ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

THE COMPETITIVENESS OF MIXED MODE COMMUTING ALTERNATIVES FOR INTERCONTINENTAL TRIPS WITH A SPECIAL FOCUS ON MARMARAY

M.Sc. THESIS

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Department of Rail Systems Engineering

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

KITALARARASI YOLCULUKLAR İÇİN ÇOKLU TÜRLÜ ALTERNATİFLERİN REKABET EDEBİLİRLİĞİ: MARMARAY ÖRNEĞİ

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To my spouse and child,

FOREWORD

In my thesis, I have analyzed the effectiveness and profitability of Marmaray for private car users. For this purpose I have generated aggregate utility models using aggregate real supply observations. I hope that the generated models and results due to these models would be helpful for further research about these kind of investments.

I kindly thank to Prof. Tezcan, who always answered my questions and shares with me resources and data and to Prof. Heinitz, who welcomed me to FH-Erfurt and gives his time for me and my study during my visit. I hope, I will work with them again in future.

January 2017

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TABLE OF CONTENTS

Page

FOREWORD ..... **ix**
TABLE OF CONTENTS ..... **xi**
ABBREVIATIONS ..... **xiii**
SYMBOLS ..... **xv**
LIST OF TABLES ..... **xvii**
LIST OF FIGURES ..... **xix**
SUMMARY ..... **xxi**
ÖZET ..... **xxiiii**
1.INTRODUCTION **1**
2.LITERATURE REVIEW **3**
3.RESEARCH FIELD AND CONSIDERATIONS **7**
3.1 Choice Options 7
3.2 Considered Zones 9
3.3 Considered Parameters 11
4.METHOD AND MODELS **13**
4.1 Data Collection 13
4.1.1. Supply Data Collection 15
4.1.2. Demand Matrix 16
4.2 Generalized Cost Calculation 18
4.3 Statistical Analysis of Collected Data 20
4.4 Utility Model 23
4.4.1. Calculating the Best Fit Model 24
4.4.2. Analyzing the Model 25
4.5 Evaluation of Mixed-Mode Alternative for Private Vehicle 28
5.CONCLUSION **31**
REFERENCES **33**
APPENDICES **35**
APPENDIX A 36
APPENDIX B 39
APPENDIX C 44
APPENDIX D 45
CURRICULUM VITAE **55**

ABBREVIATIONS

ID	: Identification for a single trip
IUAP	: Istanbul Metropolitan Area Urban Transportation Master Plan
L	: Liters
LL	: log likelihood
Mil	: Miles
Min	: Minutes
MRT	: Mass Rapid Transit
OD	: Origin-Destination
P&R	: Park and Rail
TCDD	: Turkish State Railways
TL	: Turkish Lira
VoT	: Value of Time

SYMBOLS

(M) **:** Trip via Marmaray
(N) **:** Nonmotorized trip, like walking etc.
(PT) **:** Trip via Public Transit other than Marmaray
(PV) **:** Trip via private car
(T) **:** Trip via taxi

LIST OF TABLES

Page

Table 3.1: Marmaray Station Names and Codes 8
Table 4.1: Districts, Stations and Codes 14
Table 4.14: Public Transport Demand OD 17
Table 4.15: Private Car Demand OD 17
Table 4.16: MRT Boarding Stations 19
Table 4.17: MRT Alighting Stations 19
Table 4.18: Statistical Summary of TimeDifferences for 3 Time Zones 22
Table 4.19: Results of the ANOVA Test 22
Table 4.20: Results of the t-Test 22
Table 4.21: Values of Logit Models 26
Table 4.22: Correlation Matrix for Peak Model 27
Table 4.23: Correlation Matrix for Off-peak Model 27
Table A.1: Destination Adresses 37
Table A.2: Origin Adresses 38
Table A.3: Marmaray Stations' Adresses 38
Table A.4: Marmaray Stations' Adresses 38
Table B.1: Generalized Costs of PV for Peak Hours 39
Table B.2: Generalized Costs of PT for Peak Hours 39
Table B.3: Generalized Costs of Mixed Mode for Peak Hours 40
Table B.4: Generalized Costs of PV for Off-Peak Hours 40
Table B.5: Generalized Costs of PT for Off-Peak Hours 41
Table B.6: Generalized Costs of Mixed Mode for Off-Peak Hours 41
Table B.7: Generalized Costs of PV for Weekend 42
Table B.8: Generalized Costs of PT for Weekend 42
Table B.9: Generalized Costs of Mixed Mode for Weekend 43
Table C.1: Number of Expanding 44
Table D.1: Travel Time Between O-D Pairs by Private Vehicle during Peak Hours 45
Table D.2: Travel Distance Between O-D Pairs by Private Vehicle during Peak Hours 45
Table D.3: Travel Time Between O-D Pairs by Private Vehicle during Off-Peak Hours 46
Table D.4: Travel Distance Between O-D Pairs by Private Vehicle during Off-Peak Hours 46
Table D.5: Travel Time Between O-D Pairs by Private Vehicle during Weekend .. 47
Table D.6: Travel Distance Between O-D Pairs by Private Vehicle during Weekend 47
Table D.7: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Peak Hours 48
Table D.8: Travel Distance Between Origins or Destinations and Marmaray Stations by Private Vehicle during Peak Hours 49

Table D.9: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Off-Peak Hours 50
Table D.10: Travel Distance Between Origins or Destinations and Marmaray Stations by Private Vehicle during Off-Peak Hours 51
Table D.11: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Weekend..... 52
Table D.12: Travel Distance Between Origins or Destinations and Marmaray Stations by Private Vehicle during Weekend..... 53

LIST OF FIGURES

Page

Figure 2.1: Outline of Marmaray Project 3
Figure 2.2: Outline of Transport Lines in Istanbul 5
Figure 2.3: Marmaray Average Daily Ridership 5
Figure 3.1: Choice Options Eastbound 8
Figure 3.2: Zone Map 10
Figure 4.1: Evaluation Process 29

THE COMPETITIVENESS OF MIXED MODE COMMUTING ALTERNATIVES FOR INTERCONTINENTAL TRIPS WITH A SPECIAL FOCUS ON MARMARAY

SUMMARY

As a financially huge project, which is famous worldwide, MARMARAY, an intercontinental mass rapid transit system in İstanbul, and its effectiveness for travellers have been argued since the project began.

The basis problem in this thesis is the affinity of private car users to their private cars and therefore their unconcernness to Marmaray, which might be in some cases a more profitable solution to make intercontinental trips. Of course at that point the definition of profit should be discussed, so it is done within this thesis.

The target traveller group of this research is the car owners. So the utility definition is designated with respect to car owners. The aggregate supply data is collected regarding to the intercontinental private car trips and Marmaray trips, for which door-to-door transport ensured, with the same conditions as the private cars indeed. With this point of view 2 aggregate utility models are generated using aggregate real supply observations. Actually data is collected in order to create 3 models, however after a statistical analysis of the data, it is found that 2 of them come from the same population. This situation allows to create only one model for both of these samples instead of two.

The main concern of the thesis was to show out the affinity of travellers to their private cars because of any reason. So it has come true, the concluded models proves, that the travellers are more utilitized from their intercontinental private car trips because of any reason other than price and time.

It was a suprizing fact, that the results of the simulation of our model for a mixed mode scenerio including Marmaray gives a similar value to the real shifting value of private vehicle users to Marmaray for making intercontinental trips. Although the main claim of the thesis is not a perfect modelling of user behaviour, this fact promoted the the usefulness of the generated model withing this study. On the other hand the technical approach created during the study can be called as the foundation of this study.

KITALARARASI YOLCULUKLAR İÇİN ÇOKLU TÜRLÜ ALTERNATİFLERİN REKABET EDEBİLİRLİĞİ: MARMARAY ÖRNEĞİ

ÖZET

Ülkemizde gerçekleştirilen devasa finansal boyutlara sahip ve dünya çapında ünlü olmuş bir proje olan Marmaray'ın yatırımsal verimliliği ve kullanıcılar için olan karlılığı tartışılagelmektedir. Bu kadar büyük bir finansman ile yapılan bu projenin verimliliğinin tartışılması doğal olmakla birlikte henüz projenin sadece yaka geçişi sağlayan küçük bir kısmının tamamlandığı geri kalan Halkalı'dan Gebze'ye uzanan kısmının tamamlanmadığı gerçeği göz önünde bulundurularak şu aşamada projeyi net bir şekilde değerlendirmenin mümkün olmayacağını unutmamak gerekiyor. Bu tezin asıl amacı Marmaray'ı puanlamak değildir, asıl amaç bu büyük yatırımın spesifik bir kullanıcı grubu için verimli olup olmadığı, kullanıcıların nasıl tercih eğilimleri gösterdiği üst başlıklarında toplanabilecek birçok alt amaçtan oluşmaktadır.

Marmaray'ın oluşturduğu sosyoekonomik etkilerin çok geniş bir çapda olduğunu düşünecek olursak bizim ele aldığımız problemin oldukça spesifik bir problem ve kısmi bir bakış açısı ile projeyi ele almak olduğunu itiraf etmemiz gerekiyor. Bununla birlikte mühendislerin ulaştırma yatırımlarına bakış açısını düşünecek olursak önemli ve ilgi çekici bir problem üzerine çalışılmış bu tezde sadece mühendislerin değil aynı zamanda sosyal bilimcelerin de ilgisini çekecek bulgular olduğunu sevinerek söylemeliyim. Modelleme aşaması ve teknik yaklaşım ne kadar mühendisler için ilgi çekiciyse, simülasyon sonuçları mühendisler için olduğu kadar sosyal bilimciler için de ilgi çekici. Bununla birlikte yine de bu tezi ulaştırma sistemlerine karşı kullanıcıların davranışlarını modellemek üzerine kurulmuş teknik bir çalışma olarak tanımlamak zorundayız.

