects with a Hong Kong focus. In the study, the researchers evaluated the importance of the selected criteria for considering PPP in future smart city projects. Babatunde *et al.*(2015) conducted a literature review in order to identify and classify barriers to PPP project implementation in Nigeria. In this study, 58 identified barriers were grouped into 10 major factors with factor analysis. Bjørner (2021) outlined the complexity, advantages, and barriers of the smart city projects with a case study methodology in Copenhagen in recent research. Pezzutto *et al.* (2016) investigated barriers and drivers for smart city project implementation within a Europe scope. They analyzed the strengths, weaknesses, opportunities, and threats with a quantitative feasibility study. Rana *et al.* (2018) identified the crucial barriers to smart city development with a literature review and views of the experts. Their study explored 31 barriers under main categories which are governance, economic, technology, social, environmental, and legal and ethical.

Razmjoo *et al.* (2021) determined 22 barriers and classified them under five main categories. Apart from other studies, they suggested solutions in order to overcome these barriers. The main categories were similar to previously explained work which consist of governance, social, technology, environmental, and economic. Addae *et al.* (2019) analyzed 24 barriers under 5 major clusters for smart city Accra. The major clusters were financial barriers, market barriers, policy barriers, technology barriers, and social barriers.

In this thesis, a comprehensive literature review was conducted to identify the barriers. Firstly, smart urban services and cities, intelligent infrastructure solutions, PPP, and barriers are chosen as key words during the literature research phase to detect similar focused studies in academia. To find the most important and well-known papers as a second step, leading publishers were preferred such as Elsevier, Emerald,

Taylor and Francis, Springer Publishing, SAGE Publications, and ASCE Publications. Among many studies in databases, only journal papers were focused on and the most relevant 16 current studies were selected that were published after 2010. Afterward, these studies were carefully analyzed, and 252 barriers were identified. Then, main clusters were decided to categorize the identified barriers. In this stage, PEST analysis was reformed which is a specific method to understand four major external environmental factors of the business landscape. PEST analysis consists of political factors, economic factors,social factors, and technological factors (Bonnici and Galea, 2014). It is known that this analysis was used in many decision-making problems to assess the external problems and it is also suitable for fuzzy decision maps as well (Vázquez *et al.*, 2017). For instance, the factors of Indian luxurious car market were analyzed with PEST method in the literature (Verma and Rathore, 2013). After deciding grouping method, the scopes of these factors were expanded by reviewing at similar studies in the literature.The final main clusters are named as "Economic and Financial Barriers", "Technology and Technical Barriers", "Sociocultural and Environmental Barriers", and "Political, Governmental and Legal Barriers" respectively. Next, selected barriers are grouped under main clusters after the elimination of repetitive and less relevant barriers. After this process, the number of barriers was reduced to 26.

In the final step, these barriers were reviewed with two different experts in the telecommunication and technology service provider industry and academia. After seeking their advice, the final barriers list was decided. Two different sources identified "Lack of IT infrastructure" as a barrier which was also an important element. It was reformed as "Weakness of broadband network infrastructure" barrier after expert review to focus on the exact necessity of the internet for IoT services. The scope of "Limited foreign investment" was expanded as "Foreign investors' perception of a country as high risk due to economic instability" under economic and financial barriers for better understanding. Additionally, "Limited knowhow" barrier was changed as "Lack of knowledge and expertise of the parties" to outline the private and public parties. Moreover, "Resistance to change" and "unawareness of the public on advantages of PPP" barriers were merged as one barrier due to common impact. Furthermore, 8 less

important barriers were eliminated. After expert comments and approval of the thesis advisor, 17 barriers were selected as a result. The final 17 barriers, main clusters, and the associated references were presented in Table 3.1.

Table 3.1. List of the barriers and sources.

Code	**Barriers**	**Source**
EF	**Economic and Financial Barriers**	
EF.1	Foreigninvestors' perception of a country as high risk due to economicin stability	Babatunde *et al.* (2015) Razmjoo *et al.* (2021)
EF.2	High interest & inflation rate and currency fluctuation	Babatunde *et al.* (2015) Addae *et al.* (2019) Edwards *et al.* (2020) Swamy *et al.* (2017)
EF.3	Limited capital availability	Lam and Yang (2020) Babatunde *et al.* (2015) Bjørner (2021) Pezzutto *et al.* (2016) Addae *et al.* (2019) Swamy *et al.* (2017) Patel (2020) Mosannenzadeh *et al.* (2017)

Table 3.1. List of the barriers and sources. (cont.)

Code	**Barriers**	**Source**
EF.4	High costs	Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Cheong *et al.* (2016) Mosannenzadeh *et al.* (2017)
EF.5	High lenght of paybackperiod	Pezzutto *et al.* (2016)
EF.6	Problems of delays in receiving payments	Babatunde *et al.* (2015)
TT	**Technology and Technical Barriers**	
TT.1	Absence of personal data security protection	Pezzutto *et al.* (2016) Rana *et al.* (2018) Singh and Singla (2021) Wang *et al.* (2021)
TT.2	Weakness of broadband network infrastructure	Razmjoo *et al.* (2021) Addae *et al.* (2019)
TT.3	Lack of knowledge and expertise of the parties	Lam and Yang (2020) Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Ferraris *et al.* (2020) Cheong *et al.* (2016) Patel (2020)

Table 3.1. List of the barriers and sources. (cont.)

Code	Barriers	Source
SCE	**Sociocultural and Environmental Barriers**	
SCE.1	Resistance to change and unawareness of the public on advantages of PPP	Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Jayasena *et al.* (2022)
SCE.2	Poor interaction between local government sand citizens	Pezzutto *et al.* (2016) Rana *et al.* (2018) Razmjoo *et al.* (2021) Singh and Singla (2021) Mosannenzadeh *et al.* (2017)
SCE.3	Inadequate environmental & social assessment before the implementation of projects	Pezzutto *et al.* (2016) Razmjoo *et al.* (2021)
PGL	**Political, Governmental and Legal Barriers**	
PGL.1	Political in stability	Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Jayasena *et al.* (2022)
PGL.2	Inefficiency and longed laysdue to bureaucratic procedures	Lam and Yang (2020) Babatunde *et al.* (2015) Rana *et al.* (2018) Ferraris *et al.* (2020)

Table 3.1. List of the barriers and sources. (cont.)

Code	**Barriers**	**Source**
PGL.3	Insufficient government guarantee	Babatunde *et al.* (2015) Swamy *et al.* (2017)
PGL.4	Lack of transparency	Lam and Yang (2020) Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018)
PGL.5	Insufficient legal and regulatory framework	Babatunde *et al.* (2015) Bjørner (2021) Pezzutto *et al.* (2016) Rana *et al.* (2018) Razmjoo *et al.* (2021) Addae *et al.* (2019) Ferraris *et al.* (2020) Jayasena *et al.* (2022) Edwards *et al.* (2020) Mosannenzadeh *et al.* (2017)

Following the list of barriers, it would be beneficial to look over each one's definition comprehensively for a better understanding.

3.1.1. Foreign Investors' Perception of a Country as High Risk (EF.1)

Economic instability of a developing country generates a negative impression in foreign markets. Therefore, foreign investors do not invest due to"high risk of countries" (Babatunde *et al.*, 2015). This situation is a significant barrier for countries that need foreign investment (Razmjoo *et al.*, 2021).

3.1.2. Interest and Inflation Rate and Currency Fluctuation (EF.2)

This term describes the volatility of financial indicators, high interest and inflation rates, and fluctuations of the exchange rate in a country. Economic instability is a highly critical point, especially for developing countries. Instability and uncertain financial indicators affect long-term growth, cost of living, and infrastructure delivery significantly in any economy (Edwards *et al.*, 2020). It has been mentioned with different terms in different studies like Stable "macroeconomic condition" (Swamy *et al.*, 2017), "High-interest rate" and "unstable currency" (Addae *et al.*, 2019), and "Macroeconomic fluctuations in currency or purchasing power" (Babatunde *et al.*, 2015) and "Economic instability" (Edwards *et al.*, 2020).

3.1.3. Limited Capital Availability (EF.3)

It refers to the adequate budget and limited capital of the relevant central or local government. Primarily, governments should identify the needsof citizens effectively and make good judgment in the allocation of public funds. Apart from the classic tax revenue, the availability of funds for public infrastructure is limited in the public sector. Developed countries have different types of funding while developing countries need access to different channels. For example, there are various options such as general obligation bonds, revenue bonds, green bonds, social impact bonds in the United States and the European Union. Furthermore, private sector funding channels are generally more diverse than public sources in comparison (Lam and Yang, 2020). It has been mentioned with different terms in different studies like"Limited access to capital" (Addae *et al.*, 2019), "Funding" (Bjørner, 2021), "Inability of local institutions to provide long-term financing/equity financing", "Lack of public sector project development funds to promote PPPs", "Inability of local institutions to provide long-term financing/equity financing", "Lack of public sector project development funds to promote PPPs and Poor financial projections and access to funds" (Babatunde *et al.*, 2015), "Accessibility to capital" (Pezzutto *et al.*, 2016), "Availability of finance" and "Asset availability" (Lam and Yang, 2020), "Lack of finance for infrastructure development"

(Patel, 2020), "Limited access to capital and cost disincentives" (Mosannenzadeh *et al.*, 2017) and "Availability of financing" (Swamy *et al.*, 2017).

3.1.4. High Costs (EF.4)

This term describes the high and increasing costs of design, material, technology, construction, operation, and maintenance in the project process. In addition, the lack of expertise and technological infrastructure might generate unexpected additional costs during the project cycle (Cheong *et al.*, 2016). It has been mentioned with different terms in different studies like "Costs of material,construction, and installation", "Hidden costs", "Stability of costs during the project life cycle" (Pezzutto *et al.*, 2016), "Higher operational and maintenance costs" (Rana *et al.*, 2018), "High upfront costs and High costs of technology", (Addae *et al.*, 2019), "High cost" (Cheong *et al.*, 2016) and "High costs of design, material, construction, and installation" (Mosannenzadeh *et al.*, 2017).

3.1.5. High Length of Payback Period (EF.5)

Briefly, the payback period demonstrates how long it takes an organization or project to repay its investment. Commonly, PPP projects generate income during the project life cycle which is essential for the private sector participant to get the invested money back. In unexpected situations such as not providing the money on time or delay in payment, the investor may make a loss.In this regard, private sector participantshould be well calculating and consider the high length of the payback periodin detail(Pezzutto *et al.*, 2016).

3.1.6. Problems of Delays in Receiving Payments (EF.6)

It refers to the insufficient return to be provided by the project and the problems of delays in receiving payments in the smart city projects (Babatunde *et al.*, 2015). Private sector participant may have difficulty with this situation and might not fulfill

its operational and maintenance function after the implementation of the projects.

3.1.7. Absence of Personal Data Security Protection (TT.1)

It refers to the problem of personal data being captured by others and insufficient security.Working with the private parties involve risks in terms of low privacy and security. For example, inadequate firewalls in the system can cause some threats from hackers and viruses. Thus, it is a big concern for smart city development (Rana *et al.*, 2018). It has been mentioned with different terms in different studies like"Existence of data security and privacy" (Pezzutto *et al.*, 2016), "Privacy and security issues and Issues of openness of data" (Rana *et al.*, 2018), "Protection of personal privacy" (Wang *et al.*, 2021) and "Open government data" (Singh and Singla, 2021).

3.1.8. Weakness of Broadband Network Infrastructure (TT.2)

It refers to the inadequacy of local information technology and broadband network infrastructure for the implementation of related smart urban services. The resources should be used efficiently in smart urban. In this regard, Internet of Things (IoT) provides many solutions for this type of projects. In this concept, physical objects connect and exchange data with other systems over the internet networks. Thus, lack of infrastructure can make it difficult to implement solutions.It has been mentioned with different terms in different studies like"Weakness of IT networks' infrastructure" (Razmjoo *et al.*, 2021) and "Lack of infrastructure" (Addae *et al.*, 2019).

3.1.9. Lack of Knowledge and Expertise of the Parties (TT.3)

It refers to the insufficient knowledge and experience of the relevant public and private sector participants. Technology availability and monitoring expertise are key aspects that influence the way smart urban are developed. Generally, cutting-edge technology is used in smart urban projects. Although, governments and private sector focus on these developments and technologies, their resources and budgets are not

enough to catch the pace of invention. Therefore, lack of knowledge and experience can cause various problems and delays in the implementation phase of the smart urban-projects. It has been mentioned with different terms in different studies like"Lacking technological knowledge among the planners" (Rana *et al.*, 2018), "Lack of skilled personnel and Failed past experience and lack of successful reference projects" (Addae *et al.*, 2019), "Availability of expertise" (Lam and Yang, 2020), "Expertise in designing new technologies and solutions" (Pezzutto *et al.*, 2016), "Unavailability of large companies to deliver PPP projects", "Lack of experience and expertise in both public sector and private investors and Difficulty in specifying work requirements and the quality of service" (Babatunde *et al.*, 2015), "Lack of technological capabilities" (Ferraris *et al.*, 2020), "Technical capability, and governance" (Cheong *et al.*, 2016) and "Lack of know-how for planning" (Patel, 2020).

3.1.10. Resistance to Change and Unawareness of the Public (SCE.1)

It refers to the public's resistance to new applications, technologies, projects, and their distrust towards PPPs cause of insufficient knowledge. In smart urban services, it is essential to have public engagement in order to progress successfully, especially in the planning phase (Rana et al, 2018). The public lost their trust cause of some negativities which are "non-transparent process in the selection of the private sector partner" and "high fees that are not under government control" in the last PPP projects (Jayasena *et al.*, 2022). In this regard, the public has more traditional and conservative attitude towards change.It has been mentioned with different terms in different studies like"Low awareness level of community" (Rana *et al.*, 2018), "Unawareness of the public on advantages and importance of PPP" (Jayasena *et al.*, 2022), "Public opposition or Public resistance and Cultural impediments include behaviors of people towards PPPs" (Babatunde *et al.*, 2015), "Lack of confidence in new technology and fear of failure" (Addae *et al.*, 2019) and "Public acceptance of technologies" (Pezzutto *et al.*, 2016).

3.1.11. Poor Interaction between Local Governments and Citizens (SCE.2)

It refers that local governments do not fully analyze the needs of the citizens and poor communication between citizens and local governments.Citizen participation is very importantthat enhancing public policies by taking into account local demands (Singh and Singla, 2021). If local governments do not involve the public in decision-making processes, it might cause various problems in terms of sustainability in smart urban projects (Rana *et al.*, 2018). It has been mentioned with different terms in different studies like"Citizen participation" (Singh and Singla, 2021), "Lack of good cooperation and acceptance among partners" (Mosannenzadeh *et al.*, 2017), "Lack of attention towards participation of all the stakeholders and Poor interaction between local governments and citizens" (Razmjoo *et al.*, 2021), "Communication between project participants and the public to increase awareness" (Pezzutto *et al.*, 2016), and "Lack of involvement of citizens" (Rana *et al.*, 2018).

3.1.12. Inadequate Preliminary Environmental Assessment (SCE.3)

It refers to the inadequate environmental and social assessment of local governments before the implementation of smart urbanservices (Razmjoo *et al.*, 2021). Additionally, environmental awareness is another critical issue in this barrier. Because the smart projects will be accepted by more people when dealing with publicly visible issues such as air pollution, climate change, and reduced CO2 emissions (Pezzutto *et al.*, 2016).

3.1.13. Politicalinstability (PGL.1)

This term describes the inconsistency and instability of a country's domestic and foreign policy. The term is also defined as regular and irregular forms of changes of government. Furthermore, political impacts on a project, such as the bidding process and contractor selection, can be seen as key factors influencing the success of a PPP project. Additionally, it is observed that political instability and social is-

sues related to political parties create adverse conditions for infrastructure projects (Jayasena *et al.*, 2022). It has been mentioned with different terms in different studies like "Political instability" (Rana *et al.*, 2018), "Political instability / political influence" (Jayasena *et al.*, 2022), "Political commitment over the long term"(Pezzutto *et al.*, 2016), "Lack of strong political commitment for PPPs and Uncertainty of political environment/political instability" (Babatunde *et al.*, 2015).

3.1.14. Inefficiency and Long Delays Due to Bureaucratic Procedures (PGL.2)

It refers to the inefficiency and long delays experienced due to the complexity and poor coordination between public departments. Smart urban projects involve interdisciplinary and multiple public institutions. Providing integrated public information or services can be challenging during the projects (Lam and Yang, 2020). Because it requires extra effort for different departments to work with each other harmonically like hybrid model (Ferraris *et al.*, 2020). When this hybrid workflow cannot be provided efficiently, it causes various delays. It has been mentioned with different terms in different studies like "Lengthy delays in negotiation or delays due to lengthy bureaucratic procedures", "Lack of coordination between national and regional governments", "Poor coordination between different public sector departments" (Babatunde *et al.*, 2015), "Complexity of coordination of government departments" (Lam and Yang, 2020), "Lack of fit of administrative styles and inter-departmental coordination and communication" (Ferraris *et al.*, 2020) and "Lack of cooperation and coordination between city's operational networks" (Rana *et al.*,2018).

3.1.15. Insufficient Government Guarantee (PGL.3)

Income-generating smart urbanservices may experience various expected disruptions. In such cases, the private sector participant cannot provide its receivables on time. In this regard, this barrier refers that the resulting debt is not guaranteed by the government. It has been mentioned with different terms in different studies like "Government guarantee" (Swamy *et al.*, 2017) and "Distortions of guarantees/incentives by

governments" (Babatunde *et al.*, 2015).

