AHP-BASED RISK IDENTIFICATION RISK ASSESSMENT AND RISK ALLOCATION APPROACH FOR THE MICROMOBILITY SECTOR

by

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ABSTRACT

AHP-BASED RISK IDENTIFICATION RISK ASSESSMENT AND RISK ALLOCATION APPROACH FOR THE MICROMOBILITY SECTOR

In today's world, where the micromobility sector, which is one of the most important sub-headings of the sharing economy model, in which people pay for the products and services they need for a short time, without owning them, is rapidly becoming widespread, many people and institutions are directly and indirectly affected by this situation. To minimize the negative effects and take the necessary precautions, the current situation should be revealed and the risks that may arise should be determined. After examining the sharing economy and risk allocation concepts, first of all, the risks arising from the micromobility sector were determined in this study. Afterward, the AHP method, which is one of the multi-criteria decision-making methods, was explained and the surveys prepared were evaluated by the experts, the determined risks were distributed among the alternatives, and the opportunity to guide and share responsibility for the applications to be made after that was provided. Based on this study, it was easier to determine the main topics for future research.

ÖZET

MİKROMOBİLİTE SEKTÖRÜ İÇİN AHP TABANLI RİSK TANIMLAMA RİSK DEĞERLENDİRMESİ VE RİSK PAYLAŞIMI YAKLAŞIMI

İnsanların kısa süreli ihtiyaç duydukları ürün ve hizmetlere erişim sağladıkları süre boyunca sahip olmadan ücret ödedikleri paylaşım ekonomisi modelinin ulaştırma sektöründe en önemli altbaşlıklarından biri olan mikromobilite sektörü hızla günlük yaşantının bir parçası haline gelmektedir. Bundan dolayı da doğrudan ve dolaylı şekilde birçok kişi ve kurum bu durumdan etkilenmektedir. Oluşan negatif etkilerin minimize edilmesi ve gerekli önlemlerin uygulanmaya başlanılması için mevcut durumun ortaya konulması ve ortaya çıkabilecek risklerin tespit edilmesi gerekmektedir. Paylaşım ekonomisi ve risk paylaşımı konseptlerinin incelenmesi sonrasında, bu çalışmada öncelikle mikromobilite sektörü dolayısıyla ortaya çıkan risklerin tespiti gerçekleştirilmiştir. Sonrasında çok kriterli karar verme yöntemlerinden AHP methodunun özellikleri açıklanmış ve hazırlanan anketler uzmanlar tarafından değerlendirilerek belirlenen risklerin alternatifler arasında dağılımı yapılarak bundan sonrasında yapılacak uygulamalar için yol gösterimi ve sorumluluk paylaşımı imkanı sağlanmıştır. Bu çalışma temel alınarak gelecekte yapılacak araştırmalar için temel başlıkların belirlenmesinde kolaylık sağlanmıştır.

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LIST OF ACRONYMS/ABBREVIATIONS

TDM	Transportation Demand Management
MM	Micromobility
e-PMV	Electric- Personal Motor Vehicle
e-bike	Electric Bike
e-scooter	Electric Scooter
AHP	Analytical Hierarchy Process
VMT	Vehicle Miles Traveled
ITF	International Transportation Forum
PPP	Public-Private Partnership
OECD	The Organisation for Economic Co-operation and Development
SAE	Society of Automotive Engineers
IoT	Internet of Things
GHG	Greenhouse Gas

1. INTRODUCTION

The transportation sector, which provides people and companies with access to the economic market, is an important area that has a direct impact on issues such as economic development, environmental development, urbanization and the determination of living spaces so as a result of that governments and companies are constantly trying to develop infrastructure and provide services to all people by increasing alternatives [1, 2].

The mobility concept is explained by the fact that people provide compulsory or arbitrary travel through transportation in their participation in the activities they need to perform to live. On the other hand, many negative effects such as poor air quality, inadequate parking space and loss of time due to traffic congestion arise due to these transportation movements, and the 2-wheeled electrıc motor-powered vehicles that can be used to solve them are rapidly becoming widespread in cities [3]. Nowadays, while the young population tends to use private motor vehicles less than usual, reasons such as increasing fuel prices, environmental sensitivities, and the spread of easier-to-use transportation alternatives with developing technology are effective to provide changes in transportation habits [4]. Considering that individual transportation can be realized within the framework of the possibilities and limits provided by the city where one lives and that there are more and more limited opportunities due to the inadequacy of the existing infrastructure systems, serious problems arise especially in access to transportation. Therefore, people's transportation opportunities should be developed and improved with different transportation alternatives and social equality should be ensured [5].

The demand for transportation, which indicates the number of transportation mobility that people participate in by their living conditions, varies depending on variables such as age, income level, time and region. With the number of transportation alternatives that will increase, it is predicted that there will be an increase in the number of travel demands of people due to the increase in accessibility. The main issue here is the integration between transportation modes in an affordable way, in line with the analyzes obtained from personal data. It seems that planning for increasing accessibility will bring the best solutions to transportation problems. The aim of increasing accessibility and mobility paves the way for creating transportation demand management (TDM). The purpose of the TDM is to provide more effective transportation opportunities by making innovations in infrastructure and transportation services to reduce personal vehicle dependency or redistribute demand. To achieve this, marketing and the testing of different alternatives by people should be encouraged, and its basis lies in informing people about their economic and social benefits. [6, 7].

Establishing a transportation network where personal motor vehicles are not preferred and alternatives such as walking, cycling and public transportation are used has become a focus of attention by the administrations. For this reason, arrangements are made in budgets and investment models, and cooperation with the private sector is becoming common due to the high cost of changing the existing transportation network to the governments. In this way, it is foreseen that more livable cities will be formed, traffic congestion will decrease and the places reserved for parks can be used more beneficially by the public. Although the death and injury rates per kilometer of non-motorized vehicles are higher, this is due to the inadequacy of the current infrastructure system, and data is obtained by travel over low distances. With the usage of non-motorized vehicles, it is expected that economic development will accelerate due to the decrease in fuel prices and vehicle costs and it direct impact an increase in social justice [8].

The micromobility (MM) transportation alternative has emerged today as a result of changes in mobility demand, changes in commuting habits, the adaptability of technological infrastructure to develop transportation alternatives, and growth in the economic market area covered by transportation.

Micromobility, which refers to the use of environmentally friendly light vehicles for public welfare, is causing a lot of changes and developments since it is predicted to minimize the usage of fossil fuel-powered cars, which has been regarded as problematic in the past few years. Automobile usage reduction is estimated to have effects such as reduced traffic congestion, decreased greenhouse gas emissions, lower noise pollution and improved air quality [9]. Together with the flexibility and accessibility of MM, combined with the services provided by public transport, which offers fast travel over short and long distances, it aims to reduce individual automobile use and thus create a sustainable transportation option. The driving experience is expected to improve, especially with the spread of lightweight and folding scooters [10].

E-bikes and e-scooters are examples of personal motor vehicles (e-PMV) whose driving power is provided by rechargeable lithium-ion batteries, which can move faster due to the electrical energy produced by the battery and electric motor, and whose brake and gas are controlled by a hand lever. It draws attention to city life as a new micromobility alternative that emerged with the change due to its avoidance of traffic, low carbon emissions, ease of maintenance, and economically convenient service. These two-wheeled electric vehicles are used not only for personal transportation but also for utility and cargo transport. Average speeds range from 20 to 60 km/h, these vehicles reaching top speeds of 25 km/h in China and 32 km/h in America [11]. These vehicles are more popular than standard bicycles because they are utilized for short distances. They cover more than 45 percent of non-motorized vehicles and e-PMV style vehicles, according to the results of a survey conducted in Paris and Barcelona in 2019. Electric-powered vehicle speeds can be 2-3 times higher than typical bicycle speeds with the use of electric motors, allowing for long-distance travel and solving transportation issues caused by poor infrastructure. On the other hand, the usage of sidewalks by these vehicles that allow speedy mobility may result in accidents and injuries. Because they are tiny and foldable, e-scooters are now more generally used in Europe than bicycles. They also enable a gateway to alternate modes of mobility. Bicycles are commonly used for short distances of 7-10 km in European cities [12].

Among the micromobility vehicle options, electric scooters appear to be the most common and prominent vehicle. Currently, there are changes in the transportation sector's service standpoint, and the major motivation is to build an infrastructure system that can serve people from all social classes, instead of people and products traveling quickly and across great distances which is the general aim of motorized transportation [13]. According to the Innovation Center for Mobility and Societal Change (InnoZ) GmbH scooter-sharing industry report [14], 84 percent of scooter-share systems in more than 60 cities are located in Europe. Around the world, 99 percent of scooter-sharing systems offer free-floating services, allowing users to pick up and drop off scooters wherever they wish. The number of scooters more than tripled between 2017 and 2018, and 26 scooter manufacturers offer sharing services. The fact that 97 percent of these scooters use electric power demonstrates the growing interest in electric motors. When the number of users is considered, the number of scooter-sharing service members increased from 350,000 in 2017 to 1,800,000 in 2018, almost quadrupling.

The main motivation for the use of scooters stands out as the ease of parking and the opportunity to travel regardless of public transportation and the existing infrastructure service quality [15]. Difficulty in finding parking spaces, the inadequacy of public transportation and taxi facilities, changes in demographics and urbanization, and the emergence of new business areas are among the reasons for the increased interest in micromobility, and these show that there are completely different economic perspectives behind this sector. An important step has been taken in this area with the bicycle-sharing application offered in 2013 by Jump, dockless via GPS and smartphones With its low initial fee, local government support and operational cost, an easy and economically advantageous alternative has emerged for users. As a result of the dockless system, while the market demand increased, social needs were also met. In 2017, e-scooters were put into service by the Bird company and spread to more than 100 American and 11 European cities in the same year. Another important company, Lime, provides service in more than 100 American and 27 European cities. The widespread use of ride-sharing applications constitutes an important motivation for scooter sharing. In 2015, 15% of American people used applications such as Uber or Lyft, while this figure reached 36% in 2018 [16]. As companies have grown, they have adopted the approach of producing vehicles in line with their intended use, and have chosen to alternate between hardware cost investment and maintenance and out-of-service vehicle costs [17].

However, there are concerns about the widespread use of e-scooters. In the study conducted by Gössling [18] to reveal the problems caused by the introduction of e-scooters, 10 big cities in America, Europe and Australia were selected in line with the reports of e-scooter companies, and the results were obtained by examining the qualitative content analysis of a total of 173 media broadcasts made in these cities. According to the results, it is observed that the main motivation for the spread of e-scooters is to reduce traffic congestion, while air pollution and the fight against climate change seem to be the main reasons. E-scooters, which became popular with fast and easy transportation in the eyes of users, could be put into service with delays and pauses in practice due to the necessity of legal regulations in some cities. In media publications, health-safety problems, the use of spaces in public spaces, maximum speed limits and careless use of vehicles come to the fore as main concerns before e-scooters enter service.

E-bikes, which provide faster, long-range and economical transportation, are becoming more and more common due to hardware improvements, developing battery technology, and the increase in the applicability of the economic model [19]. Bicycle-sharing applications, which emerged as an environmentally friendly solution to the last-mile problem, which defines the problem of short-distance transportation between home and public transportation or between work and public transportation, can thus close the existing gap to create an integrated transportation system. Other potential benefits of this system can be shown as increased mobility opportunities, economic savings, reduced traffic congestion, low-priced service and operation opportunities, reduced fuel consumption, increased use of public transportation, and health and environmental awareness. The 4 main features of this service are bicycles of different structures, user interface technology, advanced technology and stations. From an economic point of view, another important investor in these services, which are generally financed by local governments, is advertising companies. When the environmental effects caused by the decrease in the use of personal vehicles are examined, decreases in CO2 emissions are observed. When the issues to be considered are examined, it is necessary to make an access and vehicle tracking with electronic cards against bicycle theft, while improvements must be made to reduce the damage to the environment due to fossil fuel vehicles used in the redistribution of bicycles. When the obstacles against the adaptation of these systems are examined, limited infrastructure systems, theft, high technology investment cost, financing and security issues stand out as important topics to be considered [20].

1.1. Goals and Objectives

The goal of this thesis is to identify the risks that may be encountered during the application and evaluate these risks from different aspects and allocate them between the state and the private sector. This goal is achieved by the following objectives:

(i) To provide necessary information about the sharing economy because the micromobility sector is one of the sub-topics of the sharing economy.
(ii) To establish the necessary infrastructure for the importance of risk identification and risk allocation in projects.
(iii) To give general information about the micromobility sector and to explain the current situation about the identified main aspects, usage patterns and service operations.
(iv) To explain the mathematical method with general information about the Analytical Hierarchy Process (AHP), which is the analysis method used in the research.
(v) Establishing an idea for risk allocation by determining the relative importance of each alternative of the determined criteria.
(vi) to analyze the outputs obtained in line with the expert opinions in accordance with the outputs of the existing research.

1.2. Organization of the Thesis

First of all, a literature review examining the concept of the sharing economy and its relationship with the micromobility sector was conducted. Afterward, risk identification and risk allocation related to project risk management are explained. Then, a literature review containing general information about the micromobility sector was made and a separate literature review was made for the economic, environmental, safety and public-policy aspects. After the main risk and sub-risk criteria were determined, the application method of the AHP method was explained and the analysis part was started. The evaluations made by the experts in the analysis part are presented in the results and discussion part. Finally, the thesis was completed with the conclusion part, which summarizes the study and the outputs.

1.3. Literature Review

1.3.1. What is Sharing Mobility ?

Mobility, which defines the possibility of traveling, requires people to have information about the services and tools necessary to travel, access, use and pay [21,22].One of the most important changes experienced because of technological developments is the consumption habits of people, and this habit also affects the transportation sector and attracts people's attention to shared transportation alternatives [23]. In the studies carried out, individual vehicle ownership and usage rates are decreasing, especially in people born after 1980 who constitute the majority of the population, and there is a change in transportation behaviors and it has become a necessity to respond to this changing demand [24].

As information and communication technologies are intertwined with the economic market, there has been a chance to make assets functional without owning them. For this reason, the shared transportation model has entered our lives with the pay-as-you-go method without the costs of purchasing, maintenance and use of vehicles [25].

Shared transportation, which describes the concept that people can use a car, bicycle or other means of transportation when they need it, for a short time, without taking responsibility for owning a vehicle, usually with the help of online payment methods, has become an extremely important research and investment topic. The main reasons for the introduction of shared mobility into our lives are the inadequacy of existing transportation systems, the need for transportation alternatives to increase economic movements, the development of public transportation, the response to environmental sensitivities, the solution of problems in city planning and the increase of social equality [26].

Shared mobility includes car sharing, personal car sharing, bike sharing, scooter sharing, ride-sharing, and sharing through service providers. Many communities are benefiting from shared mobility because it improves transit accessibility, increases multimodality, reduces vehicle ownership and vehicle miles traveled (VMT) in some situations, and provides new means to access products and services. Because of their role in transportation planning, public transportation, and parking legislation, local and regional governments are the most prevalent public partners of shared mobility providers. Local governments have long sought to reduce traffic congestion, improve air quality, and regulate parking. Climate change planning has increased municipal governments' understanding of shared mobility in recent years. Security and health, taxation, insurance, parking, advertising, intermodal integration, planning, accessibility and equality, data sharing-security, and standardization are emerging as the areas of interest of local and national governments regarding shared transportation [27].

Shared mobility is one of the areas of sharing economy with the highest potential over urban transportation networks, facing significant problems due to the rapid increase in the number of private cars and motorization rates. The relevance of shared mobility has expanded in recent decades, as need to understand how to incorporate it into urban transportation networks and improve its efficiency from a social, environmental, and economic standpoint. However, most studies have treated shared mobility as if it were a stand-alone system, ignoring the complexities of its interconnections with other modes of transportation, making it extremely tough to estimate its impact on the transportation system [28].

1.3.2. What is Micromobility ?

Shared micromobility is a sub-title of shared transportation, and it defines the use of vehicles such as bicycles, e-bikes, scooters and e-scooters according to the preferred service model within the scope of service regions where services are provided by using online payment methods temporarily in line with short-term needs, as in shared transportation. Shared micromobility consists of 2 main areas: bike sharing and scooter sharing. By Shaheen and Cohen [29], bike-sharing applications are divided into 3 main different service models as station centered(docked), station-free roaming(dockless), and hybrid model. In the station-based bike-sharing model, the bike is returned to any station, while in the dockless bike-sharing model, the bike can be left anywhere within the service area. In the hybrid system, the bicycle taken from the station or anywhere can be left at the station or the desired location. Scooter-sharing services, on the other hand, are the name given to the service that allows users to travel with access to electric or motorized, or human-powered scooters as a result of joining service provider organizations. Scooter-sharing services are divided into 2 main categories by Shaheen et al. [30] as electric scooters withstanding design and moped-style scooters that are seated and travel with electric or gas-powered motors [31].

Although bicycles have been used as a means of transportation in cities for many years, traditional bicycles have begun to have difficulties in meeting this need due to the effect of urbanization. Today, the 4th generation process of bike sharing has begun, due to bicycles that can move with an electric motor without the need for human power, and the ability to provide services such as tracking and payment of vehicles regarding developing information and communication technologies.

Bicycle sharing is a shared transportation subheading that is expected to be a solution to the first-last mile problem of people who work with the method of picking up vehicles from stations located in the city, one-way or inbound, and leaving them in an area within the station or service area. Bike-sharing service providers are responsible for operations such as charging, maintenance, distribution and tracking of vehicles and earn money from their users by charging per minute or distance [31]. With the introduction of bike-sharing services, opportunities have emerged for cities to demonstrate their commitment to tackling problems such as climate change, public health problems, traffic congestion, and fossil fuel dependence.

e-Scooter sharing services, on the other hand, are a transportation alternative that has become popular in recent years, especially in America, Europe and China, and it has started to be preferred due to their ability to go faster with a longer range, especially with the support of electric motors. Service providers distribute the vehicles in the regions they serve in the cities and make them freely available to people and are responsible for operations such as maintenance and charge redistribution [31].

There are different limits in different countries regarding the hardware features of micromobility vehicles. In the definition made by the ITF, it has been determined as the general name to describe bicycle-e-bike-scooter-e-scooter, which can reach a maximum speed of 45 km / h, weigh less than 350 kg, and can move with human or electric motor power. Since the legal regulations in the world are generally made up of bicycles, the regulations regarding scooters that have just entered the market are insufficient. The speed limit in Europe is 25 km/h for electrically powered micromobility vehicles, 20-32 km/h in the United States and 25 km/h in Asia [32].

2. SHARING ECONOMY

Nowadays, it is becoming more difficult to have products and services. Depending on factors such as changing consumer habits, economic costs and environmental sensitivities. The habit of accessing and using products or services for a short period in accordance with their needs without taking responsibility for their needs is becoming a new way of consumption by people and demand is increasing regularly. Due to this demand, companies led by the private sector and venture capital have tried to generate income by providing short-term access and use of products using the developing technological infrastructure.

Product sales and ownership, which form the basis of traditional business models, are replaced by ownership as much as the short-term need for products, and it is called the economic market; sharing economy created by service providers in this field. Changing consumer habits, secure shopping opportunities with internet-based online platforms and electronic devices, and easy and fast access opportunities provided by personal phones and applications can be cited as the main reasons for this change. It is expected that the decrease in production and consumption will result in environmental contributions as well as individual savings. In the sharing economy, which appears to be a hybrid mixture of the traditional and the new business model when analyzed as an economic model, service suppliers generate economic income by attracting users to use their services [33]. Since legal, economic, sociological and many factors are taken into consideration within the scope of the sharing economy, a single definition explaining its scope cannot be made. Acquier et al. [34] stated that the sharing economy consists of three main titles in the study as a result of the literature review. These are the access economy, the platform economy, and the social economy. While the access economy describes the use of products and services in the most optimal way, not owning the products and not paying much attention to external results can cause environmental and economic problems. The most important problem is the disruption of the production leg due to insufficient support. While the platform economy covers the economy created by service providers for shopping between the product owner and the user, the emergence of monopoly and inequalities due to increasing competition seems to be the main problem. Social economy, on the other hand, includes the use of products and services, with social and environmental sensitivities, and increasing the participation of groups with a low socioeconomic level in society, without making a profit [34].