Bu tezde temel problem olarak özel araç kullanıcılarının Marmaray'ın özel araç yolculuğu ile aynı koşulları sağlayarak daha karlı bir yolculuk sağlayabiliyor olması olasılığına karşın özel araç kullanıcılarının özel araçla yolculuğa alışkın olmalarından dolayı bu tercihi yapmıyor olmaları ele alınmıştır. Bu noktada tezin kurduğu alternatif senaryoda kabul edilmiş, Marmaray ile yapılan yolculuk şartlarının özel otomobil ile yapılan bir yolculuk ile konfor bazında eşit olması argümanını vurgulamak gerekir. Bu kabulle birlikte doğal olarak diğer toplu taşıma araçları problem çözüm setlerinin içerisine dahil edilmemiş, toplu taşıma sistemlerinden sadece Marmaray'ı içeren alternatif bir senaryo kurulmuştur.

Bu şekilde yolculuk şartları olabildiğince birbirine benzetilmiş ve kurulan model ile özel araç kullanıcılarının çekicilik olarak tanımladığımız birçok sebepten dolayı zaman ve fiyat parametrelerinin dışında aynı yolculuk şartlarında bile özel araçlarını kullanmayı tercih ediyor olmaları modellenmiştir. Çekicilik kavramının matematiksel olarak modellenememesinin doğal bir durum olması bu tezin çıktı hedefi olarak kullanıcıların gösterdiği bu eğilimi modellemeyi yeterli görmemizi sağlamıştır, bu eğilimin neden ve hangi sebeplere bağlı olarak gerçekleştiği ile ilgili bir çalışma yapılmamış bununla birlikte bu şekilde bir çalışmanın büyük ulaştırma yatırımları için aslında ne kadar faydalı olacağı simülasyon sonuçları ile reddedilemez şekilde kanıtlanmıştır.

Yolculuk koşullarının benzetilmesi için özel otomobille yolculuğun en temel üstünlüğü olan kapıdan kapıya ulaşım olanağı Marmaray ile yapılan yolculuklarda "park et - bin sistemi" ve taksi ile sağlanacak varsayımı ile model oluşturulmuş ve bu bağlamda özel araçlı ve Marmaraylı kıtalararası yolculuklar için kümelenmiş veri toplanmıştır. Yukarıda da bahsedilen Marmaray'a ulaşım ve Marmaray'dan hedefe ulaşım için toplu taşıma yerine taksi veya "park et - bin sisteminin" kullanılması probleme uygun bir model oluşturulması açısından önem arz etmektedir. Ancak problem tanımına uygun bir sistem modellemesi ile daha başarılı çözümlemeler elde edileceği gerçeği göz önünde bulundurularak bu şekilde bir modelleme yöntemine gidilmiştir.

Modelleme yaklaşımının ve çözüm yönteminin inovatif olduğu bu çalışmada oluşturulmuş modelin eksiklikleri bulunmaktadır. Kümelenmiş veri kullanıyor olmanın, arz ve talep verisini farklı yıllarda toplamış olmanın modelin mükemmel olmasını engelleyici bazı sebepler olduğunu söyleyebiliriz.

Bununla birlikte spesifik bir kullanıcı grubunun bir ulaştırma sistemine karşı davranışını inceleyebilmek için kullanılabilecek alternatif kurgusal yolculuk senaryosu yaklaşımı bu tezin teknik olarak ulaştırma ekonomisi temalı analizlere kattığı en büyük artılardan biridir. Spesifik bir kullanıcı grubunun alternatif olan bir sisteme karşı nasıl davranacağını gözlemleyebilmek ancak büyük titizlikle yinelenerek yapılmış hane halkı verisi ile mümkündür, fakat bu çalışmada kullanılan yöntem ile standart talep verisi ve online navigasyon sistemleri kullanılarak toplanan kümelenmiş arz verisi ile bu davranışın simülasyonu mümkün olmaktadır. Özellikle İstanbul gibi devasa büyüklüğe sahip bir şehirdeki çok yüksek sayıdaki kullanıcı sayıları göz önünde bulundurulursa hane halkı verisi toplamanın zorluklarındansa birçok çalışma için bu tezde kullanılan yaklaşım çok daha verimli ve sonuç odaklı olacaktır.

Kıtalararası yolculuklar için kümelenmiş arz verileri toplanırken oluşan kombinasyonların sayısının fazlalığı sebebiyle araştırmanın hedef kitlesi çoğunlukla yerleşim yeri olan Asya yakasında oturup Avrupa yakasında çalışan yolcular dikkate alınacak şekilde tek yöne indirgenmiş ve bu bağlamda iki yakada toplamda 31 yerleşim merkezi dikkate alınmıştır. Çalışmanın devam etmesi ile kümelenmiş veri ile çalışıyor olmanın dezavantajları modellemenin başarısını hesaplarken görülmüş ve bunun üzerine seçilmiş 31 yerleşim merkezinden çok kuzeyde olanlar elenmiştir. Zaten Marmaray'ın sunduğu hizmetin kuzey-güney doğrultusunda eşit dağılmamış olması ve sadece şehirin güneyinde bulunuyor olması kuzey yerleşim merkezleri için kurgusal yolculuk senaryoları üretmenin anlamsız hatta bozucu bir durum oluşturacağını aşikar kılmaktadır.

Talep verisi olarak İstanbul Büyükşehir Belediyesi'nin yayınladığı ulaşım ana planı raporunda belirtilen özel araç ve toplu taşıma ile yolculuk talepleri dikkate alınmıştır. Çalışmamızda dikkate alınan yerleşim merkezleri ile İBB'nin dikkate aldığı yerleşim merkezleri bazen farklılık göstermektedir. Bu tip durumlarla karşılaşıldığında talep verilerini birleştirme veya bölme yöntemleri uygulanarak seçilen çalışma alanı için uygun talep verileri oluşturulmuştur. Bunu yaparken İBB'nin sağladığı asıl ham verinin güvenilirliği korunmuştur.

Bu doğrultuda haftaiçi akşam zirve saati, kısıtlanmamış kullanıcı tercihlerinin daha başarılı modellenebileceği haftaiçi zirve dışı saatler ve haftasonu saatleri için 3 farklı fayda modeli oluşturulması planlanmıştır. Bu bağlamda toplanan veriler üzerinde yapılan çalışmalarda haftaiçi akşam zirve saatinde toplanan veriler ile haftaiçi zirve dışı saatlerde ve haftasonu saatlerinde toplanan verilerin farklı toplumlardan geldikleri bununla birlikte zirve dışı saatlerde toplanan verilerin aynı toplumlardan geldikleri belirlenmiştir. Bunun üzerine zirve dışı zamanlar için tek bir model, zirve saat için farklı bir model oluşturularak toplamda 2 farklı model tasarlanmıştır.

Tezin temel kaygısı olan özel araç kullanıcılarının aynı koşullar ile ulaşım sağlayabilecek daha karlı seçenekler yerine özel araçlarını tercih etmeye olan eğilimlerini modelleme işi başarıyla gerçekleştirilmiş ve zaman ile maliyete bağlı olmayan herhangi başka sebeplerden ötürü kıtalararası yolculuklarda özel otomobili tercih ediyor oldukları doğrulanmıştır. Neden böyle olduğunun sorgulanması davranış biliminin alanına giriyor olmakla birlikte ulaştırma planlamaları yapılırken bu tip eğilimlerin dikkate alınmasının daha başarılı sonuçlar doğuracağına olan inancımı vurgulamak isterim.

1. INTRODUCTION

Although there are huge numbers of mass transit alternatives including bus, metro and other alternatives including tram, minibus etc. and ongoing investments, public transport in Istanbul has always been a big problem for inhabitants of the city. The system is generally crowded during peak hours and the reliability is low especially for highway systems. The very first reason for that is the belated transportation investments. Moreover, especially the urban railway systems in Istanbul have been used under their capacities for years [1], which may likely be because of wrong planning issues.

Among the public transport alternatives Marmaray is a very uptodate project, which is built by the government.Currently the tube under Bosphorus is operated seperately to carry passengers from one side of the city to the other with respective transfers to Hacıosman-Yenikapı and Aksaray-Havalimanı-Kirazlı metro lines at the European Side and Kadiköy-Kartal metro at the Asian side. When the ongoing construction works will be finished, it would be possible to score the entire project, while at this stage,only the effectiveness of the Bosphorus crossing tube could be analyzed.

In its current operational structure, Marmaray is being used under its supply capacity [2]. However, according to a recent declaration by then the minister of transport and now the prime minister Binali Yıldırım,the number of Bosphorus crossing trips through the bridges decreased aroung 6% after Marmaray has began to operate [3].

The main goal of this thesis is to focus on the under capacity usage reasons of Marmaray today, whereas the low frequency of headway of Marmaray should also be counted. For this aim, the thesis has taken private car users as the target research group and it was tried to determine a possible and profitable alternative to them. Considering the affinity of private vehicle users to theirs cars [4], this alternative was also tried to have a comfort level similar to car.

Moreover, this alternative is not a fictitious alternative, not a scenerio or a real plan to be operated in the future. The alternative is a travel plan designed by using present transportation modes and their characteristics. Via that approach, the under capacity usage problem of Marmaray could be explained.

The demand information is gathered from the household survey of Istanbul Metropolitan Municipility [5]. The supply data is established by collecting trip time and distance information of all possible intercontinental trips between selected areas in Istanbul for different days and time of days.