3.1.16. Lack of Transparency (PGL.4)

It refers to the lack of transparency and the high corruption tendency that can be experienced in a developing country. Limited transparency and unclear political responsibilities in the provision of most services can be a problem for smart city development (Rana *et al.*, 2018). In addition, transparency is very important for the public that they can follow the performance of private party operations after completion of the PPP project (Lam and Yang, 2020). It has been mentioned with different terms in different studies like"Lack of transparency and accountability" (Babatunde *et al.*, 2015), "Transparency of legislation and taxation system" (Pezzutto *et al.*, 2016), "Lack of transparency and liability" (Rana *et al.*, 2018) and "Possibility to maintain transparency of procurement and monitoring of operation" (Lam and Yang, 2020).

3.1.17. Insufficient Legal and Regulatory Framework (PGL.5)

It refers to the insufficient legal and regulatory framework in a country and the failure of authorized institutions to fulfill their duties. Government must act as facilitator and orchestrator for all relationships within the smart urban development projects in a constant framework (Ferraris *et al.*, 2020). Otherwise, parties can benefit from various gaps in this framework and may use them for their own benefitin a negative way. It has been mentioned with different terms in different studies like "Lack of independence of regulatory body", "Law and regulation changes", "Poor evaluation", "monitoring and due diligence by public sector", "Weak or poor regulatory frameworks and enforcement and Problems of administrative procedures and guidelines" (Babatunde *et al.*, 2015), "Lacking standardization", "Lack of regulatory norms", "policies and directions and Lack of regulatory norms", "policies and directions for smart city" (Rana *et al.*, 2018), "Insufficient legal and regulatory framework" (Addae *et al.*, 2019), "Improper policy and regulatory norms" (Razmjoo *et al.*, 2021), "Regulations" (Bjørner, 2021), "Tariffs regulations and Existence of regulatory stability" (Pezzutto *et al.*, 2016), "Lack

of policies and regulations" (Jayasena *et al.*, 2022), "Lack of standardization" (Edwards *et al.*, 2020), "Regulatory instability", "Non-effective regulations and Lacking or fragmented local political commitment and support on the long term" (Mosannenzadeh *et al.*, 2017) and "Lack of rules, tasks and responsibility" (Ferraris *et al.*, 2020).

3.2. Theoretical Background

This research aims to form a model to investigate barriers to PPP implementation in smart urban services in Turkey. Thus, an extensive literature review was conducted to define the main barriers. Then, the final factors will be prioritized by utilizing the selected method.

Following the identification of the major clusters and barriers to Public-Private Partnership (PPP) implementation in smart urban services in Turkey, an appropriate and efficient method should be applied to determine the priorities of the selected barriers.

In this study, 17 barriers were identified under the 4 main categories in the previous literature review section. In this regard, is necessary to choose the most effective and useful multiple-criteria decision method (MCDM) as the first step of analysis (Batmaz, 2013). It is observed that various methods were used in the literature for the same aim.Although Elimination and Choice Translating Reality (ELECTRE),the Weight Product Model (WPM), Weight Sum Model (WSM), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)are examples of the MCDM methods, the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) are shown as the most important methods (Taşlıcalı and Ercan, 2006).

This section will provide a general overview and comparison of AHP, ANP, and Fuzzy ANP.The details of the Fuzzy ANP will be explained as a selected method and the methodology used will be outlined in detail.

3.2.1. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was first introduced by Thomas L. Saaty in the 1970s and it can be used in various decision-making problems. It is identified as "a decision-making model that aids us in making decisions in our complex world" in his research (Saaty, 1988). AHP is a method for evaluating parameters and making decisions on complex problems. In AHP, all elements are compared with each other, and then the impact levels of parameters are calculated. (Saaty, 2001).AHP could give results with both qualitative and quantitative data (Baker *et al.*, 2001). According to Saaty, this model can be used in many research studies such as to measure priorities and choose among alternatives, calculate the consistency, and form a solution to complex problem(Saaty, 2008). A linear structure is generated for the implementation of AHP. Gkountis and Zayed(2015)created a brief generic framework of AHP that can be seen below.

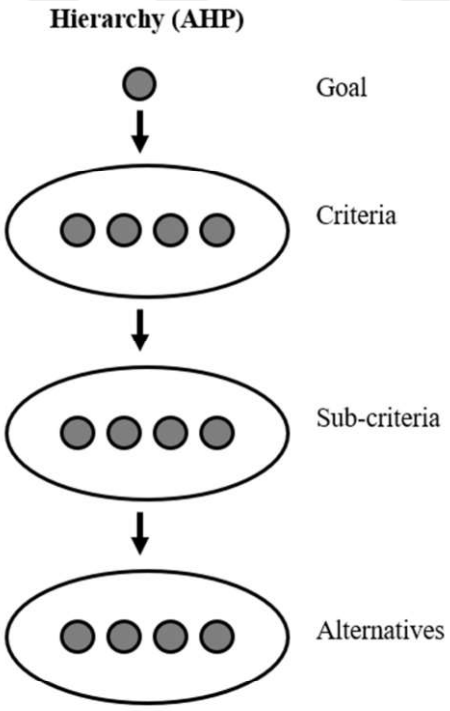

Figure 3.2. Generic framework of AHP (Gkountis and Zayed, 2015).

AHP model consists of serial steps that are creating a hierarchy with related elements, conducting pairwise comparisons, generating comparison matrices, and calculating importance weights for final ratings (Lee *et al.*, 2008). In addition, Saaty (2008) detected a scale that outlines the intensity of importance to conduct pairwise comparisons for users or interviewers. The scale shows the much higher or lower importance of an element to the other. The table can be seen below.

Table 3.2. The model scale (Saaty, 2008).

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contri butee qually to the objective
2	Weak orslight	
3	Moderate importance	Experience and judgements lightly favour one activity overran other
4	Moderateplus	
5	Strongimportance	Experience and judgement strongly favour one activity over another
6	Strongplus	
7	Very strongor demonstrated importance	An activity is favour edvery strongly over another; its dominance demon strated in practice
8	Very, verystrong	
9	Extreme importance	The evidence favouring one activity over another is of the highestpossible order of affirmation

3.2.2. Analytic Network Process (ANP)

In the literature, the ANP definedas "the Analytic Network Process (ANP) is a general theory of relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurement of the influence of elements that interact with respect to control criteria" according to Saaty (1996). It is decision-making model developed as a continuation of AHP.In addition to AHP, this model contains dependences and feedbacks between factors and clusters. In this regard, ANP can be identify as a generalized version of AHP due to taking the interdependencies among the elements into account (Saaty, 2008). Furthermore, in contrast to hierarchical structure of AHP models, ANP models have network format. This summarizes the relationship between the clusters in ANP. Additionally, inner dependency can be described as dependence between the elements in the same cluster. On the other hand, if one element is linked to different cluster, it is called as external dependency in ANP model.

In real-life decision-making examples, factors are frequently dependent on each other. In this regard, in order to make more accurate determination researchers must study and consider these inter dependencies in detail. Also, previous studies in the literature have shown that ANP represents reality more than AHP (Taşlıcalı and Ercan, 2006). In general, ANP provides researchers to create more complicated interrelationship models.

Moreover, unweighted supermatrix, weighted supermatrix, and limit supermatrix are the main sort of supermatrices in ANP. Unweighted supermatrix shows the priorities of the factors. Weighted supermatrix is calculated by multiplying each factor's priority by the priority of its cluster. Lastly, the limit supermatrix is determined by rising the weighted supermatrix to the importances (Batmaz, 2013). Gkountis and Zayed (2015) created a generic frame work of ANP that can be seen below.

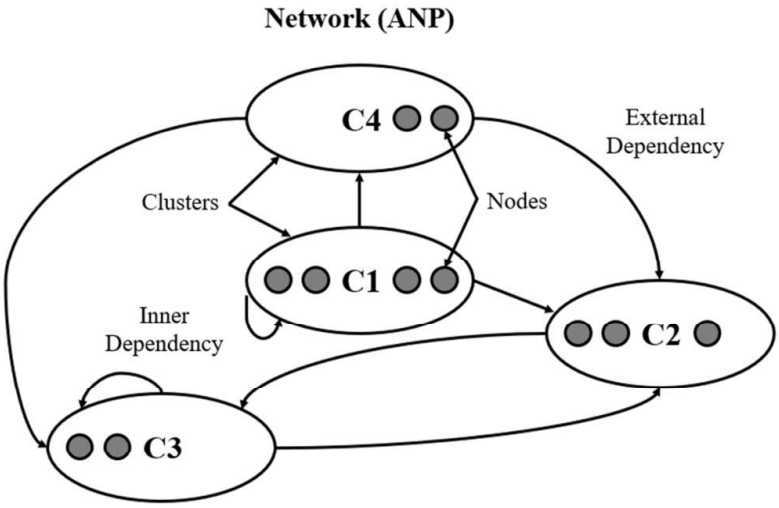

Figure 3.3. Generic framework of ANP (Gkountis and Zayed, 2015).

3.2.3. Fuzzy ANP and Chang's Extent Analysis Method

In real life, it is quite challenging to get precise data related to an analysis by human judgments. Additionally, natural language expression is preferred than exact numbers by decision-makers in general (Lee *et al.*, 2013). In this regard, Zadeh (1965) introduced the fuzzy theory and its concept for the first time. The fuzzy theory consists of three main phases that are "fuzzy set", "membership function", and "fuzzy number to change vague data into useful data efficiently". Researchers mostly apply fuzzy set theory during their analysis part when dealing with data groups with unclear boundaries. Another advantage of the theory is that the "relevant data and the sequence of possible actions are not fully known in the most real-world decision-making problems" (Lee *et al.*, 2013). In application phase of fuzzy set theory, the triangular fuzzy numbers (TFN) are the most common and convenient because of its computational simplicity and information processing(Chatterjee *et al.*, 2015).

In this study, fuzzy set theory and ANP are combined to deal with the "imprecise or uncertain judgments in multi-criterion decision making problem". In the pairwise comparison part, "fuzzy ANP applies a range of values that consider the decision

makers' imprecise or uncertain judgement scontrary to the exact values". It is also seen that decision makers find it easier tomake interval judgements rather than fixed value judgements. Because they cannot explain their preferences due to the uncertain nature of the comparison process (Chatterjee *et al.*, 2015).

The fuzzy set is described by "a membership function that assigns each attribute a continuous membership degree ranging between 0 to 1"(Zadeh, 1965). "The letters illustrate the least possible value, the most promising value, and the highest possible value in a fuzzy study respectively" (Kahraman *et al.*, 2004). In addition,"a tilde "∼" over the letter is showed to specify a fuzzy set" (Eyüboğlu, 2014).

There are many integrated fuzzy logic - ANP methods introduced by various authors in the literature. In this thesis, Chang's Extent Analysis Method was applied that is the most used method for analysis phase. The steps performed on Chang's Extent Analysis Method are explained in detail below.

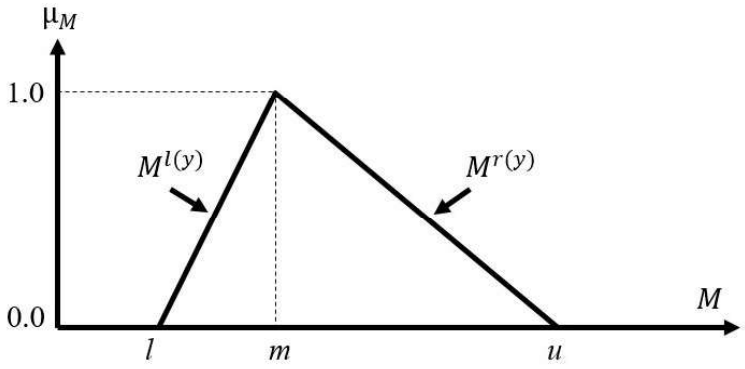

Figure 3.4. A triangular fuzzy number (Kahraman *et al.*, 2004).

The membership function of a fuzzy set is defined by the following equation. (Kahraman*et al.*, 2004),

$$\mu(x/M) = \begin{bmatrix} 0, x < l, \\ (x-l)/(m-l), l \leq x \leq m, \\ (u-x)/(u-m), m \leq x \leq u, \\ 0, x > u. \end{bmatrix}. \tag{3.1}$$

"A fuzzy number can always be given by its corresponding left and right representation of each degree of membership" (Kahraman *et al.*, 2004):

$$\widetilde{M} = M^{(}l(y)), M^{(}r(y)) = (l + (m-l)y, u + (m-u)y), y \in [0,1], \tag{3.2}$$

where $l(y)$ shows the left side illustration and $r(y)$ outlines the right-side illustration of a fuzzy number.

According to Chang's 1996 proposal for the extent analysis technique, "each object is taken and extent analysis for each goal, g_i, is performed respectively. "Thus, m extent analysis values for each object can be obtained with the following signs:

$$M_{(}g_i)^1, M_{(}g_i)^2, ..., M_{(}g_i)^m i = 1, 2, ..., n \tag{3.3}$$

where all the $M_{(}g_i)^1, j = 1, 2, ..., m$ triangular fuzzy numbers.

Step 1: The value of fuzzy synthetic extent with respect to its object is describe as

$$S_i = \sum_{(j=1)}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} \quad M_{g_i}^j\right]^{-1}, \tag{3.4}$$

$\sum_{(j=1)}^{m} M_{g_i}^j$ is calculated by performing the fuzzy addition activation of m extent analysis values for a specific matrix such that

$$\sum_{(j=1)}^{m} M_{g_i}^j \left(\sum_{j=1}^{m} l_j, \sum_{(j=1)}^{m} m_j, \sum_{(j=1)}^{m} u_j \right). \tag{3.5}$$

To obtain $\left[\sum_{(i=1)}^{n}\sum_{(j=1)}^{m} M_{g_i}^j\right]$, the fuzzy addition activity of $M_{g_i}^j \ j = 1, \ 2, ..., m$ values is calculated such that

$$\sum_{(j=1)}^{n}\sum_{(i=1)}^{m} M_{g_i}^{\bar{j}} \left(\sum_{i=1}^{n} l_j, \sum_{(i=1)}^{n} m_j, \sum_{(i=1)}^{n} u_j \right). \tag{3.6}$$

After that the inverse of the vector in above equation is calculated such that

$$\left[\sum_{(j=1)}^{n}\sum_{(i=1)}^{m} M_{g_i}\right]^{-1} \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{(i=1)}^{n} m_i}, \frac{1}{\sum_{(i=1)}^{n} l_i} \right). \tag{3.7}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is described as:

$$V(M_2 \geq M_1) = \frac{sup}{y \geq x} \left[min(\mu_{M_1}(x), \mu_{M_2}(y)) \right]. \tag{3.8}$$

The above equation can additionally be expressed as:

$$V(M_2 \geq M_1) = hgt(M1 \cap M2) = \mu_{M_2}(d), \tag{3.9}$$

$$= \begin{cases} 1, if m_2 \geq m_1, \\ 0, if l_1 \geq u_2, \\ \frac{l_1 \geq u_2}{(m_2 \geq u_2) - (m_1 \geq l_2)}, otherwise, \end{cases} \tag{3.10}$$

where d is the ordinate of the highest intersection point D between

In this step, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ which can be seen in Figure 3.5 to calculate the μ_{M_1} and μ_{M_2} values.

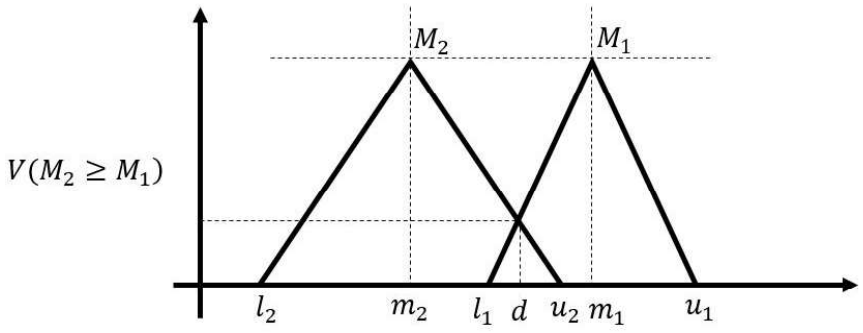

Figure 3.5. Intersection between M_1 and M_2 (Kahraman *et al.*, 2004).

Step 3: "The degree of possibility for a convex fuzzy number to be higher than k convex fuzzy numbers $M_1(i = 1, 2, ..., k)$ can be described by"

$$\begin{aligned} &V(M \geq M_1, M_2, ..., M_K) \\ &= V[(M \geq M_1) and (M \geq M_2) and ... and (M \geq M_k) \\ &= min V(M \geq Mi), i = 1, 2, 3, ..., k. \end{aligned} \tag{3.11}$$

Consider that

$$\begin{aligned} &= d^1(M_i) = min\ V(S_i \geq S_k) \\ &For k = 1, 2, ..., n; k \neq i\ Then\ the\ weight\ vector\ is\ given\ by \\ &W^l = (d^i(A_1), d^i(A_2), ..., (d^i(A_n))^T\ where\ A_i(i = 1, 2, ..., n). \end{aligned} \tag{3.12}$$

Step 4: "The weight vectors are normalized and showed as:

$$W = (d^i(A_1), d^i(A_2), ..., (d^1(A_n)))^T w, \tag{3.13}$$

where W is a non-fuzzy number. This provides the priority weights of one different over another".

Additionally, the following triangular fuzzy scale was used for the calculations in the study.

Table 3.3. Triangular fuzzy scale.

