AHP BASED EVALUATION APPROACH FOR DECISION MAKING CRITERIA OF ELECTRIC BUS IMPLEMENTATIONS

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ABSTRACT

AHP BASED EVALUATION APPROACH FOR DECISION MAKING CRITERIA OF ELECTRIC BUS IMPLEMENTATIONS

Throughout history, transportation has been one of the most important necessities among various cities. In today's world, transportation in the cities has been carried out mostly by buses. Recent developments in technology and growing concerns about the environment and greenhouse gas emissions pushed the authorities to consider electric buses in their transit fleets as a better option compared to diesel buses. Electric bus usage and interest in that area are constantly increasing with each passing day. More and more countries are trying to adapt to the new electric bus technology. To implement this relatively new technology, researches have been carried out in many aspects which include the decision-making process. This study contains information about the current situation of the electric buses and plans and classifies the criteria that have been considered as the most vital ones when implementing this new technology. The study also explains how the Analytic Hierarchical Process (AHP) works and gives the results of a survey that focuses on the electric bus implementation criteria and their relative importance according to various transportation experts from various countries.

ÖZET

ELEKTRİKLİ OTOBÜS UYGULAMALARINDA KULLANILACAK KRİTERLERİN AHP METODU KULLANARAK BELİRLENMESİ

Tarih boyunca ulaşım, şehirlerin en önemli gereksinimlerinden biri olmuştur. Günümüz şehirlerinde ulaşım çoğunlukla otobüsler yardımıyla gerçekleştirilmektedir. Teknolojideki ilerlemeler ve çevre sorunları hakkındaki duyarlılığın artması, şehir yönetimlerini dizel otobüslere göre daha çevreci olan elektrikli otobüslere itmiştir. Elektrikli otobüslerin kullanım miktarı ve elektrikli otobüslere duyulan ilgi gün geçtikçe artmaktadır. Bu yeni teknolojinin uygulanabilmesi amacıyla pek çok sayıda çalışma yapılmış ve bu çalışmaların bir kısmında çoklu karar alma mekanizmaları kullanılmıştır. Bu çalışma, günümüzde elektrikli otobüslerin durumu ve gelecek planları hakkında bilgi vermenin yanı sıra, uzman görüşleri alınarak elde edilen elektrikli otobüslerin uygulanma sürecinde göz önünde bulundurulan kriterleri açıklayıp bu kriterleri kendi içerisinde önem sırasına göre sıralamıştır. Aynı zamanda Analitik Hiyerarşi Sürecinin nasıl işlediği, bu metodun nasıl kullandığı açıklanmış olup, uzmanlar tarafından belirlenen kriterler kullanılarak oluşturulan anket dünyanın çeşitli bölgelerinden ulaşım uzmanları tarafından cevaplandırılmış ve sonuçlar analiz edilmiştir.

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LIST OF ACRONYMS/ABBREVIATIONS

AHP	Analytic Hierarchical Process
ANP	Analytic Network Process
BBA	Bachelor of Businness Administiration
BKK	Budapesti Közlekedési Központ
BSc	Bachelor of Science
CTA	Cairo Transport Authority
CTA	Transit Authority in Chicago
EGO	Ankara Electric-Watergas-Bus Agency
ELECTRE	Elimination and Choice Translating Reality
ESHOT	Electric-Water-WaterGas- Bus-Trolley Agency
EU	European Union
FAHP	Fuzzy Analytical Hierarchy Process
FMCDM	Fuzzy Multi Criteria Decision Making
IEA	International Energy Agency
IETT	İstanbul Electric-Tram-Tunnel Agency
LA Metro	Los Angeles County Metropolitan Transportation Authority
LADOT	Los Angeles Department of Transportation
MCDM	Multi Criteria Decision Making
MENA	Middle East and North Africa
MSc	Master of Science
MTA	Metropolitan Transportation Authority
PhD	Doctor of Philosophy
RTA	Road and Transport Authority
SEPTA	Southeastern Pennsylvania Transportation Authority
TOPSIS	Technique for Order Preference by Similarity to Ideal Solutions
UAE	United Arab Emirates
US	United States

USD	United States Dollar
VEIC	Vermont Energy Investments Corporation
VIKOR	VIse KriterijumsaOptimiz acija I Kompromisno Resenje
WMATA	The Washington Metropolitan Area Transit Authority

1. INTRODUCTION

Electric buses are a better option than diesel buses in a lot of ways. Especially, when the environmental aspect is concerned, electric buses prove to be a far better option than their counterparts, therefore interest in electric buses is increasing rapidly all around the world [1]. Although electric buses are superior to diesel buses, electric bus technology is relatively new and, may lead to some problems when electric buses are to be implemented. To avoid these potential problems, the criteria for electric bus implementation should be stated and addressed properly.

Deciding and analyzing these criteria could be carried out by Analytical Hierarchical Process, which is a popular multi-criteria decision-making process tool. This study briefly explains the current electric bus usage around the world and possible future aspects and states the criteria for electric bus implementations by using expert opinions using a survey analyzed via AHP. Alongside, the comments on what affects these expert's views in terms of where they are from or where they work.

1.1. Goals and Objectives

Before carrying out the electric bus implementations, it is crucial to address the aspects that should be considered and to put them in relative order based on their importance. To achieve this, the objectives listed below are aimed;

(i) To give information about the electric buses and why they should be in use.
(ii) To develop knowledge in the electric bus usage around the world and its future aspects.
(iii) To explain how AHP works and what are main aspects of it.
(iv) To specify and find the relative importance of the criteria for electric bus implementations.
(v) To analyze expert views and surveys with solid outcomes.

1.2. Organization of the Thesis

The rest of the thesis is organized as follows; in the second chapter literature review on electric bus selection with multi-criteria decision-making tools is given is followed by the section, Why Electric Buses? This gives information about electric buses and their comparison with diesel buses. Then, electric bus usage around the world part gives detailed information about the current situation in the world about electric buses, and some future expectations. This is followed by the AHP section, where the AHP method was explained and calculations were shown. After the AHP part, in the case study section, the created case study was explained. Then, in the case study comments section, these results were provided. Finally, in the last section, a conclusion that summarizes the study is presented.

1.3. Literature Review

Transportation has been one of the most important aspects of a city's development throughout history. Today transportation in the cities is mostly carried out by buses. The usage of the bus in transportation consumes significant amounts of fossil fuels which have high economical costs and also by having high emission values, affecting the lives of humans, decreases air quality, affecting the health of the citizens [2]. Emissions from the vehicles are also considered as one of the major causes of global warming [3].

In the last decades, following the decrease in the fossil fuel sources and implemented policies by the governments, new and clean transportation technologies emerged [4]. Therefore, in the last decade, more and more authorities used electric buses as a way of transport. These full electric buses are far better options than their diesel counterparts in terms of sustainability and fuel economy [5]. As more and more cities deciding to switch their fleet into electric ones, the total amount of electric buses in the world increases rapidly [3]. Because of the increasing demand for electric buses, academic literature has been growing, and more and more electric bus-related research has been carried out each passing day [6]. These researches were supported by the city planners, managers, and engineers to increase the efficiency that can be gained from electric buses. Various studies were done and various researches were published to specify or rank the importance of different factors when deciding to switch to electric buses. These multi-criteria decision-making studies include mainly AHP, fuzzy, and some hybrid applications. And the hybrid applications, analytical methods such as analytic network process(ANP), TOPSIS, VIKOR, ELECTRE, or fuzzy numbers can be seen in the recent studies about electric buses.

Yedla et al. [7] published a study about vehicle selection by using Analytical Hierarchical Process(AHP) in Delhi, using three alternative transportation options and giving six different criteria which are namely, environment(emissions), operation cost(economics), the situation of the technology(applicability), adaptability, and barricades of implementation (barriers) and explained why at the time alternative transportation options were failing. Tzeng et al. [8] studied the buses that work with alternative fuels for public transport and used MCDM to support his ideas. The paper states how much people can gain from simply using alternative-fuel buses in public transportation and focuses on economics. Hsio et al [9] researched the selection of low pollutant emission bus systems to show how much of an effect would be using low emission buses have and which criteria are considered to select them by using FAHP and TOPSIS. Patil and Heder [10] published a paper about possible investments in the alternative-fuel buses to be used in public transport which mainly focuses on the economical aspect by using MCDM. Vahdani et al. [11] published alternative-fuel buses selection by using FMCDM methods which considered and compared several fuels for buses such as electricity, fuel cell or methanol, etc. Aydın and Kahraman [12] used fuzzy and AHP methods to select bus types for public transportation. Petsching et al [13], investigated the determinants of alternative-fuel vehicles and their possible adaptations by using structural equation modeling. Yavuz et al. [14], focuses on the adaptation of a new alternative-fuel bus into a fleet and possible problems and their importance with the hesitant fuzzy method. Lanjewar et al. [15] used AHP and Grap Theory to select the best alternative fuels for buses. Onat et al. [16] rank the alternative fuel vehicles in terms of their sustainability and life cycles by using TOPSIS and Fuzzy-Set analysis. Oztaysi et al. [17] provides information regarding alternative-fuel technology and its selection by using interval-valued intuitionistic fuzzy sets. Mukherjee [18] studies the alternative-fuel bus selection to develop and maintain a sustainable urban transportation system and uses FMCDM for the selection of the fuel. Büyüközkan et al. [19] focus on deciding which kind of sustainable urban transit to use and what would be options for it by using Fuzzy Choquet Integral. Süt et al. [20] studied a ring selection in the campus area considering the emission values of the present options by using AHP and TOPSIS methods. Hamurcu and Eren [21] performed the electric bus selection by using multicriteria decision analysis focusing on green transport.

1.4. Why Electric Buses?

Electric buses, compared to their diesel counterparts, may reduce the environmental damages and health threats coming with these environmental damages. Also, they can provide a trustworthy and reliable cost-effective option for public transportation in cities. The improvements in the battery technologies in the electric bus industry for the past couple of years made electric buses offer solid benefits over diesel buses. Although battery technology has been improved a lot, electric bus technology is still improving. Since the transportation planners in cities do not know what to expect or how to manage electric buses, their usage is not as common as the diesel buses [22, 23].

Electric buses bring several benefits to the communities where they are actively used. Their emission values are significantly less than the diesel buses, thus making them eco-friendly. Just by changing the diesel buses into electric ones, the greenhouse gas emissions could be reduced in significant amounts [24].

Electric buses also deliver economic benefits since their maintenance costs are considerably lower than diesel buses because of their advanced technology, which makes them vibrate a lot less, thus decreasing the mechanical damages. Also when the utility rates are favorable, they reduce the fuel cost since producing and transforming electric costs less than fuel in most cases [22].

The electric buses decrease the number of exhaust emissions and decreasing the pollutant values in the engine which otherwise would cause ozone damages, hence increasing the air quality in communities [25].

Also, by reducing air pollution and environmental damages, electric buses may add further financial benefits to society just by not having to spend money and effort to clean the air, environment.

1.5. Electric Buses Around the World

1.5.1. Electric Buses in the United States

In the last decade, electric bus usage in the United States has been increased drastically. According to the reports, there currently are 528 fully electric buses in the country by the end of 2019 [26]. It should be stated that this number increased by a solid 29% when compared to the number of electric buses the country had in 2018 [26]. Also, places such as California, New York City, and Seattle declared their zero-emission in the transportation policies which will commit to the transformation of their fleet into electric ones by 2045 [26]. Approximately 4% of all the bus sales in public transit were carried out in the U. S were electric buses. Also, 13% of the transit agencies in the country either use electric buses in their ongoing fleets or made orders of electric buses [26]. This percentage reaches 18% when those that have been given funding to purchase electric buses, however not placed their order yet [26]. In the states, some major electric bus players are, Proterra, BYD Motors, and NFI Group [27]. The biggest steps were made by California in terms of electric bus usage in transit systems. The State of California has been the leader and first to make the moves-investments in the field. California Air Resources Board shifted to a 100% all-around electric transit buses by 2040 [28]. The state issued a policy that requires all large transit agencies-companies in the state to add 25% of electric buses to their running fleet by 2023, which will gradually increase to 50% in 2026 [29]. Another big step came from the Los Angeles Department of Transportation (LADOT) and Los Angeles County Metropolitan Transportation Authority (LA Metro) in 2017 stating that they are planning to convert all of their fleets into full electric by 2030 [30]. As of today, California has 210 electric buses that are currently in use and the state placed orders to increase that number to 450 [26].

Apart from California, other transportation agencies from different states-cities also made investments and commitments into the electrification of their fleets. Such as; New York City's MTA, the Washington Metropolitan Area, the Southeastern Pennsylvania Transportation Authority(SEPTA), the Port Authority of Allegheny County in Pittsburgh, Minneapolis Metro Transit, South Carolina, Chicago Illinois, Albequerque New Mexico, Massachusetts Boston.

<u>1.5.1.1. New York City's MTA.</u> New York City's MTA, which holds the title of the largest transportation network in the country is planning to have a bus fleet fully composed of electric buses by the end of 2040 [31]. In the year 2018 New York City's MTA has decided to add 10 more electrical buses to its ongoing fleet, which has been followed by another 15 in 2019, and these numbers are planned to increase gradually for the future [32].

<u>1.5.1.2. The Washington Metropolitan Area.</u> The Washington Metropolitan Area Transit Authority (WMATA) which is located in D.C. decided to add 14 fully electric buses into its existing fleet in 2018 [33].

<u>1.5.1.3. The Southeastern Pennsylvania Transportation Authority.</u> The Southeastern Pennsylvania Transportation Authority or SEPTA, in short, bought and had actively used 25 electric buses in the South Philadelphia area in 2019 and added another 10 of these buses in 2020. However, these buses are decided not to be used in active service before 2021 [34].

1.5.1.4. The Port Authority of Allegheny County in Pittsburgh. The Port Authority of Allegheny County in Pittsburgh decided to test and observe the outcomes of electric bus usage in the transit network. Thus, bought 2 electric buses in 2019 and declared that based on experienced outcomes, it is expected to deploy 25 more vehicles in the following years [35].

1.5.1.5. Minneapolis Metro Transit. Minneapolis Metro Transit announced its first electric bus in 2019 and the results were found to be satisfying. Therefore Minneapolis Metro Transit declared that they aim to purchase and deploy another 200 following the next decade [36].

1.5.1.6. South Carolina. A province named Seneca in South Carolina became the first city in the world to deploy a bus fleet that only contains electric buses in September 2014 [37].

1.5.1.7. Chicago, Illinois. Transit Authority in Chicago (CTA) started the usage of electric buses in the winter of 2014, which was unique because this was one of the first tests that were carried out on a large scale in winter conditions. The reason behind that winter test is the cold climate of Chicago and the concerns about a new technology's likely outcomes. However, Chicago Transit Authority was satisfied with the results and changed its entire fleet into electric ones by 2040, and it should be stated that CTA has a vast fleet that contains over 1800 buses [38].

1.5.1.8. Albuquerque, New Mexico. Albuquerque is unique in the states because it had the least satisfying testing period in the country. Albuquerque experienced a series of mechanical problems as well as problems with the work schedule of the buses, including their arrival and planned use dates. Furthermore due to the city's geographical conditions and infrastructure created some issues with the manufacturer. These problems combined led to the cancellation of its electric bus contract. Albuquerque then returned all the electric buses previously purchased, however, the city has not given hope on electric buses since it has moved forward with different electric bus procurers [39, 40].