The sharing economy defines the ability to access and use tangible products such as cars and intangible things such as money and time through online services and is used for economic reasons rather than social or cultural factors. Enforcement of laws that affect all stakeholders of this economic cycle and establishing standards and providing assurance on issues such as safety, workers' rights and health are necessary for the market to grow in a healthy competitive environment. It is estimated that natural resources will be spent less and environmental benefits will be provided to society because of the use of fewer products [35]. There are 2 elements of the sharing economy, which are the temporary possession of products and services by consumers without owning them, and the provision of these services via the internet. Today, when the sharing economy replaces collaborative consumption, cooperative consumption covers the coordinated acquisition and distribution of the product, while in the sharing economy, service is provided by third agents via the internet. In the business models developed in this field, income is generated by the short-term rental of the products, while the free use of the products together with the advertising income stands out as another alternative and seems to be an innovative sector for the future [36].

According to Hamari et al. [37] it is put forward the hypothesis that the sharing economy progresses with 4 main motivations, which are entertainment, sustainability, economy and reputation. As a result of their evaluation of 168 participants, they determined that while the aim of obtaining an economic contribution in using the applications within the scope of the sharing economy stood out as the most important motivation, environmental awareness and reputation did not directly affect the use. Another issue that is curious about the sharing economy is whether the service providers will share their revenues with the public and whether they will deliver the service they provide to every segment of society [38].

In 2015, According to the study by Matzler et al. [39] on the sharing economy business model conducted by companies, 6 steps are shown to progress optimally. First of all, instead of selling products, it is to ensure continuity by converting the use of the product into income, and to provide quality maintenance services by making the products disposed of by the users and unused resources and capacities a part of the market, then to act as an intermediary platform when necessary and to encourage shared consumption. In this way, an increase in the number of customers is expected. When the sharing economy market is examined, it is expected that the area with a market of 15 billion dollars in 2013 will have a market of 335 billion dollars in 2025 [40].

In the case of the disappearance of service providers, which are intermediaries in the sharing economy, which allows the short-term exchange of products and information between people with digitalization, the risk of conflict between the consumer and the owner is higher. Although the world's interest in this field is increasing, it has been agreed that information sharing should be provided to increase user satisfaction, even though discussions continue due to reasons such as security, inequality, and environmental effects. Owing to the sharing economy, a decrease in prices is expected thanks to supply-demand balances, pricing and effective resource use, and an increase in the service quality of companies is expected as a result of increased competition. This sector, whose systematic framework is drawn with government incentives and regulations, should become more open to innovative solutions and transform into new business models [41].

With the widespread use of mobile phones, people have the opportunity to access services in line with real-time information, and service providers have the opportunity to provide services using real-time information. These intermediary platforms help to create economic movements by providing integration between the product and the user. The data shared and stored during this integration are provided based on mutual trust, and brand perception is important in this economic model, as companies can maintain their reliability through transparent evaluations. While providing this perception, environmental approaches and smart green city concepts are beneficial. Governments apply three different approaches in the regulation of these services: intervention, non-intervention, and waiting and action [42]. Although there is a point of view regarding the sharing economy that it is a damaging innovation to the companies serving in the current system, the lack of legal regulations causes companies to hesitate to step into this sector and demand privileges from the states for their new companies. It is possible for companies to follow and direct their users with the information they obtain, and the accuracy of the information obtained cannot be assured. For this reason, sharing economy companies need to cooperate with local and national governments. Fundamentally, the issues that need to be secured are insurance, tax, liability and human rights issues [43].

Today, the largest component of the sharing economy is the shared transportation sector which includes the sector of micromobility [42]. When the shared transportation sector is examined, it is seen that the micromobility industry is the sector that receives the most investment after the shared driving sector and has made a breakthrough in the market [44]. Developing information and communication technologies enable shared transportation applications to be accessed with real-time information and using smartphones, GPS tracking and the Internet of things (IoT) pave the way to create other than traditional transportation alternatives that have become widespread and a new business model has emerged as we called shared micromobility. The temporary use of vehicles such as scooters and bicycles on a need-based rental method is called shared micromobility. While it is expected that people's participation in economic movements and their access to business centers will increase, it is expected that emissions and time costs will decrease due to reduced traffic due to the decreased vehicle use caused by preferring the use of micromobility vehicles [45].Another study, by Schor and Vallas [46] showed that it is expected that there will be a decrease in GHG emissions due to the decrease in the use of individual vehicles in the transportation sector, which has a significant share in carbon emissions with the help of sharing mobility. In the study examining the relationship between the sharing economy and the micromobility sector, Gao and Li [47] compared the economic models of the Mobike bike-sharing service serving in China and England and they have shown that the business environment is effective to create a sustainable economic model and that a sustainable structure cannot be obtained by using only environmentally friendly products. Detailed analysis of economic and social-environmental situations is essential for companies' value analysis and should not be done due to legal regulations.

3. RISK ALLOCATION

There are variations depending on the context of the definition of risk. Today, especially the field and technology in which risk is evaluated affect these risk definitions. There are problems with the objectivity of risk assessment in the emergence of this problem, especially the difference between the approach of the public and the approach of the experts, and the uncertainties about the objectivity of the experts. In the case of realization of the emerging risks, the multidimensional effects and the difficulty of measuring these effects mathematically make it difficult for the public to use technologies that may cause health risks in particular. While Fischhoff et al. [48] explain the dimensions of technological risks, they describe the effects of risk on the public and employees, while specifying the areas of benefit, cost, environment, disease, and death in the usage process, with the fear caused by uncertainty.

Although there are different opinions on the basic definition of risk, project risk is defined by the PMBOK Guide as uncertain events that are likely to have positive or negative consequences on the project. If these events occur, it is expected that there will be a decrease in the economic, temporal performance and expected quality of the project. The risk management applied in to prevent the emergence of such undesirable situations covers the processes of identifying and evaluating potential risks and implementing appropriate measures and aims to minimize the effects of the consequences they will create with the possibility of risks. Risk management is defined by the PMBOK Guide as a process consisting of six steps. These can be summarized as creating a risk management model, identifying risks, qualitative risk analysis, quantitative risk analysis, risk intervention process and risk monitoring, respectively. In these processes, information obtained from past experiences is shared and used to identify unknown or unpredictable risks [49].

Qualitative risk analysis helps to identify risks and evaluate the stage with methods such as surveys: while reviewing the possibilities and potential results and better understanding the project. In this way, risk control and distribution can be realized. Quantitative analysis, on the other hand, is used to determine the possible effects of individual uncertainties and possible cost timeouts with the help of computer programs, and there is a correlation between the results obtained and the suitability of the data used. The greater the uncertainty of risk, the more variable the response methods should be. The control over the project by the institutions and individuals who assume the consequences of uncertainties by risk allocation should increase to that extent, otherwise, the probability of failure of projects and disruptions will increase [50].

Risk allocation means dividing responsibility for gains or losses resulting from the occurrence of an event and assuming between different stakeholders and is usually determined at the beginning of the project with project contracts. The application of risk management and analysis throughout the project is because uncertainties are present at every stage of the project and cannot be completely avoided. While the aim here is to minimize the costs that will arise due to the risk to be encountered in the project, no effort is made to minimize the risk cost that each stakeholder will face, and generally, the most equitable risk sharing among the stakeholders is tried to be applied [51].

Due to the risk allocation carried out without considering the capacities of the stakeholders, there may be results such as weakness in the project management, an increase in the cost of providing the service or product, conflicts between the stakeholders and the withdrawal of the private sector from investments. Nguyen's [52] study focus on the results of the risk distribution analysis made by examining the contracts of 21 highway projects implemented with the PPP method in the USA, while the responsibility for socio-political risks is generally undertaken by the state, financial, operational and environmental risks are taken under the responsibility of the private sector. In the risks taken under joint responsibility, risks such as contract changes that may occur after the start of the project come to the fore.

To obtain results from using technology to create a more sustainable ecosystem that helps people to live under good conditions and a livable society requires risk analysis during the implementation of new technologies. Despite the risk analysis process can be changed according to the applying area it should be noted that uncertainties and assumptions need to be highlighted to consider more accurate results. İnnovation and technology applications are examined according to their financial, environmental and safety aspects and risk analysis and allocation between government, private enterprises and public agencies can help to anticipate outcomes. Also, the risk assessment process is a scientific approach, acknowledgment of the general knowledge of society and the public's perspective can help to consider different aspects of implementation [53].

According to the definition made by the Kirwan [54], infrastructure services are generally compiled under 2 headings, and they are services that ensure inclusion in economic and social life, such as structures such as transportation structures built to enable people to participate in economic activities and structures such as hospitals built to benefit from social public services. The implementation of the state-private sector cooperation method in projects that seem costly by the states in terms of finance is becoming more common day by day. This method is preferred especially in complex projects such as infrastructure projects. On the other hand, in the PPP system, which is created by the coming together of many different institutions, the uncertainties and risks that may be encountered due to integration between stakeholders, financing, operation processes and procurement issues, the issue of meeting the expectations of the public and political regulations are increasing. For this reason, interest in studies on risk management processes is increasing. Depending on the environment in which the project is implemented, economic and legal regulations are effective in the distribution of project risks among stakeholders. According to the results of the survey conducted with 65 participants who are managers of PPP projects implemented in Melbourne, Australia, it has been determined that the main factor in the success of PPP projects can be achieved by the distribution of risks among appropriate stakeholders [55]. Due to risk sharing, it is expected to increase the integration between the people responsible for different processes such as procurement, planning, implementation, operation, maintenance, and to achieve more effective planning and project management, as well as a decrease in operational costs during the process [56].

The value-for-money method, which aims to minimize the cost and to create project quality and project effectiveness with the most optimal conditions, basically means increasing the usability of the money spent and constitutes the main motivation of PPP projects. To achieve this aim, appropriate risk distribution among the stakeholders is required. Generally, while governments try to shift the responsibility of risks to the private sector, doing this improperly can cause costly damage, because of the incentives, regulations and financial opportunities demanded by the companies that undertake the risk responsibility. In addition, companies that do not want to take on too much responsibility in risk distribution can withdraw from projects that they can manage more accurately, while companies with less ability can enter these jobs. Risk distribution, which expresses the change in the risk management responsibility to be applied against the risks that may be encountered among the project stakeholders, becomes even more important when the direct relationship of risks with uncertainty is considered since these changes that occur with environmental factors will directly affect the economic situation of the stakeholders. These environmental uncertainties were gathered under 5 main headings in general and they were determined as institutional, social and industrial, economic, organizational and project-specific [57].

In an environment where the private sector can produce better quality services and products with lower economic costs, it is expected that if risks are not shared, public services will be privatized with higher costs in the tender and implementation processes and the operation process will take longer than normal. In addition, it seems that with risk sharing, the lines of duty of institutions will be determined more clearly and it will be possible to act in accordance with their business plans. In his study, Karim [58] revealed the risk factors that arise in the projects carried out with the cooperation of the state-private sector, through a comprehensive literature review, and according to the results obtained, the changes in the laws due to political problems, long project approval periods, variable state management, insufficient incentives. showed that the main problem is the applicability of the projects. If such situations continue, it is expected that the private sector will avoid taking responsibility rather than entering the projects or taking responsibility for the risks.

The low applicability of economic development models in countries with insufficient infrastructures causes an increase in investments made in countries, especially in the field of transportation. Governments can deal more with planning and laws, due to the private sector stakeholders taking on the risks they may encounter, and thus create a more stable management system in the country. In this way, more entrepreneurial investments are accelerated and the quality of life increases both socially and economically. Chou and Pramudawardhni [59] asked academicians and project managers what kind of risk distribution the 69 risk factors determined in projects should have in their study, and according to the results determined, only political risks (3%) should be covered by the state, while 21 (30%) risks are privately owned and 46 risks (67%) should be shared between the public and private sectors.

In complex projects, the method of involving the public in the decision-making processes is used to meet the sensitivities of the people such as living standards, environment, and economic situation. The public participation approach, which defines the involvement of the public in the decision-making stages during the project by sharing their knowledge and experience, is used to produce solutions to potential problems. With the use of this approach in the identification and distribution of risks, it will be possible to realize the uncertainties that may be overlooked and to plan in a way that takes into account social sensitivities [60].

4. METHODOLOGY

4.1. Analytic Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) method, developed by T. L. Saaty in 1971, is a method that can be used in physical and social fields, especially in multi-criteria decision-making situations, based on a mutual comparison between criteria. In the evaluation method designed according to the hierarchical structure created, the criteria are brought together according to the homogeneity axiom. In the application of the AHP method, three main rules should be taken into account, these are separation, comparison and the concretization of the obtained priority orders. During the separation, the criteria are separated according to their levels, and an evaluation is made from the highest level to the lowest level. In comparison, criteria at the same level are evaluated comparatively and their importance degrees are obtained according to each other. During concretization, the priority levels obtained from each level are multiplied by the lower levels to obtain local and global priority values.

4.1.1. Axioms of AHP

4.1.1.1. Reciprocal Axiom. According to this proposition, which constitutes the basic logic of AHP, the numerical equivalent of the importance of the first criterion against the other criterion among the 2 criteria compared should be used as the opposite when evaluating the importance of the second criterion compared to the first criterion. That is, it should be in the form of $aij = 1/aji$ in the evaluation matrix. In this way, inconsistencies are avoided.

4.1.1.2. Homogenity Axiom. It is a proposition stating that the level and status of the criteria being compared should be related to each other and that the dependence between the sub-criteria and the upper criteria should be logical. Binary evaluations between this axiom and criteria give more consistent results. In addition, it is not possible to make judgments that a criterion is infinitely better than another criterion.

4.1.1.3. Dependence Axiom. According to this proposition, it states that the priority levels of the criteria at the same level in the hierarchical structure should be independent of the criteria and alternatives at the lower levels. In other words, the criteria should be evaluated independently of the alternatives.

4.1.1.4. Expectations Axiom. It states that the hierarchical structure covers all criteria and alternatives. The results of the decision makers' judgments will lead to deficiencies if all criteria are not found in the hierarchical structure applied and the evaluation will be inconsistent [61].

To make logical and functional decisions in the decision-making process on complex multi-criteria issues, decision-makers are often used as judgments in the process of evaluating perspectives from environmental, social and political perspectives. In this way, in situations where uncertainty and risks are high, different factors should be reviewed to form a hierarchical structure, and the AHP method is a useful approach in this sense. In evaluations where individual approaches are insufficient in terms of knowledge and experience, the most optimal results can be found together with the benefit-cost analysis between different alternatives so that decisions can be made in the interests of the majority. The features that these decision-making processes should have were determined by Saaty [62] as the ability to easily create a decision-making structure, to be used by individuals or groups, and the ability of stakeholders to agree on the decision without the need for specific knowledge. For this reason, Saaty [62] stated that while creating the AHP, first of all, the problem definition should be made and important factors selected to be used in the creation of the structure, then these factors should be evaluated by the people's views and these evaluations should be shown numerically. As a result of the evaluation, the priorities of the factors at each level are determined and the result is obtained, and finally, the sensitivity and consistency analyzes of the obtained results are performed. One of the biggest advantages of

AHP is to help people reach judgment by reflecting on the emotions, experiences and approaches of people to the decision-making process together.

In the study Miller [63] stated that 7 elements are the ideal number in his study on the number of elements depending on the information flow that people can evaluate correctly at the same time because the information is immeasurable and dimensionless, and he explained this as the right decision-making width. It is known that people have a certain memory and evaluation capacity in the responses given depending on the information flow. In their study on the ideal number of elements, Saaty [64] examined the relationship between the dimensions of pairwise comparison matrices and the inconsistency index and consistency ratio and determined that as the number of elements increased, the decrease in the inconsistency ratio decreased. As a result of this study, they showed that a maximum of 9 criteria should be used while determining that the ideal number of elements is 7 or less. In the case of group decision-making, the geometric mean should be used to reveal the general approach of the group by bringing together individual evaluations. In this way, the importance levels of individuals are reflected in the evaluation [65].

4.1.2. Making a Pair-wise Comparison

The numerical equivalents of the evaluation are obtained by using the 1-9 comparison scales introduced by Saaty when making a pairwise comparison. During this evaluation, a square matrix is created by expressing which criterion is more important and how much more important, and $n \times (n-1)/2$ comparisons are made in an evaluation with n criteria due to the reciprocal proposition. Table 4.1 below shows the rating scale of AHP evaluation [62].

Table 4.1. Rating Scale of AHP.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective.
3	Moderate Importance	Judgement slightly favor one activity over another.
5	Strong Importance	Judgement strongly favor on activity over another.
7	Very Strong Importance	An activity is favored very strongly over another.
9	Extreme Importance	Favoring one activity over another is of the highest possible order of affirmation.

4.1.3. AHP Working Principle

4.1.3.1. Principle 1. First of all, a single purpose is determined for the solution of the problem and placed at the beginning of the hierarchical structure.

4.1.3.2. Principle 2. Different alternatives are determined to be evaluated for the solution of the problem.

4.1.3.3. Principle 3. The criteria to be considered in the evaluation of alternatives are determined at different levels and evaluated at each level, and the hierarchy formation is completed [66].

4.1.4. How does AHP Work ?

4.1.4.1. Problem and Goal Definition . First of all,the problem and purpose are clearly defined. A hierarchical structure is created so that the criteria and sub-criteria required to achieve the determined goal are related to each other.Afterward, the alternatives to be used to achieve this goal are determined and evaluated.

4.1.4.2. Creating the Comparison Matrix. The process of creating the pairwise comparison matrix and evaluating the criteria among each other is the most critical part of the AHP method, and first of all, if the number of evaluated criteria is n, a square matrix of n x n size is created. Then, using the verbal scale given above Table 4.1 among the matrix elements, the upper triangular part of the matrix is filled in such a way that each element aij bigger than 0. Then, the lower triangular part is filled in line with the reciprocal proposition so that $aij = aji$, and the comparison process is completed. In cases where extra criteria are compared, if the condition $aij = aik/ajk$ is satisfied, this matrix is consistent and its maximum eigenvalue is equal to $n(\lambda_{max} = n)$. Then, the element weights of this matrix are found by solving the eigenvector problem $A \times w = \lambda_{max} \times w$. Mathematical representation is shown as

$$\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = \lambda_{max} \times \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix}, \tag{4.1}$$

where w represents the priority eigenvector and λ_{max} represents principal eigenvalue and here A is a comparison matrix that is filled by experts. Then, the value of each matrix element a_{ij} is normalized by dividing it by the sum of the values of the elements in the column is expressed as

$$x_{ij} = \frac{a_{ij}}{\sum_i aij}, \tag{4.2}$$

where x_{ij} represents the normalized value of a_{ij}.

Then, the weights of the criteria are found with the arithmetic mean of the elements in the row in the normalized matrix and the eigenvector is obtained is expressed as

$$w_i = \sum_1^n x_{ij}/n, \tag{4.3}$$

where w_i is the weight of criteria and n is the number of elements in the row where x_{ij} defined before.

4.2. Consistency of AHP

One of the most critical issues regarding AHP is checking whether the evaluations are consistent. Due to the subjective nature of people, being influenced by their knowledge and emotions and making evaluations on intangible matters prevents them from making fully consistent judgments. In his study, Saaty stated that if there is no inconsistency in a subject, it would not be possible for new ideas to emerge and be accepted, and he mentioned that inconsistency, even if it is small, is necessary. For this reason, it is accepted that the rate of inconsistency should not exceed 10% for the evaluation made in the AHP analysis to be taken into account. If the participant comments that X is 3 times more important than Y, 5 times more important than Z, and then evaluates that Z is 7 times more important than Y, inconsistent results will emerge and the stage of re-evaluation should be returned. Although every consistent comparison requires the formation of a reciprocal matrix, not every reciprocal matrix has to give consistent results, and this is because the relationship between different criteria cannot be fully established in the dual comparison process due to human nature.

After the weights are found, the principal eigenvalue is calculated to measure whether the evaluation made is consistent. The principal eigenvalue is found as

$$\lambda_{max} = \frac{1}{n} \times \sum_{1}^{n} \frac{a_{ij} \times w_j}{w_i}, \tag{4.4}$$

where λ_{max} is the principal eigenvalue. Here a_{ij} represents the elements of comparison matrix and w_i is the weight of criteria.