Linguistic Variables	**Code**	**Triangular Fuzzy Scale**	**Opposite Fuzzy Scale**
Equally preferred	1	(1,1,1)	(1,1,1)
Equally to moderately preferred	2	$\left(\frac{1}{2}, \frac{2}{2}, \frac{3}{2}\right)$	$\left(\frac{2}{3}, \frac{2}{2}, \frac{2}{1}\right)$
Moderately preferred	3	$\left(\frac{2}{2}, \frac{3}{2}, \frac{4}{2}\right)$	$\left(\frac{2}{4}, \frac{2}{3}, \frac{2}{2}\right)$
Moderately to strongly preferred	4	$\left(\frac{3}{2}, \frac{4}{2}, \frac{5}{2}\right)$	$\left(\frac{2}{5}, \frac{2}{4}, \frac{2}{3}\right)$
Strongly preferred	5	$\left(\frac{4}{2}, \frac{5}{2}, \frac{6}{2}\right)$	$\left(\frac{2}{6}, \frac{2}{5}, \frac{2}{4}\right)$
Strongly to very strongly preferred	6	$\left(\frac{5}{2}, \frac{6}{2}, \frac{7}{2}\right)$	$\left(\frac{2}{7}, \frac{2}{6}, \frac{2}{5}\right)$

Table 3.3. STriangular fuzzy scale. (cont.)

Linguistic Variables	**Code**	**Triangular Fuzzy Scale**	**Opposite Fuzzy Scale**
Very strongly preferred	7	$\left(\frac{6}{2}, \frac{7}{2}, \frac{8}{2}\right)$	$\left(\frac{2}{8}, \frac{2}{7}, \frac{2}{6}\right)$
Very strongly to extremely preferred	8	$\left(\frac{7}{2}, \frac{8}{2}, \frac{9}{2}\right)$	$\left(\frac{2}{9}, \frac{2}{8}, \frac{2}{7}\right)$
Extremely preferred	9	$\left(\frac{8}{2}, \frac{9}{2}, \frac{10}{2}\right)$	$\left(\frac{2}{10}, \frac{2}{9}, \frac{2}{8}\right)$

3.3. Interrelation Matrix

In previous sections, the barriers are identified, and the theoretical background is explained in detail. Before creating pairwise comparison matrices, the interrelations of the selected barriers should be determined. In this regard, an expert team came together from the technology and telecommunication industries to perform these interdependencies. Generally, political decisions affect economic performance closely, especially in developing countries. Therefore, a consensus was provided about the impact of political barriers on economic sub-barriers by the experts. An interrelation matrix was created after the common decision. The table is shown below.

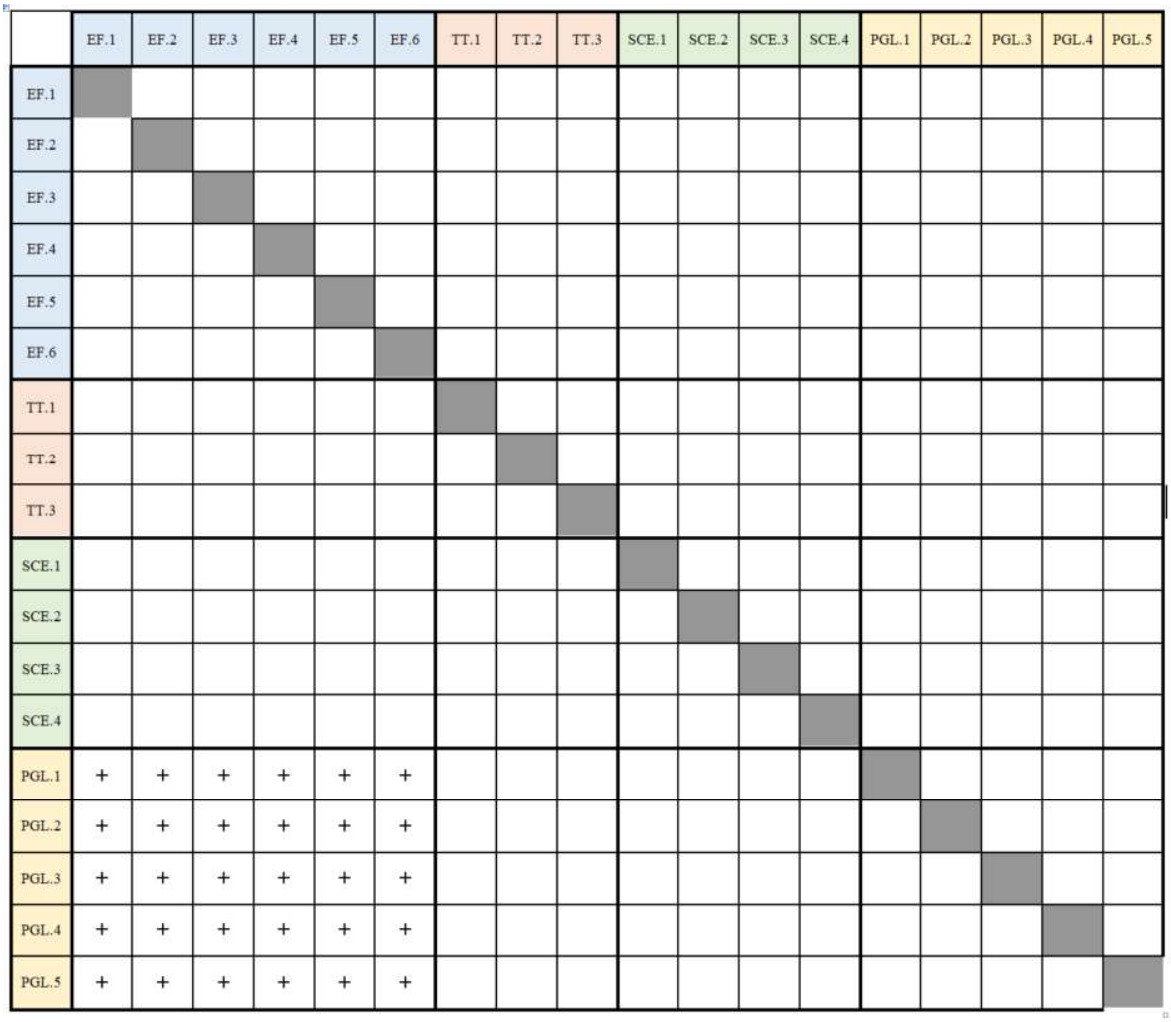

Figure 3.6. Interrelation matrix.

3.4. Model Formation

The aim of this thesis is identifying the most important barriers to Public-Private Partnership (PPP) implementation in smart urban servicesin Turkey scope. In this regard, their importance weights should be evaluated in a numerical model.

In the beginning of research methodology part, the barriers have identified with a comprehensive literature review. Although there are numerous criteria in the academia, the most significant and common barriers are selected after detailed research. Then,

selected 17 barriers were group under the 4 main categories that are “Economic and Financial Barriers”, “Technology and Technical Barriers”, “Sociocultural and Environmental Barriers”, and “Political, Governmental and Legal Barriers”.

Determining on the decision-making model was a critical point of this research as a second phase. Hence, numerous studies and models were reviewed, and it was decided to create a fuzzy ANP model due to its advantages. During multi-criteria decision-making, a fuzzy logic concept harmonically decreases the uncertainty degree in the judgments. Additionally, the ANP method analyze the interrelations of the selected barriers as another benefit of this combination. Afterwards,it was necessary to decide on the inter dependencies between the barriers. In this part, the comments of the experts contributed the model and interrelation matrix is generated with consensus. The matrix form can be seen in the previous part.

As a result of the prior steps of the methodology, the network model is generated. Arrows represent the interrelations in the Figure 3.7.

In the following parts, pairwise comparisons will be created regarding this model. Afterwards, it will be formed to the questionnaire and shared with experts for data collection. Lastly, the importance weights will be calculated with the Chang’s Extent Analysis method and analyzed with the Super Decisions program.

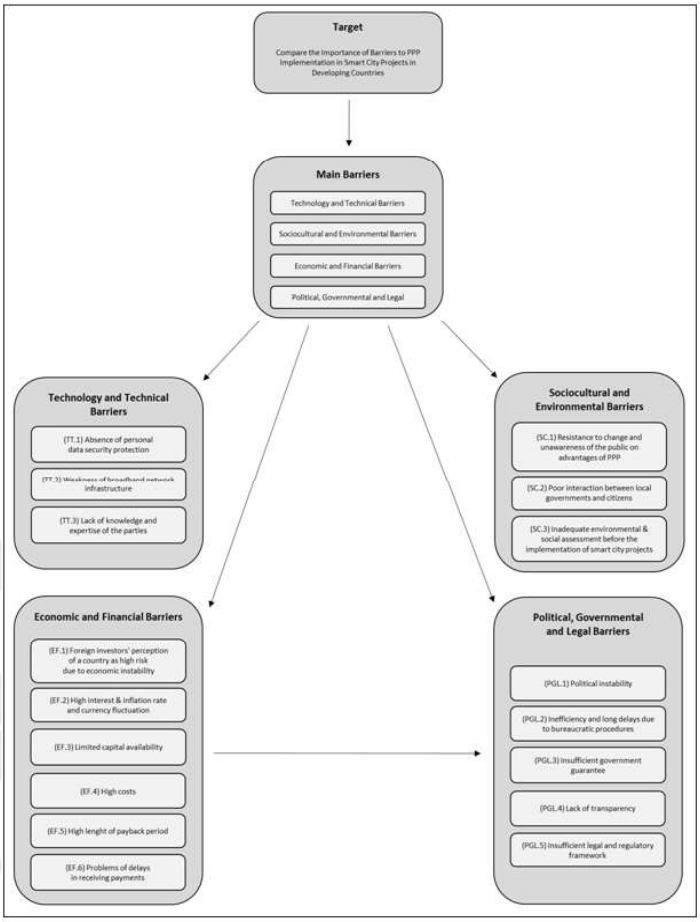

Figure 3.7. View of the network model.

3.4.1. Pairwise Comparisons

After deciding on final barriers list, interrelation of the barriers and selecting an appropriate model, importance rates of the barriers can be determined as a following step. It is very critical part of this study that have direct impact on findings. Pairwise comparisons allow participants to show which barrier is more important than the other with intensity of importance scale. Comparison matrices can be used for these pairwise comparisons. Pairwise comparison matrices consist of row and column elements. A sample pairwise comparison matrix is given in Table 3.4 below that explain how to fill these matrices.

Table 3.4. Comparison matrix.

A	B	C	D
B	1	5	1/7
C		1	3
D			1

The working structure of matrix will be explained for further understanding. A represents the parent element in sample pairwise comparison matrix. An expert should determine the relative the importance rates of B, C and Don the parent element A. The blank cells are filled with Saaty's scale that has nine points as importance degrees. The model scale table is shown in previous section. In addition to that an expert should assess the matrix row by rowto follow up regularly. The main question is "What is the influence of B relative to C and D for parent element A" in this matrix and the participants filled the matrix with this question structure. The value of 1 illustrates the equal importance of two factors in the nine-point scale and Saaty identified this as "two activities contribute equally to the objective". Another value of 3 outlines the moderate importance that also identified as "experience and judgement slightly favour one activity over another" in the literature. The value of 5 means strong importance and it is "experience and judgement strongly favour one activity over another" according to Saaty. Moreover, 7 shows the very strong or demonstrated importance of the value that identified as "an activity is favoured very strongly over another; its dominance demonstrated in practice" (Saaty, 2008).

While B criteria row is evaluated concerning "A" parent element, B criteria has 5 points with strong importance on criteria C according to the sample matrix. Similarly, it can be observed that C criteria has 3 points with moderate importance on criteria D. Although it has a different representation, the 1/7 value indicates the opposite of the equation. It means that D criteria has 7 points with very strong or demonstrated importance on criteria B.

Finally, grey cells do not need to be answered due to the opposite relationships in the matrix. Furthermore, the same factor comparison that showed as "1" should not be filled because the elements cannot be compared on themselves (Elibol, 2013). The tables below show some instances of the matrices created for this study as the first step of the pairwise comparisons. However, it was not shared with the experts in this format. It has been converted into a questionnaire for an easier and more effective evaluation. The questions were written in detail in the questionnaire. Thus, mistakes that can be made by users were minimized. In this study, 11 matrices were createdas 3x3, 4x4, 5x5, and 6x6 forms that can be seen below.

Table 3.5. Comparison matrix of the main barriers.

Main	EF	TT	SCE	PGL
EF	1			
TT		1		
SCE			1	
PGL				1

Table 3.6. Comparison matrix of the economic and financial barriers.

EF Sub	EF.1	EF.2	EF.3	EF.4	EF.5	EF.6
EF.1	1					
EF.2		1				
EF.3			1			
EF.4				1		
EF.5					1	
EF.6						1

Table 3.7. Comparison matrix of the technology and technical barriers.

TT Sub	TT.1	TT.2	TT.3
TT.1	1		
TT.2		1	
TT.3			1

Table 3.8. Comparison matrix of the sociocultural and environmental barriers.

SCE Sub	SCE.1	SCE.2	SCE.3
SCE.1	1		
SCE.2		1	
SCE.3			1

Table 3.9. Comparison matrix of the political, governmental and legal barriers.

PGL Sub	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.10. Comparison matrix of the political, governmental and legal barriers according to the 'Foreign investors'" perception of a country as high risk due to economic instability.

EF.1	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.11. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

EF.2	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.12. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "Limited capital availability".

EF.3	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.13. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High costs".

EF.4	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.14. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "High lenght of payback period".

EF.5	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

Table 3.15. Comparison matrix of the political, governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

EF.6	PGL.1	PGL.2	PGL.3	PGL.4	PGL.5
PGL.1	1				
PGL.2		1			
PGL.3			1		
PGL.4				1	
PGL.5					1

3.5. Questionnaire Design and Gathering Data

After the barriers have been determined and clustered, a questionnaire consisting of questions about PPP implementations was designed in order to analysis their influence on smart urban services.

Deep research was carried out in the literature about data collection and the number of participants for the selected Fuzzy ANP model. It is seen that at least 10 different experts participated ANP and Fuzzy ANP studies in literature.The details of the reviewed papers and the number of participants in these studies are shown in the

table below.

Table 3.16. Number of participants in reviewed papers.

Model	**Source**	**Publisher**	**Number of Participants**
Fuzzy ANP	Govindan *et al.* (2016)	Elsevier	23
Fuzzy ANP	Valmohammadi and Ghassemi(2016)	Emerald	13
Fuzzy ANP	Valmohammadi, and Dashti(2016)	Elsevier	17
Fuzzy ANP	Phochanikorn *et al.* (2020)	Springer	10
Fuzzy ANP	Kazancoğlu *et al.* (2021)	Elsevier	15
ANP	Patil *et al.* (2021)	Elsevier	11
ANP	Özdemir *et al.* (2020)	Emerald	11

Technology and telecommunication services providers were set as the target participant industries. Respondents were preferred to be experienced experts who worked in smart urban services and infrastructure projects. After that, the questionnaire was administered via e-mail to 32 experts in Turkey. Their average experience in the sector is 15,4 years. 15 experts participated in data collection. The information of the participants is shown in table 3.18. below.

Table 3.17. Information of the respondents.

No	Respondents Experience (Year)	Respondents Position	Industry	Country
1	11	Senior Product Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
2	14	Senior Project Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
3	15	Network Planning Manager	Telecommunications	Turkey
4	12	Senior Product Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
5	15	IoT Solution Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
6	17	Network Planning Director	Telecommunications	Turkey
7	13	Network Planning Senior Specialist	Telecommunications	Turkey
8	14	Network Architecture Director	Telecommunications	Turkey
9	12	IoT Solution Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
10	25	Network Planning Director	Telecommunications	Turkey
11	22	Principal Network Architect	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey
12	12	Senior Project Manager	Telecommunications	Turkey
13	14	Senior Project Manager	Telecommunications	Turkey
14	18	Senior Project Manager	Telecommunications	Turkey
15	17	Senior Project Manager	Technology Services Provider (IT, Cloud, Data, IoT, Security)	Turkey

3.6. Super Decision Software

Super Decisions is a software solution tool for multiple-criteria decision methods that are Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) (Superdecisions, 2022). This software was designed and launched by Thomas L. Saaty. It is an easy-to-use package for creating decision models with dependence and feedback and calculating weights using the matrices (Adams and Saaty, 2003). This software is used in many studies in the literature because of its simple interface and structure.

In general, a hierarchical structure is created by the users as a first step. The goal, criteria, and sub-criteria are drawn. After that, interrelations are defined between the nodes and clusters. Then, pairwise comparisons were created to collect the data from the experts. Then, a single pairwise comparison matrix was obtained by calculating the geometric mean of the pairwise comparison matrices for each matrix. It is generally used to reduce the effect of deviation elements (Akay and Pehlivan, 2018). Afterwards, the exact numbers were transformed to fuzzy number and final weights were calculated manually using Chang's Extent Analysis Method steps. The details of calculation steps can be seen in Chapter 3.2.3. Lastly, the obtained data of the research was entered into the system as an input to calculate the priorities. Thus, unweighted, weighted supermatrixes and limit matrices are calculated directly with the software package. As a result, priority and importance weights can be seen as an output (Elibol, 2013).

As a summary of this thesis, a hierarchical structure of the Fuzzy ANP model is generated in the Super Decision Software package program that can be seen in Figure 3.8 below. After that, importance weights are calculated with the help of the Excel package program due to the nature of the fuzzy numbers. Chang's Extent Analysis Method is applied in this phase for calculation. Then, calculated importance weights are entered directly instead of entering in the questionnaire section. Figure 3.8, Figure 3.9, and Figure 3.10 show the questionnaire entry and direct entry respectively. Finally, priorities are determined by the program.