1.5.1.9. Massachusetts, Boston. The Department of Energy Resources of Massachusetts tested the electric buses in the school transit field in 2015. Before Massachusetts, some companies used to use electric buses for school transportation in small numbers but these only took place in the warm climates with a few buses and Massachusetts's electric bus usage in school transit can be said to be the first full time since it included both winter and had a much more scale in terms of quantity where three school districts (Cambridge, Amherst, Concord). The buses which were working on these districts were observed and evaluated by a private company named Vermont Energy Investment Corporation (VEIC) and according to their reports these vehicles were feasible; however, the company also stated it would take more attempts and observations before using it nationwide [41].

1.5.1.10. Twin Rivers, California. Similar to Massachusetts, Twin Rivers, California Unified School District Transportation Department changed its fleet into an electric zero-emission one. Currently, this district is serving 52 school sites with 25 electric buses and California Unified School District Transportation Department plans to add 10 more electric buses into its fleet soon [42].

1.5.2. Electric Buses in Europe

In the last twenty years, reducing the emission values was one of the most important topics in the European Union. Therefore, the European Commission put the "Clean Bus Deployment Initiative" into action [43]. It should be noted that public demand for lowering the emission values was already high and these actions were supported by the local communities. There are several countries with several cities that are adopting electric bus usage in their transportation fleets.

These countries and cities are as follows [44];

1.5.2.1. Austria. Graz currently has 4 electric buses from two different brands that are working on the major route in the city.

Klagenfurt implemented one electric bus in the city to observe its outcomes and currently changing the routes regularly.

1.5.2.2. Belgium. Bruges by the funding coming from the Flemish Government added 3 electric buses to its ongoing fleet. Namur has the biggest electric bus fleet in Belgium with 11 active vehicles that were purchased from Volvo and in the following years city wants to add almost 300 hundred more electric vehicles into its fleet.

1.5.2.3. Bulgaria. Sofia has been using a single electric bus in its fleet and plans to enlarge its fleet, however, to do so, the city requires more charging stations.

1.5.2.4. Czech Republic. Hranice holds the title of the first city in the Czech Republic as well as Central Europe to have a fully electric-operated bus fleet. All the transportation lines have been using only electric buses since 2017.

Krnov has been using 2 electric buses in its fleet and based on the reactions from authorities as well as the passengers, aims to increase that number soon.

Plzen set a goal of reducing their carbon emissions from buses by changing their fleet into electric ones from 64% to 85% by 2030.

Prague is the largest city and the capital of the Czech Republic. The city is testing two different electric buses from two different companies and based on the results, the city is planning to buy 11 new vehicles of the better ones in the following years.

Trinec has currently 10 electric buses (SKODA) and this puts the city in first place in terms of the number of electric buses deployed in the city.

<u>1.5.2.5. Denmark.</u> Copenhagen has been testing 4 electric buses from two different brands from 2017 to 2019 and added 48 more into their fleet in 2019. City wants to maintain a fully electric bus fleet by 2031.

<u>1.5.2.6. Finland.</u> Espoo has been selected as a pilot zone of Helsinki. 12 electric buses have been integrated into the city's fleet and were tested between 2016-2020. Results were satisfying, so the Finnish Government decided to execute their plan for Helsinki.

Helsinki, after the pilot project of Espoo, started buying electric buses and using them in various routes. The city has a plan to buy approximately 1400 buses by the end of 2025.

Tampere's line number 2 has only electric buses in its fleet. Furthermore, it is expected to change more lines into full electric.

Turku is another city that wanted to test electric buses before changing its fleet. City bought 6 electric buses and implemented them into their lines. Based on the results, the city will draw and execute a plan.

<u>1.5.2.7. France.</u> Gaillac is a considerably small town located in France that purchased one electric bus in April 2016 and tested it until December 2017. Afterward, the bus was integrated into the ongoing fleet.

Grenoble has bought 4 electric buses from 4 different companies to select the best one and convert its fleet into full electric by the end of 2021.

Marseille has enacted a carbon-free plan in 2015 and bought 6 electric buses to test their aspects. These buses are operating in city line number 1 and will be tested until 2025. Marseille wants to become carbon-free by 2040.

Nice Airport has been using a single electric bus to test whether it is feasible or not.

Paris is the capital of France as well as considered one of the cultural capitals of the continent wants to change its fleet into a clean one which would include hybrid, electric, and biogas-fueled buses. In that regard, the city bought 23 electric buses in 2016 to test and analyze how the lines would work. From the gathered data until today, it is estimated that approximately 3500 electric buses will be in use in 2025 [45].

Strasbourg has only one electric bus working on route number 10.

Versailles decided to test one electric bus on route number 23 and if the test would be a success, the bus will be integrated into the ongoing fleet.

1.5.2.8. Germany. Aalen has been trying one electric bus since 2016, there are still no conclusions about the future of the bus.

Bad Langensalza is a small town in Germany which bought 1 electric bus from Turkey(Bozankaya) and currently is using the bus.

Berlin is considered the capital of Europe, not Germany alone. In 2015 Berlin implemented a fully electric bus line and was delighted with the results. Berlin added 90 more electric buses into its fleet reaching a total number of 123 electric buses in Berlin [46].

Bonn has bought 6 electric buses from Turkey(Bozankaya) to test them in 2016. The testing period is expected to end in 2028.

Braunschweig has one electric bus in its fleet working on line number 1.

Bremen is another city that bought one electric bus from Turkey(Bozankaya) to test in 2016. Stakeholders are yet to decide whether to increase the number of electric buses or not.

Cologne is following Köln Mobil 2025 strategy in which the city aims to reduce its carbon emissions in a great manner. To do so city bought 8 electric buses in 2015 and aims to increase that number.

Dresden is the first city to test electric buses in the Saxony region in 2015. Although electric buses are supported by the federal government, there are no active steps in increasing the number of electric buses in the city.

Eberswalde started testing one electric bus in 2014, and they're still is no conclusion.

Hamburg is one of the most active cities in Germany in terms of electric bus implementations. The city purchased 6 electric buses in 2014 and plans to buy approximately 500 more in the following 5 years.

Hanover is using its electric buses in the most demanding routes in the city, namely routes 100 and 200. City plans to increase its electric fleet, but there are no certain dates that are steps made yet.

Leipzig is another city that has not concluded the testing period. City purchased one electric bus in 2015 and it still goes on route 89.

Lübeck has been using electric buses in two of its routes, route number 21 and route number 33 since 2017. Until now passengers, as well as drivers, are happy with the results.

Mannheim is using 2 electric buses on route 63 since 2015. These buses were put into trial period until 2016, and after 2016 they were integrated into the city's ongoing bus fleet.

Münster has used fast-charging electric buses in route 14 for demonstration purposes between 2015 and 2017. Afterward, these buses were integrated into the city's bus fleet.

Oberhausen has started testing two electric buses in routes 962 and 966 since 2015. It is expected to increase the number of electric buses in the city since the feedbacks are overwhelmingly positive . Stuttgart Airport deployed 6 electric buses in 2015 and signed a full-service contract that covers the following 8 years.

1.5.2.9. Hungary. Budapesti Közlekedési Központ (BKK) plans to decrease carbon emissions by changing its fleet into clean buses. The city implemented 20 electric buses on lines 15, 16A, 39, 102, 115, 116, and 191 in 2016 and these lines are still operated mostly by these electric buses.

Szeged as the capital city Budapest tends to decrease the emissions by changing its fleet and to do so the city purchased 13 electric buses and has been using them on lines 77A, 10, and 19 since then.

1.5.2.10. Italy. Cagliari has been using 2 electric buses on route 5 since 2014.

Milan has 2 electric buses in its fleet which are traveling on route number 84 since 2014.

Turin is the pioneer of Italy in terms of electric bus usage. The city integrated 20 electric buses in its fleet in 2017 and plans to increase this amount in the future.

1.5.2.11. Netherlands. Assen has purchased 2 electric buses in 2017 and has been using them in route number 100 and plans to develop a zero-emission bus fleet in 2025. In that regard, the city is increasing its electrical bus number as much as it can.

Rotterdam has started using electric buses by integrating 2 electric buses in route number 70 in 2015 and since then the city is rapidly increasing the number of electric buses it possesses to reach a fully zero-emission fleet by 2025 which would contain approximately 250 vehicles.

Schiemonnikoog is an island that attracts tourists and the city has started using 6 electric buses in 2013. Schiemonnikoog also plans to increase its electric fleet in the future.

Amsterdam (Schiphol Airport) started operating 35 electric buses in the year 2015. These buses were produced in China and they are being charged at the airport via solar panels.

‘s-Hertogenbosch has been using 11 electric buses in their transit fleet and plans to change its fleet into a fully electric one before the year 2025.

Utrecht has started its electric bus journey in 2013 by purchasing 3 electric buses. City also shares the zero-emission policy which is supported by the Dutch Government and aims to change its fleet into a zero-emission one by the year 2025.

Zuid-Oost-Brabant covers the cities of Eindhoven and Helmond which in total has more than 750.000 population. The fleet integrated 43 electric buses in 2016 with a 10-year optional period, however, aims to change all of the 215 buses that it has to electric ones by the year 2025.

1.5.2.12. Norway. Stavanger has been the pilot zone for Norway and integrated 5 electric buses from 2 different companies.

1.5.2.13. Poland. Gdynia has been using trolleybuses for a long time and in 2015 the city added 38 electric buses to its fleet. It is planned to add another 30 buses soon.

Inowroclaw has started trying 2 electric buses in the cities occupied lines namely, routes 3, 10, and 16.

Jaworzno first bought a single electric bus in 2015 and the results were positive. Thus, the city decided to increase the number of its electric bus fleet by 22. It is planned to reach at least 1/3 ratio between electric and diesel buses.

Krakow decided to purchase 5 electric buses in 2014 and these buses are still in use.

Lodz has a single electric bus working on routes 79 and 14 which was purchased in 2015.

Lublin has the biggest electric bus fleet in Poland with 51 electric buses as well as 110 trolleybuses. In the following years, it is planned to increase the existing fleet by adding 70 electric buses and 40 trolleybuses.

Rzeszow tried electric buses in 2016 to gain experience in the field. The results were positive, so the city announced a tender for 10 electric buses. These buses are on the central routes.

Warsaw is the capital of Poland and added 16 electric buses to its inventory in 2015. Then in 2019 Warsaw purchased 130 more electric buses which were one of the biggest single purchases in Europe.

1.5.2.14. Portugal. Lisbon started to make tests about electric buses by purchasing one in 2016 and planned to increase that number to 15 in 2019, however, there still are some ongoing issues about it.

<u>1.5.2.15. Romania.</u> Bucharest bought in a total of three electric buses from two different brands in 2015 to test and have an initial experience. The city was satisfied with the results and carried out tenders in 2019 to buy 130 more electric buses for 2020 and 2021 [47].

<u>1.5.2.16. Serbia.</u> Belgrade started using in 2016 by adding 5 electric buses to its transit fleet and aims to increase this number.

<u>1.5.2.17. Slovakia.</u> Košice bought a single electric bus in 2014 and applied for funding from the EU which the EU granted in 2016 by purchasing 9 electric buses for the city. Now the city aims to increase its fleet and finally change its whole fleet into electric buses.

<u>1.5.2.18. Spain.</u> Azuqueca de Henares decided to try an electric bus that started in 2017. The bus does not take place in the fleet every day or every hour, the bus works on the workdays between 07.00 to 23.00. Based on the results the city will decide whether to increase the number or not.

Barcelona has started using electric buses in 2014 by adding 5 electric buses from three different producers. Following the tests and gathered results the city decided to buy 23 three more electric buses in 2019 and aims to introduce more than 200 electric buses in the following 5 years [48].

Bilbao started using electric buses in 2016 by adding 2 buses into its fleet. The city aims to increase the number of electrical vehicles in the following years.

Donostia-San Sebastián obtained its first electric bus in 2014 and after the experiment period, the city added 2 more electric buses in 2016 to its fleet. These busses are planned to stay in operation for 12 more years.

Madrid, the capital of Spain first introduced its electric buses in 2012. This fleet consisted of 13 electric vehicles and proved to be beneficial. In recent years city invested in better-charging stations and plans to enlarge its fleet soon.

Valladolid decided to test 5 electric buses in three different modes in 2016. These tests were focused on the performance, cost-expenses, and emissions values.

1.5.2.19. Sweden. Ale Municipality is a small town in Sweden. Municipality bought one electric bus in 2014 and has been using it successfully ever since.

Ängelholm decided to test five electric buses with three compressed natural gas buses in 2016. The test was carried out between the three years of 2016-2019, and then these busses were integrated into the city's ongoing fleet.

Eskilstuna is one of the first cities in Sweden to use electric buses. In 2015 city bought 2 electric buses and after seeing the success, the transportation authority decided to add 10 more of these electric buses into its fleet.

Gothenburg had the aim of reducing its emissions by 80% until 2020. To do so, the city started testing 10 electric buses on its main routes, and the results were overwhelmingly positive. Therefore the city declared to purchase an outstanding number of 150 electric buses in the following year [49].

Orust currently uses 3 electric buses in its transit fleet.

Södertälje was selected as a pilot zone for Stockholm, and given one electric bus to carry out tests. Results were sufficient and authorities decided to execute the electric bus plans for Stockholm as well as keeping that one bus in the town for future use.

Stockholm has been one of the pioneer cities in terms of transportation that is fueled by renewable sources. In that regard, the capital of Sweden decided to integrate 8 Volvo electric buses into its fleet and aims to maintain 100% renewable fuel transportation in the following decade.

Umeå has started considering electric buses as long as 2010. Municipality then self-funded itself for the purchase of 9 electric buses from two different companies. City integrated these buses into its fleet in 2015 and they still are in active use.

Värnamo converted its whole fleet into electric buses in 2017 by purchasing 4 electric buses from Volvo.

Västerås started using an electric bus in 2014. What's unique about it is the fact that the bus uses biogas for heating. That bus was considered the first electric bus with biogas heating.

1.5.2.20. Switzerland. Geneva has mastered the use of electric buses in its transportation with its 34 electric buses. What makes them special is the way buses charge themselves. Geneva managed to put charge stations in the bus stops, where the buses can recharge themselves sufficiently in less than 15 seconds.

Interlaken started to experience electric buses by adding 1 electric bus into its fleet in 2017.

Lucerne started its electric bus usage in the summer of 2014 by adding 26 electric buses into its fleet. These buses work in route numbers 1,2 and 7 ever since they first deployed and received amazing feedback from both drivers and the passengers.

1.5.2.21. United Kingdom. Inverness is located in Scotland and has a policy of zero-emission. In that regard, the city purchased 6 electric buses in 2015 and these buses were tested until the June of 2018. After the testing period authorities were satisfied with the results and decided to keep the buses on route number 7.

Liverpool purchased one electric bus in order the test its outcomes in 2017. Then the city declared it aims to increase the number of electric vehicles in its fleet up to 25 in the following years.

London has the biggest ongoing electric bus fleet in Europe with having more than 200 purely electric buses in its inventory. This number will gradually increase since London has already made efforts to increase the number their electric buses in their fleet [50].

Manchester has a strategy that aims to reduce emission values significantly by the year 2040. Electric bus usage in the city began far earlier than the other cities in Europe as early as 2003. Three electric buses were integrated into the ongoing fleet in the routes MS1, MS2, and MS3. Currently, there are 32 electric buses in the city's inventory and they plan to invest more in that field in the years to follow [51].

Nottingham bought the first electric buses in 2010 and gradually increased that number to 54 buses in 2018. Furthermore, the city aims to convert its whole fleet into electric buses in the next twenty years.

York started using electric buses in 2012 by adding 35 electric buses to its fleet and based on the positive results, the city decided to add 13 more into its existing fleet in 2017.