In the end, the goal of the thesis is successfully reached; two different choice models for different times and days are generated to perfom analysis. Additionally, affinity of people to their private cars is observed from the results of the models.

2. LITERATURE REVIEW

Istanbul is a metropolitan city, which has an always increasing travel demand. 11% of private car trips within the city are intercontinental trips [6]. The intercontinental trips mighteffect the road network of the city more higher than this percentage, because only the main arterials are used for intercontinental trips and congestion in themain arterials usuallyspill over to the other parts of the network. Under these circumstances, projects to facilitate intercontinental trips are obviously needed for Istanbul.

Since 2000's Turkey started to invest in railways both for intercity and urban transportation and initiated a privatization process to create a public private partnership model for transportation investments [7].One of these projects is Marmaray, its' construction has began in year 2004. The main aim of Marmaray project was to shift the traffic demand anyhow to public transport and the planning of Marmaray was performend on this basis [8]. In the (Figure 2.1), a map of Marmaray project is shown.

Figure 2.1: Outline of Marmaray Project[9].

Dündar investigated and determined in 2004 that the attractiveness of various Bosphorus crossing options, Marmaray was stated to be one of the best among the respondents [10]. Furthermore,in a study about the transportation decisions of travellers in Istanbul, that was performend before opening of Marmaray, it is found that many of the travellers will get utilitized by shorter travel time by using Marmaray but only those who use their private car at that time would utilitized by cheaper travel costs, when Marmaray is opened for service, while the public transport users would pay the same amount [11].

The Marmaray project is actually a huge mass rapid transit project, which has 19.6 kms of line at the European side, 43.4 km of line at the Asian side whereby 13.5 km tunnel and 1.40 km of tube tunnel under Bosphorus. But only the Bosphorus crossing part is famously known by people, because the rest of the project is not finished yet. On the nonfinished parts of the line, a commuter rail system was used to operate, which was then closed for Marmaray replacement, which is going to have 10 to 12 times bigger capacity than the old commuter system, when it is finished [12].

There are also special technical challenges for building Marmaray in terms of engineering, one of which is, that Istanbul will most likely experience an earthquake up to magnitude 7.5 during Marmaray's lifetime. Another big challenge for construction is the 7000 years old history of civilizations under the project area [13].

During the planning stages of the project, one of the discussions was the unnecessitiy of Marmaray, because the growth of city continues in the north direction and the Marmaray project is only beneficial for the south part of the city. Nevertheless the main purpose of constructing Marmaray in south part is to keep the growth of the city linear in east-west direction, so that the more green areas in north part can be preserved[14].

Not only the Marmaray itself but also the paralel lines and other services, which supply accessibilty to these lines are important. During the planning process of the Marmaray system in Istanbul, the other services to ensure accessibility and paralel lines were also concerned, so that a combined radial tangential system can be build at last [15]. This system can be seen in (Figure 2.2).

Figure 2.2: Outline of Transport Lines in Istanbul[15].

As stated by Oktem in 2006 there is and will be a particular amount of shift from highway to urban railway transportation [16]. Consequently, in this thesis the amount of shift could happen is tried to be determined by a mathematical model.As a pre information for this study, the average number of ridership information of Marmaray is illustrated in the (Figure 2.3).

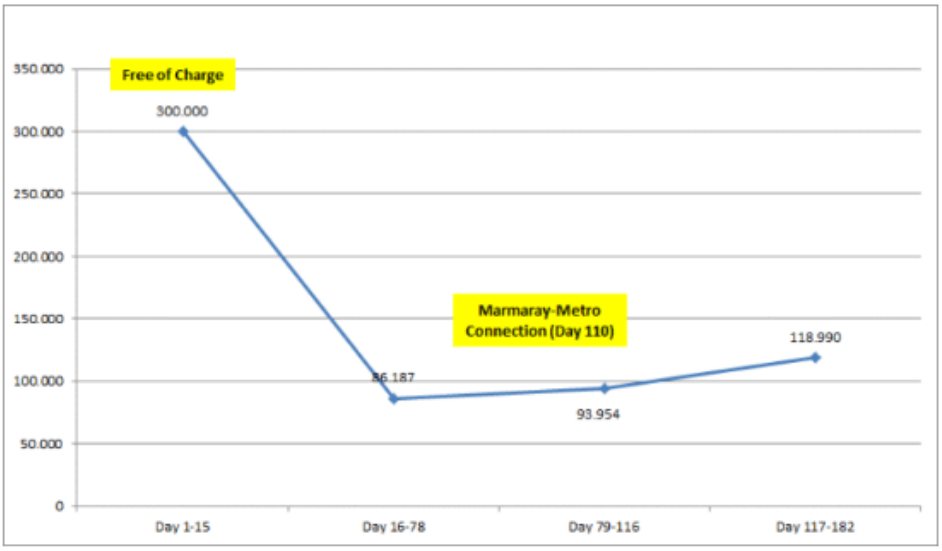

Figure 2.3: Marmaray Average Daily Ridership[17].

3. RESEARCH FIELD AND CONSIDERATIONS

As mentioned before, the goal of this thesis is to analyze the competitiveness of mixed mode commuting with Marmaray and for this purpose it is needed to calculate and detect the profitable area of the city, from where the intercontinental travelers would profit by using Marmaray instead of crossing the bridge by using their private vehicles to arrive their destination. And afterwards disclosing the travelers preference of their private car although Marmaray is more profitable. For a prosperous detection of the profitable area of Marmaray, an alternative travel option, that have a comfort level similar to the private vehicle was considered. In this option, the trip between each origin and destination was assumed to be performed by using private vehicle at the start, Marmaray for Bosphorus crossing and taxi at the end of the trip while the private vehicle was parked at the park and ride lots next to the Marmaray stations. With this method, the advantage of using car for door to door transportation will remain. Furthermore, to keep the comfort level similar to the private vehicle, public transportation modes, that could be used at any leg of the trip including metro is not considered.

3.1 Choice Options

In this study, information about different trips are collected. Considered trips are in the Europe-Asia direction (eastbound). The codes of the Marmaray stations are given in Table 3.1.There are three Marmaray stations in European side and two Marmaray stations in Asian side.(Figure 3.1) presents the structure of these trips. In (Figure3.1); PT stands for Public transport, N stands for Non-Motorized transport, PV stands for private vehicle transport, T stands for taxi and M stands for Marmaray.

Table 3.1: Marmaray Station Names and Codes.

Code	Name
MRT1	Marmaray Kazlıçeşme St.
MRT2	Marmaray Yenikapı St.
MRT3	Marmaray Sirkeci St.
MRT4	Üsküdar St.
MRT5	Marmaray Ayrılıkçeşmesi St.

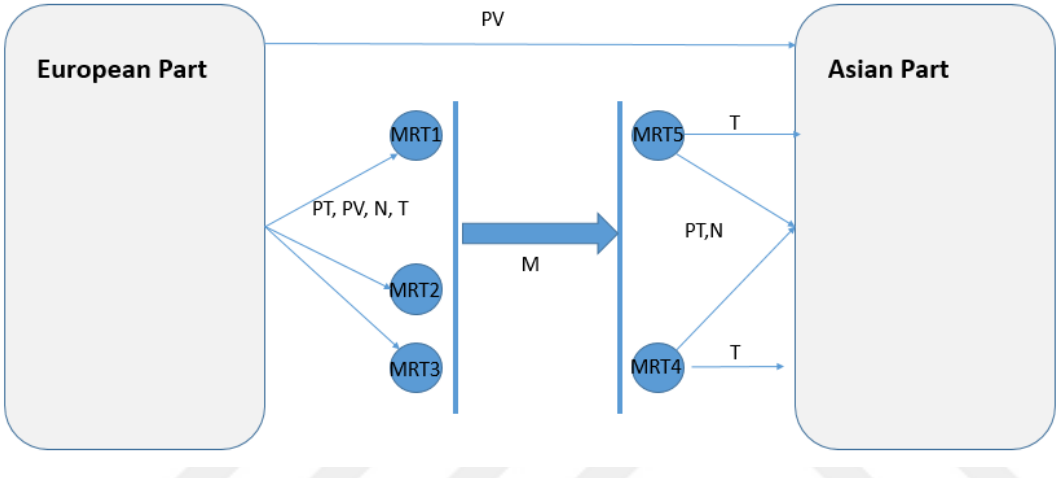

Figure 3.1: Choice Options Eastbound.

Required time and distance data for all of the trips in choice optionsneglecting public transport are collected using online Yandex and Google Maps Navigator tools. This means, any arrival solution to Marmaray via private car or taxi and any departure from Marmaray to any zone as the final destination again via private car or taxi is counted in.

3.2 Considered Zones

In this thesis, aggregate data are used and an aggregate choice model is generated to analyze the preferences of travellers. Therefore the results will be presenting the entire city comprehensively en masse, and if it is needed to setgeographical limits for the zones, it can only be done at data collection step.

Initially, the study area was selected to cover various origins between Atatürk Airport on the west and Sabiha Gökçen Airport on the east side of the city. However, even if the east and west boundries kept unchanged, a number of origins were eliminated at the northern parts. This occurred mostly, because of the geopraphical location of Marmaray, that is relatively close to 15 Temmuz Şehitler Bridge compared to Fatih Sultan Mehmet (FSM) Bridge. Consequently, for the origins that are close to the FSM bridge, using Marmaray would almost never be profitable since private vehicle users coming from those parts would need to travel very long distances towards Marmaray (south). As a result, Beykoz, Kavacık, Çekmeköy in the Asian side and Sarıyer, Kemerburgaz, Maslak, Levent, Bebek in the European side, which were originally considered to be included in this study were removed.