The consistency index value is found by using the principal eigenvalue value. In the case of having an inconsistent matrix, since $\lambda_{max} \neq n$ will occur, after principle eigenvalue is used as an index of deviation from consistency since it is known to have principle eigevalue is bigger than n in measuring this inconsistency level because all elements of matrix A are bigger than zero. By averaging other eigenvalues starting from $i = 2$ with. We calculate how far our $n - 1$ matrix eigenvalues are from the consistent case. The consistency index value is obtained as

$$CI = \frac{\lambda_{max} - n}{n - 1}, \tag{4.5}$$

where CI is the consistency ındex value, n is the number of criteria and λ_{max} is the principal eigenvalue.

Finally, using the consistency index value, the consistency ratio value is calculated. In this calculation, the random consistency index value created by Saaty that changes according to the number of criteria is used which represents the average CI values calculated from randomly generated reciprocal matrices. In obtaining the RI value, Saaty [61] randomly generated 500 diagonally symmetric matrices filled with 1-9 verbal scales and calculated whether they came lower than 0.10. The RI values used are shown below. It was stated by Saaty that the CR value should not exceed 0.1. For this reason, he showed that the number of evaluated criteria should not be large, and he stated that if the number of criteria is more than 10, the effects on the inconsistency calculation will be less. The random consistency index table is shown in Table 4.2.

Table 4.2. Random Consistency Index.

Order	1	2	3	4	5	6	7	8	9	10	11	12
R.I	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54

The consistency ratio can be found by using a consistency index and a random index. By dividing the consistency index by a random index, a consistency ratio can be obtained. This is expressed as

$$CR = \frac{CI}{RI_{(n)}}, \tag{4.6}$$

where CR is the consistency ratio, CI is the consistency index and RI represent the random consistency index.

5. CASE STUDY

The areas that need to be revealed in the study on micromobility have been examined and economic, environmental, safety and public-policy titles have been determined to review them in the most comprehensive way. When investigating the implications of the micromobility industry on sustainability, transportation behaviors, city environment, energy consumption, and safety should all be considered [67]. The key headings identified by the results of the main criteria and parameters to be utilized in the evaluations in the field of micromobility were economic, environmental, safety, and planning based on the results of the comprehensive literature review [68].

5.1. Economic Aspect

Transportation, which is one of the indispensable elements of economic development, is necessary for people to participate in economic movements with each other and is an intermediary for the realization of basic elements such as unemployment, property values, production, import-export and shopping. On the other hand, indirect negative effects such as time costs, environmental pollution and unplanned urbanization due to traffic caused by inadequate transportation infrastructure are caused by the transportation sector. Today, the most important issue is the energy consumption and energy costs experienced due to the transportation sector, and these problems are tried to be avoided by using alternative transportation vehicles. These economic effects are shaped by the environment, and it is expected that companies that offer services suitable for the region in pricing will stand out in the market competition. Depending on the changing transportation preferences, planners focus on approaches that aim to increase people's access to transportation based on easier and more efficient use of resources, rather than the approach focused on increasing the distance and speed of vehicles [69].

The micromobility sector is generally financed by investment capital and can continue to grow in this way. Micromobility companies, which can provide dockless service, are growing owing to the online payment systems that have developed with the use of the internet of things and the global positioning system in the transportation sector, together with smartphones [70].

When the e-scooter market structure is examined, the fact that this area, which is seen as an extremely competitive market due to fixed fees, can be entered when the hardware and software requirements are met, causes an increase in the number of companies. Since the pricing scheme of the companies is open, it should not be expected to generate income with a high-profit margin, and it is seen that those who enter the sector first are not far ahead, except for customer satisfaction or advertising advantage. If the new entrants to the sector make a profit, competition will increase and this will cause a decrease in pricing, and an unstable market situation will arise with the withdrawal of some companies from the sector [71]. Another important factor here is that the products offered to the customers cannot be differentiated, so it is difficult to create stabilization with these new products. Two effective financing methods in the scooter market today are the cooperation of startups with large transportation companies or their regular growth with venture capital. For example, Lime has collected $455 million and has a valuation of $1 billion, while Bird has raised $415 million and has a market capitalization of $2 billion. The most important factor in this is that the scooter industry is estimated to have a value of 18.6 billion dollars as of 2019, and this value is expected to be 40 billion dollars by 2030. When the labor costs of scooter companies are examined, it is seen that the prominent cost is the charging of vehicles and redistribution to city centers at night. In addition, the assumption that a scooter will be used for an average of 300 rides generally cannot be achieved due to reasons such as vandalism and theft, and it has been determined that annual income expectations are presented higher than they should be. When the relationship between the state and scooter companies is examined, it is observed that scooter initiatives generally expect the states to respond to their actions and they expect their work to be facilitated. In addition, in some cities, the number of companies that can provide service and the number of scooters are determined as a result of the sanctions of local governments, and companies may be left to deal with political issues rather than the market situation [71].

According to the e-scooter market study conducted by Boston Consulting Group, it is predicted that the global market will have a value of between 40-50 billion dollars by 2025. The life of scooters is seen as 3 months and in fact, they are not suitable for shared use. The most important cost item arises due to operations (collection, transfer, redistribution) and charging. Today, while competition between companies is increasing, companies are working to increase the lifespan of scooters to make a profit. The fact that the users use the brand vehicles that are closest to them makes it difficult for the companies in matters such as brand belonging and prevalence [72].

To observe the impact of social enterprises in the micromobility sector, Sunio et al. [73] conduct a study by using a mix of qualitative analysis, including auto-ethnography, interviews and online ethnography, the UP Bike Share case study, which is the first initiative serving in the Philippines, was examined. In the review, it has been shown that the idea set in motion at the university with the cooperation of the state and social enterprises can be the beginning of a change in developing countries. The importance of determining the market situation depending on the demand has been revealed in the process that is divided into 3 main headings as an idea, pre-installation and establishment.

In this study, which was conducted with a systematic literature review and examined 48 articles on micromobility and public transportation integration, the importance of having accessible, easy and affordable facilities for micromobility at public transportation stations was revealed, while the importance of having a safe, comfortable and continuous micromobility infrastructure system was emphasized. In the studies on safety, it was emphasized that motor vehicle traffic should be alleviated and regulated in the station areas [10]. As a result of this research, it can be asserted that an assessment of the economic aspect of the micromobility industry cannot be done without considering different implications. In another study that focuses on barriers to implementation of the micromobility sector, Fishman et al. [74] show that the difficulty of the membership process and the use of credit cards cause people to abstain and insufficient station capacity and integration of this system, which serves between stations, and the unavailability of the service 24/7 stands out as another important obstacle.

According to the research on the market potential of the micromobility industry prepared by the Heineke et al. [75] Mckinsey Center for Future Mobility, investors have invested more than \$5.7 billion in this field since 2015, and more than 85% of these investments are received by Chinese companies. Many startups have over \$1 billion in reviews. The fact that an average electric bike costs 400 dollars causes this interest. According to the cost and profit calculations, after 4 months on average, profits are started from the micromobility investments and the most important item of the cost is during the collection, charging and distribution of the vehicles. Assuming that an average of 8km travel can be made with micromobility, although it is determined that it can meet 60% of individual vehicle use and 20% of public transportation use, it is observed that it can only meet the needs of 8-15% due to adaptation, weather conditions and the small number of vehicles in the suburbs. According to the prepared model, the market value is expected to be 200-300 billion dollars in America, 150 billion dollars in Europe and 50 billion dollars in China in 2030. The reason for this difference is that the US charges 2 times more than Europe and 5 times more than China. At the same time, the cumulative value of these countries is a quarter of the expected market value of the autonomous vehicle market in 2030.

Users share their personal valuable information with scooter companies via mobile apps to access scooters. The location data of the scooters are used in the service operations of these vehicles, and thus, charging and redistribution services can be provided while taking precautions against risks such as theft. These data can be shared by companies with third parties and institutions due to insufficient user confidentiality agreements, and this data poses security risks. While many decisions can be made about the individual habits of the people whose travel data are collected, information about the consumption habits of the people can be obtained with this data. Dockless scooter services provide a much clearer collective analysis opportunity compared to ride-sharing applications where they are used as a solution to the last-mile problem. In case the collected personal data is shared with the state, it is possible to make improvements in the transportation network, on the other hand, if it is shared with advertising companies, it is likely to provide commercial gain to scooter companies [76].

In the shared transportation industry, which has received more than 100 million dollars of investment in the last 10 years, 72% of the investors, in general, are venture capital and individual investors, followed by technology companies with a rate of 21%. Considering that large automotive companies have only 4%, it is observed that traditional companies lag behind in adapting to this new business model. According to the study, the main reason for the use of shared transportation alternatives, which have security, affordable price and reliability features, stand out as the convenience it provides [77].

In the study using the trip level inference approach, the travel data of each bicycle and the travel that took place without the bicycle were compared. According to the results obtained, while determining the connection between the travel area and purpose and its economic effects, a cost saving of 9.95 minutes and 3.64 CNY per trip is determined, while 8.68 CNY economic benefit is provided. Considering the use of all services throughout Shanghai, 17,665 billion minutes and 6.463 billion CNY were provided annually, while an economic contribution of 15,410 CNY was provided. When the regional differences are examined, it has been determined that more economic contribution is provided in the regions where the population is dense and public transportation facilities are developed. In this way, it has been determined that bike sharing has an important contribution to the solution of the last-mile problem [78].

In another study, which was conducted with the examination of 19 different services serving in Europe and America and interviews with 19 experts from Europe and

12 from the USA, the spread of bicycle-sharing applications was examined. According to the results obtained, it has been determined that the projects that start to serve with a high number of vehicles at the entrance to the market are more prone to growth, while the cities with high-density populations start to provide service with more vehicles. It is observed that advertising companies help in providing financing for projects that are generally carried out with public-private partnerships. While the cooperation of the state, private sector, and public agencies are important in the development of policies, the importance of information exchange with the companies that carry out the operations comes to the fore [79].

In the spread of the developing micromobility sector, it is expected to have an economic structure in which demand and supply increase in conjunction with each other, because of lithium-ion batteries [80]. Micromobility solutions have become more economical, efficient, convenient to recharge, and thinner as a result of advancements in battery technology, such as increased energy density lithium-ion batteries [81]. When the prices of electric bicycles are examined, while the lead-acid battery vehicles used in China are around 100 euros, the prices may exceed 5000 euros in Europe due to high safety and battery standards [82]. One of the priorities for the rapid spread of electric micromobility vehicles in the market is the investment to be made in battery technology. Considering the relationship between this issue, which is related to the electricity storage system, and critical issues such as direct performance and charging of vehicles, lithium-ion systems are preferred for the solution. In addition, to meet these demands by the public in market penetration, the charging problem needs to be solved, so companies demand the development and expansion of the charging station structure from the administrations by paying a fee for users to charge the vehicles [83]. The charging stations used for battery charging of these vehicles consist of 4 basic parts: charging piles, concentrator, battery management system and charging management system. When the production cost of electric 2-wheeled vehicles is examined, production in the Asia-Pacific market is 10 times cheaper than in Europe and 5 times cheaper than in America, and this is because lithium-ion batteries attract more attention in Europe and America due to environmental sensitivity. For this reason, when the market is examined, 92% of the production market is dominated by China, while the main export point is in Europe. While the environmental sensitivity of these vehicles produced in the province of lead acid batteries is less, the penetration rate of ion batteries seems to be around 10%. In terms of manufacturers, the lack of integration in supply, logistics and sales in accordance with today's economic model comes to the fore, while the insufficiency of charging stations is stated as an important problem [11].

According to the study, which examines the models of bicycle sharing applications in China with the state-run or state-private sector cooperation, especially since the public transportation systems are generally built and operated by the state, it is seen as an investment carried out to increase the quality of life of the people rather than a system with a profit margin. Since bicycle-sharing applications are also seen as an extension of public transportation, it has emerged that the implementation of them by the state may be more effective. According to the results obtained by examining the data of 21 different services serving in China, a higher number of trips was obtained in the projects carried out by the state, while the possible conflicts that may arise in the operational transactions between the state-private sector and the absence of the state's aim to make a profit were stated to be effective [84].

According to the study Bedmutha et al. [85] prepared with Monte Carlo Simulation using weekly travel data and energy demand and consumption data in the city of Pittsburgh, it is predicted that the trips between 3-5 miles will be reduced by 5.6% and there will be a 50% decrease in energy demand if they are made with e-scooters. In economic terms, it has been determined that short-distance travel with an individual vehicle is 6 times more costly than using an e-scooter, and it has been shown that individuals can save 2250 dollars per year. The main obstacles to this change seem to be the inadequacy of the charging station infrastructures of the vehicles and the collection and redistribution processes.

In the study conducted by Faghih Imani and Eluru [86], in Montreal, Canada, the travel data of BIXI company were evaluated through Monte Carlo Simulation, taking into account variables such as weather, time zone, environmental conditions and bicycle infrastructure systems. The effects of infrastructure system setup were investigated. According to the results obtained, it was observed that the use of bicycles increased as the population and proximity to the city center increased, while it was observed that the use of bicycles increased as the temperature increased in the weather. It was observed that the frequency of use increased as the proximity to the public transportation stops increased, while the use of bicycle stations decreased in places where the highway density increased.

In the study examining the effect of weather conditions on bike-sharing applications, Gebhart and Noland [87], conducted a study by examining the 15-month travel data and 15-month meteorological situation of the Capital Bikeshare service, which provides service in Washington DC. According to the findings, while the number of trips decreases by more than 25% in humidity, rainy weather and extremely hot weather, average travel times decrease by more than 3 minutes when it gets dark. The 40% decrease in the number of trips in October and November compared to September shows the relationship between environmental conditions and e-scooter usage behaviors [88] .

According to the study, using the data obtained for a period of 3 months from 2 different scooter companies serving in the city of Indianapolis. The average speed of these trips was 8 km/h, a decrease of 10% in October and 30% in November compared to September was observed. While the most frequent trips are between 4 and 9 pm, it has been determined that the frequency increases during the hours of going to work and returning to work. The fact that only 15% of the vehicles that serve are active for more than 1 hour a day shows that the efficiency of the idle vehicles in the planning is low [89]. In another study conducted in the city of Indianapolis, using 6-month scooter travel data between 2018 and 2019, the findings of the study examining the relationship between weather conditions and scooter use, revealed that while the number of scooter trips in the winter months decreased by up to 80%, the daily use of scooters decreased more than 2 times [90].

When the economic impact of e-scooters is examined, there are uncertainties due to the short life span of the vehicles due to hacking and misuse. As a precaution against this, it has been determined that the weekly or monthly life of the scooters belonging to the Voi company, whose hardware features have been improved, can reach 2 years [91].

5.2. Environmental Aspect

Transportation is among the most dynamic aspects of cities, having a significant impact on other aspects of the city and also on individuals' lives. In this setting, there is a strong link connecting urban transportation and urban environmental sustainability in terms of energy consumption and emissions [67]. Congestion, carbon emissions, and accidents are all caused by the transportation industry, which is a source of a wide range of chronic and unsolved societal issues. To mitigate these effects and accomplish ambitious environmental goals, a transition to more sustainable, secure, and low-carbon mobility futures is required [73] .

According to the 2020 Transportation sector research prepared by the International Energy Agency [92] , 24% of CO2 emissions are caused by the transportation sector today, and more than 75% of this rate is due to the vehicles used in road transportation. On the other hand, the increase in CO2 emissions, which has increased by an average of 1.9% per year since 2000, has decreased by 0.5% between 2019 and 2020, with the help of the increasing use of electricity and biofuels. In addition, there was an 8% increase in GHG emissions from the transportation sector in 2021. 37% of GHG emissions come from the transport sector, and 91% of energy use comes from fossil fuels, down just 3% since the 1970s [93].

For micromobility to be sustainable, it must meet three main objectives: first of all, it must reduce greenhouse gas emissions, ensure safe and equitable transport, make the movement of jobs and workers sustainable, and provide easy and affordable transportation to people [94].

In the research, in which different transportation alternatives are compared with the criteria determined on the environment, infrastructure and user structures, the lowest energy consumption can be achieved with micromobility vehicles, despite the low footprint of public transportation vehicles and low emission gas rate per capita. It has been determined that individual motor vehicles are the most useless transportation alternative in city life [95].

it is stated by EY [91] with examining the data of the Voi scooter-sharing service in Paris, it was found that there was a 12% decrease in car usage and a 71% reduction in the carbon emissions of vehicles because of the use of e-scooter in 2019 and that more than half of the contribution to this reduction was the vehicles with replaceable batteries. It has been determined that the use of recyclable materials and the use of lithium-ion batteries lead to cooperation with logistics companies that work more effectively by adhering to the regulations in the collection and redistribution model of vehicles.

In the study conducted by Zhang and Mi [96] to measure the environmental impact of bike-sharing applications, the city of Shanghai in China was chosen because it has approximately 1.5 million dockless bikes and is the city with the second largest bike share in the world. The data used was taken from the world's largest bike-sharing service provider Mobike company, and big data techniques were used with a spatiotemporal perspective. In the study, in which a total of 1,023,529 trips were examined, the average travel distance was found to be 2.4 km and the average travel time was 16.8 minutes. With these trips, 8358 tons of oil were saved and CO2 and NOX gas emissions decreased by 25,240 and 460 tons.

In the model prepared by the Heineke et al. [77] McKinsey Center for Future Mobility for the future of micro-mobility operations, it is foreseen that 80,000 tons of CO2 emissions from vehicles will be prevented in 2030, 4 hours of transportation time will be saved per person per year, and more than 130 hectares of land can be brought to the public with the use of reduced parking spaces in Munich. According to the evaluations made by the Chinese electric vehicle manufacturing company Bywin, if a mode change is provided between an electric vehicle and a fossil fuel engine vehicle in a year, the cleaning done by 12 trees will be achieved. With each 10 thousand km of electric vehicle use, 479 km of carbon dioxide emissions are saved [11].

In the study conducted by McKinsey Company on the transportation market in Turkey, it has been determined that the micromobility sector can generally provide service in big cities and more than 60% of the trips take place in Istanbul. According to the model made for the year 2030, 900 thousand tons of CO2 emission, which is the annual CO2 production of approximately 180,000 people, can be reduced due to the mode change provided by micromobility vehicles [97].

On the other hand, the environmental problems that arise during the battery and equipment of these vehicles, and the use of fossil fuel vehicles during redistribution and operation management, are likely to outweigh the contributions [98]. With the use of micromobility vehicles, environmental damage may occur due to more energy consumption due to the decrease in the use of low-impact vehicles such as public transportation and walking instead of personal vehicles [82].

The cutting-edge method was used in the environmental impact study, taking into account the life cycles of the e-scooters used in Paris, and considering the mode changes and the life cycle of the vehicles, and according to the results obtained, the cause of carbon emissions is production, maintenance and charging rather than e-scooter operations. It has been determined that it is caused by the distribution process and the waste disposal process. According to the findings, 12000 tons of CO2 emissions per year occur due to the use of scooters, and one of the main reasons for this is determined as a mode change with public transportation vehicles working entirely with renewable energy [99].

In the preliminary study to measure the environmental effects of electric scooters during their lifetime, a Monte Carlo simulation was applied by considering the material, production, usage and operation steps. According to the results, 50% of the effect of e-scooters on global warming is caused by production and materials, while 43% of the effect is caused by the collection and redistribution of vehicles. The remainder is generated during the charging process. In addition, more than 50% of the emission can be reduced with the use of lithium-ion batteries and the use of recycled materials, while more than 20% reduction can be achieved if the collection distance of the scooters and the efficient fuel use of the pick-up vehicle. Extending the lifespan of scooters and reducing the frequency of collection of vehicles will reduce their harmful effects on the environment. In addition, it has been shown that the use of scooters will harm the environment more than the use of bicycles and buses if necessary precautions are not taken [100].

According to the sustainability report of 2019 prepared by the scooter-sharing company Voi, it has been shown that an average of 20 people can use a scooter during the day and 20 scooters can be parked instead of one vehicle in the car parks covering 15-30% of the living spaces in cities [91].