1.5.3. Electric Buses in Asia

1.5.3.1. China. When it comes to electric buses, China has outstanding numbers. China has more than 400.000 electric buses which contribute to 99% of the total electric buses in the whole world. The main reason behind that is China started to prioritize electric transit and focused on changing their ongoing fleets into electric ones [52].

According to Bloomberg New Energy Finance's Electric Buses in Cities report, China was able to put 340 electric buses into its ongoing fleets by each day in 2016. In addition to that according to the same report, China is the main producer of electric buses. Although China currently holds an immense electric fleet, the country still holds ambition towards a further increase in the number and full electrification of its transit fleet [53].

1.5.3.2. Russia. Although being not even close to the gigantic numbers that China has in terms of electric buses, the city of Moscow has the biggest electric bus fleet in Europe with 450 electric buses, followed by London. Electric buses in Moscow are produced in Russia by Russian companies, thus, decreases the prices and makes them easier to reach. In addition to its immense electric bus fleet, Moscow declared a new 150 electric buses will be purchased in the following years. Authorities in the city plan to reach 2600 electric buses by the end of 2024. Currently, electric buses in Moscow run on 36 different routes which cover almost the entire city [54].

1.5.3.3. Malaysia. Malaysian Green Technology Corp(MGCC) aims to invest in electric buses with local investors. The current aim of the state is to deploy 100 electric buses. According to MGCC board members and CEO Shamsul Bahar Mohd, there currently are some pilot electric bus programs being carried out in the country. Also, the Ministry of Transport declared its intent to help the green public transport sector in Malaysia in 2020 [55].

1.5.3.4. Indonesia. Indonesia has publicly announced its intention to change its fleet into electric buses and the city of Bali created electric bus regulations to be used in the future in 2019 which was followed by Jakarta in 2020. Currently, there are tests in the city of Aceh and the country expects to change most of its fleet to electric soon. This would mean the country is planning to integrate more than 14.000 electric buses in the following decade [56].

1.5.3.5. India. India is planning to add 6490 electric buses to its fleet in the following two years, 1850 pieces in 2021, and 4640 pieces in 2021-22 according to JMK Research and Analytics report. India integrated 1031 electric buses in March 2020, 600 in the year 2019, 400 in the year 2018, and 31 in the year 2017 across the country.

The country is planning to add more and more electric buses into its fleet, however, due to the country's size as well as population, it is not expected for India to fully transform its fleet into electricity shortly. There currently are six major electric bus producers in India and the market is growing by each month. The most important of them being Tata Motors and Olectra-BYD(A joint brand between India's Tata and China's BYD) [57].

1.5.4. Electric Buses in the Middle East and North Africa (MENA)

Many countries from all around the world are focusing on clearer transportation and have developed goals for integrating more and more electric buses into their transportation fleets. These commitments also occur in countries that are in the Middle East and North Africa (MENA) regions. Most of the countries in that region currently support the development of electric buses and adopting the latest improvements [58]. These countries include; Egypt, Morocco, Qatar, Tunisia, United Arab Emirates (UAE).

1.5.4.1. Egypt. Alexandria Public Transport Authority (APTA) has started using 15 electric buses in 2020. These buses carry an active role in 3 routes, and these buses had a trial period of 3 months. Alexandria also invested in the infrastructure and add various charging stations in the city to sustain further developments for 40 million USD [59].

Cairo tested one electric bus in 2020. Based on the results Cairo Transport Authority (CTA), decided to increase the number of electric buses in its fleet by 50. Furthermore, according to a deal made with the Ministry of Military Production, 2000 electric buses will be produced starting from 2020 in an estimated period of four years [59].

1.5.4.2. Morocco. Marrakech currently operates 10 electric buses with an additional 5 as a backup. The city aims to increase the number of electric buses in use by 48 additional buses which would work on 3 new lines by the year 2030 [60].

1.5.4.3. Qatar. Doha declared to change 25% of its ongoing fleet to electric buses by the end of 2022 for the purpose to make the fleet ready for the incoming FIFA World Cup Event. Preparations have started in late 2018 [61].

1.5.4.4. Tunisia. Tunis started to make tests about electric buses by adding electric buses to its fleet for 6 months in 2018. City plans to manufacture and integrate electric buses in the future [62].

1.5.4.5. United Arab Emirates (UAE). Abu Dhabi Department of Transportation-started the project 'Eco-Bus' in 2018. That project gathered data from 6 different stops in Abu Dhabi until March 2019. Decisions are yet to be made about the future of electric bus usage in Abu Dhabi. The concerns are mostly about the climate of the city which may reach 50 degrees Celcius during summer times [63].

Dubai Road and Transport Authority (RTA) started testing electric buses with wireless charge implementations. These tests about wireless charged electric buses have been carried out since 2015, however, there are no certain outcomes yet [64].

Sharjah Road and Transport Authority (SRTA) decided to test the electric buses for some time before integrating them into its fleet. These tests started in December 2019 and the electric buses are placed on the route of the Sharjah-Ajman line [65].

1.5.5. Electric Buses in Turkey

Although there are increasing concerns about the emission levels, public transportation in Turkey has been carried out mostly by standard conventional engine vehicles [66]. Even though Turkey has big companies such as Otokar, Bozankaya, Temsa, Karsan, and BMC producing electric buses and exports them, there are no certain regulations or standards for electric buses in the country. However, by the late 2010s, Turkey has started to implement some electric buses into the ongoing fleets. In the last decade, 119 electric buses (32 of them are trolleys) were tendered and expected to be in use by municipalities including the three largest cities in Turkey namely; İzmir (ESHOT), İstanbul(IETT), Ankara (EGO) as well as other cities as; Malatya, Eskişehir, Konya, Manisa, Elazığ, Kayseri, Gaziantep, Şanlıurfa [67].

<u>1.5.5.1. İstanbul.</u> Although İstanbul is not the official capital, it is Turkey's biggest city in every possible aspect and is often referred to as the country's financial capital. The first usage of electric buses (trolleys) started in the early 1960s in İstanbul. The main reason behind the selection of electric buses was the fact that trams in the city were no longer able to support its increasing demand; therefore, considering also the environmental effect, electric buses were put in use. Topkapı-Eminönü route was the first electric bus line in the city that dates back to May 1961. This fleet increased its numbers up to 101 in the late 1960s; however, due to frequently occurring problems such as electricity power cuts and causing congestion due to them being slow, they were removed from the transit fleet in 1984 and sold to İzmir. Currently, there are no active electric buses in İstanbul [68].

İstanbul has the biggest ongoing bus fleet in the country. There were 3 different attempts to integrate electric buses in that fleet. These tenders consisted of 200 electric buses in total as well as required charging situations and infrastructure. If it would be done, this tender would be the biggest single electric bus purchase in the world.

1.5.5.2. Ankara. Ankara is the capital of Turkey being the second-largest city in the country. Public transportation in Ankara is managed by EGO. EGO used purely buses in its transit fleets until the year 1947 in which EGO bought the first electric-buses and added them to its fleet. In the year 1947, 10 electric buses were bought which was followed by another 10 electric buses in the year 1948. These buses were implemented into the main routes of the city. The city reached a total of 33 electric buses after the purchase of 13 more electric buses in 1952, however, the maximum amount of electric buses deployed in the city reached 66 when EGO decided to add 33 more electric buses into its fleet. Although consideration of environmental impacts, the city decided to change its fleet for a non-electric one because of the occurring congestion due to electric-buses being slow. In 1981 all the electric buses in the fleet of EGO have been decommissioned. Ever since 1981 city has no running electric buses in its ongoing fleet [69]. There were some speculations about electric bus usage in Ankara in 2019, however, this news turned out to be fake [70].

1.5.5.3. İzmir. İzmir currently is the third-largest city in Turkey. Transportation in the city is managed by ESHOT. The first electric bus implementations in the city took place on 14 May 1954 by the purchase of 4 trolleys to be used in the cities. This fleet was increased to 7 trolleys in 1958 by the addition of 3 more trolleys to the fleet and in the year 1984 İzmir bought 75 more from the city of İstanbul to be used in transportation [71]. Lately, İzmir has been the pioneer in terms of electric bus usage in public transportation. In 2017 the city put the first-ever full-electric fleet into its transportation fleet. This fleet consisted of 20 full-electric buses which were manufactured by Bozankaya also planned to be fueled by solar panels [72].

1.5.5.4. Malatya. The province of Malatya issued two tenders which covered purchasing a total of 22 electric buses in 2019. At first, the province would purchase 10 electric buses and built the infrastructure required, followed by a purchase of 10+2 electric buses. By doing so, currently, the city of Malatya has the largest ongoing electric bus fleet in the country [67].

1.5.5.5. Eskişehir (Tepebaşı). Electric bus usage in the province of Eskişehir started in one of its towns called Tepebasi(Tepebaşı) due to the cooperation of a European Union project issued by the EU Commission of Research and Innovation (Horizon 2020). This project is also called Remourban (Project No: 646511). In that regard 4 electric buses were implemented(bought from Bozankaya) into the ongoing bus fleet and it is inactive use since the year 2017 [67].

1.5.5.6. Konya. Konya began using electric buses in 2016. City bought 4 Bozankaya Sileo-type buses and put these into the central lines. However, the current fleet mostly consists of classical diesel buses. It is planned to enlarge the electric bus fleet in the future, yet there are no active steps in that regard ever since 2016 [67].

1.5.5.7. Manisa. Manisa shares the title of having the most electric buses in its ongoing fleet with Malatya by holding 22 electric buses in its inventory. Similar to the Malatya case, two tenders were carried out where the first one focused on infrastructure and requirements for having electric buses, whereas the second tender was mainly about expanding the electric bus inventory. These buses also were bought from Bozankaya. Also, that second tender is the biggest electric bus purchase in a single time in Turkey [67].

1.5.5.8. Elazığ. The municipality of Elazığ bought 15 electric buses which are Turkey's first 18-meter type in 2018, and these buses are still in use [67].

1.5.5.9. Kayseri. The municipality of Kayseri recently bought 10 of 18 meters and 8 of 25 meters electric buses from Bozankaya. Different from all other tendering processes, the first tender was carried out for the electric buses where the second one was about the infrastructure and requirements for the electric buses. In addition to that, the Municipality of Kayseri also started working on a new electric bus regulation [67].

1.5.5.10. Gaziantep. Gaziantep case is different in terms of the bus producer, instead of usual Bozankaya Municipality of Gaziantep decided to align itself with the private sector. In that regard, the municipality agreed on a single electric bus which is provided from 'Toroslar Elektrik Dağıtım AŞ' which is a subbranch of the company 'EnerjiSA'. The agreement includes the donation of one electric bus (TEMSA MD9 ElectriCITY) to the municipality in the fulfillment of the project 'Smart Cities' which is funded by the 'Enerji Piyasası Düzenleme Kurumu'(Regulatory Board of Energy Market). Therefore first time in the country, a municipality started using an electric bus from a firm other than Bozankaya [67].

1.5.5.11. Şanlıurfa. The municipality of Şanlıurfa bought 10 25 meter electric buses from Bozankaya as well as power supplies, control, and signalization mechanisms and communication equipment. This tender was unique since the Municipality of Şanlıurfa worked with the Municipality of Kayseri and obtained important guidance [70].

2. THEORY

2.1. Analytic Hierarchy Process (AHP)

In the last 20 years, analyses carried out by multi-criteria decision methods became quite popular which is reasonable since humans are faced with decision-making problems in every part of their lives. Developed multi-criteria decision methods can work on various ranges of problems from basic day-to-day decisions to complex structured organizational levels. One of the most popular multi-criteria decision methods is the Analytic Hierarchy Process or AHP in short [73].

Analytic Hierarchy Process (AHP) was first introduced by Thomas L. Saaty in 1971 as a multi-criteria decision-making method [74]. The main goal of that method is to quantify the relative importance of every different element of a given set on a numerical scale. This outcome is dependent on the individual who is giving responses and assessing values to these criteria [73–75]. AHP is a very adjustable method since it can create a connection between the criteria and alternatives. Another great aspect of AHP is that it can simplify very complex problems by decomposing the problem into specific hierarchies so that the analysis can be carried out in both qualitative as well quantitative ways. Since AHP finally puts all of these together and makes connections between them, thus it would be easier to see which criteria affect the other criteria and other alternatives [73–75].

AHP has a wide range of applications since it allows using qualitative as well as quantitative criteria for evaluation. For instance, AHP can be used in selecting a car to purchase, which place to visit for a vacation or even educational decisions such as whether to go for a master's or not [76].

2.2. How Does AHP Work

AHP excels when there is a need for branching complex problems into hierarchical parts, namely the objective, criteria, and alternatives. AHP is usually explained in 3 steps which are; developing the model for the hierarchical problem, comparison of the pairs and finally giving relative weights to the criteria based on the comparisons and analysis [73].

2.3. Developing the Model

This includes the part where the model is developed which the decision will be made. The objective should be, criteria, subcriteria (if they exist), and alternatives are defined at that level.

2.4. Comparison of Pairs

In this part, the individual who is generally is the expert in that area is asked to compare the given pair between them. To do so, Saaty introduced the Saaty Scale from 1 to 9 where there are 5 levels and 4 sublevels, which stands for the relative importance of the pair one to pair two. Saaty scale can be seen in Table 2.1 below [77].

Table 2.1. Saaty scale.

AHP Scale of Importance for Comparision Pair (aij)	**Numberic Rating**	**Reciprocal**	**Decimal**
Extreme importance	9	1/9	0.111
Very strong to extremely	8	1/8	0.125
Very strong importance	7	1/7	0.143
Strongly to very strong	6	1/6	0.167
Strong importance	5	1/5	0.200
Moderately to strong	4	1/4	0.250
Moderate importance	3	1/3	0.333
Equally to moderately	2	1/2	0.500
Equal importance	1	1/1	1.000

2.5. Assessment of Relative Weights

Based on the importance value selected by the individual which is given in the table above, the pairwise calculations are carried out to assess the relative weight of each criterion. Following this step, the overall weights and priorities of the criteria are gathered together to be summarized. Finally, these sums of local criteria and priorities are put into calculations considering the calculated weights of the higher-level elements. Thus giving the overall weights of every criterion and element in a quantitive manner.

To able to carry out a successful AHP, four axioms must be checked which are, Reciprocity Axiom, Axiom for Homogeneity, Axiom for Dependence, and Axiom of Expectation [78].

2.5.1. Reciprocity Axiom

Reciprocity axioms state that if the element X has been valued as n times more important than the element Y, then the element Y must be evaluated as 1/n times more important than the element X [73].

2.5.2. Axiom for Homogeneity

The axiom for homogeneity checks if the elements X and Y are comparable in a logical manner. This does not only include being in the same field or being comparable also it should be checked that none of these elements have a superior advantage over the other one, in other words, none of these elements can also be far better than the other [73].

2.5.3. Axiom for Dependence

The axiom for dependence is valid if only there is more than one level of elements. If the level of elements is more than 1, then it should be checked that the lower-level elements are dependent on the higher-level elements [73].

2.5.4. Axiom of Expectation

Axiom of expectation checks the change in the result when a criterion or the value of the criteria has been changed. If there is a change in the result of the criteria, it is expected to have a change in the outcome as well [73].