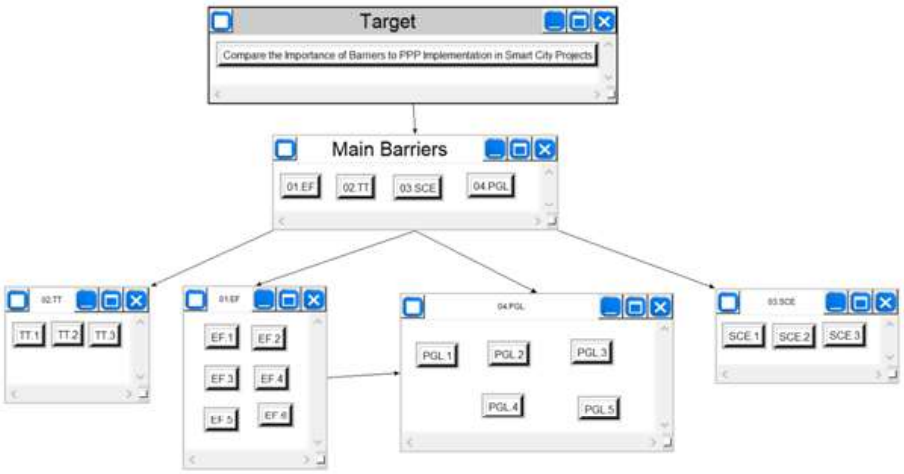

Figure 3.8. View of the network model in super decisions.

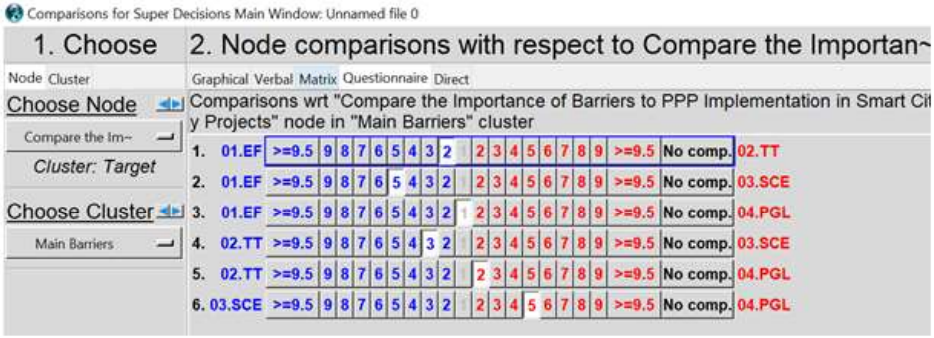

Figure 3.9. Questionnaire entry sample in super decisions.

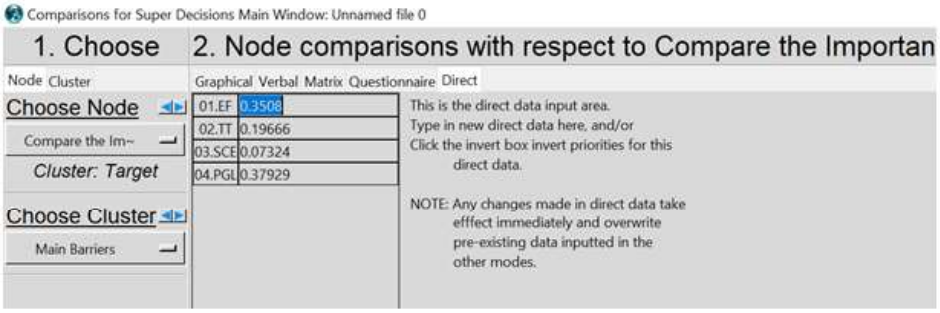

Figure 3.10. Direct data entry sample in super decisions.

4. FINDINGS

Evaluating the barriers to Public-Private Partnership (PPP) implementation in smart urban services is the main goal of this research. In this respect, the phases of research methodology were explained step by step in detail previously. The barriers that have direct impact on these projects were identified. After that, these barriers are compared with a questionnaire by the experts. The values were converted to fuzzy numbers because of reducing the uncertainty degree in the judgments. Therefore, Chang's Extent Analysis Method is applied with the obtained data to calculate the importance weights of the barriers. Then, this input was directly entered to Super Decisions multiple-criteria decision manually. Hence, the final ranking was obtained.

Importance weights of clusters and elements in respect to their influences of the investment decisions could be seen in Table 4.1 and Table 4.2 respectively.

Table 4.1. Priorities of the clusters and sub-barriers.

Code	**Cluster/Barrier Name** **Main Barriers**	**Priorities**
PGL	Political, Governmentaland Legal Barriers	0.37929
EF	Economicand Financial Barriers	0.35080
TT	Technologyand Technical Barriers	0.19666
SCE	Sociocultural and Environmental Barriers	0.07324
	Economicand Financial **Barriers**	
EF.4	High costs	0.29700
EF.2	High interest & inflation rate and currency fluctuation	0.24630
EF.3	Limited capitalavailability	0.19238
EF.5	High lenght of paybackperiod	0.13762

Table 4.1. Priorities of the clusters and sub-barriers. (cont.)

Code	**Cluster/Barrier Name** **Main Barriers**	**Priorities**
EF.6	Problems of delays in receiving payments	0.08562
EF.1	Foreigninvestors' perception of a country as high risk due to economic in stability	0.04108
	Technologyand Technical **Barriers**	
TT.3	Lack of knowledgeandexpertise of the parties	0.50551
TT.1	Absence of personal data Security protection	0.28859
TT.2	Weakness of broadband network infrastructure	0.20590
	Sociocultural and Environmental **Barriers**	
SCE.3	Inadequate environmental & socialassessment before the implementation of projects	0.36912
SCE.1	Resistance to changandun a wareness of the public on advantages of PPP	0.33080
SCE.2	Poorinteraction between local government sandcitizens	0.30008
	Political, Governmentaland **Legal Barriers**	
PGL.1	Politicalinstability	0.23225
PGL.5	Insufficient legal and regulatory frame work	0.20121
PGL.4	Lack of transparency	0.19693
PGL.2	Inefficiency and long delays due to bureaucratic procedures	0.18831
PGL.3	Insufficient government guarantee	0.18130

Table 4.2. Limiting importance weights of the sub-barriers.

Code	**Barrier Name**	**Limiting Importance Weight**
PGL.1	Political instability	0.12552
PGL.5	Insufficient legal and regulatory framework	0.10875
PGL.4	Lack of transparency	0.10643
PGL.2	Inefficiency and long delays due to bureaucratic procedures	0.10177
PGL.3	Insufficient government guarantee	0.09799
EF.4	High costs	0.07713
TT.3	Lack of knowledge and expertise of the parties	0.0736
EF.2	High interest & inflation rate and currency fluctuation	0.06397
EF.3	Limited capital availability	0.04996
TT.1	Absence of personal data security protection	0.04201
EF.5	High lenght of payback period	0.03574
TT.2	Weakness of broadband network infrastructure	0.02998
EF.6	Problems of delays in receiving payments	0.02224
SCE.3	Inadequate environmental & social assessment before the implementation of projects	0.02001

Table 4.2. Limiting importance weights of the sub-barriers. (cont.)

Code	**Barrier Name**	**Limiting Importance Weight**
SCE.1	Resistance to change and unawareness of the public on advantages of PPP	0.01794
SCE.2	Poor interaction between local governments and citizens	0.01627
EF.1	Foreign investors' perception of a country as high risk due to economic instability	0.01067

After reviewing the main clusters, it can be seen that "Political, Governmental and Legal Barriers" is the most important main barrier according to the listed importance weights. Secondly, "Economic and Financial Barriers" followed according to the analysis result. Although there is no big gap between these two main clusters, the impact of political decisions on the economy explains this small difference. After that, it is observed that "Technology and Technical Barriers" is the third most important group and there is quite a high difference in importance weights. Lastly, "Sociocultural and Environmental Barriers" is the least important cluster among the others which is also not a s surprising result. Because decision-makers generally consider the social issues after the feasibility phase of many projects.

Based on "Political, Governmental and Legal Barriers" results coming from calculation, "Political instability" is the most important barrier in this cluster. It is an expected result because the inconsistency and instability of a country's domestic and foreign policyaffects the all the investment ecosystem as a prior factor. On the other hand, "Insufficient government guarantee" is calculated as the last barrier. Nowadays, it is seen that governments adds the guarantee to the contracts to encourage the private sector. This clearly explains the reason of the least important barrier with experts' comments.

In “Economic and Financial Barriers” main cluster, “High Costs” is outlined as a leading barrier. It has been observed that increasing costs are very vital in many respects when projects and studies in practice are examined. On the contrary, “Foreign investors’ perception of a country as high risk due to economic instability” is stated as the least important sub barrier.

In the cluster of “Technology and Technical Barriers”, factor with the highest importance weight is “Lack of knowledge and expertise of the parties” due to the key aspects of technology availability and monitoring expertise. It additionally influences the development of smart urban services directly. Nevertheless, “Weakness of broadband network infrastructure” took the last place among sub barriers.

In the last cluster of “Sociocultural and Environmental Barriers”, three barriers are compared. Although “Inadequate environmental and social assessment before the implementation of projects” is ranked as a first, “Poor interaction between local governments and citizens” is calculated as the least important sub factor. In addition, there is no big difference between the barriers in this cluster.

In overall ranking,the elements with the highest importance weights are “Political instability”, “Insufficient legal and regulatory framework”, and “Lack of transparency” respectively. The first three sub-barriers come from the “Political, Governmental and Legal Barriers” main cluster and this fact shows the signification of this main barrier group among the others. On the other hand, the factor with the least importance weights is “Foreign investors’ perception of a country as high risk due to economic instability”, “Poor interaction between local governments and citizens”, and “Resistance to change and unawareness of the public on advantages of PPP” respectively.

5. DISCUSSION

In developed countries, there are examples of PPP applications for smart urban services. Even though the adoption of PPPs increasing in smart urban services, many developing markets are still having challenges with its successful implementation (Leiringer, 2003 – Yang and You, 2019). The complex structure and lack of infrastructure can be shown as some examples of these difficulties of PPP application in smart urban services. In country-specific focus, the PPP approach is not preferred for smart urban services in Turkey, a developing country. Although some PPP examples are known in transportation projects in Turkey, there is no commonly known implementation in smart urban services due to various macroenvironmental barriers. As an initial step, given the many benefits of PPP in smart urban services, these barriers should be identified in Turkey. After evaluating the barriers and their effects, the PPP model should be properly implemented in smart urban services in Turkey to provide sustainable living spaces for the citizens.

Although many papers investigated the barriers to PPP application, their scope was limited to infrastructure projects. Only a limited number of scholars have researched smart urban development projects as a focus of study. After a comprehensive literature review, it was seen that smart urban services and PPP subjects were studied separately. No study concentrated on the barriers to PPP application in smart urban services. This shows that there is a gap in the literature in this area. In this regard, considering the many advantages of PPP as an effective project delivery method in smart urban services, these elements should be combined and studied together to fill the gap in the literature.

The main objective of this thesis is to evaluate to identify and evaluate the barriers to PPP implementation in smart urban services with a Turkey scope and to obtain their importance weights. Even though there are some similarities and intersection points with conducted studies, there are additional remarkable areas where this thesis

differs from the other research. In this sense, this thesis has been discussed with other studies in three points which are analysis methods, the scope of main clusters, and prioritization of the selected barriers respectively.

Many academics aimed to select the most effective multi-criteria decision analysis method to evaluate the barriers to PPP or smart urban services implementation in previous years. In this sense, various methods are preferred by academics due to their variables and advantages in the literature. The intangible or tangible data type, data size, the number of participants and their expertise, and the number of inputs can be given as examples for these variables. For instance, Lam and Yang (2020) investigated the factors influencing PPP in Hong Kong with the Multi-Attribute Utility Analysis (MAUA) approach. In addition, Babatunde *et al.* (2015) used Kruskal–Wallis and factor analysis to evaluate the barriers to PPP projects in developing countries. A quantitative feasibility study is conducted by Pezzutto *et al.* (2015) to assess the barriers to European smart city projects.

Further more, Rana *et al.* (2018) used AHPtechnique in his investigationto prioritize the barriers to the development of smart cities with the Indian view. Differently, Addae *et al.* (2019) focused on analyzing barriers of Accra smart city with a two-step fuzzy DEMATEL. Moreover, Singh and Singla (2021) analyzed the factors for smart city implementation with the TISM approach. Lastly, Patel (2020) used Fuzzy Analytical Hierarchical Process (FAHP), as used in this thesis, to prioritize the barriers to the implementation of a smart city project. In this study, fuzzy set theory and ANP are combined to deal with the imprecise judgments in multi-criteria decision-making problem that is similar to the recent research of Patel (2020). The data is collected from the experts in the industry regarding the barriers and their comments were quite subjective. In the pairwise comparison section, Fuzzy ANP applies a range of values that into account the decision makers' imprecise or uncertain judgements contrary to the exact values. It is also observed the participants find it easier to make interval judgements rather than certain value judgements. Decision-makersare not able to easily define their preferences due to the high uncertaintyof the comparison process

(Chatterjee *et al.*, 2015). In addition to fuzzy logic, ANP structure contains dependences and feedbacks among factors and clusterswhich is not considered in previous model of the AHP (Saaty, 2008). In the light of this information, Fuzzy ANP was the most appropriate method to apply for this study.

After mentioning analysis methods of the related studies in the literature, the comparison of main clusters can be examined as a second step of discussion part. Although the barriers are clustered by academics differently due to their perspectives and study scopes, there are several similarities. Some academics applied the general PESTLE key external factors which are "Political", "Economic", "Sociological", "Technological", "Legal" and "Environmental" with different schemes. For example, Razmjoo *et al.* (2021) classified 22 barriers under five main categories that are governance, social, technology, environmental, and economic like PESTLE factors. Legal group was not included in their study. Similar to this, Addae *et al.* (2019) considered 24 barriers under 5 major clusters in the research. These major clusters were financial barriers, market barriers, policy barriers, technology barriers, and social barriers. Differently, they identified market barriers regarding related challenges instead of legal cluster as well. Additionally, Rana *et al.* (2018) identified 31 crucial barriers to smart urban servicesunder main categories which are governance, economic, technology, social, environmental, and legal and ethical. Finally, selected 58 barriers were grouped into 10 major factors in the study of Babatunde *et al.* (2015) that was very detailed clusters when we compare with others.

In this thesis, 17 barriers identified 4 main clusters after a comprehensive literature review. These are "Economic and Financial Barriers", "Technology and Technical Barriers", "Sociocultural and Environmental Barriers", and "Political, Governmental and Legal Barriers". Economic and financial barriers, as most crowdedmajor group, are combined because of their similar scopes. In addition to technology, technical barriers are joined in the second cluster to refer specialized areas. Moreover, sociocultural, and environmental barriers are merged due to their common effects on the citizens. Lastly political, governmental, and legal barriers are considered in one cluster because of their

interdependences. According to the general view, legal concerns create laws that bring justice to the society. Additionally, policies are generated for achieving these legal goals in long term. This summarizes the harmonic relationship among these elements.

Finally, importance weights of barriers to PPP implementation in smart urban services,the main goal of this study, are discussed as a third step in thissection. In literature, it is detected that prioritization of the barriers may vary due to different scope and objectives of the studies. According to Rana *et al.* (2018) who investigated the barriers for smart city development, governance and economic are recognized as the most important main categories as same as the result of this study. "Lack of involvement of citizens" evaluated as the highest rank. Their research scope only focuses on smart cities without any funding concern and citizens must beat the center of such projects. This clearly explains the importance of first barrier. Afterwards "global economy volatility"barrier followed respectively that is very similar to"high interest and inflation rate and currency fluctuation" barrier in this thesisas significant factor.

Furthermore, the paper of Lam and Yang (2020) combined the smart city and PPP topics, and they identified 16 variables from different sources. Differently, "Availability of needed data for providing smart city service" is ranked as the most important element due to their Hong Kong scope. Nowadays, many investors believe that data is the new oil for new tech era. Moreover, even after being transformed, the data can be continuously reused to generate new information, whereas oil is discarded after its transformation. In short, data helps organizations make better decisions with sustainable format. These points clarify the importance of the needed data for sustainable living spaces from the perspective of experts in Hong Kong. After that "Availability of expertise" is calculated as second important barrier which is also mentioned as "Lack of knowledge and expertise of the parties" in this thesis. It has the highest importance in the cluster of "Technology and Technical Barriers". Similarly, "lack of transparency" issue is ranked as third important barrier in overall for both studies.

Additively, Mosannenzadeh *et al.* (2017)prioritized the selected smart energy cityapplication barriers for Europe scope. There are some differences between the most developed continent and developing countries regarding theireconomic welfare comparison; however, there are several similarities as well. For instance, they included "fragmented ownership at the project level" barrier because of complex structure of agreement types which ranked as major factor (Mosannenzadeh *et al.*, 2017). This barrier was not prioritized in this thesis because developing countries have bigger challenges due to economic and political matters. Although, "Poor interaction between local governments and citizens" has low importance in this study, "lack of good cooperation and acceptance among project partners" is assessed as critical element according to them. This situation shows that when the level of development a country increases, the collaboration between the project stakeholders should also increase because of the complex bureaucratic procedures. On the other hand, "lack of skilled and trained personnel" is stated the most important barrier in technical main cluster as same as recent research of Rana *et al.* (2018) and this thesis. Similarly, "lacking or fragmented political support on the long term at the policy level" refers to combination of "Political instability" and "Insufficient legal and regulatory framework" in this thesis. This fact is monitored as vital challenge for both studies.