The origins are selected as the busy district centers of Istanbul. 15 of the origins are at the European side and 8 of them are at the Asian side.The legal district borders vary from time to time in Istanbul.The origins and the zones represented by these origins in this study is a resemblence of one of the earlier district maps of Istanbul. The study area and zones are presented in (Figure 3.2).

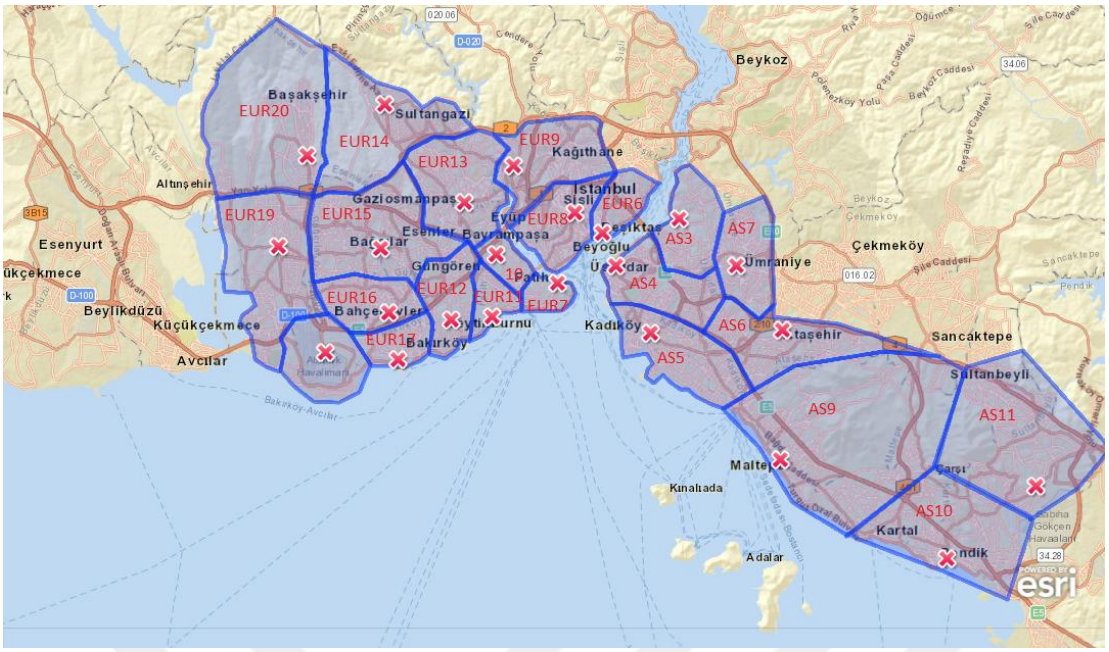

Figure 3.2: Zone Map.

Above mentioned time and distance data are collected for the center points marked with red cross in (Figure 3.2). The basis demand values in the form of number of trips between zones are gathered from the household survey of IBB in 2006 [5],which than edited for our selected zones. The final demand OD matrix can be found in Section 4.1.2. There will be further talk about the demand OD matrixand explanation of editing process in Section 4.1.2.

3.3 Considered Parameters

In order to make cost and utility calculations, some basic time and cost parameters were determined. Whole parameters at a glance are listed below with explanations.

Park and Rail Transfer Time: The time in minutes, a passenger need to walk from parked car to the Marmaray station. It is assumed as 5 minutes on average.

Park and Rail Price($C_{P\&R}$): The average price in TL, a passenger needs to pay to park the car near the Marmaray stations. An average price of 6.66 TL/day is used. This value is the whole day parking cost of the nearest park and ride station of IBB, gathered from Parking Organization of Istanbul (ISPARK) website and taken the average [18].

Value of Time (VoT): Although we don't need a VoT for creating utility models, for the initial calculation of optimum Marmaray station for generating a route, a VoT was required. In Metropolitan Area Urban Transportation Master Plan (İUAP) the VoT was given as 0.17 TL/minute for average [19].

Driving Cost($C_{driving}$): The cost per miles, which is calculated by using an average car operating cost per km plus average car consumption cost per km summation [20]. It is calculated as 1.09 TL per km, with the formula as in equation 3.1. AvrCarCons stands foraverage car consumption in this equation.The average car consumption is assumed as 0.1 lt/km and the fuel price is taken as 4.5 TL/lt. The operating cost is found by adding of 400 TL of maintentance cost, 1000 TL of tax and 5000 TL of depreciation cost, each per 10000 km, which is assumed as the average maintenance interval of a car. The equation for operating cost is as the equation 3.2. The equations with numbersfor driving and operating costs are as the equations 3.3 and 3.4 respectively.

$$C_{driving} = C_{operating} + (AvrCarCons * C_{fuel}) \quad (3.1)$$

$$C_{operating} = C_{maintenance} + C_{tax} + C_{depreciation} \quad (3.2)$$

$$C_{driving} = 0.64 + (0.1 * 4.5) = 1.09 \quad (3.3)$$

$$C_{operating} = \frac{400}{10000} + \frac{1000}{10000} + \frac{5000}{10000} = 0.64 \quad (3.4)$$

Bridge Crossing Fee(C_{bridge}): The price in TL to cross the bridge, taken as 4.75 TL.

Marmaray and Public Transport Ticket Price(C_{ticket}): The price in TL, equals 2.3 TL.

Marmaray Trip Duration: The duration with unit minute per station, taken from

Turkish State Railways (TCDD) as 3 minutes per station [27].

Marmaray Waiting Time: Taken as half of the headway of Marmaray. It is taken as 5 minutes.

Taxi Riding Cost(C_{taxi}): The price in TL, which is the sum of the initial cost for a taxi trip, which are 3.2 TL and 2 TL/km respectively [21]. Of course finding a taxi is considered to be ideally quick.

As stated, the VoT parameter is only used for the initial optimum route calculation of Marmaray. The bridge cost and driving cost parameters are used for intercontinental private car trips. All other parameters and still the driving cost parameter are used for intercontinental Marmaray trips, where a traveler is considered to drive to the parking lot close to Marmaray station, cross the Bosphorus via Marmaray and continue by a taxi to the final destination. On the other hand, for the initial modelling process, public transport travel data are calculated with respect to private car data. For weekend and off-peak data, public transport travel time is calculated by multiplying the travel time of the private car trip for the same OD pairwith 2. The same approach is done for peak time with a proportion of1.5. With this assumption,public transport trip time will always be longer than the private car trip time. Furthermore the public transport trip costs are calculated with respect to the ticket cost and the number of transfers. Details of the generalized cost approach will be explained in Section 4.2.

4. METHOD AND MODELS

Since the main idea is to disclose the private car users' affinity to their private cars, a logit model would be useful, because it can represent the probability of a users choice including its background of causes. This can be succeeded with a discrete choice model, which allows the analysis of travellers' choices according to numerous socio-economic and travel characteristics [22].

Before talking about the model, the prework for that should be explained, which includes supply and demand data collection and statistical analysis of the collected data. In addition to that, to find out the mode changing points (in our case Marmaray stations), a pre calculation based on generalized costs should be processed. This is a kind of initial calculation of an iterative process in our case. This process will also be explained below.

4.1 Data Collection

The supply data -explained in Section 4.1.1- collection is made manually and similarly with an URL query to the google maps application. These queries andthe detailed addresses of the origin and destination points can be found in Appendix A.

The origins and destinations for generating the model come up as following. Names of the origin and destination points and the codes of them can be found in Table 4.1 below.

Table 4.1: Districts, Stations and Codes.

Code	Name
EUR6	Beşiktaş
EUR7	Eminönü
EUR8	Halaskargazi
EUR9	Emniyettepe
EUR10	Edirnekapı
EUR11	Kocamustafapaşa
EUR12	Beştelsiz
EUR13	Gaziosmanpaşa
EUR14	Sultangazi
EUR15	Bağcılar
EUR16	Bahçelievler
EUR17	Bakırköy
EUR18	Atatürk Havalimanı
EUR19	Halkalı
EUR20	Başakşehir
AS3	Çengelköy
AS4	Üsküdar
AS5	Söğütlüçeşme Tren İstasyonu
AS6	Ataşehir
AS7	Ümraniye
AS9	Maltepe
AS10	Pendik
AS11	Kurtköy

4.1.1. Supply data collection

The entire origins and destinations in Table 4.1are used to collect time and distance data. This is the supply data part of the thesis, because the supply of the service for an intercontinental trip can be represented with time and distance values. Any effective parameter regarding cost and time can be added to the calculation after collecting this data.

The data consist of 2114 single measurements, including 7 samples for every single OD pair for trips via private car, 7 samples for every single pair from an origin to a Marmaray station, 7 samples for every single pair from a Marmaray station to a destination. All these samples have time and distance values in minute and miles. The data are collected 3 times in a week at random days during off-peak hours at 14.30, 3 times in week at random daysduring peak hours at 18.00 and one time in a Saturday at 14.30.

After collecting the data, average of all samples for different times for every single pair is calculated. These average values are then used for the calculation of the optimum route via Marmaray according to generalized costsandfor the generation of the choice model.

The collected time (in minutes) and distance (in miles) data for peak hours, off-peak hours and weekend can be found in Appendix D. As can be seen in these tables, travel times naturally vary at different observation periods, whereas travel distances also vary. This happens, because Yandex optimizes the route for every single route calculation, so the distance between OD pairs get changed in order to find the optimum route.