2.6. Mathematical Method of AHP

Considering there are n elements in the constructed model, the comparison matrix would have the dimensions of nxm as follows;

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nm} \end{bmatrix} \tag{2.1}$$

When the criteria are compared or in other words the ratio of the elements are needed to be calculated the formula below can be used;

$$a_{ij} = \frac{w_i}{w_j} \tag{2.2}$$

and considering the axiom for reciprocality we can obtain that

$$a_{ij} = \frac{1}{a_{ji}} \tag{2.3}$$

Following these, the next thing to do is to gather a normalized matrix $B = [b_{ij}]$ in which the elements inside the matrix B can be calculated as;

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{2.4}$$

Then, weights of the eigenvector $w = [w_i]$ can be calculated by calculating the arithmetic mean of every row in the matrix. The formulation for this process is as follows [73];

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \tag{2.5}$$

2.7. Consistency of the Matrix

Another crucial aspect in AHP analysis is consistency which tells how accurate the test taker's answer is. For instance, if the test taker gave inaccurate answers such as stating A is more important than B, followed by B is more than C, however then stated that C is more than A, would result in inconsistency. Consistency can be expressed in mathematical terms as; for all the values of i,j and k [73].

Although test makers want to have consistent results, it is unwise to expect every test taker to give perfectly consistent answers, due to human nature. Even the experts who have solid experience in their fields tend to give some answers that are inconsistent in a way. Therefore inconsistency up to a point is considered reasonable and might be tolerated in the results sections. However, results with a consistency ratio above 10% are said to be inconsistent and would not be taken into account [73].

To determine if $a_{ij}a_{jk} = a_{jk}$ the obtained results are consistent or not, and if not, whether they are at a level where they can be tolerated or not, some calculations should be made. These calculations start with developing a quantifiable measure to check with matrix A. It can be said that matrix A is fully consistent when it produces a matrix C where all of its columns are identical such as;

$$C = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \tag{2.6}$$

which is followed by dividing the column elements of original matrix A by w_i which would result in the matrix A becoming;

$$A = \begin{bmatrix} 1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & 1 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & 1 \end{bmatrix} \tag{2.7}$$

When the ratio comparisons have made, the results can be shown as [57]:

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_2 \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_2 \end{bmatrix} \tag{2.8}$$

However, the term nxw is needed, to get that the matrix on the right-hand side is multiplied with w. After this step, if $Aw = nw$ equation is satisfied, it can be stated that A is consistent. If not, then the relative weight of w_i approximated with the average of the elements of row i in the normalized matrix C. If w_{avg} were to be stated as the average vector which was computed by the explained step, it could be expressed as;

$$Aw_{avg} = \lambda_{max} w_{avg}, \lambda_{max} \geq n \tag{2.9}$$

Where, as the λ_{max} becomes closer to n, the consistency of the matrix A increases. By using this AHP calculates the consistency ratio as;

$$CR = \frac{CI}{RI} \tag{2.10}$$

In the equation RI stands for the random consistency index, whereas CI stands for the consistency index of the matrix A and can be calculated as [73];

$$CR = \frac{\lambda_{max} - n}{n - 1} \tag{2.11}$$

As stated before after calculating the consistency ratios, if the test taker had a rating lower than 10%, the results are said to be acceptable, if not it states that the test taker made some inconsistent decisions and needs to reevaluate the answers.

3. CASE STUDY

Electric buses are becoming more and more popular in the transportation field. As shown before, there are lots of countries-cities that are integrating electric buses into their existing fleet, furthermore trying to increase the number of electric buses they have. It is expected to see a significant increase in the number of electric buses in the following decades since various countries declared their intention to convert their fleets into electric ones in the following years. Although electric buses are taking place of the regular buses, they are a new technology that, not many authorities have experience with.

To overcome the problems that might come with electric bus implementations, these possible issues should be stated and classified. There are a lot of different things to consider before trying to add an electric bus into the transit fleet. To find these possible issues, authorities were asked to name their criteria and what they consider when implementing electric buses from various countries. These authorities include transportation engineers, transport fleet managers, heads of transportation of different municipalities, economists, environmental engineers, and political party members. These criteria include; the high initial costs of electric buses compared to the regular ones, which decreases the enthusiasm of investors, passenger satisfaction(some passengers do not want changes), lower upkeep and maintenance costs of electric buses, political policies of the governments and not getting enough political support since electric buses are a long term investment which would take more years than a regular political ruling period, thus not giving instant results that can be used in political propaganda, constant changes in the regulations of electric buses, geographical conditions in the cities(electric buses are not as good in inclined zones), amount of infrastructure needed as well as the need for charging stations and garages inside the city center, finding the right personnel that can drive the electric buses, and the last but not the least, people's tendency to prefer subway instead of buses.

After several interviews and questionnaires with the experts, although there are a lot of different criteria that they consider, some were repeated by almost every one of them. These criteria can be classified as; the economic aspect, public and political aspect, environmental aspect, and finally the safety aspect. After obtaining these four aspects 13 experts from various backgrounds that have expertise in public transportation were given a survey including these four criteria and were asked to give relative weights to each one of them for AHP. Before going into the AHP part, these four aspects should be explained.

3.1. Aspects Considered

3.1.1. Economic Aspect

As the title states, this aspect considers economical parts of the electric buses, such as initial purchase costs, maintenance costs, short and long term effects, however, it should be stated that the experts knew and took into consideration the carbon-pricing of electric buses which puts the emissions values expenses into the total costs. Therefore giving electric buses a solid advantage to make up for their high initial costs.

3.1.2. Public and Political Aspect

This aspect focuses on how the community would benefit from electric buses as well as the possible political favor that can be gained by implementing the electric buses. Political power and political favor are considerably important factors when something is to be implemented, and lots of politicians are looking for opportunities to increase their political power or use it as a commercial for the same purpose.

3.1.3. Environmental Aspect

The environmental aspect focuses on the effects of electric buses on the environment via emission values. It is known that electric buses compared to diesel counterparts produce significantly lower amounts of greenhouse gases, thus decreasing the environmental effects of public transportation for a huge deal.

3.1.4. Safety Aspect

The safety aspect focuses on the issues about protection and developments in that regard. For instance, electric buses with their improved technology give better control over the traffic, might reduce the congestion due to better planning and implementation as well as reducing the mechanical problems that the buses are facing since electric buses vibrate less, thus resulting in fewer mechanical problems overall.

3.2. The Survey

Experts were given 4 criteria and asked to compare them by giving values from 1 to 9 according to the Saaty Scale which was explained before and conducted pairwise comparisons. Based on their answers AHP method was implemented and results were gathered. 13 experts took part in the survey.

3.2.1. Expert A

Expert A has been working in academics for more than 7 years as transportation lecturer in a university. Expert A's survey answers can be seen below in Table 3.1.

Table 3.1. Survey answers of Expert A.

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

Expert A has given the weights as shown in the figure, he completed the survey with a consistency ratio of 2% which shows that he was consistent with his answers. Based on these answers it can be stated that he considers the economical aspect as the most important aspect among these which is followed by the safety, environmental, and according to him, the public and political aspect is the least important criterion one among these four. Based on the answers given for the survey, Expert A's AHP results can be seen in Table 3.2, and represented in Figure 3.1 below.

Table 3.2. AHP Results of Expert A.

Criterion	**Weight**	**+/-**
Economic Aspect	43.8%	7.0%
Public and Political Aspect	7.1%	1.4%
Environmental Aspect	22.8%	2.2%
Safety Aspect	26.3%	6.1%
Attribute	**Value**	
Lambda	4.049	
CR	1.8%	
GCI	0.06	
Psi	0.0%	

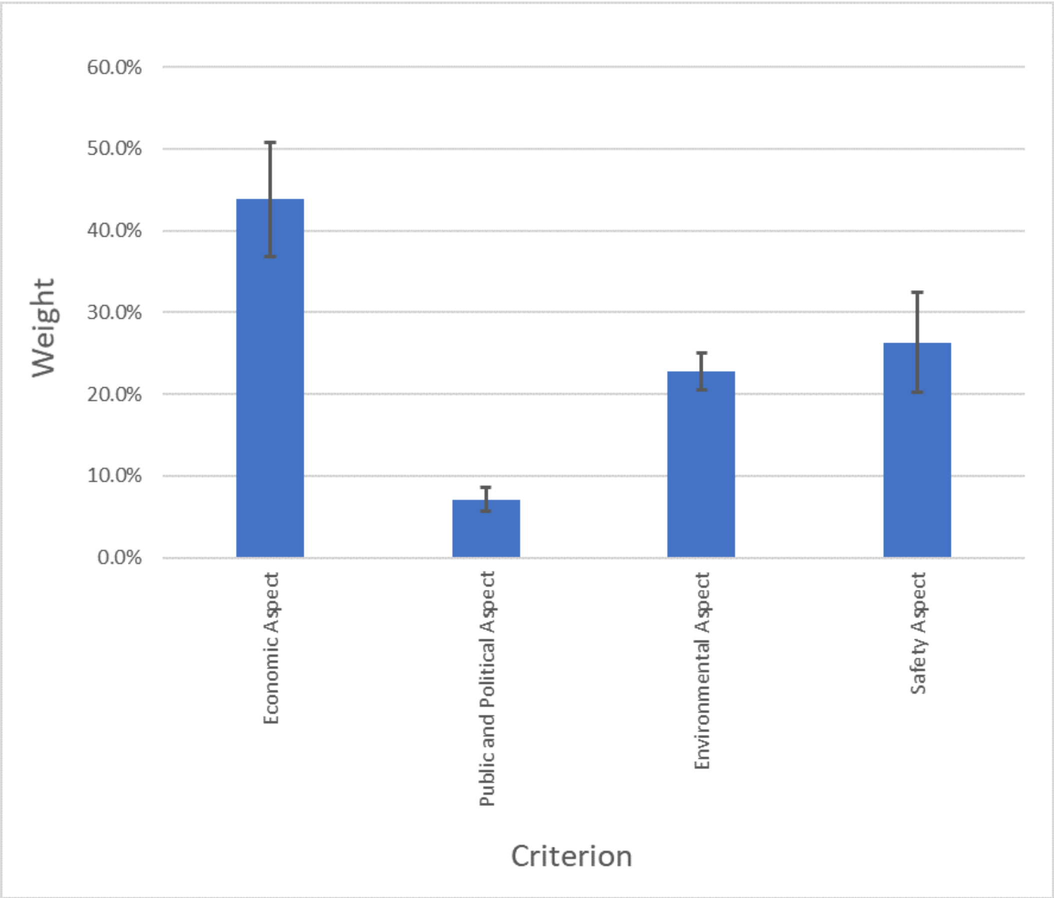

Figure 3.1. AHP results of Expert A.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 39.4%
- Public and Political Aspect: 39.4%
- Environmental Aspect: 13.7%
- Safety Aspect: 7.5%

3.2.2. Expert B

Expert B has been working as a traffic modeling expert in an university for 6 years. Expert B has expertise in the traffic management and traffic simulation tools. Expert B's survey answers can be seen below in Table 3.3.

Table 3.3. Survey answers of Expert B.

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

Expert B gave equal importance to economical and environmental aspects which are followed by the safety and public and political aspects with an amazing 0% consistency ratio Expert B's AHP results can be seen in Table 3.4, and represented in Figure 3.2 below.

Table 3.4. AHP Results of Expert B.

Criterion	Weight	+/-
Economic Aspect	39.4%	1.5%
Public and Political Aspect	7.5%	0.5%
Environmental Aspect	39.4%	1.5%
Safety Aspect	13.7%	0.9%
Attribute	**Value**	
Lambda	4.004	
CR	0.2%	
GCI	0.01	
Psi	0.0%	

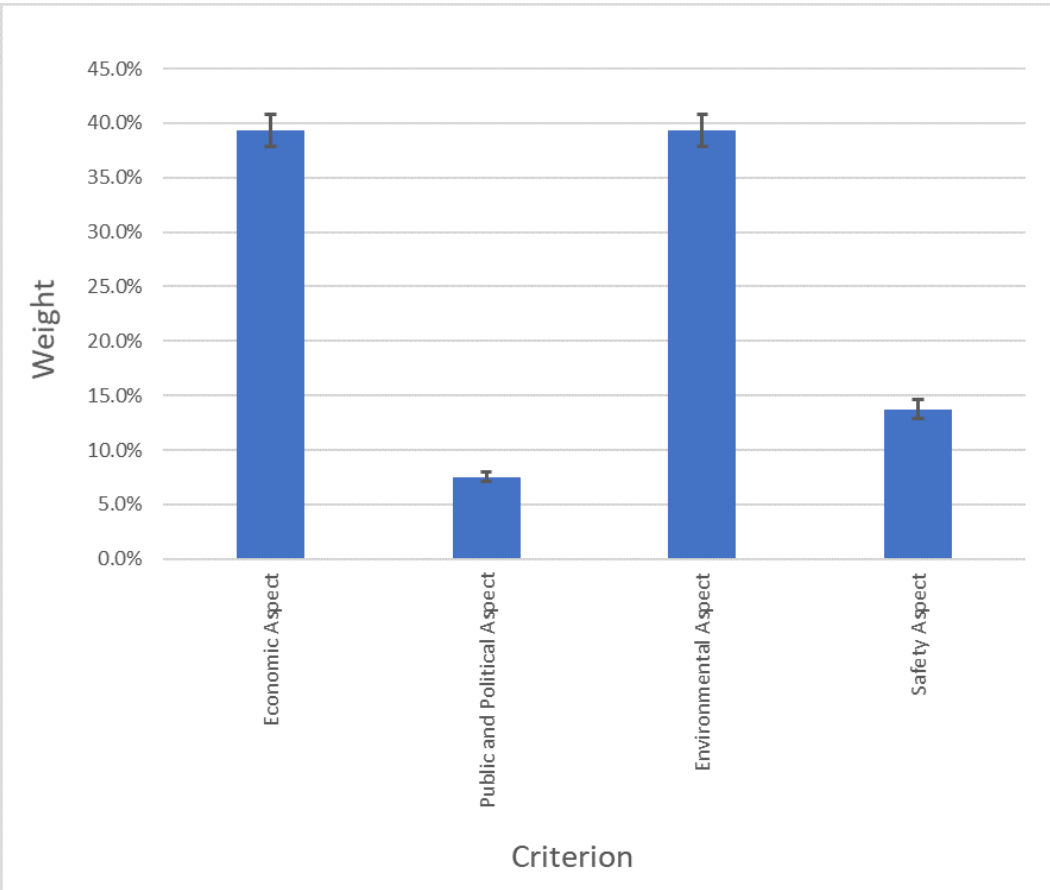

Figure 3.2. AHP results of Expert B.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 43.8%
- Public and Political Aspect: 7.1%
- Environmental Aspect: 22.8%
- Safety Aspect: 26.3%

3.2.3. Expert C

Expert C is a traffic application developer in a university. Expert C has programmed various traffic applications and has been working in a university for more than 5 years. Expert C's survey answers can be seen below in Table 3.5.

Table 3.5. Survey answers of Expert C.

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

Based on the answer that Expert C gave, it can be stated that the most important criterion for him is the environmental aspect, then the economic aspect, which is followed by the safety aspect. According to his answers, the least important criterion is the public and political aspects. It should be stated that his answers had a consistency ratio of 10% which the maximum error rate that can be accepted. Expert C's AHP results can be seen in Table 3.6, and represented in Figure 3.3 below.

Table 3.6. AHP Results of Expert C.