Addae *et al.* (2019) analyzed the barriers of smart energy city that is very similar to the study of Mosannenzadeh *et al.* (2017); whereas their scope was limited to with Accra city which is an example of developing country scope like this thesis. "Limited access to capital" has the highest importance and it is followed by "high upfront costs". In this thesis, "high costs" also analyzed as first important financial barrier after political barriers. Many experts consider that irregular changes of government can affect economic conditions directly. The ANP structure of this thesis demonstrates the effects of political decisions on economic factors was also considered in the analysis. Hence, the sub-barriers of "Political, Governmental and Legal" main cluster took the first places in the ranking. As mentioned in previous part, "political instability" ranked as most important barrier for this thesis.

As stated in the previous section, some academics only investigated the barriers on PPP with general perspective. They did not concentrate on any specific project type like energy, smart city, telecommunication, and construction. For example, Babatunde *et al.* (2015) conducted research about barriers to general PPP projects in Nigeria, Rezouki and Hassan (2019) focused on the barriers to PPP in infrastructure development with the scope of developing countries. 25 factors are defined by Rezouki and Hassan (2019) and "Corruption/ lack of transparency" is declared as the most critical element. Unfortunately, the complex structure of PPP agreements sometimes causes corruption situation. Especially in developing countries, parties who are aware of this can benefit due to insufficient monitoring mechanism. It is followed by "Scarcity of private fund in general" barrier that refers to "limited capital availability" in this thesis. As is known, there is a need for infrastructure projects in developing countries. Although PPP is seen as a solution, many private companies are struggling with their cash flow. Additionally, "potential conflicts of interests among the stakeholders" is ranked as first according to Babatunde *et al.* (2015) which is very similar to the result of Mosannenzadeh *et al.* (2017). Interestingly, "lack of innovations indesign" is observed as the lowest important barrier to PPP implementation. This result shows researchers that they need to sort out financial and political challenges before this barrier.

After discussing the outputs between this thesis and similar studies in the literature, it can be underlined that this study contributes to the literature by evaluating the barriers to Public-Private Partnership (PPP) implementation in smart urban services with a Turkey scope. Within the aspect of theoretical contribution, main clusters and sub-barriers were clearly identified. After that, inter dependencies of the clusters were obtained, and their priorities and importance weights of the barriers are calculated within the proposed model. The previous studies generally concentrate on assessing the challenges within infrastructure scope in PPPs, whereas this thesis generated a model that discovered the most important barriers, especially for the PPP approach in smart urban services. The proposed model can be a basis for researchers who aim to focus on the PPPs and smart urban concepts together. On the other hand, this thesis

has many practical contributions. First of all, the thesis introduces information and insights for city governments and private developers by indicating attributes of smart urban services and project delivery methods. Municipalities that are planning to construct smart urban services can utilize this study to assess the project delivery methods. Additionally, this thesis presents the potential barriers that local governments might encounter when they decide to generate smart urban services with the PPP approach by assessing the importance degree of the barriers in the proposed model. Therefore, the municipalities might use the study's results as a guide and carry out preparatory work with related stakeholders before the project to overcome these challenges. As stated before, political, governmental, and legal barriers were calculated as the most important main barrier group in this study. In light of these results, local governments can rebuild their regulatory framework with the support of centralized governments. After the advancement of legal guarantees and bureaucratic procedures, the public side can attract the private industry parties to make a cooperation with the PPP approach in smart urban services.

Data helps organizations to make better decisions with a creative format. As stated in the smart urban project examples, private firms might access such customer data by making a PPP agreement with the municipalities; however, the implementation of the PPP model in smart urban services is not very common. Since it is a new, complex structured, and non-traditional approach, private companies generally act more conservatively because of a lack of knowledge. In this sense, the developers of the private sector additionally might utilize this study by reviewing worldwide examples. They might contribute to the development level of smart urban services with the PPP approach by properly analyzing the barriers in the findings of this thesis. Moreover, if the barriers mentioned in this study are overcome by the cooperation between the municipality and the private sector participants, these services might be effectively applied. Therefore, citizens can utilize these smart urban services for better living conditions and a sustainable future. In short, this thesis provides information to help remove or limit these barriers for local governments, investors, and other authorities.

In a nutshell, it can be declared that the proposed model in this thesis and its outcomes are suitable for smart urban services. Although the overall picture will remain the same, there might be some differences. Also, this thesis concentrated on many significant points, but it has some limitations as well. The research scope of this thesis is limited to Turkey and this situation explains the difference in the importance weights results of the barriers. Developing countries can have many macro-environmental factors such as demographic, ecological, political, economic, socio-cultural, and technological elements. Academics might focus on these scopes separately and compare them with each other in future studies. Furthermore, the number of participants in the analysis phase and their expertise can differ from each other. 15 experts participated in the questionnaire phase of this thesis from different sectors such as telecommunication and technology. The amount can be increased, and the answers can be assessed separately to compare and justify industry-based outputs. Lastly, this thesis does not focus on real-time projects in the industry. In this respect, theoretical and practical studies can be studied at the same time for future studies. The stakeholders of real-time smart urban services can assess the drivers and barriers after their application. After that, the results can be compared with the outputs of similar papers in the literature. Smart urban services have many focuses and a comparison of the barriers might be investigated among these projects and the results of this study.

6. CONCLUSION

Urbanization pace is increasing dramatically, and it has become an important issue for governments. Nowadays, citizens prefer to live in city centers than rural areas to enhance their living standards. It should be also noted that cities will be hosting more than 68% of the world's total population in the following fifty years. Unfortunately, this fast urbanization might cause excessive use of our sources and the current infrastructure will not be enough due to the high number of uncontrolled migrations. Consequently, citizens will face with inadequate living conditions in the near future (Liu *et al.*, 2021).

These days, various organisms between people and government try to find new concepts of urban service technology solutions against these problems to raise the standards of our living spaces. In literature, this concept is called "smart urban services" which is a conceptual urban development model that combines human, collective, and technological capital (Angelidou, 2015). The main aim of smart urban services is to provide a sustainable future for people with high-quality urban services. Additionally, smart urban applications enhance quality-of-life parameters between 10-30% such as safety, time, and health (McKinsey, 2018).

It is known that smart urban services improve quality of life standards (Yang and You, 2019); whereas they are challenging projects in terms of financing, project delivery, and size. According to recent research, only 16% of cities are able to self-fund in the world (Flynn *et al.*, 2018). This research indicates that cities definitely need the support of external partnerships with private and non-profit organizations to proceed with smart urban services together. The local governments can overcome many difficulties in funding and managing smart urban development projects by reducing expenses with new technological solutions and bringing essential stakeholders together (Cruz and Sarmento, 2017) At this point, PPPs enable a collaborative project delivery model for the public and private sectors working together to generate smart urban service

projects (Liu *et al.*, 2021). This PPP project delivery model enhances the efficiency and sustainable availability of resources (Babatunde *et al.*, 2015). Municipalities can prefer this model because of numerous advantages such as access to private capital, technology, people, skills, and transfer of risk.

There are examples of PPP applications for smart urban services in some developed countries. Although the adoption of PPPs improving in smart urban services, many developing countries are still having difficulties against its successful implementation (Leiringer, 2003 – Yang and You, 2019). The complex structure and lack of infrastructure can be shown as some examples of barriers of PPP implementation in smart urban services. In market-specific focus, the PPP model is not preferred for smart urban services in Turkey, a developing country. Although some examples are known in transportation projects in Turkey, there is no commonly known application in smart urban services due to different macro environmental barriers. As a first phase, given the many benefits of PPP in smart urban services, these barriers should be clearly identified in Turkey. After determining the barriers and their effects, the PPP model should be properly applied in smart urban services in Turkey to provide sustainable living spaces for the citizens.

Despite the fact many papers investigated the barriers to PPP application, their scope was limited to infrastructure projects. Only a few studies academics examined researched smart urban development projects as a focus of study. After a comprehensive literature review, it was observed that smart urban services and PPP subjects were studied separately. There is no study that focused on the barriers to PPP implementation in smart urban services. This indicates that there is a gap in the literature in this area. In this regard, considering the many advantages of PPP as an effective project delivery method in smart urban services, these elements should be combined and studied together to fill the gap in the literature.

This thesis aims to evaluate the barriers to Public-Private Partnership (PPP) implementation in smart urban services with a Turkey scope to fill the gap in the lit-

erature. In addition to the main goal, identifying the main clusters and sub-barriers, obtaining the inter dependencies of the clusters, determining the priorities and importance weights, and deciding on the most important barriers can be shown as other objectives.

After a literature review, more than 30 current articles were analyzed and the most relevant 16 current studies were selected. Then, 252 barriers were identified after the careful evaluation. Following, repetitive and less relevant barriers were eliminated with the expert comments. Finally, 17 sub-barriers were determined. These barriers were grouped under 4 main clusters which are "Economic and Financial Barriers", "Technology and Technical Barriers", "Sociocultural and Environmental Barriers", and "Political, Governmental and Legal Barriers".

After deciding on the barriers, an effective method to analyze the priorities must be determined. In this regard, different various multiple criteria decision methods were reviewed. Analytic Hierarchy Process (AHP) is very trendy method in the literature. Considering the inter dependency factor among the barriers, ANP (Analytic Network Process) was selected which is also an extended model of AHP. ANP structure contains dependences and feed backs among factors and clusters which is not considered in the AHP (Saaty, 2008). Then, fuzzy set theory and ANP were combined to deal with the imprecise judgments in multi-criteria decision-making problem in this thesis. Because the data was collected from the participants in the sector regarding the comparison of barriers and their comments were quite subjective. In the pairwise comparison section, Fuzzy ANP applies a range of values that into account the decision makers' uncertain judgements contrary to the exact values. Hence, Fuzzy Analytical Network Process was the most appropriate methodology to apply for this thesis. Following, the interrelation of the barriers was classified and pairwise comparisons were created. After, answers of participants on each pairwise comparison matrices were analyzed. Lastly, the data was entered in "Super Decision", a decision-making software,to find the priorities and importance weights of the barriers.

It is observed that "Political, Governmental and Legal Barriers" is the most important main cluster according to the importance weights. Then, it is followed by "Economic and Financial Barriers" cluster. While there is no big difference among these two main clusters, the effect of political decisions on the economy explains this gap. In overview of sub-barrier analysis results, "Political instability" is the calculated as the most important challenge because of inconsistent decisions in country's domestic and foreign policy that affects the all the investment ecosystem negatively as a prior barrier. "Insufficient legal and regulatory framework" followed as second vital barrier. After domination of "Political, Governmental and Legal Barriers" cluster, "High costs" and "Lack of knowledge and expertise of the parties" were outlined as critical barriers from different clusters. It is also observed that "Foreign investors' perception of a country as high risk due to economic instability" is the least important barrier to PPP implementation of smart urban services from the views of experts.

This thesis contributes to the literature by reviewing the barriers to Public-Private Partnership (PPP) implementation in smart urban services with a Turkey scope. Within the theoretical contribution, main clusters and sub-barriers were identified. Then, interdependencies of the clusters were obtained, and their priorities and importance weights of the barriers are determined within the model. Existing studies mostly focus on assessing the barriers within infrastructure scope in PPPs, however, this study developed a model that discovered the most important barriers, especially for the PPP approach in smart urban services. The proposed model might be a basis for researchers who aim to concentrate on the PPPs and smart urban concepts.

On the other hand, this study has many practical contributions. Firstly, the thesis presents information and insights for local governments and private investors by indicating attributes of smart urban services and project delivery methods. Local governments who are planning to build smart urban services might utilize this thesis to evaluate the current project delivery methods. Moreover, this study presents the potential barriers that municipalities may encounter when they decide to build smart urban services with the PPP model by evaluating the importance degree of the barriers

in the model. Thus, the municipalities can use the study's results as a guide and carry out preparatory work with relevant stakeholders before the project to overcome these barriers. Political, governmental, and legal barriers were evaluated as the most important main barrier group in this thesis. In light of these findings, local governments can reconstruct their regulatory framework with the support of centralized governments. After the improvement of legal guarantees and bureaucratic procedures, the public side can attract the private sector parties to make a cooperation with the PPP model in smart urban services.

Nowadays, many firms seek ways to get access to data beyond their customer bases due to numerous benefits for their business growth. Many private organizations believe that data is the new oil for the new tech era. Moreover, even after being transformed, the data can be continuously reused to generate new information, whereas oil is discarded after its transformation. In short, data helps organizations to make better decisions with a sustainable format. As mentioned in the smart urban project examples, private companies can access such customer data by making a PPP agreement with the local government, but it is known that the application of the PPP model in smart urban services is not very common. Since it is a new, complex structured, and non-traditional method, the private sector participants can act more conservatively due to lack of knowledge. In this regard, the developers of the private industry also can utilize this thesis by reviewing worldwide examples. They can contribute to the development of smart urban services with the PPP model by properly analyzing the barriers in the findings of this thesis. Additionally, if the barriers mentioned in this thesis are overcome by the cooperation between the local government and the private sector, these projects can be effectively implemented. Thus, citizens can utilize these smart urban services for better living conditions and sustainable future.In brief, this study provides information to help remove or limit these barriers for local governments, investors, and other authorities.

Additionally, this thesis focused on various important elements, but it has some limitations that can be addressed for future academic studies as well. Firstly, the

scope of this thesis can be shown as the most significant limitation that focusing on only Turkey. Developed, developing, and underdeveloped countries have different macro-environment factors which are demographic, ecological, political, economic, sociocultural, and technological aspects. These factors can lead to significant differences in participants' assessments. In this regard, academics can focus on these scopes separately and compare them with each other in the future. Secondly, there were 15 experts who participated in the survey part of this thesis from different sectors such as telecommunication and technology. The amount can be enhanced, and the answers can be assessed separately to compare and justify industry-based outputs. Lastly, this thesis does not focus on real-time exact projects in the industry. In this sense, theoretical and practical studies can be studied at the same time for future papers. The stakeholders of real-time smart urban services can assess the drivers and barriers after their implementation. Then, these results can compare with the outputs of similar papers in the literature. Smart urban services have numerous focuses and a comparison of the challenges can be investigated between these current projects and the results of this study.

REFERENCES

Adams, W.J.L., and R. Saaty, 2003, "Super Decisions Software Guide", *Super Decisions*, Vol. 9, pp. 43-55.

Addae, B.A., L. Zhang, P. Zhou and F. Wang, 2019, "Analyzing Barriers of Smart Energy City in Accra with Two-Step Fuzzy Dematel", *Cities*, Vol. 89, pp. 218-227.

Aghimien, D.O., C. Aigbavboa, D.J. Edwards, A.M. Mahamadu, P. Olomolaiye, H. Nash and M. Onyia, 2020, "A Fuzzy Synthetic Evaluation of the Challenges of Smart City Development in Developing Countries", *Smart and Sustainable Built Environment*, Vol. 3, No. 16-29, pp.405-421.

Akbıyıklı, R. and D. Eaton, 2005 "A Comparison of PFI, BOT, BOO and BOOT Procurement Routes for Infrastructure Construction Projects", *Fifth International Postgraduate Research Conference in the Built and Human Environment*, Salford, United Kingdom.

Akıllı Şehirler, 2022, "Bursa Smart City", https://akillisehir.bursa. bel.tr /project /gelecegin- sehirleri -programi/, accessed on November 18, 2022.

Akıllı Şehirler, 2022j, "Gaziantep Cycling Potential Measurement and Evaluation System", https://www.akillisehirler.gov.tr/ proje-envanteri / gaziantep - bisikletli-potansiyelini - olcme -ve - degerlendirme-sistemi/, accessed on November 12, 2022.

Akıllı Şehirler, 2022i, "Gaziantep Green Wave System", https://www. akillisehirler. gov.tr/ 2021/ 09/ 24/yesil -dalga-uygulamasi/, accessed on November 14, 2022.

Akıllı Şehirler, 2022b, "Istanbul Intelligent Park Management System", https://www. akillisehirler .gov. tr/ 2019/ 09/ 12/ istanbul -buyuksehir -belediyesi -akilli-park-yonetimi/, accessed on November 8, 2022.

Akıllı Şehirler, 2022e,"SUMPIZMIR",https://www. akillisehirler. gov. tr/ proje-envanteri/ izmir-sustainable- urban-mobility-plan-sumpizmir/, accessed on November 15, 2022.

Akıllı Şehirler, 2022a, "akıllısehir", https://www.akillisehirler.gov.tr/en/, accessed on June 21, 2022a.

Akıllı Şehirler, 2022d, "Ankara Intelligent Waste Collection System", https://www. akillisehirler. gov.tr /proje-envanteri /ankara -akilli -atik -toplama-sistemi/, accessed on November 15, 2022.

Akıllı Şehirler, 2022c,"Istanbul Smart Recycling Container", https://www.akillisehirler .gov.tr /2019/09/12/ istanbul -buyuksehir -belediyesi - akilli - geri - donusum - konteyneri/, accessed on November 13, 2022.

Akıllı Şehirler, 2022f, "Izmir Agricultural Forecasting and Early Warning System", https:// www.akillisehirler .gov .tr /proje -envanteri /izmir -tarimsal -tahmin -ve -erken -uyari -sistemi/, accessed on November 15, 2022.

Akıllı Şehirler, 2022h, "LoveChip", https:// akillisehir .bursa .bel. tr/ project /sevgi-cipi/, accessed on November 13, 2022.

Akintoye, A., C. Hardcastle, M. Beck, E. Chinyio and D. Asenova, 2003, "Achieving Best Value in Private Finance Initiative Project Procurement", *Construction Management and Economics*, Vol. 21, No. 5, pp. 461-470.

Al Khalil, M.I., 2002, "Selecting the Appropriate Project Delivery Method Using AHP", *International Journal of Project Management*, Vol. 20, No. 6, pp. 469-474.

Alawadhi, S., A. Aldama-Nalda, H. Chourabi, J.R. Gil-Garcia, S. Leung, S. Mellouli and S. Walker, 2012, "Building Understanding of Smart City Initiatives", *International Conference On Electronic Government*, Berlin, Heidelberg.