5.3. Safety Aspect

Considering the external costs of the transportation sector, the most important external costs for the micromobility sector are traffic safety and accidents [101]. The fact that personal protective equipment is not provided to users by service providers reduces the usage rate and causes an increase in injury and death rates in accidents [102]. Considering the health and safety issue, the most important step is to design the roads and streets in accordance with the use of micromobility vehicles, and it is expected that this will facilitate the implementation of rules such as speed limits [103]. Because there are many effective factors in terms of safety and factors such as lane width, traffic density, single-lane roads, routes of large commercial vehicles and population density should be considered [12].

When the death rates per kilometer of micromobility vehicles, which raises concerns in terms of safety, are compared with the death rates due to driving, it has been determined that the death rate is 18 times higher in Europe and 30 times higher in the world [82].

According to the results of the study conducted by the ITF on the safety of micromobility vehicles, it has been determined that safety tendency is lower in users who receive service from shared services, especially when 4% of users use helmets and similar personal protective equipment. More than 80% of the deaths in accidents occur as a result of accidents with other vehicles, while 40% of users indicate poor road infrastructure as the cause of these accidents, while 25% indicate weather conditions [32].

To examine the injuries and accidents caused by scooter use in the USA, Namiri et al. [104] conduct study by using scooter-derived hospital data from 2014-2018 obtained from The National Electronic Injury Surveillance System (NEISS) were analyzed using linear regression. According to the results of the analysis, a rapid increase was observed in injuries due to scooter use between 2017 and 2018, and the increase rate was found to be 222%. 36% of these injuries were experienced by female drivers. The most common forms of injury are fractures, abrasions and tears. When the patients who applied to the hospital due to injury were examined, the rate of injury between the ages of 18-34 increased by 185%.

Another study examining injuries caused by standing scooter use in the USA is Trivedi et al. [105] conducted by Patient records of 2 health departments in Southern California between September 2017 and August 2018 were examined, and according to the results, 249 injuries occurred in this time period, and 33.7% of these injuries were experienced by female drivers. While 91.6% of the injuries were experienced by drivers, 8.4% were caused by non-drivers. 40.2% of the injuries occurred in the head region, and 94.3% of the injuries were not wearing a helmet.

Fishman et al. [74] reveal in a study on the barriers emerging in the use of the shared bike service CityCycle, which started to serve in Melbourne and Brisbane in Australia in 2010, it was determined that the biggest obstacle emerged as a result of the survey conducted on 3 different bicycle user groups was the issue of safety, while insufficient cycling infrastructure was the reason for this. Governments focusing on investing in road infrastructure and the insensitivity of motor vehicle drivers are shown as the reasons. On the other hand, some participants state that they do not prefer to use the application because of the compulsory use of helmets [74].

In the survey conducted with 749 participants to see the user perspective on scooter use in Germany in 2019, criteria were evaluated from different perspectives using the Likert scale. According to the results obtained, even if there is awareness of environmental benefits, the accident and safety situation poses an important problem [15].

5.4. Public-Policy Aspect

It is an extremely important and complex issue that people have equal opportunities in accessing transportation vehicles and that the opportunities and damages arising from the transportation sector can be shared fairly. To prevent social inequalities that arise due to the deprivation of transportation opportunities for people with low socioeconomic status, an affordable transportation alternative is required and is tried to encourage the use of integrated transportation systems instead of personal vehicles for this method. These problems are tried to be prevented by the equal use of resources, the fair distribution of services to regions, and regulations in pricing [106]. There is increasing awareness in the transportation and energy sector with the aim of reducing carbon emissions. For this reason, electrification comes to the fore, especially in public transportation and personal vehicles, and it is completed by institutions in order to be effective in regulations and policies, especially by local governments in city life [80]. Aside from the macroeconomic advantages of infrastructure improvements, the link between mobility and well-being has prompted policymakers and government agencies to keep investing in the construction and maintenance of a comprehensive multi-modal transport system [107].

A comprehensive and transparent approach is required when planning transportation. Considering the population growth, economic, social and cultural changes, long-term projections should be evaluated and investments should be made in this way. The concept of planning itself is a social approach, and projects involving citizens, the state and private sector, who are the stakeholders of the transportation sector, and in which resources such as time and money are used in the most optimum way should be highlighted. Ensuring information-data flow throughout the transportation planning process becomes a basic requirement. Uncertainties such as the lack of experience in the micromobility sector, the lack of a precise method on how the data collected with the help of mobile applications should be used, the regulations do not draw the boundaries of private sector-state cooperation, and the future economic, social and environmental effects reduce the functionality of the investments to be made and adaptation prolonging the process. Comprehensive analysis of basic data such as transportation time, transportation distance, transportation locations and transportation densities is indispensable to understanding transportation demands and transportation alternatives suitable for demand and taking action accordingly. [69, 108].

When the problems that need to be solved for the widespread use of micromobility vehicles are examined, to ensure fairness in accessibility, the operation costs in low-density low-income regions are higher than the income level, the inadequacy of regulations regarding the occupation of public spaces, the lack of preference because there may be deficiencies in the supply of vehicles during the day, maintenance and distribution costs, problems that users may experience in accessing technological infrastructure, the inadequacy of infrastructure and accidents and injuries that may occur due to low awareness of car drivers are the main topics. In the solution of these problems, states should support the adaptation process by taking responsibility for issues such as mediating the flow of information, encouraging cooperation, economic incentives and tax reductions, creating appropriate regulations with pilot applications, and creating a secure and transparent system for data sharing [107].

With applications that bring together many different transportation alternative data, people have the chance to choose between different transportation alternatives. City governments should support their development by making appropriate arrangements with these new alternatives, plans should be made using the real-time data obtained, and companies should be given incentives such as ease in parking fees in economic terms [109]. There will be situations where local governments usually offer docked bike-sharing application services, dockless bike-sharing applications will be used more and will outperform the competition and therefore will not be welcomed by the municipalities [110].

The regulation of the micromobility sector should be done under 3 main headings. These are market failures, the use of public space, and social goals [101]. After a large amount of travel data is obtained, it is necessary to analyze the transportation demand according to the regions. In addition, while conducting operations regarding the condition of the vehicles, legal regulations need to be made according to these data [103]. Apart from this, intensive service and easy access and competition between different transportation modes are other market failure issues that need to be regulated. The absence of any regulation or license required for the use of e-scooters in the city causes these vehicles to occupy public spaces. The efficient distribution of scooters in the city is an important factor that will reduce traffic congestion, and the use and safety of the big data obtained should be regulated [101]. If the cost of using micromobility vehicles is higher than other means of transport, social inequality may arise for people of low socioeconomic status [98]. The policy to be implemented is to create a licensed regulated management system, to obtain vehicle data, regulate the market, hold users accountable for vehicles and monitor vehicle status [11].

It is observed that if many bike-sharing service providers withdraw from the sector, their users do not return the deposits paid during membership which causes grievances. For this reason, managers are expected to protect users with financial interventions. Due to the low financial profit margin of bike-sharing applications, data collection and sharing is an important income, therefore, regulations on data security should be introduced. When the examples of the regulations are examined, in accordance with the law enacted in 2018 in Singapore, it was mandatory for service providers to become licensed, the bicycle operation capacities of the companies were limited, and certain areas were determined in the parking lots and certain times were given for the collection of vehicles parked inappropriately. Operation and safety standards of bike-sharing services have been determined within the framework of the rules that started to be implemented in London in 2017, and local government approval has become a must before entering the market. In Tianjin, on the other hand, within the framework of the law that came into force, user security is protected in problematic issues such as deposits and data. The four main perspectives identified are an effective use of public spaces, increased equity, improved planning and protection of users [110].

In the study investigating the relationship between micromobility and social behavior in New Zealand, a survey was conducted with a social practice approach. 491 questionnaires were filled in by participants from 4 different cities. According to the results, the lack of a smartphone and credit card required for scooter use prevented 5% of the participants from using scooters, while 69% of the participants stated that they used a scooter at least once, with the start of the service in 2019 by the Lime company. While 13% found the application and the locking process difficult, 45% of the participants stated that they found it difficult and dangerous to use scooters. While only 49% of the users defined the sidewalks as a suitable driving environment for scooters, 90% of these users stated that they had to use the sidewalks during their travels [111].

With the widespread use of micromobility vehicles on the streets, the most obvious external cost created by free-roaming bicycles or scooters is the damage to the environment and public spaces as a result of improper parking and storage, and therefore it is expected to cause regulations [110]. One of the most important issues related to micromobility vehicles is how to share space in public spaces, and legal arrangements should be made to solve problems such as pavement occupation, visual pollution, and damage to public spaces [103]. The fact that different companies compete for areas such as parking areas and charging stations exacerbates this problem. Shaheen et al. [112] put forward the micromobility curb management, which covers the policy-design-implementation phases for this problem. In this process, the areas where vehicles can be left and their numbers are determined with the written or developed pilot regions and legal regulations, while the implementation process can be carried out together with the equipment and operation control of the vehicles, with parking arrangements and economic sanctions. The main source of dissemination of micromobility vehicles, which are expected to become more widespread with the help of the developing battery technology, will be through regulations and policies. If automation technology is combined with vehicles, it is thought that solutions can be found in the problem of occupation of public space, together with minimizing the problems that vehicles may cause in matters such as charging and redistribution. It is essential to set security standards for data security of travel, which are expected to become safer with education, infrastructure and hardware improvements. With the use of travel data collected by companies by planners, it is possible to provide a higher quality service by providing integration between micromobility vehicles and multimodal travel.

In the study on e-scooters placed in Bergen, Norway, the state-private sector relationship was examined, the actions and collaborations taken by the municipality against the vehicles placed by the Ryde company were observed, and the 3-question analysis was completed with interviews and surveys with experts. With the Nivel system, which was created in cooperation with the state and private agencies, digital control of micromobility vehicles was provided with real-time data. The aim is to bring together the use of public space and regional usage information, transportation mode change information and travel-personal information required in the management of micromobility vehicles and to include them in the innovation process. According to the transportation planning authority, 80% of trips with e-scooter are used instead of walking and public transportation. While emphasizing that data analysis and sharing are inevitable in the development of the micromobility sector with the system created, it has been observed that companies take decisions considering the profit margin for equality in public service instead of serving in places where the population is low. The public-private partnership should be established with regional adaptive regulations and financial support, especially in the management and pricing of public spaces, data sharing, and transfer, to provide equal access to the public [80].

In the study prepared by the National League of Cities in 2019 for the successful implementation of micromobility vehicles in cities, it is necessary to develop different pilot projects and to test the financial structure, sustainability and applied policies of the companies, and in these pilot projects, infrastructure service improvements, security measures, data usage regulations, equality and It has been shown that issues such as intercity cooperation should be highlighted. Access to transportation is shown as one of the most important sources of socioeconomic inequality, and since dockless service systems do not guarantee accessibility, this inequality is likely to increase. For this reason, in some cities in America, the minimum number of vehicles to be found in the regions is determined by regulations. In addition, it is recommended to reduce pricing, offer different payment system alternatives, examine the relationships between travel data and low-income regions, and develop incentive mechanisms [113].

For e-scooters to create the expected economic and social impact in the future, necessary political arrangements must be made by national and local governments, while in some cities such as Madrid and Copenhagen, administrations restrict their usage areas and service areas because of concerns about safety and environmental effects [91].

5.5. Mode-shift Operation Impacts of Micromobility

In the study on the effects of e-scooters, 30000 imaginary trips were created in Chicago using multimodal network analysis. According to the results, the trips not made with personal vehicles can increase by more than 70% for trips between 0.5-2 miles, and because it is used for short distances, it will not create competition with public transportation vehicles, and by providing a 16% increase in access to business opportunities within 30 minutes, new job opportunities and economic opportunities can be created. It has been determined that it will contribute to development [114].

In another study conducted by examining the data of 6 scooter sharing companies serving in Washington DC and the travel data of Capital bike-share (CaBi), which provides bike-sharing services, it was determined that an increase in scooter and bicycle use was observed as the temperature increased and the viewing angle improved, while every 1% increase in temperature usage increased by 2%. It has been found to increase the use of more than 1,000 micromobility vehicles. Another interesting result is that for every 1% increase in fuel prices, there is a 3% increase in scooter usage [115].

The biggest obstacle in front of the increase in the use of public transportation is the problems that people experience in accessing alternatives to public transportation from places such as home, work and school, this problem is called the first-last mile problem and together with the use of e-scooter, there will be a problem between e-scooter service providers and public transportation managers. It is predicted that these problems can be avoided with cooperation focused on data sharing [91].

When the profiles of people benefiting from the micromobility service are examined, it is observed that people with high socioeconomic and educational levels, young and middle-aged people tend to use these services who is generally living in areas close to different transportation alternatives [112].

According to the study conducted by the LDA consultancy firm, the results of the online survey were conducted with 5464 participants and sent to 18.000 annual and monthly members of Capital Bikeshare firm, which provides service with 1500 bicycles and 165 stations in Columbia DC. transportation mode changes have been revealed. According to the results obtained, the most important reason for use was convenience and fast transportation. While 56% of the trips take place for reasons other than business needs, 40% of the participants stated that they drive less. According to the participants, a weekly savings of 15.75 dollars was achieved, while 64% of the participants stated that without the Capital Bikeshare application, at least one trip would not have been made due to the distance. When the effects of public transportation were examined, 47% of the participants stated that they used the subway less and 39% said that they used the buses less [116].

The online survey study conducted by Transport for London in 2010, the study was conducted with the participation of 3500 members of the London bike-sharing application. According to the results obtained, the rate of people quitting using their own vehicles because of the bicycle was determined as 1%. This result shows that with the use of bicycles, people prefer to use bicycles instead of transportation alternatives such as walking or public transportation.

According to the results of the daily survey study conducted with 154, 218 and 275 participants, respectively, in Beijing, Shanghai, and Hangzhou cities in 2010 to measure the effect of the bicycle-sharing system, which is widely used in China, on transportation behaviors, when the changes in transportation modes are examined, the use of private vehicles is in three cities it decreased by %5.19, 0.46%, 3.99%. It was determined that the highest changes occurred in the bus and walking alternatives in all 3 cities. When the reason for using bike-sharing applications is examined, time-saving and easy access to alternatives come to the fore with a rate of over 40% [117].

In the bike sharing system, which was started in 2008 in Hangzhou, China, service was provided at 2416 stations with 60,000 bikes in 2011. According to the results of the survey conducted with 806 participants between January and March 2010 to determine the main factors and barriers to bicycle adaptation, the mode change was on bus, walking and taxi. The fact that the majority of the participants have a personal vehicle indicates that vehicle owners are more interested in bike sharing. 40% of the participants stated that they use bicycles for transportation to work or home and they prefer the stations closest to these locations [9].

According to the 2019 micromobility report prepared by NACTO in 2020, 136 million trips in America were made by bicycle, e-bike and scooter, an increase of 60% compared to 2018. While the average duration of these trips is between 11-12 minutes, the average travel distance is determined as 1.15 miles. The average cost of these trips is $4.7. When the mode changes in 6 cities were examined, it was determined that the use of individual vehicles decreased by 45%, preferred over walking by 28% and public transportation by 9%. The prominent obstacle, on the other hand, is due to the pavement occupations that occur after irregular parking. 88% of the survey participants indicate that riding on bicycle paths is an important factor for safety reasons. More than 73% of users are under the age of 40, while 66% are men [118].

In another study was conducted with the data of the Nice Ride Minneapolis service, which covers the cities of Minneapolis and St.Paul, serving with 190 stations in the twin-cities region, and examines the relationship between access to stations and frequency of use, a difference-in-difference model was prepared with quasiexperimental analysis and 1249 individual user data obtained between 2010-2015 was used. According to the results obtained, the frequency of bicycle use increases as the distance of the transportation network gets shorter and access to the station becomes easier. While the frequency of bicycle use decreases by 26% in people living close to the metro station, it is expected that there will be a 7% increase in bicycle use in areas where intensive service is not provided, if stations are established. With the 0.1-mile extension of the bicycle paths, the frequency of driving increases by 1.6% in men and 1.1% in women. It has been observed that the placement of independent stations in regions with low station density will not directly affect the frequency of use [119].

In the model prepared by the McKinsey Center for Future Mobility for the future of micro-mobility operations, which started to serve in the city of Munich, passenger travel kilometers were distributed considering the cannibalization potential and the potential for more than 10 different micromobility use cases. According to the model, it is expected that a solution for the first-last mile problem has emerged, when it is predicted that the use of micromobility, which covers 1% of total travel today, will reach a value of 8-10% with 250 million trips in 2030 according to the model, and 40% of these 250 million trips will be made by motor vehicles if micromobility is not available thus it is estimated that mod-shift goal of micromobility vehicles can be achieved [97].

In one of the preliminary studies on the use of E-scooters in European cities, observed driving habits and possible obstacles in a case study they created in Munich, Germany. The duration of use, locations and purposes of use of the scooters, which were distributed to the created test groups, were monitored for 56 days, and then a survey was conducted with the users. According to the results obtained, while the average travel distance is 11.2 km, the use for commuting to work and for entertainment in leisure time draws attention with a rate of 38%-31%. According to the results of the post-use survey, it was observed that the main reason for choosing scooters was to avoid traffic, while the lack of usage restrictions and traffic regulations, the low frequency of charging stations and the cost were negative for users. In addition, bad weather conditions and safety issues cause drivers to abstain from using scooters. The most obvious benefit seems to be the possibility of easy parking against parking problems [3].

In the survey conducted with 749 participants to see the user perspective on scooter use in Germany in 2019 when the change in transportation mode is examined, it has been observed that the use of scooters is generally preferred instead of using a personal vehicle, walking and cycling with a distance of less than 2 km [15].

In the case study conducted in Brighton, England, travels with electric bicycles distributed to 80 people were examined for 2 months and user behaviors were investigated. While an average of 20 miles of use per week is observed, there has been a decrease of approximately 20% in individual vehicle use. In addition, 70% of the participants stated that the frequency of physical activity increased [120].

In another study examining the demographic structure of bike-sharing service users, conducted a survey and panel study in the Australian cities of Melbourne and Brisbane. While more than 70% of the users are men, it has been determined that the predominant age group is people between the ages of 18-34. The fact that more than 75% of the users have at least a bachelor's degree indicates that the rate of use increases as the level of education increases. While more than 72% of regular users state that they have a bike station close to work or home, the main concern is the inadequacy of the bike infrastructure and the safety problem [121].

When the mode changes are examined, the rate of those who prefer e-scooters instead of walking and cycling is 53%, while the rate of those who prefer to use e-scooters instead of individual vehicle use is around 23%. While 36% of the users stated that they preferred these services for public transportation integration, it was determined that they were an important solution to the last-mile problem. While 54% of the participants were between the ages of 25-34, 74% stated that they had at least a bachelor's degree. More than 60% of users are male while over 58% are performed by white. While a total of 171 accident injury records were opened, 56% of users stated that safety improvements should be made [88].

5.6. Trip Distance and Trip Duration

According to the scooter-sharing usage behaviors research conducted by the Innovation Center for Mobility and Societal Change (InnoZ) GmbH in 2017, the travel times and distances are examined, the average distance of 4-5 km and the travel time of 15-20 minutes come to the fore as the general usage type.

In the study conducted by Noland [122] on the usage patterns of e-scooters in Louisville, Kentucky, with the data obtained from the open data platform, check-out time, trip duration and trip distance data were examined from two companies, including Bird and Lime companies, which offer scooter-sharing services. According to the results obtained, an average of 400 trips per day are made with scooters, while the average travel time of these trips is 15.59 minutes and the average travel distance is 2.14 km. The average speed of these trips was calculated as 9.13 km/h. When the effect of weather conditions on travel was examined, it was determined that as the wind speed increased, the travel distances became shorter and the number of travels decreased on rainy days. About 35% of personal trips are made over distances of 2km and about 75% of them are less than 10km. It is observed that e-scooters are used for travel between 0.5-4 km.