Criterion	**Weight**	+/-
Economic Aspect	28.0%	11.2%
Public and Political Aspect	9.0%	4.3%
Environmental Aspect	48.1%	22.6%
Safety Aspect	14.9%	1.6%
Attribute	**Value**	
Lambda	4.234	
CR	8.6%	
GCI	0.31	
Psi	8.3%	

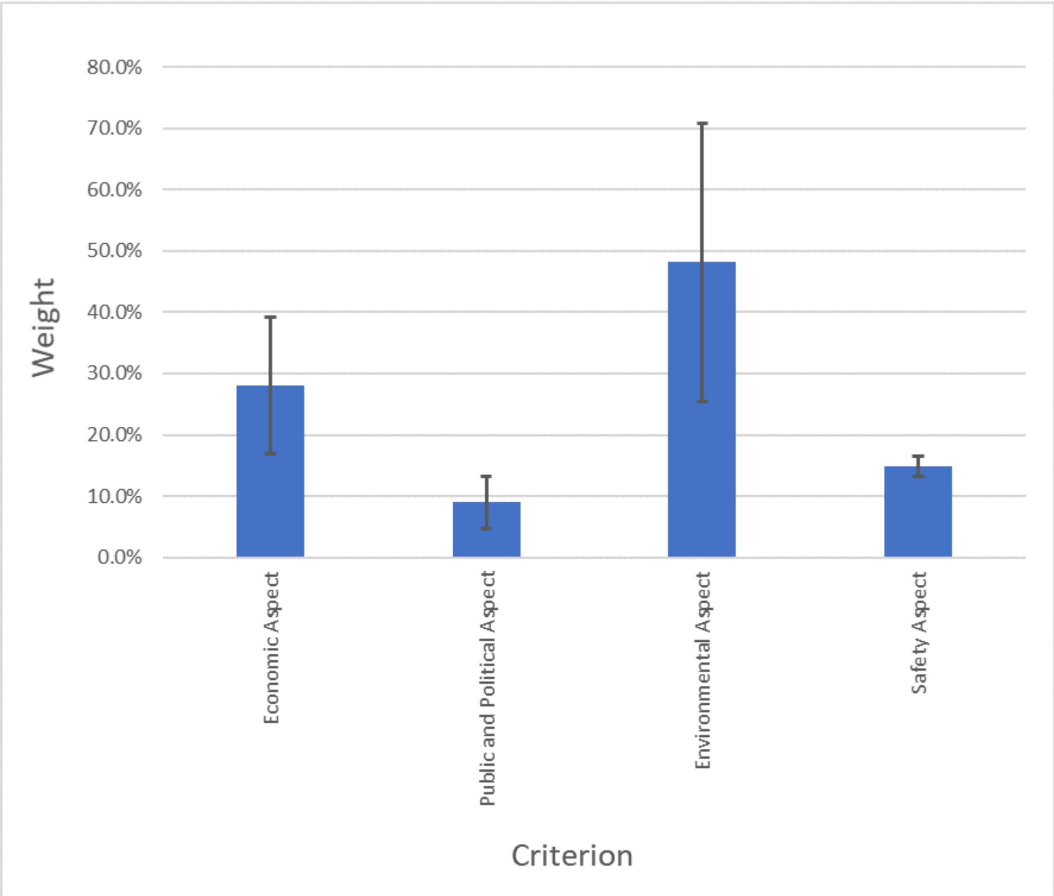

Figure 3.3. AHP results of Expert C.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 48.1%
- Public and Political Aspect: 28.0%
- Environmental Aspect: 14.9%
- Safety Aspect: 9.0%

3.2.4. Expert D

Expert D has been working as the occupational health and safety expert in large-scale projects including various tunnels, airports, bridges and highways and have more than 30 years of experience. Expert D's survey answers can be seen below in Table 3.7.

Table 3.7. Survey answers of Expert D.

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

According to his answers, it can be stated that Bülent Şahin prioritizes the safety aspect the most, which is followed by the environmental aspect, public and political aspect and the least important criteria is economics. Also, he had an acceptable 5% consistency ratio. Expert D's AHP results can be seen in Table 3.8, and represented in Figure 3.4 below.

Table 3.8. AHP Results of Expert D.

Criterion	**Weight**	+/-
Economic Aspect	5.0%	1.8%
Public and Political Aspect	14.2%	6.8%
Environmental Aspect	29.3%	7.7%
Safety Aspect	51.5%	14.2%
Attribute	**Value**	
Lambda	4.192	
CR	7.0%	
GCI	0.25	
Psi	0.0%	

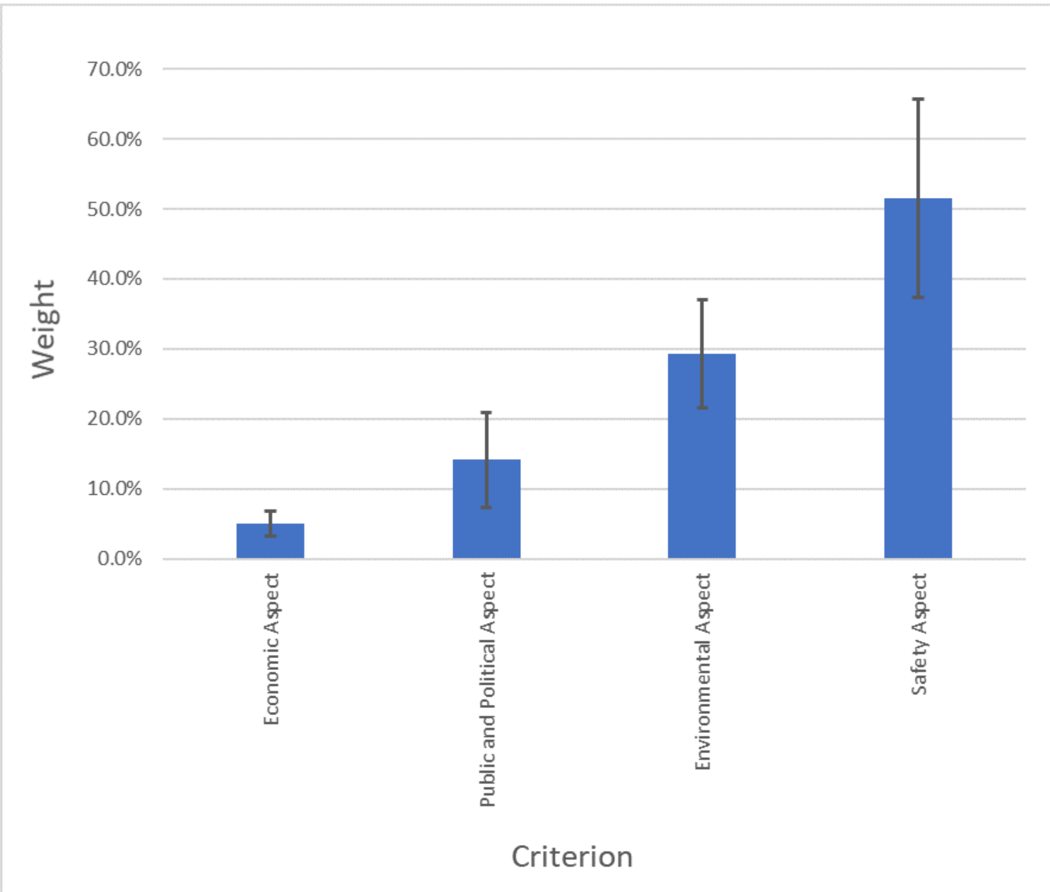

Figure 3.4. AHP results of Expert D.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 51.5%
- Public and Political Aspect: 29.3%
- Environmental Aspect: 14.2%
- Safety Aspect: 5.0%

3.2.5. Expert E

Expert E has been working as a finance manager in a transportation facility in the UK. The Expert has 9 years of work experience and worked in several different countries in the EU. Expert E's survey answers can be seen below in Table 3.9.

Table 3.9. Survey answers of Expert E.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	5
	Environmental Aspect	A	5
	Safety Aspect	A	2
Public and Political Aspect	Environmental Aspect	B	7
	Safety Aspect	B	5
Environmental Aspect	Safety Aspect	B	2

Based on his answers, it can be said that according to Expert E the most important criteria is the environmental aspect, which is followed by the safety aspect. According to the answers, the economical aspect stands in third place and the least important criteria for him is the public and political aspects. He also had an acceptable 5% consistency ratio. Expert E's AHP results can be seen in Table 3.10, and represented in Figure 3.5 below.

Table 3.10. AHP Results of Expert E.

Criterion	**Weight**	+/-
Economic Aspect	15.6%	6.2%
Public and Political Aspect	5.1%	1.8%
Environmental Aspect	52.9%	16.9%
Safety Aspect	26.4%	2.5%
Attribute	**Value**	
Lambda	4.146	
CR	5.4%	
GCI	0.19	
Psi	0.0%	

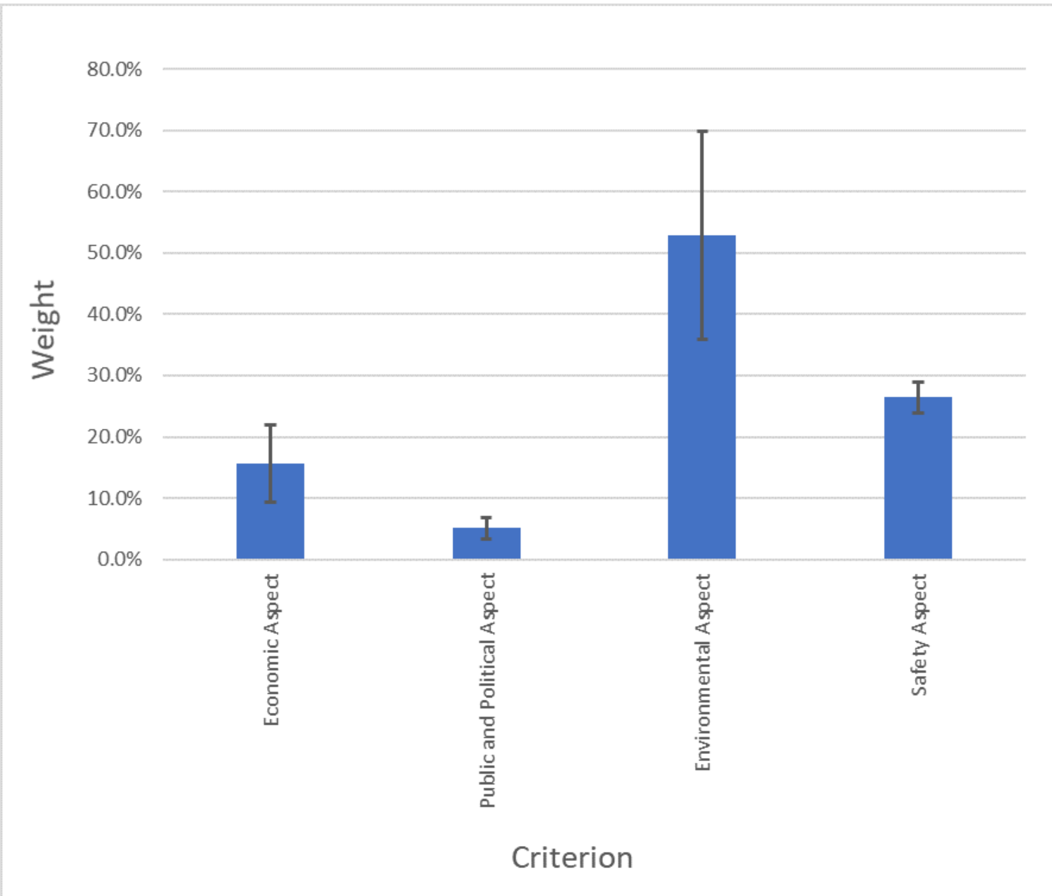

Figure 3.5. AHP results of Expert E.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 52.9%
- Public and Political Aspect: 26.4%
- Environmental Aspect: 15.6%
- Safety Aspect: 5.1%

3.2.6. Expert F

Expert F has been working as a road maintenance and infrastructure engineer in a private company in Finland for more than 9 years. Expert F's survey answers can be seen below in Table 3.11.

Table 3.11. Survey answers of Expert F.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	5
	Environmental Aspect	A	6
	Safety Aspect	A	9
Public and Political Aspect	Environmental Aspect	B	2
	Safety Aspect	B	3
Environmental Aspect	Safety Aspect	B	3

According to the survey, Expert F considers safety as the prime criteria among these four, which is followed by the environmental aspect and public and political aspect. For him, the least important criterion is the economic aspect. Expert F's AHP results can be seen in Table 3.12, and represented in Figure 3.6 below.

Table 3.12. AHP Results of Expert F.

Criterion	**Weight**	+/-
Economic Aspect	4.4%	1.0%
Public and Political Aspect	16.9%	3.7%
Environmental Aspect	25.2%	6.4%
Safety Aspect	53.5%	14.8%
Attribute	**Value**	
Lambda	4.093	
CR	3.4%	
GCI	0.12	
Psi	0.0%	

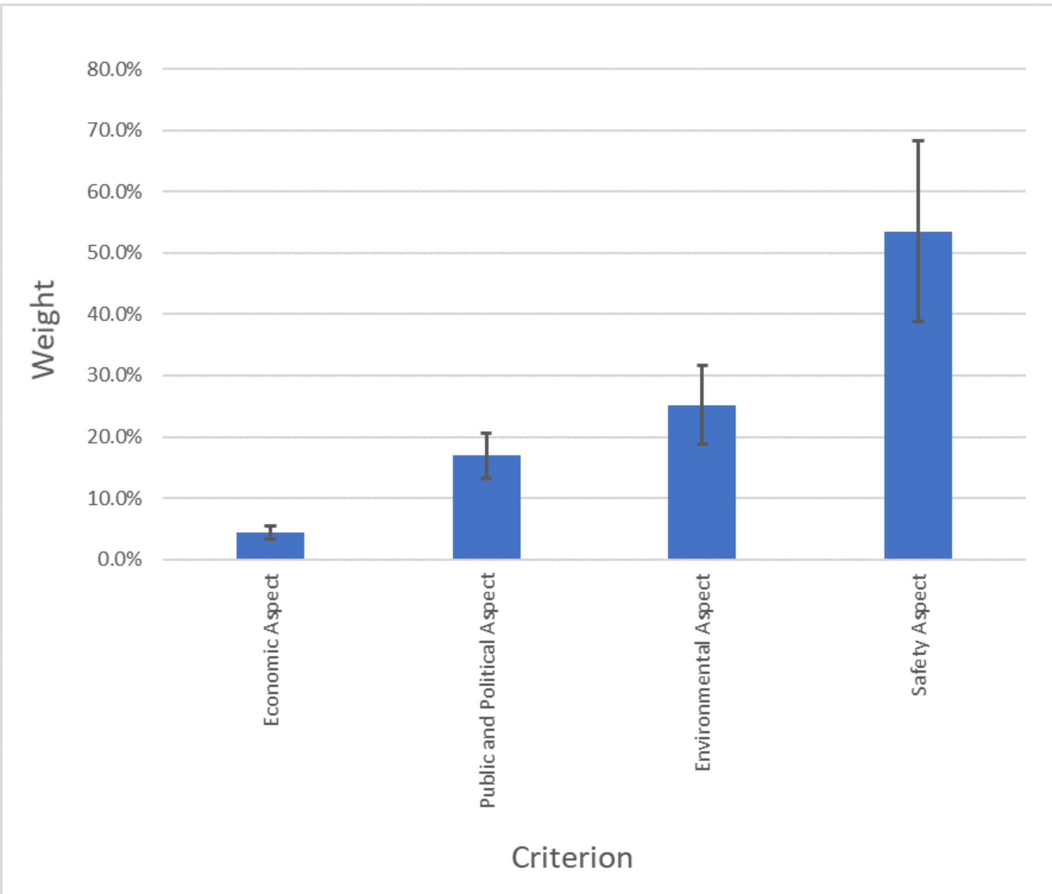

Figure 3.6. AHP results of Expert F.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 53.5%
- Public and Political Aspect: 25.2%
- Environmental Aspect: 16.9%
- Safety Aspect: 4.4%

3.2.7. Expert G

Expert G is an architect who focuses on the field of transportation architecture in London. Expert G has more than 10 years of work experience and is currently working in the UK. Expert G's survey answers can be seen below in Table 3.13.