Albino, V., U. Berardi and R.M. Dangelico, 2015, "Smart Cities: Definitions, Dimensions, Performance, and Initiatives", *Journal of Urban Technology*, Vol. 22, No. 1, pp. 3-21.

Alim, S. and J. Polak, 2016, "Public–Private Partnerships for Future Urban Infrastructure", *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law*, Vol. 169, No. 4, pp. 150-158.

Angelidou, M., 2015, "Smart Cities: A Conjuncture of four Forces", *Cities*, Vol. 47, pp. 95-106.

Babatunde, S.O., S. Perera, L. Zhou and C. Udeaja, 2015, *Barriers to Public Private Partnership Projects in Developing Countries: A Case of Nigeria*, Engineering, Construction and Architectural Management.

Baker, D., D. Bridges, R. Hunter, G. Johnson, J. Krupa, J. Murphy and K. Sorenson, 2001, *Guidebook to Decision-Making Methods Aiken*, Westinghouse Savannah River Company, South Carolina, USA.

Bakıcı, T., E. Almirall and J. Wareham, 2013, "A Smart City Initiative: The Case of Barcelona", *Journal of the Knowledge Economy*, Vol. 4, No. 2, pp. 135-148.

Ball, M. and P.J. Maginn, 2005, "Urban Change and Conflict: Evaluating the Role of Partnerships in Urban Regeneration in the UK", *Housing Studies*, Vol. 20, No. 1, pp. 9-28.

Barnett, M., 1987, "Role of the Merchant Banker in Projects", *International Journal of Project Management*, Vol. 5, No. 4, pp. 197-203.

Barrionuevo, J.M., P. Berrone and J.E. Ricart, 2012, "Smart Cities, Sustainable Progress", *Iese Insight*, Vl. 14, No. 14, pp. 50-57.

Batmaz, A., 2013, *Investment Decision Making in Renewable Energy Investments*, M.S.

Thesis, Boğaziçi University.

Bjorner, T., 2021, "The Advantages of and Barriers to Being Smart in a Smart City: The Perceptions of Project Managers within a Smart City Cluster Project in Greater Copenhagen", *Cities*, Vol., 114, pp. 103187.

Chang, D.Y., 1996, "Applications of the Extent Analysis Method on Fuzzy AHP", *European Journal of Operational Researh*, Vol. 95, No. 3, pp. 649-655.

Chatterjee, K., A. Bandyopadhyay, A. Ghosh and S. Kar, 2015, "Assessment of Environmental Factors Causing Wetland Degradation, Using Fuzzy Analytic Network Process: A Case Study on Keoladeo National Park, India", *Ecological Modeling*, Vol. 316, pp. 1-13.

Cheong, S.M., G.W. Choi and H.S. Lee, 2016, "Barriers and Solutions to Smart Water Grid Development", *Environmental Management*, Vol. 57, No. 3, pp. 509-515.

CNN, 2022, "The Green City of the Future - Sustainable Recovery: Defining the Future of Tokyo", https://sponsorcontent. cnn. com /int /tokyo -sustainable -recovery /green-tokyo/, accessed on November 19, 2022.

Çomu, S., Z. Kural and B. Yücel, 2020, "Selecting the Appropriate Project Delivery Method for Real Estate Projects Using Fuzzy AHP", *Journal of Construction Engineering*, Vol. 3, No. 4, pp. 249-263.

Consultancy.asia, 2020, "Singapore is the globe's top country for autonomous driving", https://www. consultancy. asia/news /3382/singapore -is -the -globes-top -country -for -autonomous -driving, accessed on November 17, 2022.

Cruz, C.O. and J.M. Sarmento, 2017, "Reforming Traditional PPP Models to Cope with the Challenges of Smart Cities", *Competition and Regulation in Network Industries*, Vol. 18, No. 1-2, pp.94-114.

Dener, M.U.R.A.T., 2018, "Smart City Applications in Turkey, Education Research Highlights in Mathematics", *Science and Technology*, Vol. 67.

The European PPP Expertise Centre's (EEC), 2022,"EPEC PPP Guide", https://www. eib. org /epec /g2g/ index.htm, accessed on November 29, 2022.

Elibol A., 2013, *A Risk Assessment Model with Analytic Network Process In Commercial Real Estate Development Projects*, M.S., Thesis, Boğaziçi University.

Erridge, A. and J. Greer, 2002, "Partnerships and Public Procurement: Building Social Capital Through Supply Relations", *Public Administration*, Vol. 80, No. 3, pp. 503-522.

EU-Japan, 2015, "Tokyo Smart City Development in Perspective of 2020 Olympics Opportunities for EU-Japan Cooperation and Business Development", https://www. eu-japan. eu/ sites/ default/ files/ publications/ docs/ smart2020 tokyo_ final. pdf, accessed on November 18, 2022.

European Commission, 2003, "Guidelines for Successful Public-Private Partnerships", https://ppp.gov.ie/ wp/ files/ documents/ guidance/ other_ guidance/ EU- Guidelines -for- Successful- PPP.pdf, accessed on June 9, 2022.

EuropeanCommission, 2018, "Financingmodelsforsmartcities", https://www. uraia. org/ documents/ 109/2013 _Smart _Cities _Platform _European _Union _-Financing _Models-ENG. pdf, accessed on June 14, 2022.

Eyüboğlu E., 2014, *Global and Domestic Supplier Selection for Tech-Enabled Property Management and Hospitality Industry Using Fuzzy AHP*, M.S. Thesis, Boğaziçi University.

Ferraris, A., G. Santoro and A.C. Pellicelli, 2020, "Openness of Public Governments in Smart Cities: Removing the Barriers for Innovation and Entrepreneurship", *International Entrepreneurship and Management Journal*, Vol. 16, No. 4, pp.

1259-1280.

Fishman, T.D., M. Flynn, 2018, *Using Public-Private Partnerships to Advance Smart Cities*, Deloitte Center for Government Insights, London, UK.

Flynn, M., A.K. Rao, J. Horner and D.S. Gashi, 2018, *Smart Cities Funding and Financing in Developing Economies: Assisting Development Cities to Finance Their Infrastructure Gap Through Private Sector Participation Approaches*, Sponsored by Deloitte.

Giffinger, R. and H. Gudrun, 2010, "Smart Cities Ranking: An Effective Instrument for the Positioning of the Cities?", *Architecture, City And Environment*, Vol. 4, No. 12, pp. 7-26.

Giffinger, R., C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanovic and E. Meijers, 2007, *Smart Cities, Ranking of European Medium-Sized Cities, Final Report*, Centre of Regional Science, Vienna UT.

Gujarat International Finance Tec-City (GIFT Gujarat), 2022, "Gujarat International Finance Tec-City (GIFT)", https://www. giftgujarat. in/, accessed on November 13, 2022.

Gkountis, I. and T. Zayed, 2015, "Subway Infrastructure Condition Assessment", *Journal of Construction Engineering and Management*, Vol. 141, No. 12, pp. 04015042.

Govindan, K., K.M. Shankar and D. Kannan, 2016, "Application of Fuzzy Analytic Network Process for Barrier Evaluation in Automotive Parts Remanufacturing Towards Cleaner Production–A Study in an Indian Scenario", *Journal of Cleaner Production*, Vol. 114, pp. 199-213.

Grimaldi, D. and V. Fernandez, 2019, "Performance of an Internet of Things Project in the Public Sector: The Case of Nice Smart City", *The Journal of High Technology*

Management Research, Vol. 30, No. 1, pp. 27-39.

Grimsey, D. and M.K. Lewis, 2002, "Evaluating the Risks of Public Private Partnerships for Infrastructure Projects", *International Journal of Project Management*, Vol. 20, No. 2, pp. 107-118.

Gujarat International Finance Tec-City (GUDCLTD), 2022, "Gujarat International Finance Tec-City (Gift) Project", https://www. gudcltd. com/ gujarat- international-finance- tech-city, accessed on November 8, 2022.

Harrison, C., B. Eckman, R. Hamilton, P. Hartswick, J. Kalagnanam, J. Paraszczak and P. Williams, 2010, "Foundations For Smarter Cities", *IBM Journal of Research and Development*, Vol. 54 No. 4, pp. 1-16.

Hart, O, 2003, "Incomplete Contracts and Public Ownership: Remarks, and an Application to Public[U+2010]Private Partnerships", *The Economic Journal*, Vol. 113, No. 486, pp. C69-C76.

Howes, R. and H. Robinson, 2006, *Infrastructure for the Built Environment: Global Procurement Strategies*, Routledge.

Huang, Y.L. and S.P. Chou, 2006, "Valuation of the Minimum Revenue Guarantee and the Option to Abandon in BOT Infrastructure Projects", *Construction Management and Economics*, Vol. 24 No. 4, pp. 379-389.

India Meteorological Department (IMD), 2022, "Smart City Observatory", https://www .imd. org/ smart- city- observatory/ home/, accessed on December 3, 2022.

Info Barcelona, 2020, "Energy production forms part of the revamp to the Ronda de Dalt", https://www.barcelona. cat/ infobarcelona/ en/ tema/ climate- emergency/ energy- production- forms- part- of- the- revamp- to- theronda- de-dalt_ 986073. html, accessed on November 24, 2022.

I-REC Standard is empowering (IREC), 2022, "The Catalan Government will locate the platform for the integration of renewable energy and storage led by IREC in Gurb", https://www. irec. cat/ press-society/ news/ climate- action- to- locate- the- platform- for- the- integration- of-renewable- energy- and- storage- led- by- irec- in-gurb/, accessed on November 12, 2022.

Jayasena, N.S., D.W. Chan, M.M. Kumaraswamy and A.B. Saka, 2022, "Applicability of Public-Private Partnerships in Smart Infrastructure Development: The Case of Hong Kong", *International Journal of Construction Management*, Vol. 1, pp. 1-13.

Kahraman, C., U. Cebeci and D. Ruan, 2004, "Multi-Attribute Comparison of Catering Service Companies Using Fuzzy AHP: The Case of Turkey", *International Journal of Production Economics*, Vol. 87, No. 2, pp. 171-184.

Kazancoğlu, Y., M. Sağnak, S.K. Mangla, M.D. Sezer and M.O. Pala, 2021, "A Fuzzy Based Hybrid Decision Framework to Circularity in Dairy Supply Chains Through Big Data Solutions", *Technological Forecasting and Social Change*, Vol. 170, pp. 120927.

Kenig, M.E., 2011, *Project Delivery Systems*, AGC of America: Farmington Hills, MI, USA.

Kumaraswamy, M.M. and D.A. Morris, 2002, "Build-Operate-Transfer-Type Procurement in Asian Megaprojects", *Journal of Construction Engineering and Management*, Vol. 128, No. 2, pp. 93-102.

Lam, P.T. and W. Yang, 2020, "Factors Influencing the Consideration of Public-Private Partnerships (PPP) for Smart City Projects: Evidence from Hong Kong", *Cities*, Vol. 99, pp. 102606.

Lee, A.H., W.C. Chen and C.J. Chang, 2008, "A Fuzzy AHP and BSC Approach

for Evaluating Performance of IT Department in the Manufacturing Industry in Taiwan‘", *Expert Systems with Applications*, Vol. 34, No. 1, pp. 96-107.

Lee, S.K., G. Mogi and K.S. Hui, 2013, "A Fuzzy Analytic Hierarchy Process (AHP)/Data Envelopment Analysis (DEA) Hybrid Model for Efficiently Allocating Energy R And D Resources: In the Case of Energy Technologies Against High Oil Prices", *Renewable and Sustainable Energy Reviews*, Vol. 21, pp. 347-355.

Leiringer, R., 2003, *Technological Innovations in the Context of Public-Private Partnership Projects*, Ph.D. Thesis, Boğaziçi University.

Leyva, M., J. Hechavarria, N. Batista, J.A. Alarcon and O. Gomez, 2018, "A Framework for PEST Analysis Based on Fuzzy Decision Maps", *Revistaespacios*, Vol. 39, No. 16.

Li, B. and A. Akintoye, 2003, "An Overview of Public-Private Partnership", *Public-Private Partnerships: Managing Risks and Opportunities*, Vol. 7, pp. 3-30.

Li, B., A. Akintoye, P.J. Edwards, and C. Hardcastle, 2005, "Critical Success Factors for PPP/PFI Projects in the UK Construction Industry", *Construction Management and Economics*, Vol. 23, No. 5, pp. 459-471.

Libelium, 2016,"Saving water with Smart Irrigation System in Barcelona", https://www. libelium. com/ libeliumworld/ success- stories/ saving- water- with-smart- irrigation-system- in- barcelona/, accessed on November 24, 2022.

Link NYC, 2021, https://www. link.nyc/, accessed on December 29, 2021.

Liu, T., S. Mostafa, S. Mohamed and T.S. Nguyen, 2020, "Emerging Themes of Public-Private Partnership Application in Developing Smart City Projects: A Conceptual Framework", *Emerald Publishing Limited*, Vol. 11, No. 1, pp. 138-156.

Lombardi, P., S. Giordano, H. Farouh and W. Yousef, 2012, "Modelling the Smart City

Performance", *Innovation: The European Journal of Social Science Research*, Vol. 25, No. 2, pp. 137-149.

Luo, J., A. Gale, and X. He, 2001, "Investing in the Chinese Industry Via Joint Ventures Construction", *Building Research and Information*, Vol. 29, No. 4, pp. 277-285.

Macrotrends, 2022, "Tokyo, Japan Metro Area Population 1950-2023", https://www. macrotrends. net/ cities/ 21671/ tokyo/ population#: :text= The %20 current %20 metro % 20area % 20population, a%200 . 18 %25 %20decline %20from %202021., accessed on November 23, 2022.

Mahesa, R., Y. Anggoro, and R. Nugroho Perwiro Atmojo, 2021, "Smart Urban Services: Sustainable Development with the Smart City Concept in The New Jakarta City", *In The 2021 International Conference on Computer*, Control, Informatics and Its Applications.

Marsal-Llacuna, M.L., J. Colomer-Llinàs and J. Meléndez-Frigola, 2015, "Lessons in Urban Monitoring Taken from Sustainable and Livable Cities to Better Address the Smart Cities Initiative", *Technological Forecasting and Social Change*, Vol. 90, pp. 611-622.

McKinsey, 2018, "Smart Cities: Digital Solutions for a More Livable Future", https:// www. mckinsey. com/ /media /mckinsey/ business %20functions /operations/ our %20insights /smart %20cities %20digital %20solutions %20for %20a %20more %20livable %20future/ mgi- smart- cities- full-report.pdf, accessed on June 9, 2022.

My Hero Academia (MHA), 2019, "Home Team UPGRADE: Bot-Avengers, Assemble!", https:// www.mha. gov. sg/home- team- news/ story/ detail/ home- team-upgrade- bot- avengers- assemble!/, accessed on November 20, 2022.

Mosannenzadeh, F., M.R. Di Nucci and D. Vettorato, 2017, "Identifying and Prioritizing Barriers to Implementation of Smart Energy City Projects in Europe: An

Empirical Approach", *Energy Policy*, Vol. 105, pp. 191-201.

Norwood, S.R., and N.R. Mansfield, 1999, "Joint Venture Issues Concerning European and Asian Construction Markets of the 1990's", *International Journal of Project Management*, Vol. 17, No. 2, pp. 89-93.

Ojasalo, J. and H. Kauppinen, 2016, "Collaborative Innovation with External Actors: An Empirical Study on Open Innovation Platforms in Smart Cities", *Technology Innovation Management Review*, Vol. 6, pp. 12.

Özdemir, A.I., I. Erol, I.M. Ar, I. Peker, A. Asgary, T.D. Medeni and I.T. Medeni, 2020, "The Role of Blockchain in Reducing the Impact of Barriers to Humanitarian Supply Chain Management", *Emerald Publishing Limited,* Vol. 32, No. 2, pp. 454-478.

Özdoğan, I.D., and M. Talat Birgönül, 2000, "A Decision Support Framework for Project Sponsors in the Planning Stage of Build-Operate-Transfer (BOT) Projects", *Construction Management and Economics*, Vol. 18, No. 3, pp.343-353.

Özlem, A.K.A.Y. and N.Y. Pehlivan, 2018, "Cep Telefonu Seçiminin Bulanık Analitik Hiyerarşi ve Bulanık Analitik Ağ Süreci ile Belirlenmesi", *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, Vol. 40, pp. 161-175.

Pakkala, P., 2002, "Innovative Project Delivery Methods for Infrastructure", *Finnish Road Enterprise*, Helsinki, Vol. 19.

Patel, S.J., and C.R. Patel, 2020, "A Stakeholders Perspective on Improving Barriers in Implementation of Public Bicycle Sharing System (PBSS)", *Transportation Research Part A: Policy and Practice*, Vol. 138, No. 353-366.

Patil, A., V. Shardeo, A. Dwivedi, J. Madaan and N. Varma, 2021, "Barriers tTo Sustainability in Humanitarian Medical Supply Chains", *Sustainable Production and Consumption*, Vol. 27, pp. 1794-1807.

Pezzutto, S., R. Fazeli and M. De Felice, 2016, "Smart City Projects Implementation in Europe: Assessment of Barriers and Drivers", *International Journal of Energy Research*, Vol. 2, No. 2, pp. 46-55.

Phochanikorn, P., C. Tan and W. Chen, 2020, "Barriers Analysis for Reverse Logistics in Thailand's Palm Oil Industry Using Fuzzy Multi-Criteria Decision-Making Method for Prioritizing the Solutions", *Granular Computing*, Vol. 5, No. 4, pp. 419-436.