According to the results obtained by examining 29 conference papers, academic publications, reports and articles selected among 143 researchers, transportation needs can be met at a distance of less than 8 km with micromobility vehicles, and this distance constitutes more than 50% of the travels made in America, Europe and China. Although the duration and distance of travel by bicycle are longer than scooters, the rate of using electric bicycles increases as the travel distance increases. The average travel distance by scooter is around 2.4km, while the travel time varies between 8-12 minutes. On the other hand, the average travel time of e-bikes varies between 15-20 minutes, while the travel distance is around 4.5 km [67].

In the study, which examines the travel time differences between dockless electric micromobility vehicles and ride-sharing vehicles from a regional and temporal perspective, the vehicle data of 6 different micromobility companies (Bird, Lime, Skip, Jump, Lyft, Spin) serving in Washington DC. taken from the District Department of Transportation records, and the data shared by the Uber company in the ride-sharing data were used. According to the results obtained, it was observed that Skip company, which serves the largest vehicle fleet, has the highest number of daily usage, while the average travel times and distances are close, and travels are around 2.4 km and 12 minutes. In the time-based analysis of travel, it has been observed that micromobility vehicles are used more frequently during weekday commuting hours. When the regional and temporal differences with the ride-sharing applications are examined, it is observed that micromobility vehicles provide faster travel, especially in the city center during the hours of 8-9 am and 5-pm when the traffic is congested, while the ride-sharing applications have the chance to travel 1.5 minutes faster on average in the regions outside the city and during the rest of the day [123].

In a study to determine the economic impact of dockless bike sharing on users, by using the travel data of Mobike, which operates in Shanghai, China, and owns 40% of the total bike-sharing market. According to 18.906.447 travel data made with 635 thousand vehicles, the average travel speed is 10.4 km/h, the average travel time is 10.2 minutes and the average travel distance is 1.56 km [78]. In another study examining the relationship between docked and dockless bike-sharing applications and user behaviors, the travel data of Ford GoBike, which provides docked service in San Francisco, and Jump company, which provides dockless service, were used. According to the results obtained in the study using travel behavior analysis, discrete choice analysis, and geospatial suitability analysis, it was determined that dockless service vehicles were preferred. While it was determined that trips made by dockless system vehicles are 3 times more in terms of distance and 2 times more in terms of time than trips made with vehicles that provide docked service, an average of 0.8 trips per day and 2.3 miles more travel distance per vehicle were obtained with the dockless system [124].

According to the analysis made by the Society of Automotive Engineers(SAE), there are differences between the average travel distances according to the type of micromobility vehicles. While more than 70% of trips by bike and e-scooter are shorter than 1 mile, this rate drops to 35% for trips made by e-bike. When the trips in 4 different cities of America are examined, it is determined that 98% of the trips made by e-scooter are shorter than 5 miles, while this figure covers more than 60% of the trips made in the USA, and considering that 76% of these trips are made with individual automotive, it allows mode change. The main problems associated with the use of micromobility vehicles are bad weather conditions and their inadequacy for cargo and goods transportation [70].

The effects of e-scooter use were investigated with the pilot project application developed with 10000 vehicles offered by 3 different companies for 4 months in Chicago in 2020. While more than 540,000 trips were made in total, the average duration of these trips was determined as 18.3 minutes and the average travel distance was measured as 2.1 miles [88].

In other study, the average travel time was determined as 8 minutes, while the average travel distance was determined as 1.13 km, in the analysis made with 425 thousand travel data in a 3-month period of 2 scooter companies serving in the city of Indianapolis [90].

5.7. Description of Alternatives

Three different alternatives have been identified in the sharing of responsibility in the implementation of service and product operations in the micromobility sector. These are the alternatives to be implemented under government control, implemented by the private sector, and implemented with government-private sector cooperation.

5.7.1. 5.7.1 Governments control, operate and management of the micromobility industry

The main motivation for the government-run system for implementation of the micromobility sector, which is the first alternative, is that the state will be able to apply a more comprehensive and proper method in determining and applying international and national standards. It is thought that the state will show more sensitivity for the benefit of society on issues such as the necessity of legal regulations, security, use of public space, and data security.

5.7.2. Operation and management of the micromobility sector by private companies

The second alternative, which defines the state of being a practitioner and responsible in the micromobility sector of the private sector, comes to the fore in issues such as finding financing and providing quality service. The fact that new technological investments generally grow depending on venture capital and that the quality of products and services will increase while pricing decreases due to competition among companies reveals the importance of this private sector.

5.7.3. Operation and Management of micromobility projects in cooperation with the public and private sectors

The third alternative, which defines state-private sector cooperation, is an important alternative because private investments will increase, especially depending on the state's providing a financially and politically suitable environment. While the government determines service and usage standards through legal regulations, it explains the private sector's taking on more duties and responsibilities in business and operation processes.

5.8. Description of Main Criteria and Sub-Criteria

5.9. Economic Aspect

One of the main criteria evaluated while determining the risks that may occur in the micromobility sector is the economic aspect, and the situations that pose a risk to the government and companies financially are evaluated under this criterion.

5.9.1. Vehicles are open to problems such as theft and hacking

It refers to the case of damage to the vehicles in case of careless use of micromobility vehicles on unsuitable roads and the fact that vehicles used and parked in dockless services are not protected against theft.

5.9.2. High vehicle maintenance and redistribution transaction costs

It refers to the high cost of distribution operations in different service areas with the collection of micromobility vehicles for maintenance and charging.

5.9.3. Significant decrease in micromobility vehicle use in bad weather conditions

It shows the decrease in the frequency of use of vehicles, especially in winter, windy and rainy weather.

5.9.4. State's interference in private sector competition and loss of private sector investors

It refers to the state preventing private sector initiatives through legal regulations in market competition and making attempts by the state.

5.10. Environmental Aspect

The risks to be created by the micromobility sector in terms of the environment have been evaluated under the environmental aspect criterion.

5.10.1. More emissions of emissions during the collection and redistribution of scooters compared to public transport

It refers to the increase in emissions when fossil fuel-powered vehicles are used during the collection and redistribution operations of vehicles.

5.10.2. Visual pollution as a result of careless parking and stacking of vehicles

It indicates the state of public damage and visual pollution as a result of vehicles occupying the pavements

5.11. Safety Aspect

In terms of human health and safety, the risks that will arise due to the micromobility sector have been evaluated under the safety aspect.

5.11.1. High rates of serious injury and accident

It refers to situations such as injury and death as a result of accidents, especially in vehicles used without personal protective equipment.

5.11.2. Low use of personal protective equipment

Indicates that personal protective equipment such as helmets and knee pads are not used due to insufficient legal regulations and people's preferences.

5.12. Public - Policy Aspect

5.12.1. Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process

It indicates a situation that the data obtained from the use of the vehicles is generally obtained by the private sector and there is insufficient data for the decision-making processes in the administrative sense, due to the new usage habits and not enough data for analysis.

5.12.2. Protection and sharing of personal data

It indicates a situation where the security of the sharing and use of the personal data obtained is uncertain due to the lack of legal regulations and the lack of a control system.

5.12.3. Lack of legal regulations on the use of micromobility vehicles

It indicates the situation of confusion and problems that may occur in the transportation system due to the lack of necessary legal arrangements for service providers and users in the use of vehicles.

6. THE SURVEY

The experts first compared the 4 main criteria among themselves using the 1-9 Saaty scale. Afterward, the sub-criteria of each main criterion were compared and the global and local priority degrees were found. Finally, each criterion was evaluated for 3 different alternatives, and the priority degrees of the alternatives were obtained. During this evaluation, the AHP method described above was used and the results were obtained accordingly.

6.1. Expert A

Expert A is an academician in the field of transportation and has been teaching in this field for more than 15 years at the university. The main criteria pair-comparison answers completed by Expert A are shown in Table 6.1

Table 6.1. Pair-comparison matrice by Expert A.

Criterion A	Criterion B	A or B	Scale(1-9)
Economic Aspect	Environmental Aspect	A	5
	Safety Aspect	A	3
	Poblic-Policy Aspect	A	3
Environmental Aspect	Safety Aspect	B	5
	Poblic-Policy Aspect	B	3
Safety Aspect	Public-Policy Aspect	B	2

According to the pairwise comparison matrix filled by Expert A, the economic aspect was the most important criterion among the 4 main criteria, followed by the public-policy criterion and the security criterion. The least priority criterion was determined as the environmental aspect and the weights of criteria and attributes of evaluation are shown in Table 6.2

Table 6.2. Weight and Attributes of Expert A Evaluation.

Criterion	**Weight**
Economic Aspect	50.4%
Environmental Aspect	6.8%
Safety Aspect	19.3%
Public-Policy Aspect	23.5%
Attribute	**Value**
Consistency Ratio	8.2%
Lambda	4.223
GCI	0.29
Psi	0.00

While the Consistency ratio value was determined as 8.2%, it was determined that the evaluation made was consistent because this value was below 10%. While the lambda value used in the calculation was found to be 4223, the GCI and Psi values were found to be 0.29 and 0.00. The weights of the criteria were determined as follows as a result of the evaluation;

- Economic aspect 50.4%
- Environmental aspect 6.8%
- Safety aspect 19.3%
- Public-policy aspect 23.5%

The criteria weights are shown in Figure 6.1

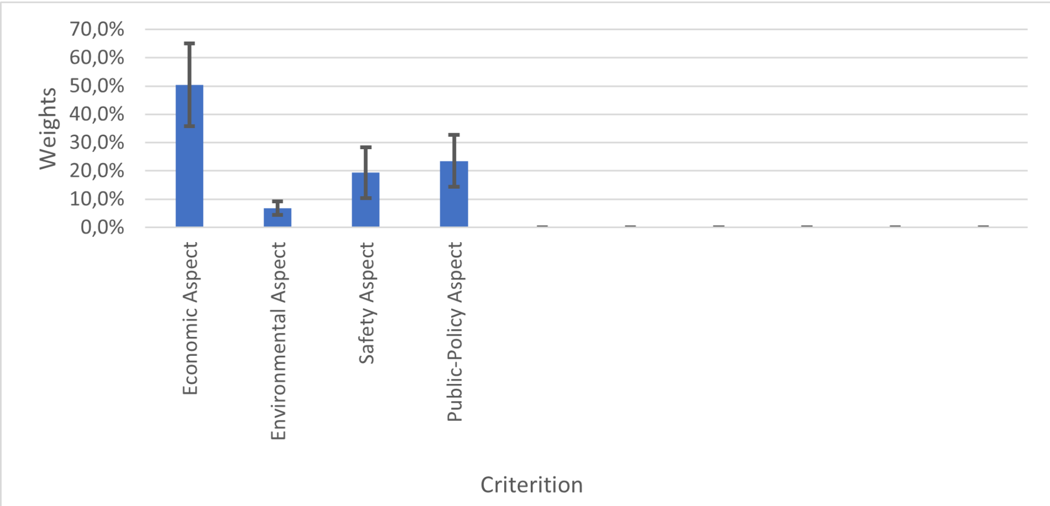

Figure 6.1. Percentage of Criteria Weight Expert A.

Local weights were obtained with pairwise comparison matrices made on behalf of the sub-criteria determined for each main criterion. The pairwise comparison matrix of economic sub-criteria evaluated by Expert A is shown in Table 6.3 below and AHP results are shown in Table 6.4.

Table 6.3. Pairwise comparison of Economic Aspect Sub-criteria.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	B	1
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	B	5
	State Interference in Private Sector Competition	B	5
Vehicle Maintenance and Redistribution Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	B	5
	State Interference in Private Sector Competition	B	7
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	2

Table 6.4. Weights and Attributes of Economic Aspect Subcriteria.

Criterion	**Weight**
Theft and Hacking of Vehicles	7.9%
Vehicle Maintenance and Redistribution Cost	7.2%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	33.3%
State Interference in Private Sector Competition	51.5%
Attribute	**Value**
Consistency Ratio	1.7%
Lambda	4.045
GCI	0.06
Psi	0.00

According to the results of the evaluation made by Expert A, the most important of the 4 economic criteria is the government's intervention in the private sector competition with 51.5% weight, followed by the decrease in vehicle use due to bad weather conditions with a weight of 33.3%. Theft and hacking of vehicles with a weight of 7.9% and the costs of maintenance and redistribution of vehicles with a weight of 7.2% are the 2 least important criteria. The assessment with an inconsistency rate value of 1.7% is consistent because it is below 10%. A visualization of the resulting weights is shown in Figure 6.2

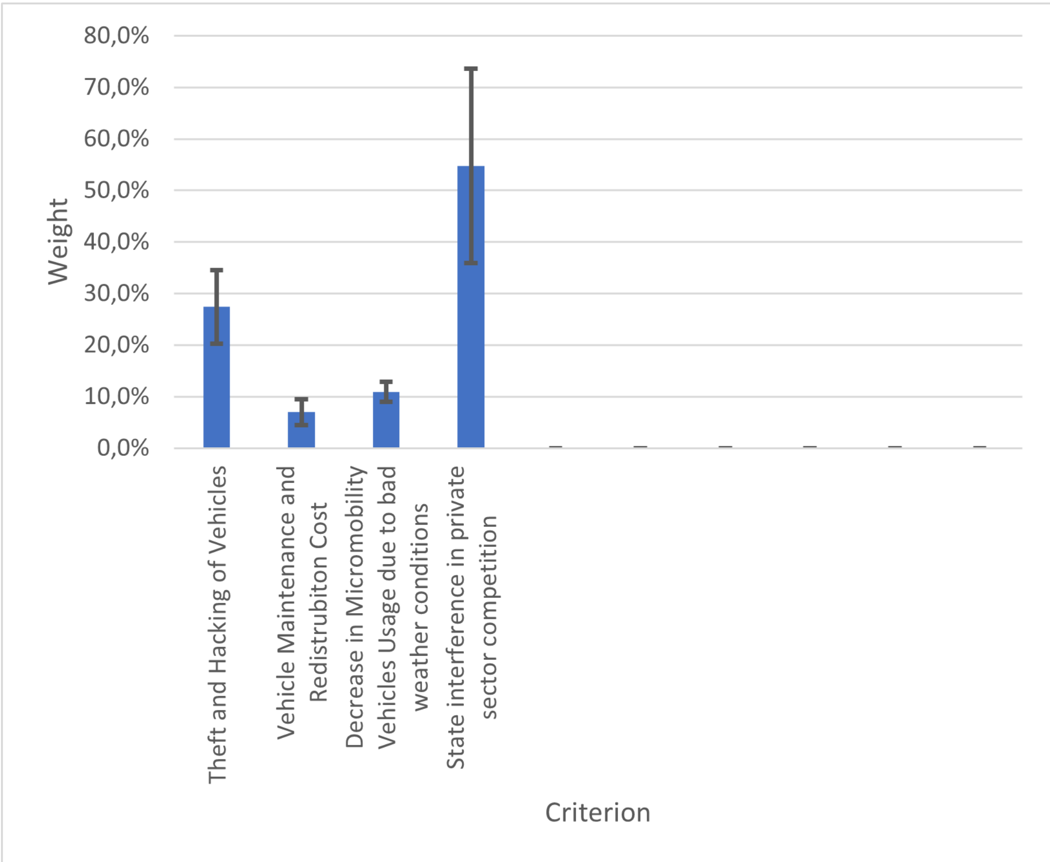

Figure 6.2. Percentage of Weights of Economic Subcriteria.

The pairwise comparison matrix made by Expert A in the evaluation of environmental criteria and the obtained AHP results are shown in Tables Table 6.5 and Table 6.6 According to the results obtained, while the visual pollution criterion was the most important criterion with 83.3 % weight, the high GHG emissions occurred in the collection and distribution of vehicles with 16.7% weight took the second place. It was determined that the evaluation made was consistent due to the 0.0% inconsistency rate obtained due to the comparison of the 2 criteria.

Table 6.5. Environmental Aspect Subcriteria Comparison Matrix.

Criterion A	**Criterion B**	A or B	Scale (1-9)
High Level of GHG Emissions During the Collection and Redistribution of Vehicles	Visual Pollution	B	5

Table 6.6. Weights and Attributes of Environmental Subcriteria.

Criterion	**Weight**
High Level of GHG Emissions During the Collection and Redistribution of Vehicles	16.7%
Visual Pollution	83.3%
Attribute	**Value**
Consistency Ratio	0.00

Completed pairwise comparison and AHP results for safety criteria are shown in Tables Table 6.7 and Table 6.8 below. According to the obtained AHP results, high accident and injury incident was the most important criterion with 83.3% weight, while not using personal protective equipment with a weight of 16.7% took the second place. The consistency ratio value is calculated as 0.0% and the evaluation is consistent.

Table 6.7. Safety Aspect Subcriteria Comparison Matrix.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Rates of the Injury and Accidents	Low use of Personal Protecting Equipment	A	5

Table 6.8. Weights and Attributes of Safety Subcriteria.

Criterion	**Weight**
High rates of serious injury and accident	83.3%
Low use of personal protective equipment	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0.00
Lambda	2000

In the final subcriteria pairwise comparison matrix completed by Expert A, 3 different risk factors determined for the public-policy aspect were evaluated. The resulting pairwise comparison matrix is shown in table Table 6.9. The results of the evaluation are consistent because the AHP results completed with an inconsistency rate of 6.8% have a rate of less than 10%. When the weights obtained are examined, the most important risk factor is the lack of legal regulations with a weight of 73.1%, followed by the lack of data for performance measurements with a weight of 18.8%, and the risk factors of data protection and sharing with a weight of 8.1%. Weight results and AHP values are shown in Table 6.10.

Table 6.9. Public-Policy Aspect Subcriteria Comparison Matrix.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Insufficient Data,	Protection and sharing of Data	A	3
	Lack of legal regulations	B	5
Protection and sharing of Data	Lack of legal regulations	B	7

Table 6.10. Weights and Attributes of Public-Policy Subcriteria.

Criterion	**Weight**
Insufficient Data creates Performance Management Problems	%18,8
Protection and Sharing of Data	%8,1
Lack of Legal Regulations	%73,1
Attribute	**Value**
Consistency Ratio (CR)	%6,8
Lambda	3065
GCI	0,19

6.2. Evaluation of Alternatives for Risk Factors with AHP by Expert A

After finding the local and global weights obtained as a result of the AHP evaluation of the main and sub-criteria for each risk factor, the 3 alternatives determined were evaluated for each risk criterion. In this way, the priority weights of the alternatives for risk allocation were determined. A pairwise comparison matrix of 3 different alternatives is shown in Table 6.11. for Expert A to take responsibility for theft and hacking economic risk criteria.

Table 6.11. Evaluation of Alternatives for Theft and Hacking Risk Criteria.

Criterion	**Theft and Hacking**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	B	7
	Government-Private Run System	B	5
Private-Run System	Government-Private Run System	A	3

According to the evaluation results made by Expert A in the fight against the Theft and Hacking problem, the best alternative micromobility operations are carried out by private companies with 64.9% weight, this is followed by the state-private sector cooperation alternative with 27.9% weight. The most ineffective alternative in the responsibility sharing of this risk factor, with a weight of 7,2%, seems to be the alternative of conducting the operations by the state. Obtained AHP results and consistency values are shown in Table 6.12

Table 6.12. Weights and Attributes of Alternatives for Theft and Hacking Criteria.

Alternative	**Weight**
Government-Run System	%7,2
Private-Run System	%64,9
Government-Private Run System	%27,9
Attribute	**Value**
Consistency Ratio (CR)	%6,8
Lambda	3065
GCI	0,19

The AHP results and alternative weights for maintenance and redistribution of economic risk factors are shown in Table 6.13 and Table 6.14

Table 6.13. Evaluation of Alternatives for Maintenance and Redistribution Risk Criteria.

Criterion	**Maintenance and Redistribution**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	5
	Government-Private Run System	B	2
Private-Run System	Government-Private Run System	B	5

Table 6.14. Weights and Attributes of Maintenance and Redistribution Cost Criteria.

Alternative	**Weight**
Government-Run System	%35,2
Private-Run System	%8,9
Government-Private Run System	%55,9
Attribute	**Value**
Consistency Ratio (CR)	%5,6
Lambda	3054
GCI	0,16

For the economic risk factor of the decrease in vehicle usage due to bad weather conditions, the operation management by the state is the best alternative by Expert A, while the pairwise comparison matrix and AHP results are shown in Table 6.15 and Table 6.16 below.