Table 3.13. Survey answers of Expert G.

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

Based on the answers that the Expert gave, it can be said that he considers the environmental aspect as the most important criterion among these four which is followed by the public and political aspect, the safety aspect, and lastly the economic aspect. Expert G's AHP results can be seen in Table 3.14, and represented in Figure 3.7 below.

Table 3.14. AHP Results of Expert G.

Criterion	**Weight**	+/-
Economic Aspect	8.8%	1.5%
Public and Political Aspect	25.2%	6.3%
Environmental Aspect	54.7%	16.7%
Safety Aspect	11.3%	4.4%
Attribute	**Value**	
Lambda	4.127	
CR	4.6%	
GCI	0.17	
Psi	0.0%	

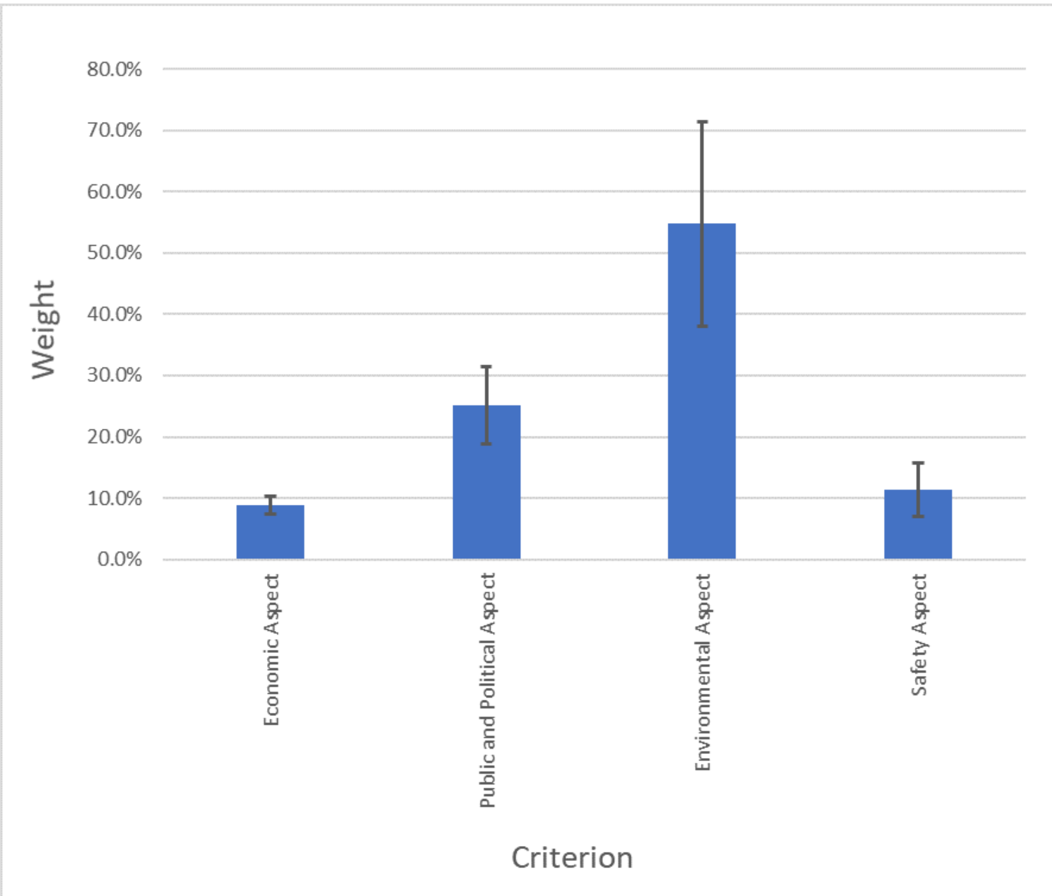

Figure 3.7. AHP results of Expert G.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 54.7%
- Public and Political Aspect: 25.2%
- Environmental Aspect: 11.3%
- Safety Aspect: 8.8%

3.2.8. Expert H

Expert H has been working as a full time instructor in a university for about 21 years. The expert has solid knowledge in the field of transportation. Expert H's survey answers can be seen below in Table 3.15.

Table 3.15. Survey answers of Expert H.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	3
	Environmental Aspect	A	1
	Safety Aspect	A	1
Public and Political Aspect	Environmental Aspect	B	1
	Safety Aspect	B	1
Environmental Aspect	Safety Aspect	B	1

Based on the answers given, it can be concluded that according to the expert, although there are no big differences, the most important criterion is the economic aspect which is followed by the environmental and safety aspects which the expert considers equally important and the least important criterion is the public and political aspect. Expert H's AHP results can be seen in Table 3.16, and represented in Figure 3.8 below.

Table 3.16. AHP Results of Expert H.

Criterion	**Weight**	+/-
Economic Aspect	33.1%	14.6%
Public and Political Aspect	18.8%	5.9%
Environmental Aspect	24.1%	5.7%
Safety Aspect	24.1%	5.7%
Attribute	**Value**	
Lambda	4.155	
CR	5.7%	
GCI	0.20	
Psi	0.0%	

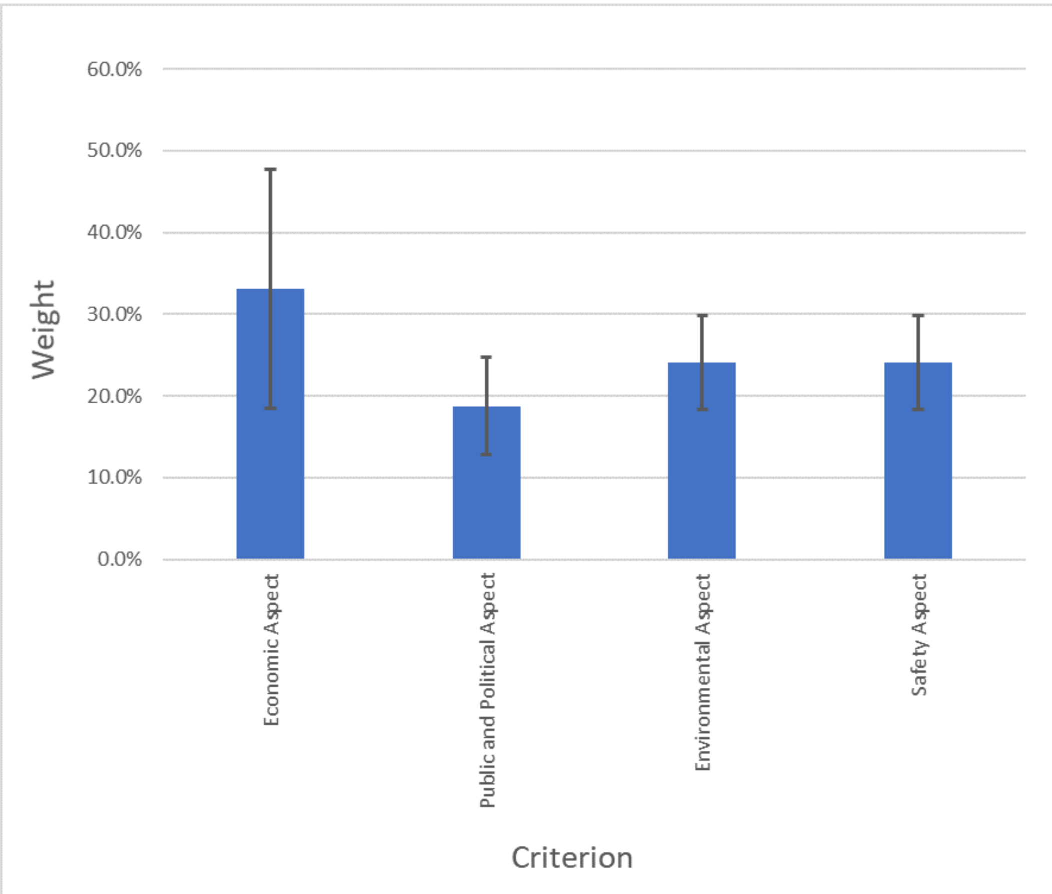

Figure 3.8. AHP results of Expert H.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 33.1%
- Public and Political Aspect: 24.1%
- Environmental Aspect: 24.1%
- Safety Aspect: 18.8%

3.2.9. Expert I

Expert I has been working as a traffic control engineer in Croatia in a private firm and have 5 years of experience. Expert I's survey answers can be seen below in Table 3.17.

Table 3.17. Survey answers of Expert I.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	3
	Environmental Aspect	A	5
	Safety Aspect	A	6
Public and Political Aspect	Environmental Aspect	B	2
	Safety Aspect	B	4
Environmental Aspect	Safety Aspect	B	2

Expert I´s answer shows that the most important criterion for him is the safety aspect, which is followed by the environmental aspect, then the public and political aspect. According to his answers, the least important criterion is the economic aspect. Expert I's AHP results can be seen in Table 3.18, and represented in Figure 3.9 below.

Table 3.18. AHP Results of Expert I.

Criterion	**Weight**	+/-
Economic Aspect	6.3%	1.5%
Public and Political Aspect	14.9%	2.6%
Environmental Aspect	28.3%	2.6%
Safety Aspect	50.5%	9.7%
Attribute	**Value**	
Lambda	4.049	
CR	1.8%	
GCI	0.06	
Psi	0.0%	

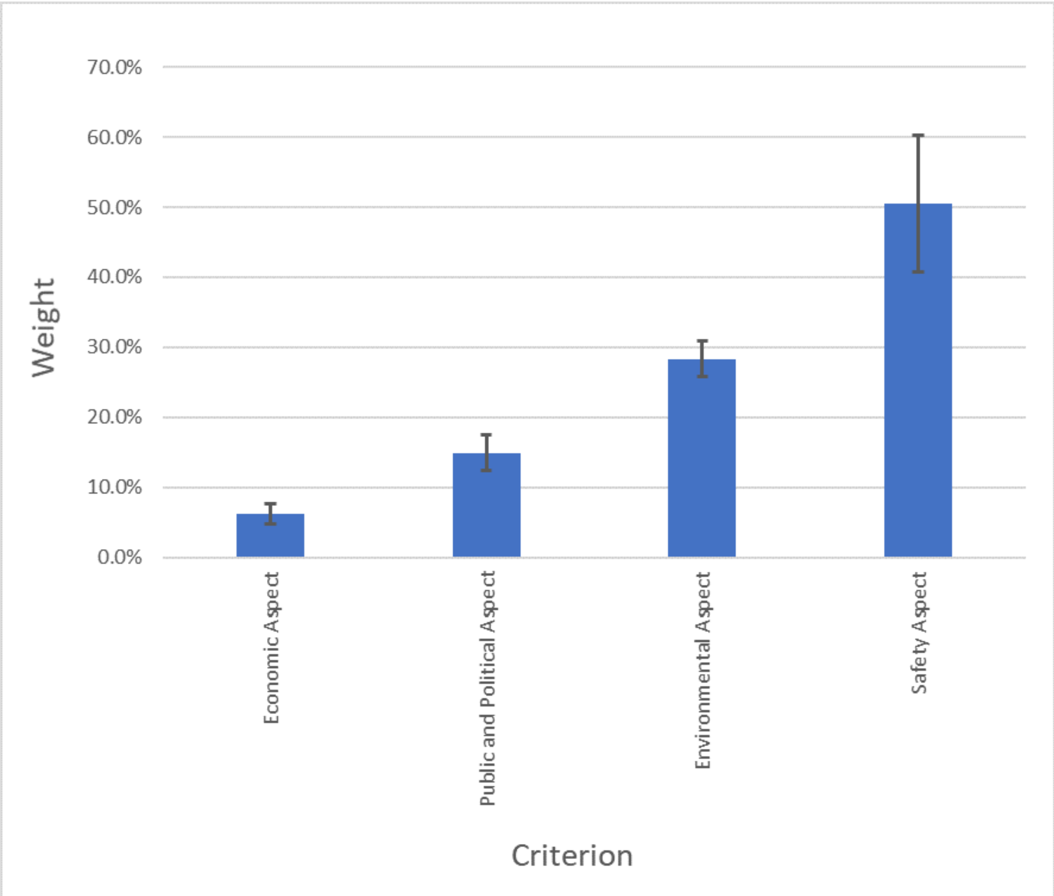

Figure 3.9. AHP results of Expert I.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 50.5%
- Public and Political Aspect: 28.3%
- Environmental Aspect: 14.9%
- Safety Aspect: 6.3%

3.2.10. Expert J

Expert J has been working as a director of state agencies in different cities in Turkey, mainly environment and urban planning directorates. The expert has more than 30 years of experience in state affairs. Expert J's survey answers can be seen below in Table **??**.

Table 3.19. Survey answers of Expert J.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	3
	Environmental Aspect	A	6
	Safety Aspect	A	2
Public and Political Aspect	Environmental Aspect	B	7
	Safety Aspect	B	3
Environmental Aspect	Safety Aspect	B	6

Based on the answers he gave, it can be stated for him that the most important criterion is the public and political aspect, which is followed by the safety aspect and economic aspect. The least important criterion according to him is the environmental aspect. Expert J's AHP results can be seen in Table 3.20, and represented in Figure 3.10 below.

Table 3.20. AHP Results of Expert J.

Criterion	**Weight**	+/-
Economic Aspect	18.2%	6.0%
Public and Political Aspect	51.6%	17.5%
Environmental Aspect	4.6%	1.8%
Safety Aspect	25.6%	7.5%
Attribute	**Value**	
Lambda	4.174	
CR	6.4%	
GCI	0.23	
Psi	0.0%	

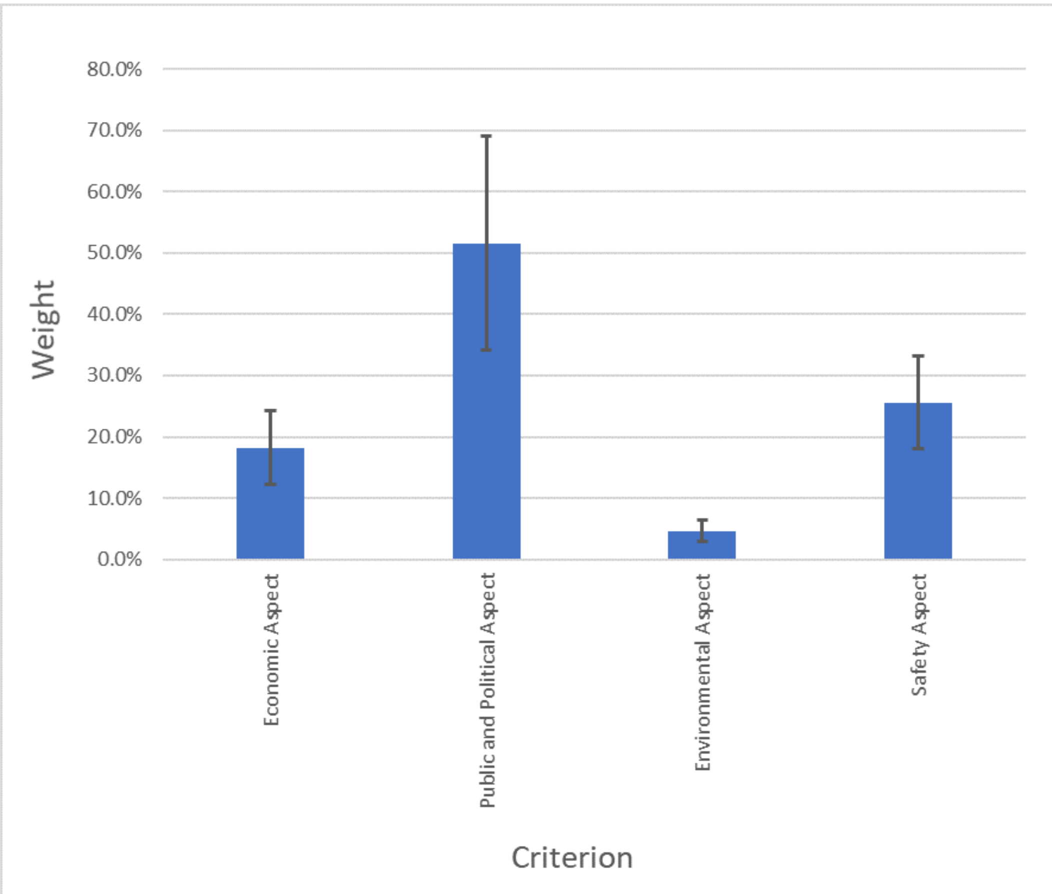

Figure 3.10. AHP results of Expert J.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 51.6%
- Public and Political Aspect: 25.6%
- Environmental Aspect: 18.2%
- Safety Aspect: 4.6%

3.2.11. Expert K

Expert K is a transportation engineering working in a private firm in Romania. The expert has more than 5 years of field experience. Expert K's survey answers can be seen below in Table 3.21.