Public–Private Partnership (PPP) Council, 2022,"Definitions and Models", https:// www. pppcouncil. ca/ web/ P3_Knowledge _Centre/ About_P3s/ Definitions_ Models. aspx#: : text= Design %2DBuild %2DFinance %2DMaintain, under %20a %20long %2Dterm %20agreement., accessed on November 17, 2022.

PwC provides industry-focused assurance (PwC), 2019, "Creating the Smart Cities of the Future", https:// www. pwc. com/ gx/ en/ sustainability/ assets/ creating-the- smart- cities- of- the-future.pdf , accessed on June 9, 2022.

Ramita Verma, M.B.A., 2013, "PEST Analysis for Indian Luxurious Car Market", *International Journal of Management and Social Sciencs*, Vol. 2, No. 1, pp. 22-26.

Rana, N.P., S. Luthra, S.K. Mangla, R. Islam, S. Roderick and Y.K. Dwivedi, 2019, "Barriers to the Development of Smart Cities in Indian Context", *Information Systems Frontiers*, Vol. 21, No. 3, pp. 503-525.

Razmjoo, A., P.A. Ostergaard, M. Denai, M.M. Nezhad and S. Mirjalili, 2021, "Effective Policies to Overcome Barriers in the Development of Smart Cities", *Energy Research and Social Science*, Vol. 79, pp.102175.

Rezouki, S.E. and J.K.A. Hassan, 2019, "An Evaluation of Barriers Obstructing the Applicability of Public Private Partnership (PPP) in Infrastructure Development",

Civil Engineering Journal, Vol. 5, No. 12, pp. 2643-2664.

Saaty, T.L., 2001, *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex world*, RWS Publications, Pittsburgh, Pennsylvania, United States.

Saaty, T.L., 1996, "Decision Making with Dependence and Feedback: The Analytic Network Process", *International Journal of Scientific Engineering and Research*, Vol. 4922, No. 2.

Saaty, T.L., 2008, "Decision Making with the Analytic Hierarchy Process", *International Journal of Services Sciences*, Vol. 1, No. 1, pp. 83-98.

Saaty, T.L., 1988, *What is the Analytic Hierarchy Process?, In Mathematical Models For Decision Support*, Advanced Science Institutes Series, Discontinued series (NATO ASI F), Berlin, Heidelberg.

Sainati, T., N. Brookes and G. Locatelli, 2017, "Special Purpose Entities in Megaprojects: Empty Boxes or Real Companies?", *Project Management Journal*, Vol. 48, No. 2, pp. 55-73.

Sammut-Bonnici, T. and D. Galea, "PEST analysis, 2014, https:// www. mindtools. com., accessed on December 19, 2022.

Saunders, A., 1998, "Aspects of Funding for BOO Projects, Engineering", *Construction and Architectural Management, Main Products, Circuit Breaker (MCB)*, Vol. 5, No. 1, pp. 22-30.

Selim, A.M. and A.S. ElGohary, 2020, "Public-private Partnerships (PPPS) in Smart Infrastructure Projects: The Role of Stakeholders", *Hindawi Scientific Journals*, Vol. 16, No. 1, pp. 317-333.

Shen, L.Y., A. Platten and X.P. Deng, 2006, "Role of Public Private Partnerships to

Manage Risks in Public Sector Projects in Hong Kong", *International Journal of Project Management*, Vol. 24, No. 7, pp. 587-594.

Singh, A., and A.R. Singla, 2021, "Modeling and Analysis of Factors for Implementation of Smart Cities: TISM Approach", *Journal of Modeling in Management, Emerald Publishing Limited*, Vol. 17, No. 4, pp. 1587-1622.

Startlandnews, 2022, "Kansas City's Smart City taking shape with kiosks' arrival", https:// www.startlandnews. com/ 2016/03/ kansas- citys- smart- city- taking-shape- kiosks- arrival/, accessed on December 24, 2022.

Statista, 2022, "Population of Istanbul in Turkey from 2007 to 2021", https:// www. statista. com/ statistics/ 899051/ turkey- population- of-istanbul/, accessed on December7, 2022.

Superdecisions, 2022, https:// www. superdecisions. com/, accessed on June 12, 2022.

Swamy, R.R.D., P. Tiwari and A. Sawhney, 2018, "Assessing Determinants Of PPP Project Performance: Applying AHP to Urban Drinking Water Sector in India", *Emerald Publishing Limited, Property Management*, Vol. 36, No. 1, pp. 67-85.

Tang, L., Q. Shen and E.W. Cheng, 2010, "A Review of Studies on Public–Private Partnership Projects in the Construction Industry", *International Journal of Project Management*, Vol. 28, No. 7, pp. 683-694.

Taşlıcalı, A.K. and S. Ercan, 2006, "The Analytic Hierarchy and the Analytic Network Processes in Multicriteria Decision Making: A Comparative Study", *Journal of Aeronautics and Space technologies*, Vol. 2, No. 4, pp. 55-65.

The Guardian, 2015, "Singapore introduces Robocoach to keep older citizens in shape", https:// www. theguardian. com/ technology/ 2015/ oct/ 14/ singapore - introduces - robocoach- to- keep- older- citizens- in- shape, accessed on November 27, 2022.

Tiong, R.L. and J. Alum, 1997, "Distinctive Winning Elements in BOT Tender", *Engineering, Construction and Architectural Management, Main Products: Circuit Breaker (MCB)*, Vol. 4, No. 2, pp. 83-94.

Valmohammadi, C. and A. Ghassemi, 2016, "Identification and Prioritization of the Barriers of Knowledge Management Implementation Using Fuzzy Analytical Network Process: A Case Study of the Iranian Context", *Vine was an American short-form (VINE), Journal of Information and Knowledge Management Systems*, Vol. 47, No. 10, pp. 459–480.

Valmohammadi, C. and S. Dashti, 2016, "Using Interpretive Structural Modeling and Fuzzy Analytical Process to Identify and Prioritize the Interactive Barriers of E-Commerce Implementation", *Information and Management*, Vol. 53, No. 2, pp. 157-168.

Wang, K., Y. Ke, T. Liu, and S. Sankaran, 2021, "Social Sustainability in Public–Private Partnership Projects: Case Study of the Northern Beaches Hospital in Sydney, Engineering", *Emerald Publishing Limited, Construction and Architectural Management*, Vol. 29, No. 6, pp. 2437-2460.

Weforum, 2019, "How Japan is Using Technology for the 2020 Olympics", https:// www. weforum. org/ agenda/ 2019/ 06/ why- japanese- innovation- is- surging-ahead -of -the -2020 -olympics/, accessed on November 24, 2022.

Winch, G.M., 2000, "Institutional Reform in British Construction: Partnering and Private Finance", *Building Research and Information*, Vol. 28, No. 2, pp. 141-155.

Woodward, D.G., 1995, "Use of Sensitivity Analysis in Build-Own-Operate-Transfer Project Evaluation", *International Journal of Project Management*, Vol. 13, No. 4, pp. 239-246.

World Bank, 2019, "PPP Arrangements", https:// ppp. worldbank. org/ public-private- partnership/ agreements, accessed on July 17 2021.

Yang, J.Q. and J.L. You, 2019, "Research on the Application of PPP Model in Smart City Projects", *In IOP Conference Series: Earth and Environmental Science*, Vol. 330, No. 5, pp. 052039-052060.

Zadeh, L.A., 1996, "Fuzzy Sets, In Fuzzy Sets", *Fuzzy Logic and Fuzzy Systems: Selected Papers by Lotfi a Zadeh*, Vol. 4, pp. 394-432.

Zhang, X., 2004, "Improving Concessionaire Selection Protocols in Public / Private Partnered Infrastructure Projects", *Journal of Construction Engineering and Management*, Vol. 130, No. 5, pp. 670-679.

Zhang, X.Q., M.M. Kumaraswamy, W. Zheng and E. Palaneeswaran, 2002, "Concessionaire Selection for Build-Operate-Transfer Tunnel Projects in Hong Kong", *Journal of Construction Engineering and Management*, Vol. 128, No. 2, pp. 155-163.

APPENDIX A: THE FINAL BARRIERS LIST

Table A.1. The final barriers list after literature review.

Code	**Barriers**	**Source**
EF	**Economicand Financial Barriers**	
EF.1	Foreigninvestors' perception of a country as high risk due to economicinstability	Babatunde *et al.* (2015) Razmjoo *et al.* (2021)
EF.2	High interest & inflation rate andcurrencyfluctuation	Babatunde *et al.* (2015) Addae *et al.* (2019) Edwards *et al.* (2020) Swamy *et al.* (2017)
EF.3	Limited capitalavailability	Lam and Yang (2020) Babatunde *et al.* (2015) Bjørner (2021) Pezzutto *et al.* (2016) Addae *et al.* (2019) Swamy *et al.* (2017) Patel (2020) Mosannenzadeh *et al.* (2017)
EF.4	High costs	Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Cheong *et al.* (2016) Mosannenzadeh *et al.* (2017)

Table A.1. The final barriers list after literature review. (cont.)

Code	**Barriers**	**Source**
EF	**Economicand Financial Barriers**	
EF.5	High lenght of paybackperiod	Pezzutto *et al.* (2016)
EF.6	Problems of delays in receivingpayments	Babatunde *et al.* (2015)
TT	**Technologyand Technical Barriers**	
TT.1	Absence of personal data securityprotection	Pezzutto *et al.* (2016) Rana *et al.* (2018) Singh andSingla (2021) Wang *et al.* (2021)
TT.2	Weakness of broadband network infrastructure	Razmjoo *et al.* (2021) Addae *et al.* (2019)
TT.3	Lack of knowledge and expertise of the parties	Lam and Yang (2020) Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Ferraris *et al.* (2020) Cheong *et al.* (2016) Patel (2020)
SCE	**Sociocultura land Environmental Barriers**	
SCE.1	Resistance to change and unawareness of the public on advantages of PPP	Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Addae *et al.* (2019) Jayasena *et al.* (2022)

Table A.1. The final barriers list after literature review. (cont.)

Code	**Barriers**	**Source**
EF	**Economicand Financial Barriers**	
SCE.2	Poorinteraction between local government sand citizens	Pezzutto *et al.* (2016) Rana *et al.* (2018) Razmjoo *et al.* (2021) Singh andSingla (2021) Mosannenzadeh *et al.* (2017)
SCE.3	Inadequate environmental & social assessment before the implementation ofprojects	Pezzutto *et al.* (2016) Razmjoo *et al.* (2021)
PGL	**Political, Governmentaland Legal Barriers**	
PGL.1	Politicalinstability	Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018) Jayasena *et al.* (2022)
PGL.2	Inefficiency and long delaysdue to bureaucratic procedures	Lam and Yang (2020) Babatunde *et al.* (2015) Rana *et al.* (2018) Ferraris *et al.* (2020)
PGL.3	Insufficient government guarantee	Babatunde *et al.* (2015) Swamy *et al.* (2017)
PGL.4	Lack of transparency	Lam and Yang (2020) Babatunde *et al.* (2015) Pezzutto *et al.* (2016) Rana *et al.* (2018)

Table A.1. The final barriers list after literature review. (cont.)

Code	**Barriers**	**Source**
EF	**Economicand Financial Barriers**	
PGL.5	Insufficient legal and regulatory framework	Babatunde *et al.* (2015) Bjørner (2021) Pezzutto *et al.* (2016) Rana *et al.* (2018) Razmjoo *et al.* (2021) Addae *et al.* (2019) Ferraris *et al.* (2020) Jayasena *et al.* (2022) Edwards *et al.* (2020) Mosannenzadeh *et al.* (2017)

APPENDIX B: QUESTIONNAIRE BASED ON THE INTERVIEWS

Table B.1. Information about expert.

Information about Expert	
Expert's Name/ Surname	
JobTitle	
Work Experience (years)	
The types of Projects Completed by the Expert	

Table B.2. Linguistic variables.

Code	**Linguistic variables**
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Verystrongly to extremely preferred
9	Extremely preferred

Table B.3. Example selection for barriers.

Example Selection for Barriers																	
																	Barrier2 is **Very Strongly preferred** than Barrier1
Barrier 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Barrier 2**
Barrier 3 is **Strongly to very strongly preferred** than Barrier 4																		
Barrier 3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Barrier 4**

Table B.4. Compare the main barriers to public-private partnership (PPP) implementation in smart urban services by importance .

Compare the main barriers to Public-Private Partnership.																		
Economic and Financial Barriers (EF)	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	Technology and Technical Barriers (TT)
Economic and Financial Barriers (EF)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Sociocultural Barriers (SCE) and Environmental
Economic and Financial Barriers (EF)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Political. Governmental and Legal Barriers (PGL)
Technology and Technical Barriers (TT)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Sociocultural and Environmental Barriers (SCE)
Technology and Technical Barriers (TT)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Political. Governmental and Legal Barriers (PGL)
Sociocultural and Environmental Barriers (SCE)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Political. Governmental and and Legal Barriers (PGL)

Table B.5. Pairwise comparison with respect.

Pairwise comparison with respect.																		
Foreign investors' perception of a country as high risk due to economic instability (EF.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High interest and inflation rate and currency fluctuation (EF.2)
Foreign investors' perception of a country as high risk due to economic instability (EF.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Limited capital availability (EF.3)
Foreign investors' perception of a country as high risk due to economic instability (EF.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High costs (EF.4)
Foreign investors' perception of a country as high risk due to economic instability (EF.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High lenght of payback period (EF.5)
Foreign investors' perception of a country as high risk due to economic instability (EF.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Problems of delays in receiving payments (EF.6)
High interest and inflation rate and currency fluctuation (EF.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Limited capital availability (EF.3)

Table B.5. Pairwise comparison with respect. (cont.)

High interest and inflation rate and currency fluctuation (EF.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High costs (EF.4)
High interest and inflation rate and currency fluctuation (EF.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High lenght of payback period (EF.5)
High interest and inflation rate and currency fluctuation (EF.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Ödemelerde Yaşanan gecikme sorunları (EF.6)
Limited capital availability (EF.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High costs (EF.4)
Limited capital availability (EF.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High lenght of Paybackperiod (EF.5)
Limited capital availability (EF.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Problems of delays in receiving payments (EF.6)
High costs (EF.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High lenght of Payback period (EF.5)
High costs (EF.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Problems of delays in receiving payments (EF.6)
High length of paybackperiod (EF.5)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Problems of delays in receiving payments (EF.6)

Table B.6. Pairwise comparison with respect to technology and technical barriers (TT).

Pairwise comparison with respect.																	
Absence of personal data security protection (TT.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Weakness of broadband network infrastructure (TT.2)
Absence of personal data security protection (TT.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of knowled Geand expertise of the parties (TT.3)
Weakness of broadband network infrastructure (TT.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Knowledge and expertise of the parties (TT.3)

Table B.7. Pair wise comparison with respect to sociocultural and environmental barriers (SCE).

Pair wise comparison with respect to Sociocultural																	
Resistance to change and unawareness of the public on advantages of PPP (SCE.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Poorinter action between local government sand citizens (SCE.2)
Resistance to change and unawareness of the public on advantages of PPP (SCE.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inadequate environmental and social assessment before the implementation of projects (SCE.3)
Poorinteraction Between Local Government sand citizens (SCE.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inadequate environmental and social assessment before the implementation of projects (SCE.3)

Table B.8. Pair wise comparison with respect to political. Governmental and legal barriers (PGL).

Pair wise comparison																	
Political instability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government Guarantee (PGL.3)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government Guarantee (PGL.3)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)

Table B.9. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "Foreign investors' perception of a country as high risk due to economic in stability".

Pair wise comparison the Political.																	
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient government guarantee (PGL.3)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	9	8	Lack of transparency (PGL.4)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Insufficient Government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)

Table B.10. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

Pair wise comparison the Political.																	
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.3)
Politicalin Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency And long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.3)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)

Table B.11. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "Limited capital availability".

Pair wise comparison the Political.																	
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient government guarantee (PGL.3)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency And long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient government guarantee (PGL.3)
Inefficiency And long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Inefficiency And long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)

Table B.12. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "High costs".

Pair wise comparison the Political.																	
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delaysdue to bureaucratic procedures (PGL.2)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Politicalin Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Inefficiency and Long delays due to bureau craticprocedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Insufficient Government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Insufficient Government Guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal Andregulatory framework (PGL.5)

Table B.13. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "High length of payback period".

Pair wise comparison the Political.																	
Political in Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Political in stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Political in Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Insufficient Government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)

Table B.14. Pair wise comparison the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

Pair wise comparison the Political.																	
Politicalin Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inefficiency and long delays due to bureaucratic procedures (PGL.2)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Politicalin stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Politicalin Stability (PGL.1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient Government guarantee (PGL.3)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Transparency (PGL.4)
Inefficiency and long delays due to bureaucratic procedures (PGL.2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal And regulatory framework (PGL.5)
Insufficient government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of transparency (PGL.4)
Insufficient Government guarantee (PGL.3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)
Lack of transparency (PGL.4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Insufficient legal and regulatory framework (PGL.5)

APPENDIX C: PAIRWISE COMPARISONS MATRICES AND ANALYSIS RESULTS

Table C.1. Comparison matrix of the main barriers.

Main	EF			TT			SCE			PGL		
EF	**1.00**	**1.00**	**1.00**	1.00	1.50	2.00	1.50	2.00	2.50	0.67	1.00	2.00
TT	0.50	0.67	1.00	**1.00**	**1.00**	**1.00**	1.00	1.50	2.00	0.40	0.50	0.67
SCE	0.40	0.50	0.67	0.50	0.67	1.00	**1.00**	**1.00**	**1.00**	0.40	0.50	0.67
PGL	0.50	1.00	1.50	1.50	2.00	2.50	1.50	2.00	2.50	**1.00**	**1.00**	**1.00**

Table C.2. Value of fuzzy synthetic extent of pairwise comparisons for the main barriers.