Table 6.15. Evaluation of Alternatives for Decrease of Usage due to Bad Weather Risk Criteria.

Criterion	**Bad Weather Conditions**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	5
	Government-Private Run System	A	3
Private-Run System	Government-Private Run System	B	2

Table 6.16. Weights and Attributes of Alternatives for Decrease of Usage due to Bad Weather Conditions Criteria.

Alternative	**Weight**
Government-Run System	%64,8
Private-Run System	%12,1
Government-Private Run System	%23,1
Attribute	**Value**
Consistency Ratio (CR)	%0,4
Lambda	3004
GCI	0,1

Likewise, according to the AHP assessment made by Expert A, in the intervention of private sector competition by the state, which is the last economic risk factor, it was determined with a weight of 63.7% that operations should be carried out by the state in the micromobility sector. The obtained pairwise comparison matrix and AHP results are shown in Tables Table 6.17 and Table 6.18

Table 6.17. Evaluation of Alternatives for State Interference in Private Sector Risk Criteria.

Criterion	**State Interference**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	3
	Government-Private Run System	A	5
Private-Run System	Government-Private Run System	B	3

Table 6.18. Weights and Attributes of Alternatives for State Interference in Private Sector Criteria.

Alternative	**Weight**
Government-Run System	%63,7
Private-Run System	%25,8
Government-Private Run System	%10,5
Attribute	**Value**
Consistency Ratio (CR)	%4
Lambda	3039
GCI	0,12

According to the results of the evaluation of the alternatives with AHP for environmental risk factors, expert A has predicted that the state will take responsibility for the risks with 73.1% and 67.4% weights for both the high GHG emissions resulting from the company operations for micromobility vehicles and the visual pollution risk factors. The obtained pairwise comparison matrices and AHP results of GHG emissions criteria are shown in tables Table 6.19 and Table 6.20

Table 6.19. Evaluation of Alternatives for High GHG Emissions Risk Criteria.

Criterion	**High GHG Emissions**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	7
	Government-Private Run System	A	5
Private-Run System	Government-Private Run System	B	3

Table 6.20. Weights and Attributes of Alternatives for High GHG Emissions Criteria.

Alternative	**Weight**
Government-Run System	%73,1
Private-Run System	%8,1
Government-Private Run System	%18,8
Attribute	**Value**
Consistency Ratio (CR)	%6,8
Lambda	3065
GCI	0,19

For Visual Pollution risk criteria, AHP evaluation matrice and results are shown in Table Table 6.21 and Table 6.22

Table 6.21. Evaluation of Alternatives for Visual Pollution Risk Criteria.

Criterion	**Visual Pollution**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	5
	Government-Private Run System	A	4
Private-Run System	Government-Private Run System	B	3

Table 6.22. Weights and Attributes of Alternatives for Visual Pollution Criteria.

Alternative	**Weight**
Government-Run System	%67,4
Private-Run System	%10,1
Government-Private Run System	%22,6
Attribute	**Value**
Consistency Ratio (CR)	%8,9
Lambda	3086
GCI	0,26

Among the alternatives for the high accident and injury risk factor examined under the security aspect, the most appropriate one is the execution of the operations by the state with a weight of 54%, while in the risk factor of not using personal protective equipment, all alternatives seem to share the risk with equal responsibility with a weight of 33% by expert A. The obtained pairwise comparison matrices and AHP results are shown in Tables Table 6.23 and Table 6.24

Table 6.23. Evaluation of Alternatives for Serious Injury and Accidents Risk Criteria.

Criterion	**Serious Injury and Accidents**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	3
	Government-Private Run System	A	2
Private-Run System	Government-Private Run System	B	2

Table 6.24. Weights and Attributes of Alternatives for Serious Injury and Accidents Criteria.

Alternative	**Weight**
Government-Run System	%54
Private-Run System	%16,3
Government-Private Run System	%29,7
Attribute	**Value**
Consistency Ratio (CR)	%1
Lambda	3009
GCI	0,03

In tables Table 6.25 and Table 6.26 low use rate of personal protecting equipment evaluation matrix and results are shown;

Table 6.25. Evaluation of Alternatives for Low use rate of Personal Protecting Equipment Risk Criteria.

Criterion	**Personal Protecting Equipment**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	1
	Government-Private Run System	A	1
Private-Run System	Government-Private Run System	A	1

Table 6.26. Weights and Attributes of Alternatives for Low use of PPE Criteria.

Alternative	**Weight**
Government-Run System	%33,3
Private-Run System	%33,3
Government-Private Run System	%33,3
Attribute	**Value**
Consistency Ratio (CR)	%0
Lambda	3000
GCI	0,00

Among the risk factors examined under the public-policy aspect, the private sector takes responsibility with a weight of 63.7% for the problem of insufficient data available for the performance measurements of micromobility vehicles, while the risks of protection of the obtained data and deficiencies in the legal regulations are 64.9%

and 73.1%. It has been determined that the state should assume the responsibility for risks. Pairwise comparison matrices and AHP results completed by Expert A for Insufficient management due to inadequate data are shown in Tables Table 6.27 and Table 6.28

Table 6.27. Evaluation of Alternatives for Insufficient Management due to Inadequate Data Risk Criteria.

Criterion	**Inadequate Data**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	B	5
	Government-Private Run System	B	3
Private-Run System	Government-Private Run System	A	3

Table 6.28. Weights and Attributes of Alternatives for Inadequate Data Criteria.

Alternative	**Weight**
Government-Run System	%10,5
Private-Run System	%63,7
Government-Private Run System	%25,8
Attribute	**Value**
Consistency Ratio (CR)	%4
Lambda	3039
GCI	0,12

AHP matrix and results for Protection and Sharing of Data risk criteria are shown in Table 6.29 and Table 6.30.

Table 6.29. Evaluation of Alternatives for Protection and Sharing of Data Risk Criteria.

Criterion	**Protection and Sharing of Data**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	7
	Government-Private Run System	A	3
Private-Run System	Government-Private Run System	B	5

Table 6.30. Weights and Attributes of Alternatives for Protection and Sharing of Data Criteria.

Alternative	**Weight**
Government-Run System	%64,9
Private-Run System	%7,2
Government-Private Run System	%27,9
Attribute	**Value**
Consistency Ratio (CR)	%6,8
Lambda	3065
GCI	0,19

AHP matrix and results for lack of legal regulations risk criteria filled by expert A are shown in Table 6.31 and Table 6.32

Table 6.31. Evaluation of Alternatives for Lack of Legal Regulations Risk Criteria.

Criterion	**Lack of Legal Regulations**		
Alternative A	**Alternative B**	**A or B**	**Scale (1-9)**
Government-Run System	Private-Run System	A	7
	Government-Private Run System	A	5
Private-Run System	Government-Private Run System	B	3

Table 6.32. Weights and Attributes of Alternatives for Lack of Legal Regulations Criteria.

Alternative	**Weight**
Government-Run System	%73,1
Private-Run System	%8,1
Government-Private Run System	%18,8
Attribute	**Value**
Consistency Ratio (CR)	%6,8
Lambda	3065
GCI	0,19

6.3. Overall AHP results for Expert A :

As a result of the evaluation completed by Expert A, global weights for each risk factor were obtained by multiplying the local weights determined for the main criteria and the local weights determined for the sub-criteria. Afterward, the global weights of the alternatives for each risk factor were found by multiplying the local weights determined for the alternatives and the global weights determined for the risk factors, and the final results were obtained by adding the global weights of the alternatives for all risk factors. In this process, attention was paid to the fact that the sum of the weights of the 3 alternatives was 1, and according to the AHP results completed by expert A, the management and operations by the government in the micromobility sector is the most important with 0.576 weight, while the private sector-run system and state-private sector cooperation have close priority weights with 0.204 and 0.220 The resulting table is shown in Table 6.33 below.

Table 6.33. Overall AHP results for Alternatives by Expert A.

EXPERT A					
Main Criteria	Local Weight	Risk Criteria	Government-Run	Private-Run	Government-Private-Run
			Global Weight of Alternative		
Economic Aspect	0,504	R1	0,00	0,03	0,01
		R2	0,01	0,00	0,02
		R3	0,11	0,02	0,04
		R4	0,17	0,07	0,03
Environmental Aspect	0,068	R5	0,01	0,00	0,00
		R6	0,04	0,01	0,01
Safety Aspect	0,193	R7	0,09	0,03	0,05
		R8	0,01	0,01	0,01
Public-Policy Aspect	0,235	R9	0,00	0,03	0,01
		R10	0,01	0,00	0,01
		R11	0,13	0,01	0,03
		Priority of Alternative	0,58	0,20	0,22

6.4. Expert B

Expert B is a civil engineer, has a master's and doctorate education in the field of transportation engineering and is an expert who has been working in consultancy firms serving in this field for 3 years. A pair-wise comparison study was conducted for all main and sub-criteria and alternatives by expert B, who is knowledgeable about the AHP evaluation method. According to the results of the double-comparison made between the 4 main criteria, the criteria with the highest priority value were determined as the economic criteria with 45% weight and the safety criteria with 43.1%, while the environmental criteria were determined as 7.5% and the public-policy criteria were determined as the lowest weighted criteria with 4.5%. Pairwise comparison matrices completed by Expert B and the resulting weight tables are shown in Appendix A. Among the sub-criteria of the economic main criterion, according to the pairwise comparison matrices completed by expert B, the most important criterion was determined as theft and hacking of vehicles with a weight of 66.3%, while the maintenance costs of the vehicles and the decrease in use in bad weather conditions were found to have 13.1% and 11.7% weight so they are close to the degree of importance. The completed pairwise comparison matrices and results tables for the economic sub-criteria are shown in Appendix B. According to the results of the AHP evaluation made among the environmental sub-criteria, the GHG emissions that will occur in the collection and redistribution of vehicles with a weight of 90% were determined as the criterion that should be given the highest priority. Following this, with 10% weight, visual pollution was determined as the second priority. AHP matrices and weight tables are shown in Appendix C. Among the safety criteria, high accident and injury rates with a weight of 83.3% emerged as a priority risk compared to not using personal protective equipment with a weight of 16%. AHP evaluation matrices and result tables are shown in Appendix D. Among the public-policy criteria, which is the last sub-criteria evaluation, according to the pairwise comparison matrices made by expert B, the risk criterion that should be given first with a weight of 59.2% was the lack of legal regulations, while the protection and sharing of personal data took the second place with 33.3%. The least important criterion is the availability of insufficient data for performance measurement. Pairwise comparison matrices and the results obtained are shown in Appendix E. Three alternatives were evaluated for all risk criteria by Expert B. According to the evaluations made for the economic sub-criteria, while the risk of theft and hacking should be tackled with 59.2% of the weight of the state-private sector cooperation, despite the high maintenance and redistribution costs, the private sector should take responsibility with a weight of 59.2%. On the other hand, the state should assume the risk with 57.1% regarding the low usage that will occur in bad weather conditions. Regarding the intervention of the state in the private sector, with a high weight of 74%, the state should take responsibility and prevent this risk from occurring. In the fight against environmental risks, expert B stated in his assessments that the private sector should take responsibility. On the other hand, it has been obtained from the results of the pairwise comparisons that the state should take responsibility with a high rate of security risks. For the public-policy risk criteria, it was obtained from the evaluation results made by expert B that the state should take the necessary responsibility of more than 70% weight. Pairwise comparison matrices filled by Expert B and result tables are shown in Appendix F.

6.5. Expert C

Expert C has a master's and doctorate degrees in transportation engineering and is a transportation expert, especially about autonomous-connected vehicles, who has been involved in various projects in this field. All risk criteria have been evaluated by Expert C within the scope of the AHP hierarchy. All of the obtained results were considered consistent as they had an inconsistency ratio of less than 10Among the 4 main criteria evaluated by Expert C, the security criterion was the most prioritized with a weight of 71%. This is followed by economic, environmental and public-policy criteria, respectively. The resulting pairwise comparison matrices and result tables are shown in Appendix A. Among the economic criteria, the state's intervention in the private sector was determined as the highest economic risk criterion, with a weight of 69.2%. Pairwise comparison matrices and results tables between the economic sub-criteria obtained are shown in Appendix B. Among the environmental criteria, GHG emissions were determined as a much more important criterion with a weight of 25% versus 75% compared to visual pollution. In addition, among the safety risks, the high accident and injury rate was determined as 87.5% among the most important risk factors. Result tables are shown in Appendix C and D. The lack of the necessary regulations was determined by expert C as the most important risk criterion with a weight of 67.2% among the public-policy sub-criteria. Pairwise comparison matrices are shown in Appendix E.

According to the alternatives evaluated by Ekspert C, all the alternatives related to the low use in bad weather conditions in the sharing of responsibility regarding the economic risk criteria have equal responsibility with 33.3% weight, while the alternative with the highest priority in the other three criteria has been determined as the execution of the system by the private sector. While the risk allocation related to the visual pollution risk was made, the alternative with the highest priority with a weight of 73.1% was that the system was run by the state, while all alternatives were determined to have equal priority in the fight against GHG emission. Among the safety criteria, it was stated that the private sector should take responsibility with 64.9% weight in the fight against the low rate of use of personal protective equipment, while it was determined that the state should take responsibility with a weight of 73.1% against accidents and injuries. Among the public-policy criteria, while the three alternatives have equal responsibility with 33.3% weight for the risk of protecting and sharing personal data, it has been determined that the private sector should take responsibility in combating the insufficient data required to increase and measure performance. Pairwise comparison matrices filled by Expert C and result tables are shown in Appendix F.

6.6. Expert D

Expert D holds a Ph.D. in transport engineering and is a transport specialist specializing in traffic signaling. All risk criteria and alternatives were evaluated by Expert D with the help of pairwise comparison matrices in accordance with the AHP analysis method and consistent results were obtained. Among the main criteria, security risks were identified as having the highest priority, with a weight of 69.4%, similar to Expert C. The resulting tables are shown in Appendix A. While the criterion with the highest priority among the economic risk criteria was determined as the decrease in the frequency of use in bad weather conditions, the risk criterion with the highest priority among the environmental risks was determined as visual pollution with a weight of 75%. The results obtained are shown in Appendix B and C. Among the security criteria, a high accident and injury rate was determined as the most important criterion with a weight of 75%, while the protection and sharing of personal data was determined as the least important criterion with a weight of 7.8% among the public-policy criteria. The resulting tables are shown in Appendix D and E. While it was determined by Expert D that it should take close responsibility for three alternatives for economic criteria, it was determined that the system should be managed by the state against environmental criteria. It has been determined that the stakeholder that should take the highest responsibility for security risks is the private sector. While it has been determined that the best way to fight risks is determined by the cooperation of the state-private sector in obtaining the necessary data for performance measurement, it has been determined that the state should have the highest responsibility against the risk of protecting personal data. The resulting tables are shown in Appendix F.

6.7. Expert E

Expert E is a transportation specialist who has a master's degree in transportation engineering and works as a research assistant at a state university. Risk criteria and alternatives related to the use of micromobility vehicles were evaluated by expert E using the AHP analysis method and paired comparison matrices, their weights were found and risk allocation was made. According to the evaluation made by Ekspert E, the criterion with the highest weight among the main criteria was the economic aspect, while the criterion with the lowest importance was the safety aspect. Pairwise comparison matrices and results tables are shown in Appendix A. While the risk criterion with the highest weight among the economic sub-criteria is the risk that vehicles are exposed to theft and hacking, the most important risk criterion in terms of environmental aspect was determined as GHG emission emissions with a weight of 88.9%. Among the sub-criteria evaluated within the scope of the safety aspect, the accident and injury risk criterion was determined as the criterion with the highest weight. In addition, for the public-policy aspect, the most prioritized risk criterion was determined as the lack of sufficient data for the performance measurements of the vehicles. The results obtained are shown in Appendix B, C, D and E. According to the evaluations among the alternatives for the economic risk criteria, it has been determined that the most priority alternative, micromobility applications should be managed by the private sector and take responsibility for the risk. While determining from the results of the analysis that the most efficient alternative for environmental and security risk criteria, micromobility applications should be managed by the state, it was determined by the obtained weights that the private sector should be involved in performance measurement and improvements, on the other hand, that the system should be supported by the state against data protection and legal regulation deficiencies. . The results obtained are shown in Appendix F.

6.8. Expert F

Expert F has a master's degree in transportation engineering and is an expert working in companies serving in the field of logistics. All criteria and alternatives were evaluated consistently in accordance with the AHP hierarchy. According to the completed pairwise comparison matrices among the main criteria, the security aspect was determined as the most important criterion with a weight of 55.7%. The result tables are shown in Appendix A. According to the evaluations made for the economic aspect sub-criteria, the intervention of the state in the private sector stands out as the criterion with the highest weight. Among the environmental sub-criteria, the risk of GHG emission release was determined as a much more important risk factor than visual pollution, while the high risk of accident and injury was evaluated as having a higher degree of importance than not using personal protective equipment. In addition, among the three criteria evaluated within the scope of the public-policy aspect, the inadequacy of data for performance measurement and management has emerged as the top priority criterion, with a weight of 64.8%. The resulting tables are shown in Appendix B, C, D and E. According to the weight degrees of the alternatives evaluated for the economic sub-criteria, the private sector has emerged as having a high importance in all criteria except the state's intervention in the private sector. Contrary to this, the execution of the system by the state in terms of responsibility for environmental risks is stated as much more important than the other two alternatives. For the risk criteria evaluated within the scope of the security aspect, the three alternatives have been determined as having equal importance with 33.3% weight by expert F. In addition, among the 3 alternatives for public-policy risk criteria, the alternative with the highest degree of importance has been determined as the operation of micromobility applications by the state. The results obtained are shown in Appendix F.

6.9. Expert G

Expert G is a Ph.D. student in transportation engineering and is an expert involved in various academic projects. According to the results of the analysis, which was determined to be consistent in accordance with the AHP method, the criterion with the highest importance among the main criteria was determined as the environmental aspect with 66.4%. The results obtained are shown in Appendix A.

While the vulnerability of micromobility vehicles to risks such as theft and hacking and the intervention of the state in the private sector were determined as the two most important economic sub-criteria, the ratio of GHG emission emissions to visual pollution was stated as much more important. Similarly, the risk of accident and injury was determined as the most important safety risk. The public-policy criterion, which has the highest degree of importance, was determined by expert G as the protection and sharing of personal data. Pairwise comparison matrices and analysis results completed by Expert G are shown in Appendix B, C, D and E. According to the results of the alternatives evaluated by Expert G, it was determined that the highest weighted alternative applications should be carried out by the state for all risk criteria except the maintenance and redistribution cost of micromobility vehicles and the risk criteria of low use that will occur in bad weather conditions. The results obtained are shown in Appendix F.

6.10. Expert H

Expert H is a specialist in traffic data analysis with a Ph.D. in transport engineering. According to the results of the AHP analysis obtained, the most important criterion among the main criteria was the security aspect, while among the alternatives evaluated within the scope of combating these risks, the two alternatives with the highest importance were the implementation of micromobility applications with government and government-private sector partnerships. The results obtained are shown in Appendix A. Among the sub-criteria evaluated for the environmental and safety aspects, the most important risk criteria are GHG emissions and high accident and injury rates, respectively, while the lack of legal regulations and insufficient data for performance measurement and management are the two most important public-policy sub-criteria with close weights. The results obtained are shown in Appendix B, C, D and E. According to the AHP analysis results obtained for the alternatives evaluated by Expert H, it was determined that the importance of government and private sector cooperation in the fight against risk criteria was emphasized in general. In the criteria evaluated within the scope of environmental and security aspects, especially the alternative of running the system by the state has higher degrees of importance, while among the risk criteria evaluated within the scope of the economic and public-policy aspect, the private sector stands out as having a higher responsibility in risk sharing. The results obtained are shown in Appendix F.