4.1.2. Demand Matrix

The public transport users have of course considered Marmaray for their intercontinental trips and it is clear, that they have profited from Marmaray, although the success of Marmaray investment still get discussed [23]. But the main concern is the private car users, who have considered Marmaray after it is built.With these arguments it is a must for this thesis to consider the demand of the private car users and find out their shift to Marmaray if it exists.

In this study, the OD matrix of demand values for private car and public transport users for the year 2006 is used. During that time, there was no Marmaray at all. The nonconsidered districts of the city are taken away from the matrix. And the demand values for divided districts in our final zones map are found by dividing the demand values of the initial districts. The divided districts are Fatih (divided into EUR7-10-11), Küçükçekmece (divided into EUR18-19) and Tuzla (divided into AS10-11). Additionally, Bağcılar and Esenler, Bayrampaşa and Gaziosmanpaşa, Güngören and Zeytinburnu, Sultanbeyli and Maltepe are unified into the zones EUR15, EUR13, EUR12 and AS9 respectively.

This demand matrix is used to generate the model for travellers, who have choices of public transport or private car. The concluded demand OD matrices for public transport and private vehicle, which is used in further modelling and calculations can be found in Table 4.2 and Table 4.3 respectively. The analysis will be based on this model but with Marmaray considering trips' data. This approach will be explained under Section 4.4.

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Table 4.2: Public Transport Demand OD.

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	315	315	498	498	642	642	563	233
EUR7	54	54	265	265	247	247	306	36
EUR8	315	315	498	498	642	642	563	233
EUR9	449	449	1.527	1.527	1.993	1.993	1.932	279
EUR10	449	449	1.527	1.527	1.993	1.993	1.932	279
EUR11	449	449	1.527	1.527	1.993	1.993	1.932	279
EUR12	796	796	4.297	4.297	4.901	4.901	4.177	197
EUR13	1.592	1.592	4.921	4.921	7.035	7.035	9.385	1.274
EUR14	54	54	265	265	247	247	306	36
EUR15	125	125	762	762	1.004	1.004	593	109
EUR16	125	125	762	762	1.004	1.004	593	109
EUR17	159	159	476	476	586	586	843	117
EUR18	34	34	156	156	363	363	399	87
EUR19	34	34	156	156	363	363	399	87
EUR20	200	200	683	683	598	598	1.175	77

Table 4.3: Private Car Demand OD

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	134	134	351	351	466	466	598	57
EUR7	57	57	212	212	248	248	158	1
EUR8	134	134	351	351	466	466	598	57
EUR9	214	214	672	672	1.296	1.296	1.116	117
EUR10	214	214	672	672	1.296	1.296	1.116	117
EUR11	214	214	672	672	1.296	1.296	1.116	117
EUR12	129	129	772	772	674	674	736	116
EUR13	916	916	2.159	2.159	4.612	4.612	3.515	263
EUR14	57	57	212	212	248	248	158	1
EUR15	56	56	342	342	500	500	566	74
EUR16	56	56	342	342	500	500	566	74
EUR17	64	64	237	237	345	345	589	79
EUR18	78	78	175	175	144	144	397	18
EUR19	78	78	175	175	144	144	397	18
EUR20	117	117	261	261	650	650	466	41

4.2 Generalized Cost Calculation

Because the route of private car trips are gathered from Google Maps, there is no need to make a comparison between different route alternatives and decide on the best route between OD pairs. However, for Marmaray trips, it is needed to calculate which station would be selected for each trip between each OD pair.In order to determine the selected Marmaray stations, the generalized costs of reaching to different stations are compared and the one with the lowest generalized cost is assumed to be selected.

By using the car driving cost ($C_{driving}$), ticket cost and value of time variables, the total cost of every single trip is calculated, so that the optimum stations of Marmaray are found to generate the cheapest route alternative. After determining the selected Marmaray station the total travel cost and travel time for designated alternative to private vehicle can be calculated.

The expressions for the generalized cost calculation of direct private vehicle trips, public transport trips and private vehicle-Marmaray-taxi (mixed mode) trips are given in the equations 4.1, 4.2 and 4.3 respectively. In these equations; TT stands for total travel time, TC stands for total travel cost, TD stands for travel distance,$C_{driving}$ stands for driving cost, C_{taxi} stands for taxi driving cost, PV stands for private vehicle, PT stands for public transport, MRT stands for Marmaray in the equations.$C_{transfer}$ is the extra cost of transfers to be added to the C_{ticket} .

$$TC_{PV} = TT * VoT + TD * C_{driving} \quad (4.1)$$

$$TC_{PT} = TT * VoT + C_{ticket} + C_{transfer} \quad (4.2)$$

$$TC_{mixedm} = (TT_{toMRT} + TT_{MRT} + TT_{fromMRT}) * VoT + C_{ticket} + C_{P\&R} + TD_{toMRT} * C_{driving} + C_{taxi} * TD_{fromMRT} \quad (4.3)$$

The optimum Marmaray stations to board at European side and alight at Asian side for each OD pair are found using this approach, which can be found in the Table 4.4 and Table 4.5 respectively.

Table 4.4: MRT Boarding Stations.

	Peak	Off-Peak	Weekend
EUR6	MRT3	MRT2	MRT3
EUR7	MRT3	MRT3	MRT3
EUR8	MRT2	MRT2	MRT2
EUR9	MRT2	MRT2	MRT2
EUR10	MRT2	MRT2	MRT2
EUR11	MRT1	MRT1	MRT1
EUR12	MRT1	MRT1	MRT1
EUR13	MRT2	MRT2	MRT2
EUR14	MRT2	MRT2	MRT2
EUR15	MRT2	MRT2	MRT2
EUR16	MRT1	MRT1	MRT1
EUR17	MRT1	MRT1	MRT1
EUR18	MRT1	MRT1	MRT1
EUR19	MRT1	MRT1	MRT2
EUR20	MRT2	MRT1	MRT2

Table 4.5: MRT Alighting Stations.

	Peak	Off-Peak	Weekend
AS3	MRT4	MRT4	MRT4
AS4	MRT4	MRT4	MRT4
AS5	MRT5	MRT5	MRT5
AS6	MRT5	MRT5	MRT5
AS7	MRT4	MRT4	MRT4
AS9	MRT5	MRT5	MRT5
AS10	MRT5	MRT5	MRT5
AS11	MRT5	MRT5	MRT5

The generalized cost results for every mode and for every considered OD pair can be found in Appendix B for peak hours, for off peak hours in week and for weekend time respectively. According to these results, it is found, that for off-peak hours 22% of the trips are cheaper with the private vehicle-marmaray-taxi alternative, whereas for peak hours 33% of them are cheaper with the same alternative mixed mode.

4.3 Statistical Analysis of Collected Data

As stated before, the data were collected for three different time periods. Naturally, the means of different times of day would be different from each other. Additionally the main concern of this thesis is the time and cost differences between private vehicle trips and Marmaray trips. Regarding this situation, a statistical analysis for time differences between intercontinental private vehicle trips and Marmaray trips for this three different groups is made. Since the collected row data is time but not cost time data is considered in this section. The difference is calculated basically by subtracting the total travel time of mixed mode alternative from the total travel time of private vehicle mode.Basic statistical summary of these groups can be seen in Table 4.6.

For an analysis of all three groups together, a oneway analysis of variance test is made to find out, if all of these samples come from the same population. H_0 hypothesis is defined as, that means of all groups are equal, which leads us to the assumption, that all of the groups come from the same population, whereas H_1hypothesis is not all of them coming from the same population.

The most useful way to test the population similarity of sample groups in a binarian way is the oneway analysis of variance (ANOVA) test [24]. The F value results of ANOVA Test shows us the similarity of the population. F value is defined in the equation 4.4.

$$F = \frac{Varia\,bility\ \ between\ \ groups}{Variability\ \ \ wit\,hin\ groups} \qquad (4.4)$$

According to the ANOVA calculation, the calculated F value is found as greater than the critical F value, because of which it can be concluded, that not the samples of all of the groups come from the same population with 5% significance level. The details of ANOVA test can be seen in Table 4.7. In this table, df stands for degree of freedom, SS stands for sum of squares and MS stands for mean squares, whereas SS, MS and F value for statistic is calculated by the equations 4.5, 4.6 and 4.7 respectively for between groups variation and the equations 4.8 and 4.9 is used for within groups calculation of SS and MS values. In these equations; n stands for total number of observations,$\bar{x}$ stands for mean of all n observations, nj stands for size of sample from population j, $\bar{x}$j stands for mean of sample from population j, s_j^2 stands for variance of sample from population j, whereas j has got values from 1 to k, which is the number of samples.

$$SS_{bg} = \sum nj * (\bar{x}_j - \bar{x})^2 \quad (4.5)$$

$$MS_{bg} = \frac{SS_{bg}}{k-1} \quad (4.6)$$

$$F = \frac{MS_{bg}}{SS_{wth}} \quad (4.7)$$

$$SS_{wth} = \sum (nj - 1)s_j^2 \quad (4.8)$$

$$MS_{wth} = \frac{SS_{wth}}{n-k} \quad (4.9)$$

After finding out, that not all of them come from the same population, it is time to find out, if any of them come from the same population.A t-test for two sample groups with unequal variances is commonly used for this purpose [24], so it is done. It is a matter of chance to select the first two pair for using t-test and the off-peak and weekend groups were initially selected. The defined H_0 in this computation is again, that the samples of two different groups come from the same population. After making a two tailed t-test, since we are looking for if means of the populations of the groups are the same or not, it is found with 5% significance level, that it is not to be stated, that the means of these groups are different from each other, because the t statistic value is less than the t critical value. The results of the t-test can be seen in Table 4.8 on the following page.