	L	M	U
S1	0.181	0.308	0.541
S2	0.126	0.206	0.337
S3	0.100	0.150	0.240
S4	0.196	0.336	0.541

Table C.3. Degree of possibility of pairwise comparisons for the main barriers.

V(S1>S2)	1.000	V(S2>S1)	0.602	V(S3>S1)	0.272	V(S4>S1)	1.000
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	0.671	V(S4>S1)	1.000
V(S1>S4)	0.925	V(S2>S4)	0.518	V(S3>S4)	0.193	V(S4>S1)	1.000

Table C.4. The minimum degree of possibility of pairwise comparisons for the main barriers.

d'(A1)	V (S1 $\geq$ S2. S3. S4) = 0.925
d'(A2)	V (S2 $\geq$ S1. S3. S4) = 0.518
d'(A3)	V (S3 $\geq$ S1. S2. S4) = 0.193
d'(A4)	V (S4 $\geq$ S1. S2. S3) = 1.000
Weightvector	W = (0.925; 0.518; 0.193; 1.000)
Normalized weight vector	W' = (0.351; 0.197; 0.073; 0.379)

EF	EF.1			EF.2			EF.3			EF.4			EF.5			EF.6		
EF.1	1.00	1.00	1.00	0.33	0.40	0.50	0.40	0.50	0.67	0.29	0.33	0.40	0.50	0.67	1.00	0.67	1.00	2.00
EF.2	2.00	2.50	3.00	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	1.00	1.50	2.00	1.50	2.00	2.50
EF.3	1.50	2.00	2.50	0.67	1.00	2.00	1.00	1.00	1.00	0.50	0.67	1.00	0.50	1.00	1.50	1.00	1.50	2.00
EF.4	2.50	3.00	3.50	0.50	1.00	1.50	1.00	1.50	2.00	1.00	1.00	1.00	1.50	2.00	2.50	2.00	2.50	3.00
EF.5	1.00	1.50	2.00	0.50	0.67	1.00	0.67	1.00	2.00	0.40	0.50	0.67	1.00	1.00	1.00	0.50	1.00	1.50
EF.6	0.50	1.00	1.50	0.40	0.50	0.67	0.50	0.67	1.00	0.33	0.40	0.50	0.67	1.00	2.00	1.00	1.00	1.00

Figure C.1. Comparison matrix of the economic and financial barriers.

Table C.5. Value of fuzzy synthetic extent of pairwise comparisons for the economic and financial barriers.

	L	M	U
S1	0.057	0.094	0.180
S2	0.119	0.218	0.387
S3	0.092	0.174	0.323
S4	0.152	0.266	0.436
S5	0.073	0.137	0.264
S6	0.061	0.111	0.215

V(S1>S2)	0.328	V(S2>S1)	1.000	V(S3>S1)	1.000	V(S4>S1)	1.000	V(S5>S1)	1.000	V(S6>S1)	1.000
V(S1>S3)	0.524	V(S2>S3)	1.000	V(S3>S2)	0.821	V(S4>S2)	1.000	V(S5>S2)	0.641	V(S6>S2)	0.472
V(S1>S4)	0.138	V(S2>S4)	0.829	V(S3>S4)	0.648	V(S4>S3)	1.000	V(S5>S3)	0.825	V(S6>S3)	0.661
V(S1>S5)	0.714	V(S2>S5)	1.000	V(S3>S5)	1.000	V(S4>S5)	1.000	V(S5>S4)	0.463	V(S6>S4)	0.288
V(S1>S6)	0.880	V(S2>S6)	1.000	V(S3>S6)	1.000	V(S4>S6)	1.000	V(S5>S6)	1.000	V(S6>S5)	0.842

Figure C.2. The degree of possibility of pairwise comparisons for the economic and financial barriers.

Table C.6. The minimum degree of possibility of pairwise comparisons for the economic and financial barriers.

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5. S6) = 0.138
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5. S6) = 0.829
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5. S6) = 0.648
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5. S6) = 1.000
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4. S6) = 0.463
d'(A6)	V (S6 $\geq$ S1. S2. S3. S4. S5) = 0.288
Weight vector	W = (0.138; 0.829; 0.648; 1.000; 0.463; 0.288)
Normalized weight vector	W' = (0.041; 0.246; 0.192; 0.297; 0.138; 0.086)

Table C.7. Comparison matrix of the technology and technical barriers.

TT	TT.1			TT.2			TT.3		
TT.1	**1.00**	**1.00**	**1.00**	0.67	1.00	2.00	0.50	0.67	1.00
TT.2	0.50	1.00	1.50	**1.00**	**1.00**	**1.00**	0.40	0.50	0.67
TT.3	1.00	1.50	2.00	1.50	2.00	2.50	**1.00**	**1.00**	**1.00**

Table C.8. Value of fuzzy synthetic extent of pairwise comparisons for the technology and technical barriers.

	L	M	U
S1	0.171	0.276	0.529
S2	0.150	0.259	0.419
S3	0.276	0.466	0.727

Table C.9. The degree of possibility of pairwise comparisons for the technology and technical barriers.

V(S1>S2)	1.000	V(S2>S1)	0.935	V(S3>S1)	1.000
V(S1>S3)	0.571	V(S2>S3)	0.407	V(S3>S2)	1.000

Table C.10. The minimum degree of possibility of pairwise comparisons for the technology and technical barriers.

d'(A1)	V (S1 $\geq$ S2. S3) = 0.571
d'(A2)	V (S2 $\geq$ S1. S3) = 0.407
d'(A3)	V (S3 $\geq$ S1. S2) = 1.000
Weight vector	W = (0.571; 0.407; 1.000)
Normalized weight vector	W' = (0.289; 0.206; 0.506)

Table C.11. Comparison matrix of the sociocultural and environmental barriers.

SCE	SCE.1			SCE.2			SCE.3		
SCE.1	**1.00**	**1.00**	**1.00**	0.50	1.00	1.50	0.67	1.00	2.00
SCE.2	0.67	1.00	2.00	**1.00**	**1.00**	**1.00**	0.50	0.67	1.00
SCE.3	0.50	1.00	1.50	1.00	1.50	2.00	**1.00**	**1.00**	**1.00**

Table C.12. Value of fuzzy synthetic extent of pairwise comparisons for the main barriers

	L	M	U
S1	0.167	0.327	0.659
S2	0.167	0.291	0.585
S3	0.192	0.382	0.659

Table C.13. The degree of possibility of pairwise comparisons for the sociocultural and environmental barriers.

V(S1>S2)	1.000	V(S2>S1)	0.920	V(S3¿S1)	1.000
V(S1>S3)	0.895	V(S2>S3)	0.812	V(S3>S2)	1.000

Table C.14. The minimum degree of possibility of pairwise comparisons for the sociocultural and environmental barriers.

d'(A1)	V (S1 $\geq$ S2. S3) = 0.895
d'(A2)	V (S2 $\geq$ S1. S3) = 0.812
d'(A3)	V (S3 $\geq$ S1. S2) = 1.000
Weight vector	W = (0.895; 0.812; 1.000)
Normalized weight vector	W' = (0.331; 0.300; 0.369)

PGL	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	1.00	1.50	2.00	1.50	2.00	2.50	0.50	1.00	1.50	0.50	1.00	1.50
PGL.2	0.50	0.67	1.00	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.40	0.50	0.67	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.50	0.67	1.00
PGL.4	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.67	1.00	2.00
PGL.5	0.67	1.00	2.00	0.50	1.00	1.50	1.00	1.50	2.00	0.50	1.00	1.50	1.00	1.00	1.00

Figure C.3. Comparison matrix of the political. Governmental and legal barriers.

Table C.15. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers.

	L	M	U
S1	0.116	0.252	0.470
S2	0.086	0.181	0.415
S3	0.084	0.161	0.369
S4	0.086	0.194	0.443
S5	0.095	0.213	0.443

Table C.16. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers.

V(S1>S2)	1.000	V(S2>S1)	0.808	V(S3>S1)	0.737	V(S4>S1)	0.849	V(S5¿S1)	0.894
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	0.936	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	0.962	V(S3>S4)	0.898	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	0.909	V(S3>S5)	0.842	V(S4>S5)	0.947	V(S5>S4)	1.000

Table C.17. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers.

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 0.808
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 0.737
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 0.849
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 0.894
Weight vector	W = (1.000; 0.808; 0.737; 0.849; 0.894)
Normalized weight vector	W' = (0.239; 0.188; 0.172; 0.198; 0.209)

EF.1	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	0.50	1.00	1.50	1.00	1.50	2.00	0.50	1.00	1.50	0.67	1.00	2.00
PGL.2	0.67	1.00	2.00	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.50	0.67	1.00	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.67	1.00	2.00
PGL.5	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00

Figure C.4. Comparison matrix of the political. Governmental and legal barriersac cording to the "Foreign investors' perception of a country as high risk due to economic instability.

Table C.18. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and Legal Barriers according to the "Foreign investors'" perception of a country as high risk due to economic instability.

	L	M	U
S1	0.093	0.219	0.471
S2	0.089	0.199	0.500
S3	0.089	0.185	0.471
S4	0.084	0.199	0.471
S5	0.076	0.199	0.412

Table C.19. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers according to the "Foreign investors'" perception of a country as high risk due to economic instability.

V(S1>S2)	1.000	V(S2>S1)	0.953	V(S3>S1)	0.919	V(S4>S1)	0.950	V(S5>S1)	0.941
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	0.966	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	1.000	V(S3>S4)	0.967	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	1.000	V(S3>S5)	0.968	V(S4>S5)	1.000	V(S5>S4)	1.000

Table C.20. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers according to the "Foreign investors'" perception of a country as high risk due to economic instability.

d'(A1)	V (S1 ≥ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 ≥ S1. S3. S4. S5) = 0.953
d'(A3)	V (S3 ≥ S1. S2. S4. S5) = 0.919
d'(A4)	V (S4 ≥ S1. S2. S3. S5) = 0.950
d'(A5)	V (S5 ≥ S1. S2. S3. S4) = 0.941
Weight vector	W = (1.000; 0.953; 0.919; 0.950; 0.941)
Normalized weight vector	W' = (0.210; 0.200; 0.193; 0.199; 0.198)

EF.2	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	1.50	2.00	2.50	2.00	2.50	3.00	0.50	1.00	1.50	1.00	1.50	2.00
PGL.2	0.40	0.50	0.67	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.33	0.40	0.50	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50
PGL.5	0.50	0.67	1.00	0.50	1.00	1.50	0.50	1.00	1.50	0.67	1.00	2.00	1.00	1.00	1.00

Figure C.5. Sample table comparison matrix of the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

Table C.21. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

	L	M	U
S1	0.153	0.301	0.529
S2	0.083	0.169	0.379
S3	0.085	0.166	0.397
S4	0.081	0.188	0.397
S5	0.081	0.176	0.370

Table C.22. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

V(S1>S2)	1.000	V(S2>S1)	0.632	V(S3>S1)	0.643	V(S4>S1)	0.683	V(S5>S1)	0.634
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	0.988	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	0.941	V(S3>S4)	0.933	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	0.979	V(S3>S5)	0.969	V(S4>S5)	1.000	V(S5>S4)	0.958

Table C.23. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High interest and inflation rate and currency fluctuation".

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 0.632
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 0.643
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 0.683
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 0.634
Weight vector	W = (1.000; 0.632; 0.643; 0.683; 0.634)
Normalized weight vector	W' = (0.278; 0.176; 0.179; 0.190; 0.176)

EF.3	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	1.50	2.00	2.50	1.50	2.00	2.50	0.50	1.00	1.50	0.50	1.00	1.50
PGL.2	0.40	0.50	0.67	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.40	0.50	0.67	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50
PGL.5	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	0.67	1.00	2.00	1.00	1.00	1.00

Figure C.6. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the "Limited capital availability".

Table C.24. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Limited capital availability".

	L	M	U
S1	0.127	0.269	0.496
S2	0.082	0.173	0.395
S3	0.086	0.173	0.423
S4	0.081	0.192	0.414
S5	0.085	0.192	0.441

Table C.25. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Limited capital availability".

V(S1>S2)	1.000	V(S2>S1)	0.736	V(S3>S1)	0.755	V(S4>S1)	0.788	V(S5>S1)	0.803
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	1.000	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	0.942	V(S3>S4)	0.947	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	0.942	V(S3>S5)	0.946	V(S4>S5)	1.000	V(S5>S4)	1.000

Table C.26. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Limited capital availability".

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 0.736
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 0.755
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 0.788
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 0.803
Weight vector	W = (1.000; 0.736; 0.755; 0.788; 0.803)
Normalized weight vector	W' = (0.245; 0.180; 0.185; 0.193; 0.197)

EF.4	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	1.00	1.50	2.00	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50
PGL.2	0.50	0.67	1.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.67	1.00	2.00	0.50	1.00	1.50	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50
PGL.5	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	0.67	1.00	2.00	1.00	1.00	1.00

Figure C.7. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the "High costs".

Table C.27. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs".

	L	M	U
S1	0.089	0.219	0.441
S2	0.089	0.185	0.471
S3	0.089	0.199	0.500
S4	0.080	0.199	0.441
S5	0.084	0.199	0.471

Table C.28. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs".

V(S1>S2)	1.000	V(S2>S1)	0.920	V(S3>S1)	0.954	V(S4>S1)	0.947	V(S5>S1)	0.951
V(S1>S3)	1.000	V(S2>S3)	0.966	V(S3>S2)	1.000	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	0.967	V(S3>S4)	1.000	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	0.967	V(S3>S5)	1.000	V(S4>S5)	1.000	V(S5>S4)	1.000

Table C.29. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High costs".

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 0.920
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 0.954
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 0.947
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 0.951
Weight vector	W = (1.000; 0.920; 0.954; 0.947; 0.951)
Normalized weight vector	W' = (0.210; 0.193; 0.200; 0.198; 0.199)

EF.5	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	0.67	1.00	2.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.2	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50	0.67	1.00	2.00	0.67	1.00	2.00
PGL.3	0.67	1.00	2.00	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50
PGL.5	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50	0.67	1.00	2.00	1.00	1.00	1.00

Figure C.8. Comparison matrix of the Political. Governmental and Legal Barriers (PGL) according to the "High lenght of payback period".

Table C.30. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period".

	L	M	U
S1	0.088	0.200	0.510
S2	0.083	0.200	0.480
S3	0.092	0.200	0.540
S4	0.075	0.200	0.420
S5	0.079	0.200	0.450

Table C.31. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period".

V(S1>S2)	1.000	V(S2>S1)	1.000	V(S3>S1)	1.000	V(S4>S1)	1.000	V(S5>S1)	1.000
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	1.000	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	1.000	V(S3>S4)	1.000	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	1.000	V(S3>S5)	1.000	V(S4>S5)	1.000	V(S5>S4)	1.000

Table C.32. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "High lenght of payback period".

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 1.000
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 1.000
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 1.000
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 1.000
Weight vector	W = (1.000; 1.000; 1.000; 1.000; 1.000)
Normalized weight vector	W' = (0.200; 0.200; 0.200; 0.200; 0.200)

EF.6	PGL.1			PGL.2			PGL.3			PGL.4			PGL.5		
PGL.1	1.00	1.00	1.00	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50
PGL.2	0.50	1.00	1.50	1.00	1.00	1.00	0.50	1.00	1.50	0.50	1.00	1.50	0.50	1.00	1.50
PGL.3	0.67	1.00	2.00	0.67	1.00	2.00	1.00	1.00	1.00	0.67	1.00	2.00	0.67	1.00	2.00
PGL.4	0.67	1.00	2.00	0.67	1.00	2.00	0.50	1.00	1.50	1.00	1.00	1.00	0.67	1.00	2.00
PGL.5	0.67	1.00	2.00	0.67	1.00	2.00	0.50	1.00	1.50	0.50	1.00	1.50	1.00	1.00	1.00

Figure C.9. Comparison matrix of the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

Table C.33. Value of fuzzy synthetic extent of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

	L	M	U
S1	0.079	0.200	0.450
S2	0.075	0.200	0.420
S3	0.092	0.200	0.540
S4	0.088	0.200	0.510
S5	0.083	0.200	0.480

Table C.34. The degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

V(S1>S2)	1.000	V(S2>S1)	1.000	V(S3>S1)	1.000	V(S4>S1)	1.000	V(S5>S1)	1.000
V(S1>S3)	1.000	V(S2>S3)	1.000	V(S3>S2)	1.000	V(S4>S2)	1.000	V(S5>S2)	1.000
V(S1>S4)	1.000	V(S2>S4)	1.000	V(S3>S4)	1.000	V(S4>S3)	1.000	V(S5>S3)	1.000
V(S1>S5)	1.000	V(S2>S5)	1.000	V(S3>S5)	1.000	V(S4>S5)	1.000	V(S5>S4)	1.000

Table C.35. The minimum degree of possibility of pairwise comparisons for the political. Governmental and legal barriers (PGL) according to the "Problems of delays in receiving payments".

d'(A1)	V (S1 $\geq$ S2. S3. S4. S5) = 1.000
d'(A2)	V (S2 $\geq$ S1. S3. S4. S5) = 1.000
d'(A3)	V (S3 $\geq$ S1. S2. S4. S5) = 1.000
d'(A4)	V (S4 $\geq$ S1. S2. S3. S5) = 1.000
d'(A5)	V (S5 $\geq$ S1. S2. S3. S4) = 1.000
Weight vector	W = (1.000; 1.000; 1.000; 1.000; 1.000)
Normalized weight vector	W' = (0.200; 0.200; 0.200; 0.200; 0.200)