6.11. Expert I

Expert I has a master's degree in transportation engineering and is a specialist in a company that provides consultancy services in the field of transportation. According to the results of the AHP analysis, the most important criterion among the main criteria was determined as the economic aspect with 56.5% weight. The results obtained are shown in Appendix A. According to the results of the evaluation made among the economic sub-criteria, the intervention of the state in the private sector has been determined as having a much higher degree of importance compared to the other three criteria. The results obtained are shown in Appendix B. While the increase in GHG emissions was determined as the environmental risk with the highest degree of importance, high accident and injury rates were stated to be of much higher importance among the safety risk criteria than not using personal protective equipment. The results obtained are shown in Appendix C and D. Among the public-policy criteria, the protection and sharing of personal data was determined as the most important sub-criterion with a weight of 63.7%. Obtained results are shown in Appendix E. Among the three alternatives, expert I determined that the alternative micromobility applications should be carried out by the government, with the highest weight of importance for all risk criteria except lack of data for performance measurement and maintenance and redistribution costs. The results obtained were shown in Appendix F.

6.12. General Overview

After the individual priority weights of the micromobility main criteria and sub-criteria were evaluated by 9 different experts and the risk-sharing results among the alternatives were found, these results were obtained by averaging the joint evaluation results of 9 experts. According to the results obtained, the criterion with the highest weight among the 4 aspects evaluated among the main criteria was found to be the security aspect with a weight of 0.376. This is followed by the economic aspect with a weight of 0.333. This result shows that experts think that the most prioritized risks will arise due to security and economic performance. According to the evaluations made among the economic sub-criteria, the state's intervention in the private sector was determined as the economic sub-title with the highest degree, with a weight of 0.386. This is followed by the economic losses that micromobility vehicles can cause by being exposed to theft and hacking with a weight of 0.290. In the fight against these two risks, the alternative with the highest priority was that micromobility practices should be carried out by the state. Among the sub-criteria examined around the environmental aspect and the safety aspect, the increase in GHG emissions due to micromobility operations emerged as the most important environmental risk with a weight of 0.698, while the high accident and injury risks were determined as the safety criteria that should be given the highest priority with a weight of 0.809. Finally, among the sub-criteria evaluated within the scope of the Public-policy aspect, the lack of legal regulations was determined as the most important risk criterion with a weight of 0.409. This is followed by the criterion of the inadequacy of data required for performance measurement and the criterion of data protection and sharing. The overall weight and priority table obtained are shown in Table 6.34 below.

Table 6.34. General Overview of Evaluation of Experts.

EXPERT A					
Main Criteria	Local Weight	Risk Criteria	Government-Run	Private-Run	Government-Private-Run
			Global Weight of Alternative		
Economic Aspect	0,33	R1	0,03	0,03	0,03
		R2	0,01	0,03	0,02
		R3	0,02	0,02	0,02
		R4	0,06	0,04	0,03
Environmental Aspect	0,16	R5	0,06	0,03	0,03
		R6	0,03	0,01	0,01
Safety Aspect	0,37	R7	0,16	0,07	0,08
		R8	0,02	0,02	0,02
Public-Policy Aspect	0,14	R9	0,01	0,02	0,01
		R10	0,02	0,01	0,01
		R11	0,03	0,01	0,02
		Priority of Alternative	0,47	0,28	0,25

6.13. Sensitivity Analysis

After determining the priorities of all risk criteria with the AHP method, the sensitivity analysis method was applied to reveal which risk criteria are more important in terms of cost. Considering the uncertainties of the risks during the sensitivity analysis, the priority weights determined by the AHP were accepted as the realization probabilities. The probability of realization of the risk criteria is shown in the Table 6.35

below. The most important risk criteria are selected and used in the sensitivity analysis. Their impact on economic evaluation is considered with the parameters that are changed during the implications of performance evaluations.

Table 6.35. Probability of Risk Criteria.

Risks Criteria	**Probability**
Theft and Hacking	%10
High Maintenance and Redistribution Cost	%5
Bad Weather Conditions	%6
State Interference	%13
High GHG Emissions	%12
Visual Pollution	%5
High injury and accident Rates	%30
Absence of PPE	%7
Data inadequancy	%4
Data Protection and Sharing	%4
Lack of Regulations	%5

A pilot program scenario was created for the sensitivity analysis. In the scenario created, it is assumed that 1000 micromobility vehicles provide service in operations for 1 month.

In the sensitivity analysis, the following variables were used as variable parameters, respectively.

- Life-span of Vehicles: The service life of the vehicles is accepted as 30 days in the scenario where the risks do not occur. In case of realization of risks, cost calculation was made by changing the usage period of the vehicles.
- Vehicles in Service (Month): The usage period of the vehicles and the total number of vehicles serving in one month have been determined.

- Vehicle Cost: It is used to calculate the vehicle cost that arises due to the mishaps that occur in the lifetime of the vehicles.
- Trip Duration: Travel time and how many minutes the vehicles travel in a single use were determined. A determination was made between the periods obtained in academic studies and company data.
- Price of Trips: The revenue generated by charging per minute is calculated using the travel time obtained.
- Cost of Service: It is used in the cost calculation by using the total average of maintenance, redistribution and charging costs per vehicle usage.
- Number of Trips (Day): How many times a vehicle is used for travel during the day is used in cost calculations.

After the parameters were determined, the profit-loss graph was created by calculating the income-expense with the help of iterations for the 6 risk criteria that are expected to affect the cost the most.

6.13.1. Theft and Hacking Risk Criteria

As a result of the removal of the vehicles from the service after problems such as theft or hacking, both the narrowing of the service area and the cost changes that will occur due to re-purchasing the vehicle have been taken into account. After parameters is obtained, three Iterations example of Cost Calculations is shown in Table 6.36 below. Total number of Iterations for sensitivity analysis was obtained as 100. By using these parameters changes expanse, income and profit is calculated by each risk criteria.

Table 6.36. Theft and Hacking Risk Criteria Cost Analysis.

Iteration	Probability	Lifespan of Vehicles	Number of Vehicles	Trip Duration(min) /Price of 1 Trip		Cost of Service($)	Number of trips (per vehicle / day)
1	0,13	162	4860000	9	1,80	1,93	4
2	0,03	300	9000000	9	1,80	1,72	7
3	0,15	151	4530000	7	1,40	1,91	2

For sensitivity analysis 5 different risk is selected additional to theft and hacking risk criteria. 5 different risk is used and same iterations table is created as follows ;

- High Redistribution and Maintenance Cost
- Decrease of Usage due to Bad Weather Conditions
- State's Interference in Private Sector Competition
- Lack of Regulations
- High Injury and Accidents Rates

According to the results of the sensitivity analysis, it was determined that the most important risk criteria are the maintenance, distribution and charging operation costs of the vehicles, considering the effects of the risk criteria on the parameters and their financial provisions. In addition, it has been determined that in order to maximize the income level, the risks of accident and injury should be eliminated and the regulatory deficiencies should be resolved. As shown in the literature review, the relationship between these two risk criteria was also demonstrated by sensitivity analysis. The resulting profit-loss graph is shown in Figure 6.3 below.

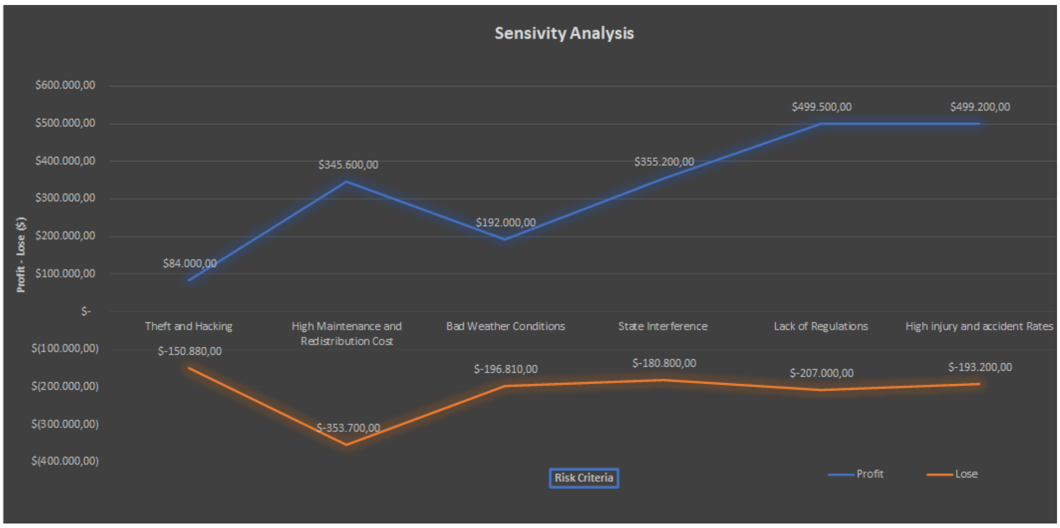

Figure 6.3. Sensitivity Analysis for Risk Criteria.

7. DISCUSSION

The purpose of comprehensively evaluating the micromobility sector from many aspects, which forms the basis of this study, was completed with the determination of risk criteria and the application of the AHP method, which is a reliable multi-criteria decision-making method where the determined criteria and alternatives are evaluated by experts. When the results obtained were examined, it was determined that each expert emphasized different risk criteria and alternatives. This occurs because micromobility applications are taking place as a new technology today and the user experience has not developed enough, and it fits the situation of being evaluated from a single perspective observed in academic studies in this field. It should be taken into account that the economic, environmental, security and public-policy aspects, which are the 4 main criteria determined in this study, are interconnected and that the improvement made in one area will reduce the possibility of risks in other areas. An example of this is that with the improvement of safety systems, there will be an increase in the use of e-scooters and bicycles, thereby improving economic performance. On the other hand, increasing the safety performance requires investment in infrastructures because it has been determined that the accident rate of micromobility vehicles used in the same lanes as motor vehicles is 3 times higher. For this reason, the operations of companies that provide micromobility services are prohibited in countries such as Spain, Germany and France, which are behind in reaction to the pace of technological development. Sectoral development is hindered by the government's intervention in the private sector [12]. For this reason, the relations of the evaluated criteria, both separately and with each other, were taken into consideration when evaluating the results.

The fact that the security aspect that emerged as a result of the analysis is the most important aspect shows that users have reservations and it is one of the main reasons why they do not prefer micromobility vehicles in their daily life. It can be said that the inadequacy of national and local regulations and the implementation of different legal practices in different regions play an important role in this. This result is parallel with the finding in the study by Gössling [18] that the most important obstacle to the use of micromobility tools is public perception. According to the results of the evaluation made by the experts, two main factors should be taken into consideration as the reason for the state's intervention in the private sector, which emerges as the most important risk scale among the sub-criteria of the economic aspect, which is in the second order of importance. The first of these can be determined by Deighton-Smith [110] as the effort to prevent competition that will occur with the docked sharing systems put into service by the state in the existing transportation network, and the restrictions to be applied to protect the public against the problems that will arise in terms of security with the execution of the micromobility sector by the municipalities. To eliminate these deficiencies, licensing procedures, vehicle maintenance controls and infrastructure arrangements are required to be applied to private companies, and more importantly, it is necessary to plan according to mutual data sharing and performance measurements to the demands and needs of the public. In addition, because the micromobility market is not stable and the price is low due to the high competition, it is necessary to take measures to increase the quality of service and also necessary rules and regulations should be determined before private companies are allowed to start providing services without obtaining the necessary permits to enter the market and to wait for the development of services over time [71]. For this reason, it was stated by Deighton-Smith [110] that attempts should be made to help reduce market errors as the most functional regulation model.

When it comes to the necessity of the regulations, the environmental aspect comes at the beginning of the most affected aspects depending on the regulations made. Although it was determined as the third most important risk criterion in the evaluations, it should be taken into consideration due to its mutual relations with the public-policy aspect. There are conflicting academic studies regarding the environmental effects of micromobility vehicles. Despite the publications stating that fossil fuel vehicles used in the maintenance and redistribution processes of vehicles will increase GHG emissions and that environmental damage will be greater than the benefits due to the reduction in the use of environmentally friendly public transportation, it is stated that GHG emissions will decrease due to the decrease in individual vehicle use and air pollution will decrease [82, 125]. In this regard, integration between micromobility vehicles and public transportation infrastructure should be ensured to reduce the use of individual vehicles. One of the main ways to achieve this is to make easy, accessible and affordable parking spaces for micromobility vehicles at public transportation stations, thus preventing visual pollution and occupation of public spaces. In addition, one of the most critical issues is to increase the level of accessibility to micromobility vehicles and public transportation stations and to provide equal access to all segments of the public. For this reason, it becomes inevitable for the state to cooperate with the private sector and create an equitable transportation system [10, 67]. The biggest problems in providing equal transportation opportunities are the problems experienced in providing services to people living in areas far from the city center, long distances between public transportation stations and houses, and the use of micromobility vehicles in short distances due to infrastructure inadequacies, high usage fees and problems in accessing online payment systems [125].

It is very clear that the method that should be used in the solution of all the above-mentioned economic, safety and environmental risks is the creation of a suitable service environment with planning and regulations. In planning, the most important issue to be considered is the use and interpretation of data to be obtained from micromobility vehicles. Here, it is clear that the existing database will be insufficient to solve all the problems, and the data to be used in decision-making mechanisms for performance measurements and improvement and problem detection is limited. [94]. The main reason for this is the unwillingness of private companies to share data and their lack of sufficient storage infrastructure. It is necessary to make arrangements to create a secure sharing network regarding the use and sharing of personal and travel data obtained, and in this context, it has been determined by the analysis that the responsibility of the government is high. In addition, the use of the obtained data for commercial purposes should be prevented and companies should be prohibited from making profits through data trading. In this way, it is expected that the prejudice of the public against micromobility vehicles will decrease [101, 102]. Public benefit can be achieved by including the public in the planning process made by using these data [31].

In this study, which was prepared to show the importance of joint action in the decision-making and implementation mechanisms of all components that will be affected by different perspectives to advance by laying solid foundations in the micromobility sector, both the relationship between different risk criteria and the main duties of the responsible institutions were determined.

With this research, in addition to the studies in the literature, the risks were identified and the responsible persons were revealed. The effects of the micromobility sector, which has a transitional habitat, were analyzed in detail. To obtain the most accurate results in future studies in this field, it is necessary to obtain healthier results by using the data obtained from existing applications apart from simulations. Since it is a new subject in the literature, cooperation should be organized between the companies providing services in this field and the academy to avoid data limitations. Otherwise, it becomes possible to have negative consequences for people and companies due to the length of the theoretical results becoming operational in practice.

8. CONCLUSION

One of the most important sub-headings of the sharing economy, the sharing transportation sector, the most up-to-date and growing micromobility sector, introduces many different unknowns and innovations into our lives. As this research reveals, the government, private sector and society are directly or indirectly affected by the micromobility sector, apart from the people who use these vehicles. To prevent bad results, risk criteria were determined and risk shared between alternatives and recommendations for improvements for the next steps were made at the end of the research. It has been revealed that trying to develop this field only by the state or the private sector will not yield correct results and a one-sided perspective in problem solving will not eliminate the risks.

The evaluation was made from all perspectives with the comprehensive literature review method used in the determination of risks. In the determination of alternatives, it was ensured that results suitable for current conditions were obtained by focusing between the state and the private sector. A hierarchical structure was created with the AHP method used in the evaluation of risks, the effects of different aspects were shown and a reliable multi-criteria decision-making method was applied. The importance of risk sharing and the current impact of the sharing economy are analyzed in detail, allowing the reader the opportunity to look at the micromobility sector from a wider perspective. Due to the expertise of the experts who made the evaluation, inconsistent results were prevented and the way to use the results obtained in practice in a way that facilitates human life was opened. With the determination of economic, environmental, safety and public-policy aspects as the main topics within the AHP hierarchy, it was ensured that all stakeholders affected by the micromobility sector were a part of the research.

According to the results of the AHP analysis obtained, it is expected that the determination of the necessity of minimizing the risks with the cooperation of the state-private sector is expected to contribute to the academic literature as a study showing the importance of cooperation, coinciding with the state's inability to prepare the necessary infrastructural and legal ground for the rapid investments of the private sectors today. Otherwise, the possibility that the micromobility sector, which cannot reach its potential, will become disfunctional with the emergence of the risks determined in the study and that the micromobility sector will be deleted from the markets before it can complete its development should always be considered.

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APPENDIX A: MAIN CRITERIA PAIR-WISE COMPARISON

Expert B :

Table A.1. Pair-comparison matrice by Expert B.

Criterion A	Criterion B	A or B	Scale(1-9)
Economic Aspect	Environmental Aspect	A	7
	Safety Aspect	A	1
	Poblic-Policy Aspect	A	9
Environmental Aspect	Safety Aspect	B	6
	Poblic-Policy Aspect	A	2
Safety Aspect	Public-Policy Aspect	A	9

Table A.2. Weights and Attributes of Main Criteria by Expert B.

Criterition	Weight
Economic Aspect	45%
Environmental Aspect	7.5%
Safety Aspect	43.1%
Public-Policy Aspect	4.5%
Attribute	Value
Consistency Ratio (CR)	0.7%
Lambda	4,019
GCI	0,03
Psi	0,00%

Expert C :

Table A.3. Pair-comparison matrice by Expert C.

Criterion A	**Criterion B**	**A or B**	**Scale(1-9)**
Economic Aspect	Environmental Aspect	A	3
	Safety Aspect	B	7
	Poblic-Policy Aspect	A	5
Environmental Aspect	Safety Aspect	B	9
	Poblic-Policy Aspect	A	1
Safety Aspect	Public-Policy Aspect	A	9

Table A.4. Weights and Attributes of Main Criteria by Expert C.

Criterition	**Weight**
Economic Aspect	17.5%
Environmental Aspect	6.5%
Safety Aspect	71%
Public-Policy Aspect	5.5%
Attribute	Value
Consistency Ratio (CR)	6.7%
Lambda	4,182
GCI	0,24
Psi	0,00%

Expert D :

Table A.5. Pair-comparison matrice by Expert D.

Criterion A	**Criterion B**	**A or B**	**Scale(1-9)**
Economic Aspect	Environmental Aspect	A	1
	Safety Aspect	B	7
	Poblic-Policy Aspect	A	5
Environmental Aspect	Safety Aspect	B	7
	Poblic-Policy Aspect	A	4
Safety Aspect	Public-Policy Aspect	A	9

Table A.6. Weights and Attributes of Main Criteria by Expert D.

Criterition	**Weight**
Economic Aspect	13.7%
Environmental Aspect	12.7%
Safety Aspect	69.4%
Public-Policy Aspect	4.2%
Attribute	Value
Consistency Ratio (CR)	7.5%
Lambda	4,205
GCI	0,27
Psi	0,00%

Expert E:

Table A.7. Pair-comparison matrice by Expert E.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Environmental Aspect	A	3
	Safety Aspect	A	5
	Public-Policy Aspect	A	9
Environmental Aspect	Safety Aspect	A	5
	Public-Policy Aspect	A	6
Safety Aspect	Public-Policy Aspect	A	3

Table A.8. Weights and Attributes of Main Criteria by Expert E.

Criterition	**Weight**
Economic Aspect	56.1%
Environmental Aspect	29.7%
Safety Aspect	9.7%
Public-Policy Aspect	4.5%
Attribute	Value
Consistency Ratio (CR)	6.5%
Lambda	4,177
GCI	0,23
Psi	0,00%

Expert F:

Table A.9. Pair-comparison matrice by Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Environmental Aspect	A	5
	Safety Aspect	B	3
	Public-Policy Aspect	A	7
Environmental Aspect	Safety Aspect	B	5
	Public-Policy Aspect	A	2
Safety Aspect	Public-Policy Aspect	A	8

Table A.10. Weights and Attributes of Main Criteria by Expert F.

Criterition	**Weight**
Economic Aspect	30.7%
Environmental Aspect	8.7%
Safety Aspect	55.7%
Public-Policy Aspect	5%
Attribute	Value
Consistency Ratio (CR)	5.7%
Lambda	4,148
GCI	0,19
Psi	0,00%

Expert G:

Table A.11. Pair-comparison matrice by Expert G.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Environmental Aspect	B	9
	Safety Aspect	A	2
	Public-Policy Aspect	A	1
Environmental Aspect	Safety Aspect	A	5
	Public-Policy Aspect	A	5
Safety Aspect	Public-Policy Aspect	B	3

Table A.12. Weights and Attributes of Main Criteria by Expert G.