As an additional explanation of considering differences of time data, the Equation 4.10 shows the time difference calculation, where TT_{PV} stands for travel time of privat vehicle and $TT_{mixedmode}$ stands for travel time of mixed mode.

$$TT_{difference} = TT_{PV} - TT_{mixedmode} \quad (4.10)$$

Table 4.6: Statistical Summary of TimeDifferences for 3 Time Zones.

Groups	Count	Sum	Average	Variance
$TT_{difference}$ @ off-peak	120	-778.15	-6.48	126.63
$TT_{difference}$ @ peak	120	3971.04	33.09	201.08
$TT_{difference}$ @ weekend	120	-829.73	-6.91	187.94

Table 4.7: Results of the ANOVA Test.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	126680.15	2	63340.08	368.51	1.53E-87	3.02
Within Groups	61362.35	357	171.88			
Total	188042.51	359				

Table 4.8: Results of the t-Test.

	$TT_{difference}$ @ off-peak	$TT_{difference}$ @ weekend
Mean	-6.48	-6.91
Variance	126.63	187.94
Observations	120	120
Hypothesized Mean Difference	0	
df	229	
t Stat	0.27	
P(T<=t) one-tail	0.40	
t Critical one-tail	1.65	
P(T<=t) two-tail	0.79	
t Critical two-tail	1.97	

As conclusion, we can say, that according to these tests, the samples from off-peak observations and weekend observationscome from the same population.Consequently, that the sample from the peak hour observationsat weekdays come from another population, since according to the ANOVA test, it was found, that not all of the groups are from the same population.

4.4 Utility Model

As mentioned before, the concluded approach of modelling is to model the choice behaviour of the travellers between their private cars and the alternative, which is the public transport in our case (for intercontinental trips).

This model is constructed using collected supply data and demand data from 2006. This is a real choice model for private car and public transport. Then the alternative mode for private car trip is used instead of the public transport mode to find out the behaviour of travellers against the alternative mode. This approach is explained in Section 4.5. briefly.

The alternative mode is the mixed mode trip, which is begining with private car until reaching Marmaray station and get finished with a taxi after getting off from Marmaray. So the calculated cost for this mode is the sum of private car travel cost until Marmaray, P&R cost (including the Marmaray ticket) and the taxi cost to reach the destination from Marmaray station. The time for this trip is the summation of duration of all these modes and transfer times.

As stated before, an aggregate utility logit model is constructed. Normally a logit model get constructed by using the perceived values of trip attributes of individuals. However in this study, although the method is kept as the same, the individiuals are artificially generated using the values in demand matrix for each OD pair and the observed aggregate supply data. This means, that the average of the collected data for each OD pair is expanded so many times as this OD pair is demanded by real people, whose value can be found in our demand matrix. This approach ensures, that every OD pair is represented so much as it is demanded by real people.The number of expanding (added rows) for every single OD pair can be found in Appendix C.

According to conclusion of the statistical analysis, the off-peak in week and weekend trips can be modelled as a unified model, since the samples of them come from the same population, whereas another model for peakhour should construced apartly.

As stated in Section 3.2., we have very varying distance of trips between different zones, which are sometimes very close to each other and sometimes very far away from each other. Like a normalizing process in statistics, we have considered the unit variables instead of direct time and cost. So in final we have had as variables; time per miles and cost per miles but also miles itself to represent the effect of the farness of the zones to eachother.

In final after expanding process, which is explained before, we have 8800 ID's for peak hours in weekdays to create peak model and 17599 ID's for off-peak model, which is generated for weekend and off-peak hours in weekdays.

4.4.1. Calculating the best fit model

After the explained approach and considerations, the calculation process will be explained in this section regarding these explanations.

The model used in this study is a binary logit model. The method of logit model is based on representing every possible choice for every single trip between OD pairs, with respect to their observed demands by travellers, regarding the observed modal shares. This method is commonly used for transportation demand analysis and modelling of traveller behaviour. A binary choice model is needed because we model the choice of the traveller between private car and the alternative.The utility equations of our model is as in Equations 4.10 and 4.11, where the PV is presenting the private vehicle and PT is presenting public transport (the alternative mode). UT and UC are unit time and unit cost values respectively, whereas ML stands for kms of distance. Unit values are simply found by dividing the time or cost value by miles.

$$U(PT) = \alpha_0 + \alpha_T * UT + \alpha_C * UC \qquad (4.11)$$

$$U(PV) = \alpha_T * UT + \alpha_C * UC + \alpha_{ML} * ML \quad (4.12)$$

$\alpha_0, \alpha_T, \alpha_C$ and α_{ML} are the generic coefficients, which are have the same value in both of the utility functions. The reason for using generic coefficients is the aggregate data, which we have used to generate the model and which represents the behaviour of the all travellers in a joint way. The probability of travellers to make a choice for every id is calculated according to the Equations 4.12 and 4.13 for PT and PV respectively.

$$P(PT) = \frac{e^{U(PT)}}{e^{U(PT)} + e^{U(PV)}} \qquad (4.13)$$

$$P(PV) = \frac{e^{U(PV)}}{e^{U(PT)} + e^{U(PV)}} \qquad (4.14)$$

For the maximum likelihood calculation to find the best fit model to our data the following Equation 4.14 is used, where the natural logarithm of the selected mode's probability is considered for the total log likelihood summation. The probability of the mode is shown as P_{mode} (β), whereas δ_{mode} become 1 if this mode is selected and 0 otherwise. This is the most preferred method for maximum likelihood calculation [25].

$$\mathrm{LL}(\beta) = \sum \ln \delta_{mode} \ (P_{mode}(\beta)) \qquad (4.15)$$

4.4.2. Analyzing the model

For analyzing the model, different approaches are made, one of which is the t-tests of the calculated best fit coefficients and constants, which can be found in the Table 4.9 below.

To analyze the total model the -2LL test is made according to an evaluation, which is similar to the evaluation by Hensher et al. [26], which shows us the evolution of our model according to a base model, which is in our case a market share model consisting of a single constant parameter.

The market share model is shown as $LL(M)$, whereas our model is shown as $LL(\beta)$.The formula of the -2LL test is in Equation 4.15 below, in which if -2LL get smaller, the model likelihood would be better.

$$-2LL = -2 * [LL(M) - LL(\beta)] \qquad (4.16)$$

Regarding the same base model, a ρ^2 analysis is also made to test the goodness of fit of the model, which can also be seen in the table below. The formula for the ρ^2 test is as in equation 4.16, in which if ρ^2 converges to 1, the goodness of fit would be perfect, which is only theoretically possible.

$$\rho^2 = (1 - \frac{LL(\beta)}{LL(M)}) \qquad (4.17)$$

The t-tests and the tests of the models can be seen for the both peak and off-peak models in Table 4.9.

Table 4.9: Values of Logit Models.

	Peak Model		Off-peak Model	
Variable	Coefficient	t-test	Coefficient	t-test
	Private Vehicle			
Unit Time	-0.014	-1.366	-0.034	-3.625
Unit Cost	-2.357	-1.160	-3.354	-1.967
Miles	0.034	5.798	0.032	7.044
	Alternative Mode			
Constant	-2.8731	-0.791	-4.546	-1.493
Unit Time	-0.014	-1.366	-0.034	-3.625
Unit Cost	-2.357	-1.160	-3.354	-1.967
Number of Observations	8801		11816	
LL(β)	-5548.993		-7467.430	
LL(M)	-5597.329		-7526.124	
-2LL	96.672		117.388	
ρ^2	0.009		0.008	

On the other hand the correlation matrix of the variables of the models is also considered for analyzing the models, these matrices for both models can be seen below in Table 4.10 and Table 4.11.

Table 4.10: Correlation Matrix for Peak Model.

	TT	TC	UT	UC	ML
TT	1				
TC	-0.382	1			
UT	0.372	-0.572	1		
UC	-0.749	0.793	-0.414	1	
ML	0.407	0.372	-0.622	-0.136	1

Table 4.11: Correlation Matrix for Off-peak Model.

	TT	TC	UT	UC	ML
TT	1				
TC	-0.533	1			
UT	0.611	-0.626	1		
UC	-0.828	0.790	-0.565	1	
ML	0.293	0.373	-0.483	-0.138	1

According to the correlation matrix of the both time cost and their unit variables of the models, it is easy to see, that using units instead of the variables theirselves make us avoid from the disruptive effect of the correlated variables on the model. Indeed, it was not possible to create a meaningful model with meaningful coeffiecients for the variables while using time and cost variables directly, as experienced in our work.

The correlation values of the unit variables with respect to each other are acceptable to create a model. We have correlation values between 0.35 and 0.41 for most of the variables except the correlation between unit time and miles variables, which is about 0.62, but still it is accepted to be able to be used for modelling. So the created models are based on the unit cost, unit time and the ML variables.

According to Table 4.9, all of the coefficients except the one for distance (ML) have a negative sign. In other words, as expected, travel time and cost contributes to a disutility for the travellers, while distance of the trip causes a positive effect for selecting private car instead of the public transport. As can be seen from the t-tests of the coefficients, the t-value of ML variable is far beyond the 5% siginificance level for the test, which leads us the think, that the effect of distance longness of the trip does certainly exist. Whereas the t-value of the unit cost variables has got a 10% significance level and the same of the unit time is even smaller, which means that the fitness of the variables are in descending order miles-unit cost-unit time.

The biggest value of the coefficients is the the value of the unit cost coefficient, which means, that the unit cost of the trip has got the biggest effect on the travellers choice. When we look at the time coefficient, it is seen, that it has got the smallest effect for peak model and almost the same effect as the miles for off-peak model, which are still far behind cost coefficient in both of the models.