Table 3.21. Survey answers of Expert K.

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

Based on the answers, it can be stated that according to the expert, the most important criteria are the economic and environmental aspects that hold an equal value. This is followed by the safety aspect and the least important criterion is the public and environmental aspect. Expert K's AHP results can be seen in Table 3.22, and represented in Figure 3.11 below.

Table 3.22. AHP Results of Expert K.

Criterion	**Weight**	+/-
Economic Aspect	39.6%	3.3%
Public and Political Aspect	6.0%	0.8%
Environmental Aspect	39.6%	3.3%
Safety Aspect	14.7%	2.2%
Attribute	**Value**	
Lambda	4.021	
CR	0.8%	
GCI	0.03	
Psi	0.0%	

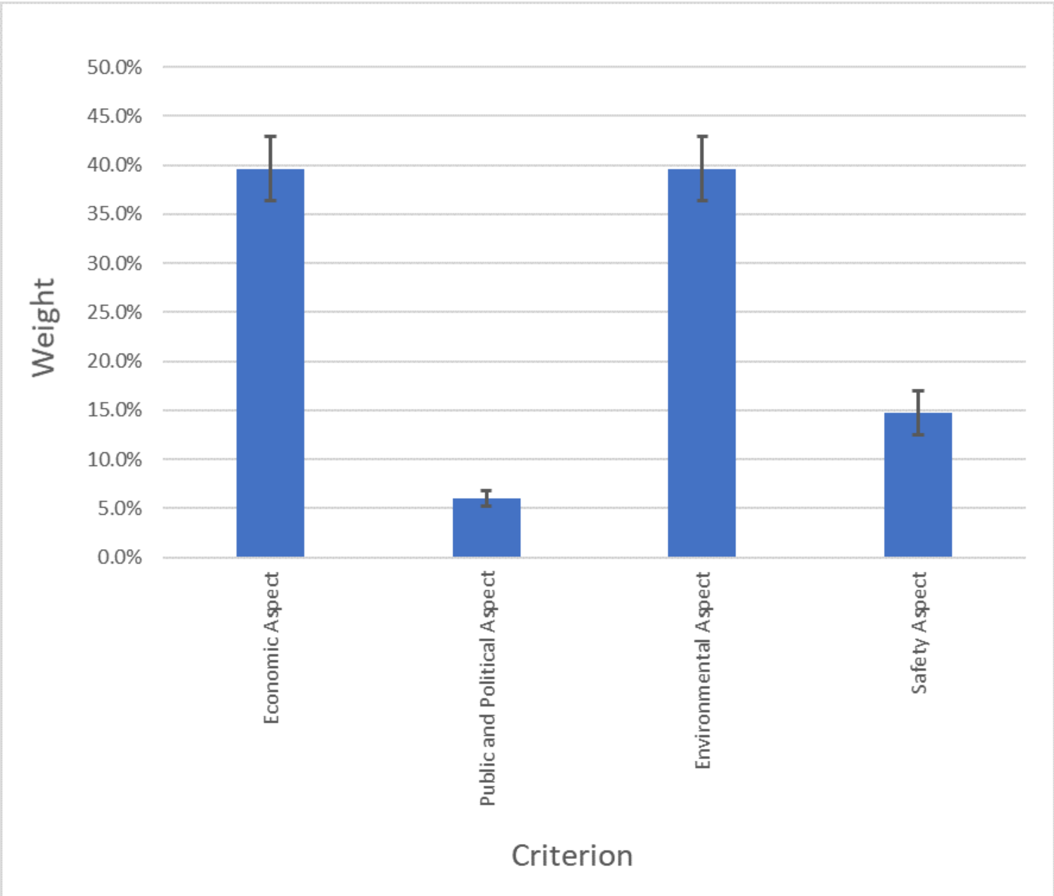

Figure 3.11. AHP results of Expert K.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 39.6%
- Public and Political Aspect: 39.6%
- Environmental Aspect: 14.7%
- Safety Aspect: 6.0%

3.2.12. Expert L

Expert L has been working in the Municipality of Vilnius as an engineer in the field of traffic signalization and has approximately 10 years of experience. Expert L's survey answers can be seen below in Table 3.23.

Table 3.23. Survey answers of Expert L.

Criterion A	**Criterion B**	**A or B**	**Scale (1-9)**
Economic Aspect	Public and Political Aspect	A	5
	Environmental Aspect	A	6
	Safety Aspect	A	4
Public and Political Aspect	Environmental Aspect	B	1
	Safety Aspect	B	2
Environmental Aspect	Safety Aspect	B	1

According to the answers, the expert finds the most important criterion as the public and political which is followed by the safety aspect. The environmental aspect holds a third place where the least important criterion according to the expert is the economic aspect. Expert L's AHP results can be seen in Table 3.24, and represented in Figure 3.12 below.

Table 3.24. AHP Results of Expert L.

Criterion	**Weight**	+/-
Economic Aspect	6.2%	0.8%
Public and Political Aspect	36.8%	8.3%
Environmental Aspect	32.3%	5.7%
Safety Aspect	24.7%	5.6%
Attribute	**Value**	
Lambda	4.057	
CR	2.1%	
GCI	0.08	
Psi	0.0%	

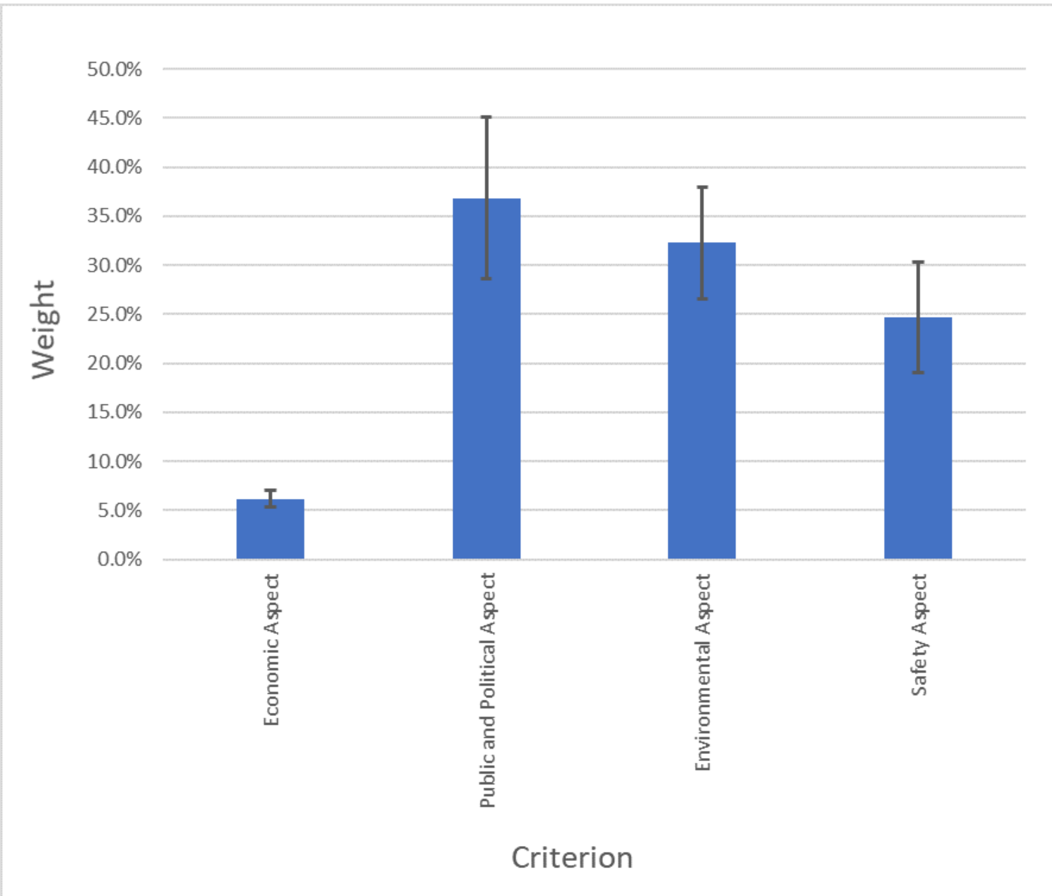

Figure 3.12. AHP results of Expert L.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 47.3%
- Public and Political Aspect: 28.4%
- Environmental Aspect: 17.0%
- Safety Aspect: 7.3%

3.2.13. Expert M

Expert M is currently working in Krakow, Poland on the environmental impacts of the development of the cities. The expert has a solid background in the environmental policies that the EU has been working on, and has more than 10 years of experience. Expert M's survey answers can be seen below in Table 3.25.

Table 3.25. Survey answers of Expert M.

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

According to the answer that is given by Tim, he finds the environmental and safety aspects as the most important criteria. That is followed by the public and political aspects, and the least important criterion is the economic aspect. Expert M's AHP results can be seen in Table 3.26, and represented in Figure 3.13 below.

Table 3.26. AHP Results of Expert M.

Criterion	**Weight**	+/-
Economic Aspect	4.8%	1.5%
Public and Political Aspect	8.5%	3.8%
Environmental Aspect	43.3%	10.3%
Safety Aspect	43.3%	10.3%
Attribute	**Value**	
Lambda	4.155	
CR	5.7%	
GCI	0.20	
Psi	0.0%	

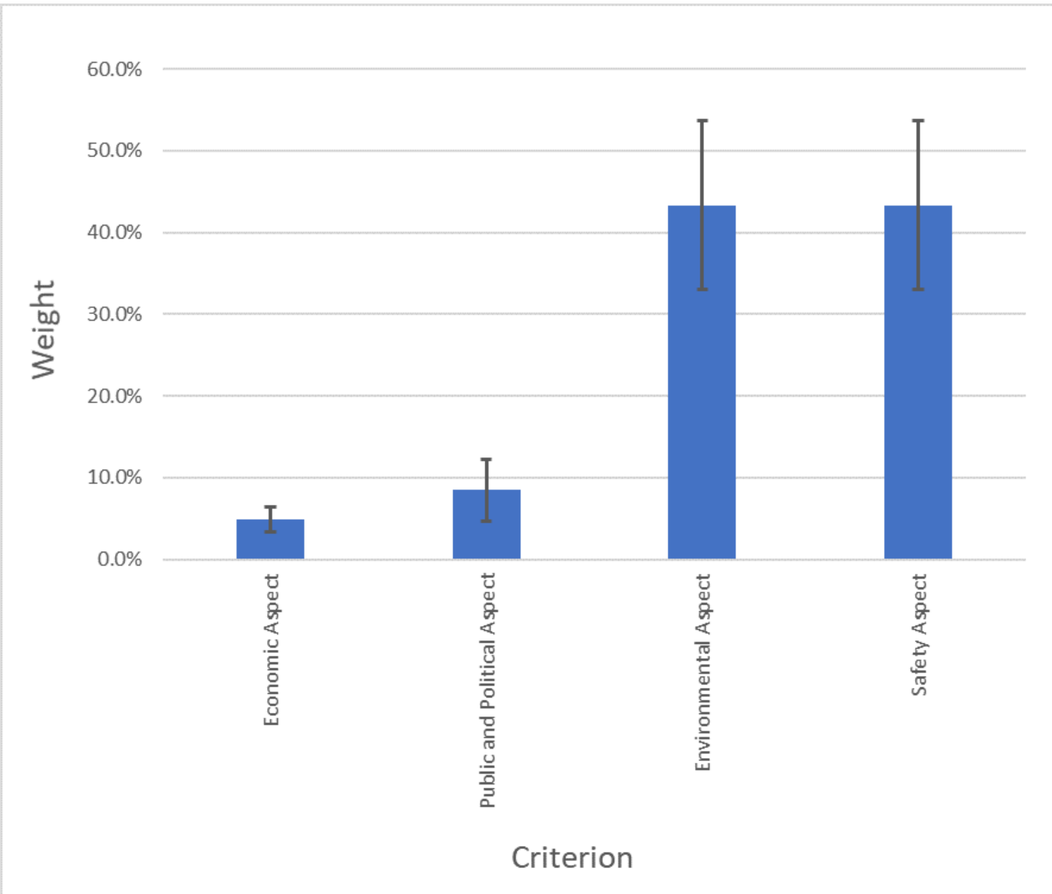

Figure 3.13. AHP results of Expert M.

AHP analysis obtained the weights for each criterion as shown in the table and graph above;

- Economical Aspect: 43.3%
- Public and Political Aspect: 43.3%
- Environmental Aspect: 8.5%
- Safety Aspect: 4.8%

3.3. Analysis Results

When all the individual experts' results in the survey taken into account, relative weights of each aspect can be seen in Figure 3.14 below.

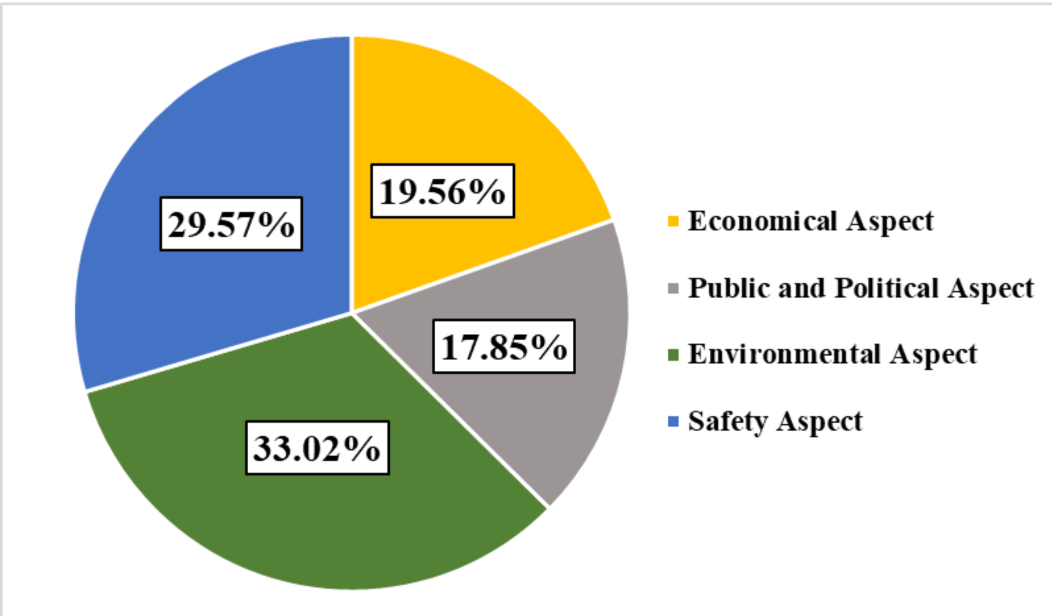

Figure 3.14. Overall results.