Criterition	**Weight**
Economic Aspect	11.5%
Environmental Aspect	66.4%
Safety Aspect	7.4%
Public-Policy Aspect	14.6%
Attribute	Value
Consistency Ratio (CR)	7.9%
Lambda	4,215
GCI	0,28
Psi	0,00%

Expert H:

Table A.13. Pair-comparison matrice by Expert H.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Environmental Aspect	A	3
	Safety Aspect	B	3
	Public-Policy Aspect	A	1
Environmental Aspect	Safety Aspect	B	6
	Public-Policy Aspect	B	8
Safety Aspect	Public-Policy Aspect	A	3

Table A.14. Weights and Attributes of Main Criteria by Expert H.

Criterition	**Weight**
Economic Aspect	18.4%
Environmental Aspect	5.6%
Safety Aspect	51.1%
Public-Policy Aspect	25%
Attribute	Value
Consistency Ratio (CR)	7.2%
Lambda	4,196
GCI	0,26
Psi	0,00%

Expert I:

Table A.15. Pair-comparison matrice by Expert I.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Environmental Aspect	A	7
	Safety Aspect	A	5
	Public-Policy Aspect	A	3
Environmental Aspect	Safety Aspect	B	3
	Public-Policy Aspect	B	5
Safety Aspect	Public-Policy Aspect	B	3

Table A.16. Weights and Attributes of Main Criteria by Expert I.

Criterition	**Weight**
Economic Aspect	56.5%
Environmental Aspect	5.5%
Safety Aspect	11.8%
Public-Policy Aspect	26.2%
Attribute	Value
Consistency Ratio (CR)	4.3%
Lambda	4,117
GCI	0,15
Psi	0,00%

APPENDIX B: ECONOMIC SUBCRITERIA AHP COMPARISON

Expert B:

Table B.1. Economic Subcriteria Evaluation by Expert B.

Criterion A	Criterion B	A or B	Scale (1-9)
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	7
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	5
	State Interference in Private Sector Competition	A	7
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	2
	State Interference in Private Sector Competition	A	1
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	A	2

Table B.2. Weights and Attributes of Economic Subcriteria by Expert B.

Criterition	Weight
Theft and Hacking of Vehicles	66.3%
Vehicle Maintenance and Redistrubiton Cost	13.1%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	11.7%
State Interference in Private Sector Competition	8.9%
Attribute	**Value**
Consistency Ratio (CR)	7.3%
Lambda	4200
GCI	0.26
Psi	0.00%

Expert C:

Table B.3. Economic Subcriteria Evaluation by Expert C.

Criterion A	Criterion B	A or B	Scale (1-9)
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	1
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	5
	State Interference in Private Sector Competition	B	7
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	5
	State Interference in Private Sector Competition	B	7
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	9

Table B.4. Weights and Attributes of Economic Subcriteria by Expert C.

Criterition	**Weight**
Theft and Hacking of Vehicles	13.4%
Vehicle Maintenance and Redistrubiton Cost	13.4%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	4%
State Interference in Private Sector Competition	69.2%
Attribute	**Value**
Consistency Ratio (CR)	8.8%
Lambda	4239
GCI	0.31
Psi	0.00%

Expert D:

Table B.5. Economic Subcriteria Evaluation by Expert D.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	1
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	B	5
	State Interference in Private Sector Competition	A	3
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	B	3
	State Interference in Private Sector Competition	A	5
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	A	7

Table B.6. Weights and Attributes of Economic Subcriteria by Expert D.

Criterition	**Weight**
Theft and Hacking of Vehicles	15.8%
Vehicle Maintenance and Redistribution Cost	20.5%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	58%
State Interference in Private Sector Competition	5.7%
Attribute	**Value**
Consistency Ratio (CR)	3.9%
Lambda	4106
GCI	0.14
Psi	0.00%

Expert E:

Table B.7. Economic Subcriteria Evaluation by Expert E.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	3
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	6
	State Interference in Private Sector Competition	A	7
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	2
	State Interference in Private Sector Competition	A	4
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	A	2

Table B.8. Weights and Attributes of Economic Subcriteria by Expert E.

Criterition	**Weight**
Theft and Hacking of Vehicles	58.7%
Vehicle Maintenance and Redistribution Cost	23.4%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	8.3%
State Interference in Private Sector Competition	9.6%
Attribute	**Value**
Consistency Ratio (CR)	6.9%
Lambda	4189
GCI	0.25
Psi	0.00%

Expert F:

Table B.9. Economic Subcriteria Evaluation by Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	1
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	2
	State Interference in Private Sector Competition	B	2
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	2
	State Interference in Private Sector Competition	B	2
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	2

Table B.10. Weights and Attributes of Economic Subcriteria by Expert F.

Criterition	**Weight**
Theft and Hacking of Vehicles	23.2%
Vehicle Maintenance and Redistribution Cost	23.2%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	14%
State Interference in Private Sector Competition	39.5%
Attribute	**Value**
Consistency Ratio (CR)	2.2%
Lambda	4061
GCI	0.08
Psi	0.00%

Expert G:

Table B.11. Economic Subcriteria Evaluation by Expert G.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	3
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	4
	State Interference in Private Sector Competition	B	2
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	4
	State Interference in Private Sector Competition	B	3
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	4

Table B.12. Weights and Attributes of Economic Subcriteria by Expert G.

Criterition	**Weight**
Theft and Hacking of Vehicles	31.6%
Vehicle Maintenance and Redistribution Cost	16.8%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	7.2%
State Interference in Private Sector Competition	44.3%
Attribute	**Value**
Consistency Ratio (CR)	7.9%
Lambda	4215
GCI	0.28
Psi	0.00%

Expert H:

Table B.13. Economic Subcriteria Evaluation by Expert H.

Criterion A	Criterion B	A or B	Scale (1-9)
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	2
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	3
	State Interference in Private Sector Competition	B	5
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	4
	State Interference in Private Sector Competition	B	6
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	7

Table B.14. Weights and Attributes of Economic Subcriteria by Expert H.

Criterition	Weight
Theft and Hacking of Vehicles	17.4%
Vehicle Maintenance and Redistribution Cost	13.1%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	5.7%
State Interference in Private Sector Competition	63.9%
Attribute	**Value**
Consistency Ratio (CR)	7.8%
Lambda	4212
GCI	0.28
Psi	0.00%

Expert I:

Table B.15. Economic Subcriteria Evaluation by Expert I.

Criterion A	Criterion B	A or B	Scale (1-9)
Theft and Hacking of Vehicles	Vehicle Maintenance and Redistrubiton Cost	A	5
	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	A	3
	State Interference in Private Sector Competition	B	3
Vehicle Maintenance and Redistrubiton Cost	Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	B	2
	State Interference in Private Sector Competition	B	5
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	State Interference in Private Sector Competition	B	5

Table B.16. Weights and Attributes of Economic Subcriteria by Expert I.

Criterition	Weight
Theft and Hacking of Vehicles	27.4%
Vehicle Maintenance and Redistribution Cost	7%
Decrease in Micromobility Vehicles Usage due to Bad Weather Conditions	10.9%
State Interference in Private Sector Competition	54.8%
Attribute	**Value**
Consistency Ratio (CR)	4.8%
Lambda	4131
GCI	0.17
Psi	0.00%

APPENDIX C: ENVIRONMENTAL SUBCRITERIA AHP COMPARISON

Expert B :

Table C.1. Environmental Subcriteria Evaluation by Expert B.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	9

Table C.2. Weights and Attributes of Environmental Subcriteria by Expert B.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	90%
Visual pollution as a result of careless parking and stacking of vehicles	10%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert C :

Table C.3. Environmental Subcriteria Evaluation by Expert C.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	3

Table C.4. Weights and Attributes of Environmental Subcriteria by Expert C.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	75%
Visual pollution as a result of careless parking and stacking of vehicles	25%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert D :

Table C.5. Environmental Subcriteria Evaluation by Expert D.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	B	3

Table C.6. Weights and Attributes of Environmental Subcriteria by Expert D.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	25%
Visual pollution as a result of careless parking and stacking of vehicles	75%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert E :

Table C.7. Environmental Subcriteria Evaluation by Expert E.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	8

Table C.8. Weights and Attributes of Environmental Subcriteria by Expert E.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	88.9%
Visual pollution as a result of careless parking and stacking of vehicles	11.1%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert F :

Table C.9. Environmental Subcriteria Evaluation by Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	5

Table C.10. Weights and Attributes of Environmental Subcriteria by Expert F.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	83.3%
Visual pollution as a result of careless parking and stacking of vehicles	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert G :

Table C.11. Environmental Subcriteria Evaluation by Expert G.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	5

Table C.12. Weights and Attributes of Environmental Subcriteria by Expert G.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	83.3%
Visual pollution as a result of careless parking and stacking of vehicles	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert H :

Table C.13. Environmental Subcriteria Evaluation by Expert H.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	5

Table C.14. Weights and Attributes of Environmental Subcriteria by Expert H

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	83.3%
Visual pollution as a result of careless parking and stacking of vehicles	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

Expert I :

Table C.15. Environmental Subcriteria Evaluation by Expert I.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High Level of GHG emissions during the collection and redistribution of vehicles	Visual pollution as a result of careless parking and stacking of vehicles	A	5

Table C.16. Weights and Attributes of Environmental Subcriteria by Expert I.

Criterition	**Weight**
High Level of GHG emissions during the collection and redistribution of vehicles	83.3%
Visual pollution as a result of careless parking and stacking of vehicles	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0%
Lambda	2000

APPENDIX D: SAFETY SUBCRITERIA AHP COMPARISON

Expert B :

Table D.1. Safety Subcriteria Evaluation by Expert B.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	5

Table D.2. Weights and Attributes of Safety Subcriteria by Expert B.

Criterition	**Weight**
High rates of serious injury and accident	83.3%
Low use of personal protective equipment	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert C :

Table D.3. Safety Subcriteria Evaluation by Expert C.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	7

Table D.4. Weights and Attributes of Safety Subcriteria by Expert C.

Criterition	Weight
High rates of serious injury and accident	87.7%
Low use of personal protective equipment	13.3%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert D :

Table D.5. Safety Subcriteria Evaluation by Expert D.

Criterion A	Criterion B	A or B	Scale (1-9)
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	3

Table D.6. Weights and Attributes of Safety Subcriteria by Expert D.

Criterition	Weight
High rates of serious injury and accident	75%
Low use of personal protective equipment	25%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert E :

Table D.7. Safety Subcriteria Evaluation by Expert E.

Criterion A	Criterion B	A or B	Scale (1-9)
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	6

Table D.8. Weights and Attributes of Safety Subcriteria by Expert E.

Criterition	**Weight**
High rates of serious injury and accident	85.7%
Low use of personal protective equipment	14.3%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert F :

Table D.9. Safety Subcriteria Evaluation by Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	3

Table D.10. Weights and Attributes of Safety Subcriteria by Expert F.

Criterition	**Weight**
High rates of serious injury and accident	75%
Low use of personal protective equipment	25%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert G :

Table D.11. Safety Subcriteria Evaluation by Expert G.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	4

Table D.12. Weights and Attributes of Safety Subcriteria by Expert G.

Criterition	**Weight**
High rates of serious injury and accident	80%
Low use of personal protective equipment	20%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert H :

Table D.13. Safety Subcriteria Evaluation by Expert H.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	3

Table D.14. Weights and Attributes of Safety Subcriteria by Expert H.

Criterition	**Weight**
High rates of serious injury and accident	75%
Low use of personal protective equipment	25%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

Expert I :

Table D.15. Safety Subcriteria Evaluation by Expert I.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
High rates of serious injury and accident	Low use rate of personal protecting equipment	A	5

Table D.16. Weights and Attributes of Safety Subcriteria by Expert I.

Criterition	**Weight**
High rates of serious injury and accident	83.3%
Low use of personal protective equipment	16.7%
Attribute	**Value**
Consistency Ratio (CR)	0.0%
Lambda	2000

APPENDIX E: PUBLIC-POLICY SUBCRITERIA AHP COMPARISON

Expert B :

Table E.1. Public-Policy Subcriteria Evaluation by Expert B.

Criterion A	Criterion B	A or B	Scale (1-9)
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	A	5
	Lack of legal regulations on the use of micromobility vehicles	B	7
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	B	2

Table E.2. Weights and Attributes of Safety Subcriteria by Expert B.

Criterition	Weight
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	7.5%
Protection and sharing of personal data	33.3%
Lack of legal regulations on the use of micromobility vehicles	59.2%
Attribute	**Value**
Consistency Ratio (CR)	1.5%
Lambda	3014

Expert C :

Table E.3. Public-Policy Subcriteria Evaluation by Expert C.

Criterion A	Criterion B	A or B	Scale (1-9)
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	B	5
	Lack of legal regulations on the use of micromobility vehicles	B	9
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	B	3

Table E.4. Weights and Attributes of Safety Subcriteria by Expert C.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	6.3%
Protection and sharing of personal data	26.5%
Lack of legal regulations on the use of micromobility vehicles	67.2%
Attribute	**Value**
Consistency Ratio (CR)	3%
Lambda	3029

Expert D :

Table E.5. Public-Policy Subcriteria Evaluation by Expert D.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	A	7
	Lack of legal regulations on the use of micromobility vehicles	B	1
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	B	5

Table E.6. Weights and Attributes of Safety Subcriteria by Expert D.

Criterion	Weight
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	48.7%
Protection and sharing of personal data	7.8%
Lack of legal regulations on the use of micromobility vehicles	43.5%
Attribute	**Value**
Consistency Ratio (CR)	1.3%
Lambda	3013

Expert E :

Table E.7. Public-Policy Subcriteria Evaluation by Expert E.

Criterion A	Criterion B	A or B	Scale (1-9)
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	A	5
	Lack of legal regulations on the use of micromobility vehicles	A	8
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	A	3

Table E.8. Weights and Attributes of Safety Subcriteria by Expert E.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	74.2%
Protection and sharing of personal data	18.3%
Lack of legal regulations on the use of micromobility vehicles	7.5%
Attribute	**Value**
Consistency Ratio (CR)	4.6%
Lambda	3044

Expert F :

Table E.9. Public-Policy Subcriteria Evaluation by Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	A	3
	Lack of legal regulations on the use of micromobility vehicles	A	5
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	A	2

Table E.10. Weights and Attributes of Safety Subcriteria by Expert F.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	64.8%
Protection and sharing of personal data	23%
Lack of legal regulations on the use of micromobility vehicles	12.2%
Attribute	**Value**
Consistency Ratio (CR)	0.4%
Lambda	3004

Expert G :

Table E.11. Public-Policy Subcriteria Evaluation by Expert G.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	B	3
	Lack of legal regulations on the use of micromobility vehicles	B	4
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	A	2

Table E.12. Weights and Attributes of Safety Subcriteria by Expert G.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	6.3%
Protection and sharing of personal data	26.5%
Lack of legal regulations on the use of micromobility vehicles	67.2%
Attribute	**Value**
Consistency Ratio (CR)	1.9%
Lambda	3018

Expert H :

Table E.13. Public-Policy Subcriteria Evaluation by Expert H.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	A	3
	Lack of legal regulations on the use of micromobility vehicles	A	1
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	B	5

Table E.14. Weights and Attributes of Safety Subcriteria by Expert H.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	40.5%
Protection and sharing of personal data	11.4%
Lack of legal regulations on the use of micromobility vehicles	48.1%
Attribute	**Value**
Consistency Ratio (CR)	3%
Lambda	3029

Expert I :

Table E.15. Public-Policy Subcriteria Evaluation by Expert I.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	Protection and sharing of personal data	B	5
	Lack of legal regulations on the use of micromobility vehicles	B	3
Protection and sharing of personal data	Lack of legal regulations on the use of micromobility vehicles	A	3

Table E.16. Weights and Attributes of Safety Subcriteria by Expert I.

Criterion	**Weight**
Due to insufficient data, managers are insufficient in measuring micromobility vehicle performances and in improving the process.	10.5%
Protection and sharing of personal data	63.7%
Lack of legal regulations on the use of micromobility vehicles	25.8%
Attribute	**Value**
Consistency Ratio (CR)	4%
Lambda	3039

APPENDIX F: OVERALL AHP COMPARISON OF ALTERNATIVES

Expert B :

Table F.1. General Overview of Expert B Evaluation.

EXPERT B				
Main Criteria	**Local Weight**	**Priority of Alternative**		
Economic Aspect	0,45		**Government Run System**	0,402
Environmental Aspect	0,075		**Private- Run System**	0,269
Safety Aspect	0,431			
Public-Policy Aspect	0,045		**Government-Private Run System**	0,331

Expert C :

Table F.2. General Overview of Expert C Evaluation.

EXPERT C				
Main Criteria	**Local Weight**	**Priority of Alternative**		
Economic Aspect	0,751		**Government Run System**	0,541
Environmental Aspect	0,065		**Private- Run System**	0,254
Safety Aspect	0,71			
Public-Policy Aspect	0,055		**Government-Private Run System**	0,210

Expert D :

Table F.3. General Overview of Expert D Evaluation.

<table>
<tr><th colspan="5">EXPERT D</th></tr>
<tr><th>Main Criteria</th><th>Local Weight</th><th rowspan="5">Priority of Alternative</th><th rowspan="2">Government Run System</th><td rowspan="2">0,212</td></tr>
<tr><td rowspan="2">Economic Aspect</td><td rowspan="2">0,137</td></tr>
<tr><th rowspan="2">Private- Run System</th><td rowspan="2">0,516</td></tr>
<tr><td>Environmental Aspect</td><td>0,127</td></tr>
<tr><td>Safety Aspect</td><td>0,694</td><th rowspan="2">Government-Private Run System</th><td rowspan="2">0,273</td></tr>
<tr><td>Public-Policy Aspect</td><td>0,042</td></tr>
</table>

Expert E :

Table F.4. General Overview of Expert E Evaluation.

<table>
<tr><th colspan="5">EXPERT G</th></tr>
<tr><th>Main Criteria</th><th>Local Weight</th><th rowspan="5">Priority of Alternative</th><th rowspan="2">Government Run System</th><td rowspan="2">0,303</td></tr>
<tr><td rowspan="2">Economic Aspect</td><td rowspan="2">0,561</td></tr>
<tr><th rowspan="2">Private- Run System</th><td rowspan="2">0,499</td></tr>
<tr><td>Environmental Aspect</td><td>0,297</td></tr>
<tr><td>Safety Aspect</td><td>0,097</td><th rowspan="2">Government-Private Run System</th><td rowspan="2">0,198</td></tr>
<tr><td>Public-Policy Aspect</td><td>0,045</td></tr>
</table>

Expert F :

Table F.5. General Overview of Expert F Evaluation.

EXPERT G				
Main Criteria	**Local Weight**	**Priority of Alternative**	**Government Run System**	0,378
Economic Aspect	0,307			
Environmental Aspect	0,087		**Private- Run System**	0,306
Safety Aspect	0,557			
Public-Policy Aspect	0,05		**Government-Private Run System**	0,316

Expert G :

Table F.6. General Overview of Expert G Evaluation.

EXPERT G				
Main Criteria	**Local Weight**	**Priority of Alternative**	**Government Run System**	0,651
Economic Aspect	0,115			
Environmental Aspect	0,664		**Private- Run System**	0,119
Safety Aspect	0,074			
Public-Policy Aspect	0,146		**Government-Private Run System**	0,229

Expert H :

Table F.7. General Overview of Expert H Evaluation.

EXPERT H				
Main Criteria	**Local Weight**	**Priority of Alternative**		
Economic Aspect	0,184		**Government Run System**	0,499
Environmental Aspect	0,056		**Private- Run System**	0,225
Safety Aspect	0,511		**Government-Private Run System**	0,277
Public-Policy Aspect	0,25			

Expert I :

Table F.8. General Overview of Expert I Evaluation.

EXPERT I				
Main Criteria	**Local Weight**	**Priority of Alternative**		
Economic Aspect	0,565		**Government Run System**	0,588
Environmental Aspect	0,055		**Private- Run System**	0,153
Safety Aspect	0,118		**Government-Private Run System**	0,257
Public-Policy Aspect	0,263			