Obviously, using an alternative of the private car has always a negative constant value and it has the biggest value among the list, so the travellers have got an affinity to use their private cars in all cases, but only sometimes because of the other realistic parameters like time and cost, make them use an alternative. Additionally the amount of car ownership in Istanbul is quite low, there are about 137 car per 1000 people in İstanbul in year 2009 [19], if this amount would be more, than obviously we would have a bigger negative coefficient for using the alternative mode, since people would have chance to use their private car. As an example for this case can be given the peakhour traffic and the increasing operating cost of the car because of congestion. For all that, it is to be considered, that the significance of the constant value is 10% according to the t-test.

The models are not very successful, as can be seen from the goodnes of fit and the 2LL tests, but still it can lead us to make the assumption, that the travellers have got a negative stand point to the alternatives of the private car.This stand of the travellers is our main concern, when talking about the mixed mode using including Marmaray as an alternative to the private car for intercontinental trips.

4.5 Evaluation of Mixed-Mode Alternative for Private Vehicle

Evaluating the private car vs alternative mode model for private car vs Marmaray including mixed modefor a door to door trip with quite same comfort as a private car trip is our mission for final analysis of Marmaray alternative. As stated before the alternative mode is designated with a beginning by a private car until the optimum Marmaray station and than ending with a taxi trip to the final destination after the optimum Marmaray station. The cost and time values are collected and calculated for this scenerio as well, which is explained before. The evaluation process can easily be understood by the following flowchart in (Figure 4.1).

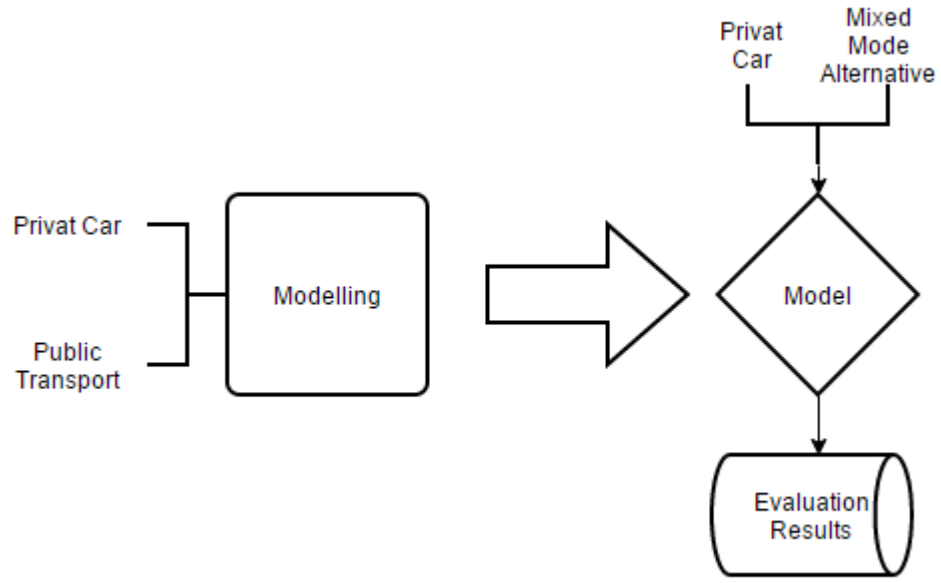

Figure 4.1 : Evaluation Process.

The sum of the probability of the modes are the probability of the travellers to use these modes. In our case, the output of this probability summation gives us the proportion of the travellers, which would use our designated alternative mode instead of Marmaray. Therefore, the amount of the private car users, which would use our alternativemixed-mode scenerio via Marmaray is calculated using these models at last. The two outputs for this proportion between private car users and the travellers, who give over using the bridges and choose to make the trip via Marmaray, is explained in the following paragraph.

The proportion of the Marmaray scenerio using travellers instead of using bridges is about 5.6% for peak hours and 3.2% for off-peakhours according to the results. Basically, it means, that this percent of the travellers quit using bridges to make an intercontinental trips, whereas the rest insist on their private vehicles in the case, that they have the chance to use the alternative mixed-mode.

As can be seen from the results, even with a high cost of taxi in addition to parking fee, ticket costs and again the car operating cost until reaching Marmaray there are some travellers, who will use Marmaray instead of crossing the bridge with a catastrophic congestion especially during peak hours.

The percentages of the shifts also reveal, that the shift of off peak travellers to the Marmaray alternative is less than the peak travellers. This situation is not hard to explain with the arguments of non mandatory trips of off-peak hours and the less traffic congestion on the bridges during off-peak hours.

5. CONCLUSION

The huge investments on transportation in Istanbul will supply without doubt advantages for citizens. The point of view of the thesis includes both the demanders and the investors' sides. From the travellers' side, Marmaray is a very efficient project for public transport users, but that is an already concluded idea of previous researchs on Marmaray, which are mentioned in literature review section[10]. With the modelling of the mode choice behaviour of the intercontinental travellers in Istanbul, different facts about them are and can further be stated by this thesis, which are already explained in Model Analysis section. Even though the generated model was not a perfect fit one, the facts, that the off-peak hour travellers have a higher affinity to the private car and the main argument for making a modal choice is the cost argument, can obviously be stated doubtless.

Technically, a new method for evaluating an alternative scenerio is used in this thesis, which is modelling between a defined and an alternative undefined mode. In our case, the modelling is done for private car as the defined mode and for an alternative mode. The alternative mode was public transport for intercontinental trips. After modelling is finished, the alternative mode is basically switched with the mixed mode including Marmaray, which in our case specifically designated for private car owners. This approach of choosing behaviour analysis of travellers can be used rather before making new investments, so basically it can serve as a preliminary evaluation tool, that supports the planning studies.

The results of the evaluation for mixed mode alternative follows some of the implications, which are made from the model itself, such as the higher affinity of off-peak hour travellers to their private cars. One of the interesting facts of the simulation results is, that although there are money consuming steps for the mixed mode alternative like taxi and parking lot, there are still people, who will shift from using the bridge to the Marmaray mixed mode, which is obviously because of

dramatically increasing travel times and predictibly because of the feel of being limited and dependency in congested traffic.

As stated in Section 4, that explains methodology widely, as a preprocess for modelling, generalized costs of private car and alternative modes are calculated.These costs are not only used for finding out the optimum route via Marmaray, but also used to compare the deterministic results of the generalized costs calculation with the results of our logit model simulation. The conclusion of this comparison is also quiteinteresting. For off-peak hour 22% of the considered trips are cheaper with the mixed mode alternative via Marmaray, but according to the results of the simulation only 3.2% of the travellers shift from bridges to this alternative scenerio.The situation is similar for peak hour travellers with only a shift of 5.6% to the alternative mode, although 33% of the considered trips are cheaper with the alternative mode.

This instance shows the effect of the uncalculatable arguments. There may be given many examples for these kind of arguments, such as privacy concerns of people, feelings of using a vehicle or in general cultural habits. In this thesis, it is only proved that they exist.However which ones are present and how much they are could not be determined. These kind of arguments may also be taken into account, while the investments are being planned, since it is clear, that this society with these cultural habits will use this investment.

Nevertheless, there is a shift from the bridges to Marmaray. And the result of the simulation of our model is consistent with the real fact, that the amount cars crossing the bridge are decreased after Marmaray is built, which is announced by then the minister of transport and now prime minister Binali Yıldırım [3]. Indeed the proportion of this shift (6%), which is announced by the ministerium is quite close to our simulation results. It is to be hoped that more successful and more comprehensive models will be created before making new investments to ensure better planning. For this purpose policy support of government is needed. And it is also to be hoped that the Marmaray project will have an increasing efficieny both on travellers' and the government sides.

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APPENDICES

APPENDIX A: Query Code
APPENDIX B: Generalized Costs Table
APPENDIX C: Number of Expanding
APPENDIX D: Collected Supply Data

APPENDIX A

The further explanation about the use of google map application can be found in link below:

https://developers.google.com/maps/documentation/distance-matrix/intro#DistanceMatrixResponses

Because of the quota limitations of one time queries in the application, the entire query can be made in 5 times and so all of the time and distance values from any starting point to any destination point via private car and using Marmaray alternatives can be gathered from the query in json form.

Below are the 5 query urls:

https://maps.googleapis.com/maps/api/distancematrix/json?units=imperial&origins=sar%C4%B1yer,istanbul|kemerburgaz,istanbul|maslak,istanbul|bebek,istanbul|levent,istanbul|be%C5%9Fikta%C5%9F,istanbul|emin%C3%B6n%C3%BC,istanbul|halaskargazi,istanbul|emniyettepe,istanbul|mihrimah+sultan+camii,istanbul|koca+mustafa+paşa,istanbul|be%C5%9Ftelsiz,istanbul|gaziosmanpa%C5%9Fa,istanbul|sultangazi,istanbul|ba%C4%9Fc%C4%B1lar,istanbul|bah%C3%A7elievler,istanbul|bak%C4%B1rk%C3%B6y,istanbul|atat%C3%BCrk+havaliman%C4%B1,istanbul|halkal%C4%B1,istanbul|ba%C5%9Fak%C5%9Fehir,istanbul&destinations=beykoz,istanbul|kavac%C4%B1k,istanbul|%C3%A7engelk%C3%B6y,istanbul|Üsküdar+iskelesi,istanbul|s%C3%B6%C4%9F%C3%BCtl%C3%BC%C3%A7e%C5%9Fme+tren+istasyonu,istanbul&departure_time=now&units=metric&language=tr_TR&key=AIzaSyAIXHzVXdLRU_wINW0V67wPUYQNFdxUiaA