Based on this result, it can be stated that the environmental aspect has the highest importance among all other aspects by 33.02% which is followed by the safety aspect with 29.57%. Survey results show that the economical aspect holds a 19.56% value and the least important aspect is the public and political aspect which holds a share of 17.85%.

In addition to the overall results, experts can be placed into groups based on two conditions, the development of the country that they are working in and the field of occupation(state, private sector, or academics).

3.3.1. Based on Country

There is no doubt that the situation of a country in terms of economic and sociological aspects would have an impact on the people that live/work there. So it is expected to see different results from the experts from different countries. Experts were separated into two groups based on the country they are living in right now as, developed countries namely, the UK, Germany, Finland, and developing countries such as Turkey or Croatia.

In the Figure 3.15 below shows the overall results of the participants that are living/working in the developed countries.

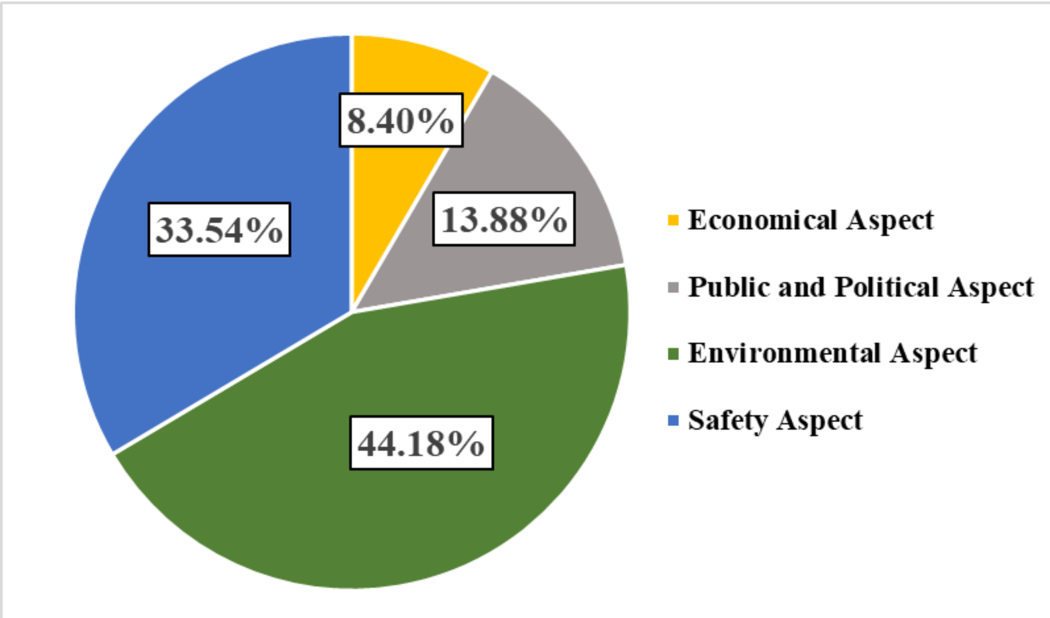

Figure 3.15. Overall results of the participants that are living/working in the developed countries.

Survey results show that participants from developed countries find the environmental aspect the most important criteria amongst others by a solid 44.18%, which is followed by the safety aspect with another solid 33.54%. The least two important criteria for the experts are the public and political aspects with 13.88% and the economical aspect with 8.40%. Considering the current policies of these countries to decrease greenhouse gas emissions and develop better technology for safer traffic, and not having to care too much about economics or politics are the main reasons behind these results.

However, for the case of developing countries, the overall results change since these countries should also consider economics and politics alongside environmental impacts and safety issues. Weights can be seen in Figure 3.16.

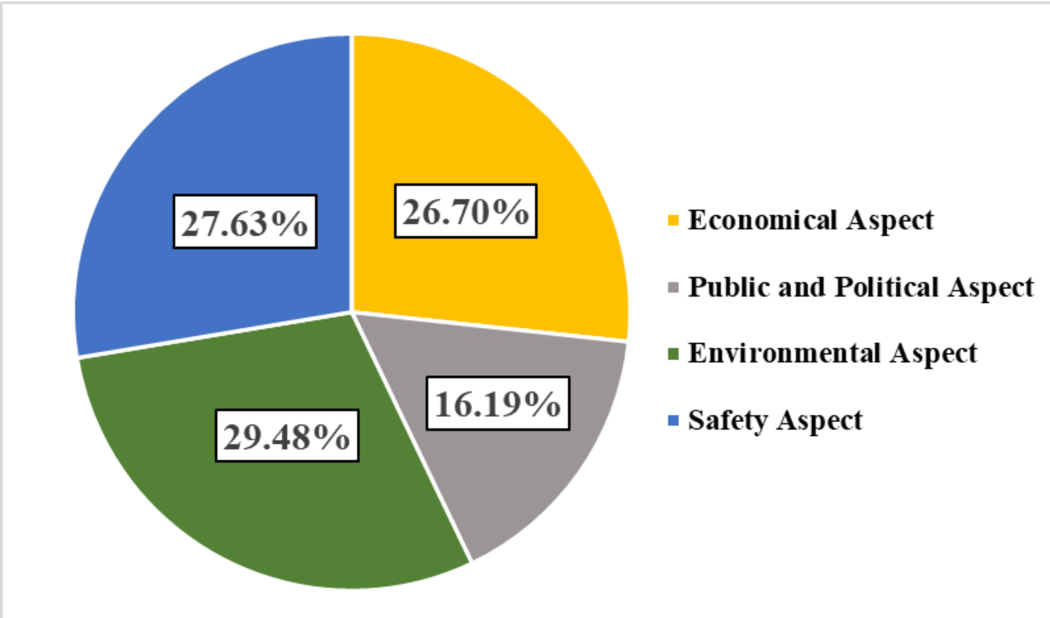

Figure 3.16. Overall results in the developing countries.

Overall results state that the most important aspect is the environmental aspect by 29.48%, however, it is not the most important aspect by a lot, since it is closely followed by the safety aspect with 27.63% and economical aspect by 26.70% and public and political aspect by 16.19%. When compared to the developed countries, experts in developing countries consider every aspect relatively similar to each other.

3.3.2. Based on the Field of Occupation

Field of occupation is another aspect that affects a person's way of seeing things, thus test takers were divided into three groups, experts that are working in state affairs, private sector, and academics' results were gathered separately.

The transportation field has been managed mostly by engineers and based on the education they received, an engineer prioritizes safety amongst all others. The results in the Figure 3.17 below show the experts that are working in the private sector.

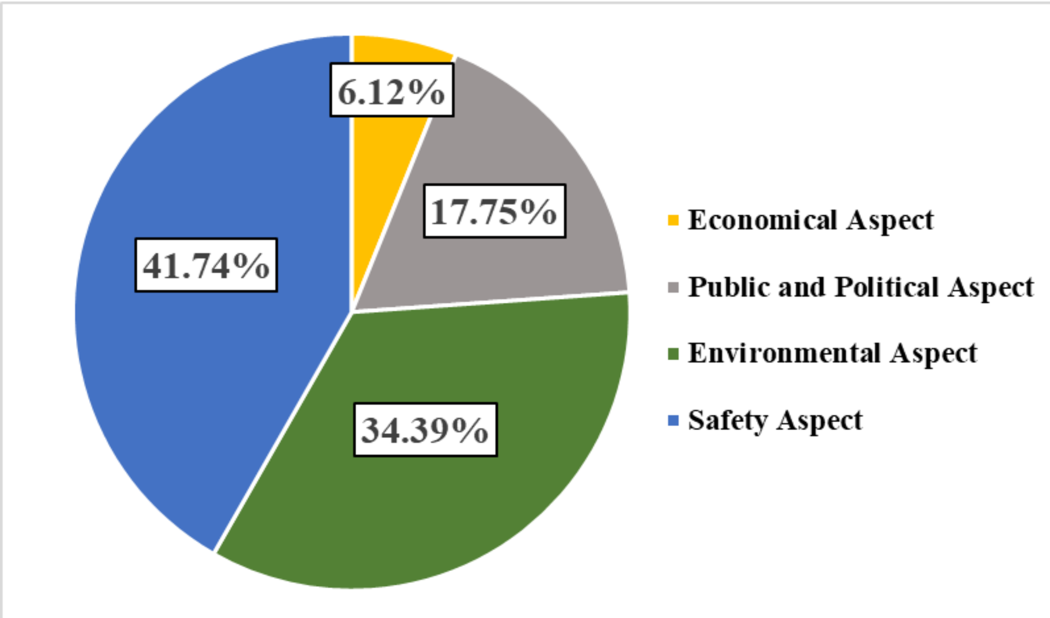

Figure 3.17. Results of Experts from private sector.

Experts from the private sector stated that the most important criteria are the safety aspect by 41.74% which is closely followed by the environmental aspect by 34.39%. Whereas the public and political aspects hold a share of 17.75%, the economical aspect does not hold a significant value and stays at 6.12% value. This low economical importance can be explained as, the experts are mostly engineers who implement the required things, not buy or decide what to buy.

Figure 3.18 below represent the experts who are working in the state affairs, governmental fields of occupations.

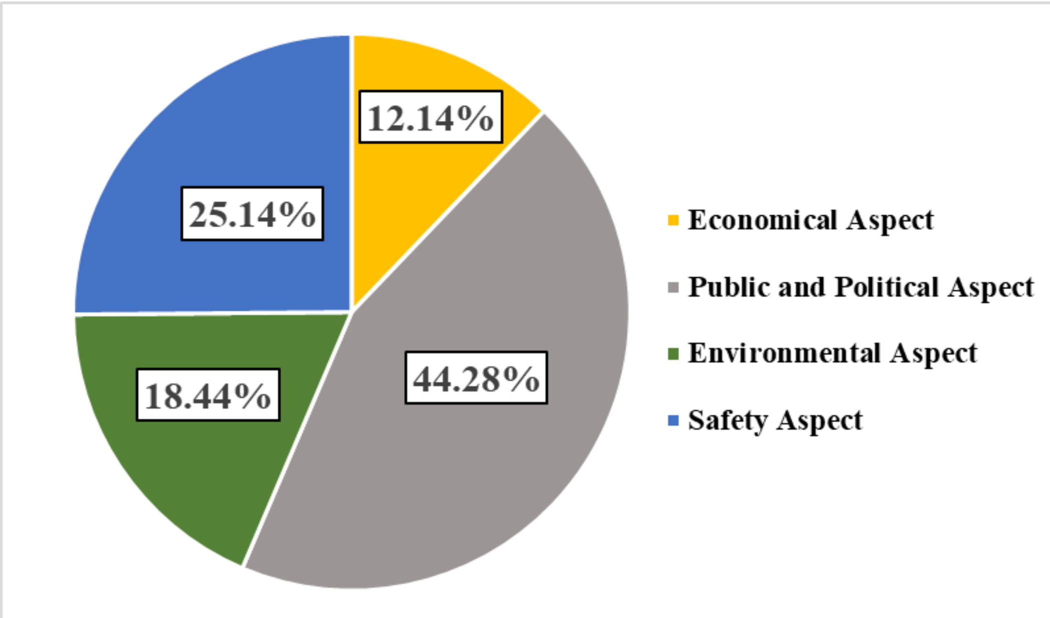

Figure 3.18. Relative weights of each aspect.

Experts who work in state affairs considers public and political aspect as the most important aspect amongst other aspects by 44.28% which is quite logical based on what they value the most. This is followed by the safety aspect with %25.14, the environmental aspect with 18.44%, and the economical aspect with 12.14%. Apart from the obvious public and political aspects, it can be stated that the experts have a more balanced approach when compared to the experts from the private sectors.

Lastly, experts that are working in the academic field can be seen in the Figure 3.19 below.

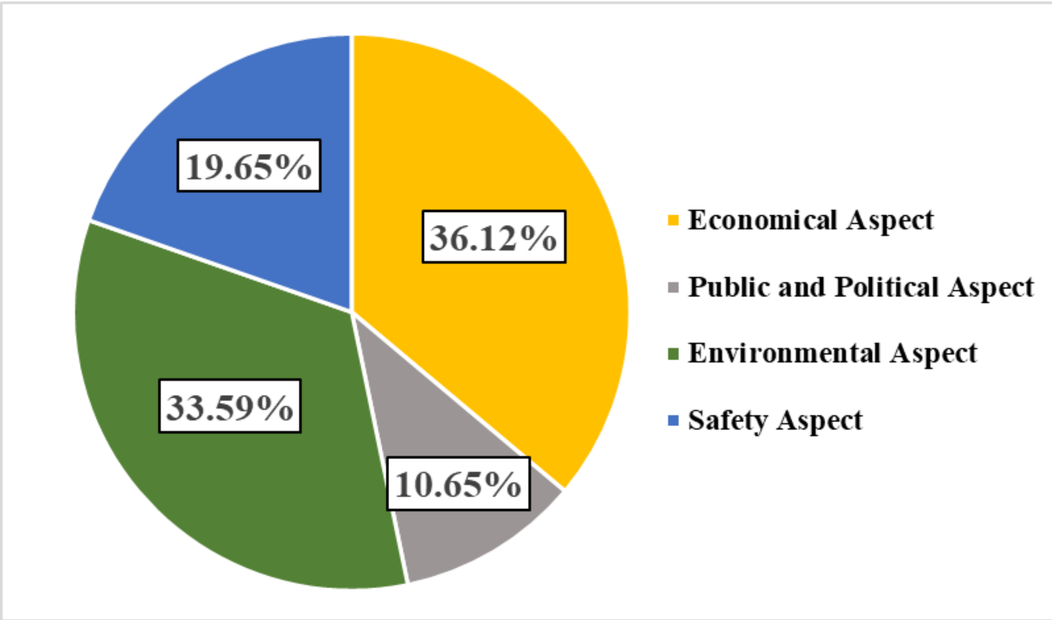

Figure 3.19. Results of Experts that are working in the academics.

As can be seen in the pie chart, the results are quite balanced. The experts that are working in the academic field consider the economical aspect as the most important aspect with 36.12%, which is closely followed by the environmental aspect by 33.59%. The safety aspect holds a share of 19.65% where the public and political aspect holds only 10.65%, which makes sense since academics do not normally involve in politics.

4. CONCLUSION

Electric bus usage in the world increases rapidly, since more and more countries changing their fleet into electric ones. It is expected to see full-electric fleets before the 2050s and even before the 2030s in some European countries. Although electric buses are proved to be better than diesel buses in terms of economics, emission values, and technology, being relatively new comes with experience issues. Transportation experts from all around the world were asked to name the most important aspects when implementing the electric buses and they all considered these 4 aspects are the main aspects which are, economical aspect, environmental aspect, public and political aspect, and safety aspect. Based on these criteria a survey was made and was filled by the experts. The outcome of the survey was calculated by using the AHP method. The results were listed and explained in the study. Overall results showed that the most important aspect according to the experts in the environmental aspect, which is followed by the safety aspect, economical aspect and the results showed that the least important aspect is the public and political aspect. However, individual groupings showed that the result of the survey depends heavily on two main factors, where the expert is living/working and what field is the expert working in. Experts from developed countries consider that environmental and safety aspects are a lot more important than public and political aspects, whereas developing countries have a more balanced approach towards these criteria. Also, results showed that experts that work in the private sector care mostly about safety and the environment, where experts that are working in the state affairs considers public and political aspect as the most important aspects. Experts from the academy also showed balanced results with economical and environmental aspects being slightly more important.

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