https://maps.googleapis.com/maps/api/distancematrix/json?units=imperial&origins=sarıyer,istanbul|kemerburgaz,istanbul|maslak,istanbul|bebek,istanbul|levent,istanbul|beşiktaş,istanbul|eminönü,istanbul|halaskargazi,istanbul|emniyettepe,istanbul|mihrimah+sultan+camii,istanbul|koca+mustafa+paşa,istanbul|beştelsiz,istanbul|gaziosmanpaşa,istanbul|sultangazi,istanbul|bağcılar,istanbul|bahçelievler,istanbul|bakırköy,istanbul|atatürk+havalimanı,istanbul|halkalı,istanbul|başakşehir,istanbul&destinations=ataşehir,istanbul|ümraniye,istanbul|çekmeköy,istanbul|maltepe,istanbul|pendik,istanbul
&departure_time=now&units=metric&language=tr_TR&key=AIzaSyAIXHzVXdLRU_wINW0V67wPUYQNFdxUiaA

https://maps.googleapis.com/maps/api/distancematrix/json?units=imperial&origins=sarıyer,istanbul|kemerburgaz,istanbul|maslak,istanbul|bebek,istanbul|levent,istanbul|beşiktaş,istanbul|eminönü,istanbul|halaskargazi,istanbul|emniyettepe,istanbul|mihrimah+sultan+camii,istanbul|koca+mustafa+paşa,istanbul|beştelsiz,istanbul|gaziosmanpaşa,istanbul|sultangazi,istanbul|bağcılar,istanbul|bahçelievler,istanbul|bakırköy,istanbul|atatürk+havalimanı,istanbul|halkalı,istanbul|başakşehir,istanbul&destinations=kurtköy,istanbul&departure_time=now&units=metric&language=tr_TR&key=AIzaSyAIXHzVXdLRU_wINW0V67wPUYQNFdxUiaA

https://maps.googleapis.com/maps/api/distancematrix/json?units=imperial&origins=sarıyer,istanbul|kemerburgaz,istanbul|maslak,istanbul|bebek,istanbul|levent,istanbul|beşiktaş,istanbul|eminönü,istanbul|halaskargazi,istanbul|emniyettepe,istanbul|mihrimah+sultan+camii,istanbul|koca+mustafa+paşa,istanbul|beştelsiz,istanbul|gaziosmanpaşa,istanbul|sultangazi,istanbul|bağcılar,istanbul|bahçelievler,istanbul|bakırköy,istanbul|atatürk+havalimanı,istanbul|halkalı,istanbul|başakşehir,istanbul&destinations=Marmaray+Kazlıçeşme|Marmaray+Yenikapı|Marmaray+Sirkeci&departure_time=now&units=metric&language=tr_TR&key=AIzaSyAIXHzVXdLRU_wINW0V67wPUYQNFdxUiaA

https://maps.googleapis.com/maps/api/distancematrix/json?units=imperial&origins=Üsküdar+iskelesi,istanbul|ayrılıkçeşme,istanbul&destinations=beykoz,istanbul|kavac%C4%B1k,istanbul|%C3%A7engelk%C3%B6y,istanbul|%C3%BCsk%C3%BCdar,istanbul|s%C3%B6%C4%9F%C3%BCtl%C3%BC%C3%A7e%C5%9Fme+tren+istasyonu,istanbul|ataşehir,istanbul|ümraniye,istanbul|çekmeköy,istanbul|maltepe,istanbul|pendik,istanbul|kurtköy,istanbul
&departure_time=now&units=metric&language=tr_TR&key=AIzaSyAIXHzVXdLRU_wINW0V67wPUYQNFdxUiaA

The full adresses of the destinations and origins and Marmaray stations are below:

Table A.1: Destination Adresses.

"Beykoz, Gümüşsuyu, 34820 Beykoz/İstanbul, Türkiye",
"Kavacık, 34810 Beykoz/İstanbul, Türkiye",
"Çengelköy, 34680 Üsküdar/İstanbul, Türkiye",
"Mimarsinan, Üsküdar İskelesi, Hacı Hesna Hatun Cami Sk (Cami Sk.) No:9, 34664 Üsküdar/İstanbul, Türkiye",
"Hasanpaşa, Söğütlüçeşme, 34722 Kadıköy/İstanbul, Türkiye"
"Ataşehir, Küçükbakkalköy, 34750 Ataşehir/İstanbul, Türkiye",
"Ümraniye/İstanbul, Türkiye",
"Çekmeköy/İstanbul, Türkiye",
"Maltepe/İstanbul, Türkiye",
"Pendik, Kaynarca, 34890 Pendik/İstanbul, Türkiye"
"Kurtköy, 34912 Pendik/İstanbul, Türkiye"

Table A.2: Origin Adresses.

"Sariyer, Sarıyer/İstanbul, Türkiye",
"Kemerburgaz, Mithatpaşa, 34075 Eyüp/İstanbul, Türkiye", "Maslak, Şişli/İstanbul, Türkiye", "Bebek, 34342 Beşiktaş/İstanbul, Türkiye", "Esentepe, Levent, 34394 Şişli/İstanbul, Türkiye", "Beşiktaş/İstanbul, Türkiye", "Eminönü, Rüstem Paşa, 34116 Fatih/İstanbul, Türkiye", "Halaskargazi, 34371 Şişli/İstanbul, Türkiye", "Emniyettepe, 34060 Eyüp/İstanbul, Türkiye", "Karagümrük Mh.,Mihrimah Sultan Cami, 34091 Fatih/İstanbul, Türkiye", "Koca Mustafa Paşa, 34098 Fatih/İstanbul, Türkiye", "Beştelsiz, 34020 Zeytinburnu/İstanbul, Türkiye", "Gaziosmanpaşa/İstanbul, Türkiye", "Sultangazi/İstanbul, Türkiye", "Bağcılar/İstanbul, Türkiye", "Bahçelievler/İstanbul, Türkiye", "Bakırköy/İstanbul, Türkiye", "Yeşilköy, Atatürk Havalimanı (IST), 34149 Bakırköy/İstanbul, Türkiye", "İstasyon, Halkalı, 34303 Küçükçekmece/İstanbul, Türkiye", "Başakşehir, Başak, 34480 Başakşehir/İstanbul, Türkiye"

Table A.3: Marmaray Stations' Adresses.

"Mimarsinan, Üsküdar İskelesi, Hacı Hesna Hatun Cami Sk (Cami Sk.) No:9, 34664 Üsküdar/İstanbul, Türkiye",
"Acıbadem, Ayrılıkçeşme, 34718 Kadıköy/İstanbul, Türkiye"

Table A.4: Marmaray Stations' Adresses.

"Kazlıçeşme, Kazlıçeşme İstasyonu, ZakirbaşıSk., 34020 Zeytinburnu/İstanbul, Türkiye",
"Aksaray Mahallesi, Yenikapı Marmaray, Langa Bostanları Sokak, Fatih/İstanbul, Türkiye", "Hoca Paşa, Sirkeci Marmaray, Vezir Cami Çk. No:4, 34110 Fatih/İstanbul, Türkiye"

APPENDIX B

Table B.1: Generalized Costs of PV for Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	66.9	74.6	39.1	34.4	37.3	45.9	42.9	55.7
EUR11	70.2	77.0	41.8	38.9	40.3	48.2	46.8	58.5
EUR12	73.7	83.4	46.7	40.2	43.4	52.6	49.6	62.4
EUR13	72.9	83.3	41.6	38.9	43.7	50.7	50.5	62.8
EUR14	89.8	90.4	52.1	53.9	56.7	65.1	58.8	72.4
EUR15	83.8	95.5	55.7	50.8	53.8	62.9	65.5	71.8
EUR16	80.6	87.8	54.0	49.1	51.5	59.5	60.4	68.6
EUR17	80.1	90.7	53.1	46.8	50.3	58.2	60.5	68.7
EUR18	84.5	95.7	58.4	52.7	55.5	63.4	64.5	72.7
EUR19	91.5	103.7	63.8	57.3	61.5	69.2	70.0	78.1
EUR20	88.9	97.1	61.5	54.4	57.8	72.8	70.9	77.1
EUR6	57.8	67.3	26.6	25.5	26.9	39.1	30.7	46.3
EUR7	60.9	69.1	34.2	28.7	32.0	40.2	40.0	48.7
EUR8	64.6	68.4	29.9	27.9	30.0	41.2	34.1	49.0
EUR9	74.6	78.0	35.2	38.8	41.1	50.8	44.9	58.0

Table B.2: Generalized Costs of PT for Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	37.5	35.9	25.5	23.9	24.8	29.3	27.5	34.0
EUR11	37.8	38.1	28.0	26.9	25.9	30.3	29.6	34.4
EUR12	40.2	38.8	29.1	27.3	26.1	31.4	30.7	36.4
EUR13	39.5	36.1	26.0	26.4	25.1	30.7	29.3	36.0
EUR14	41.8	38.3	30.2	34.8	34.0	35.3	33.4	39.3
EUR15	42.9	40.1	30.7	30.3	30.4	34.7	34.1	40.0
EUR16	41.2	40.8	30.2	29.6	29.1	33.6	32.7	38.3
EUR17	41.2	40.1	30.5	29.2	29.0	33.4	32.6	38.4
EUR18	42.1	41.6	31.7	30.3	30.0	34.5	33.8	39.4
EUR19	42.1	41.7	32.8	33.0	32.9	37.1	35.9	40.5
EUR20	43.0	40.5	31.2	32.6	32.3	37.2	35.8	40.5
EUR6	31.7	30.3	19.4	20.0	19.1	23.0	20.8	28.6
EUR7	33.6	34.5	24.2	22.4	22.1	26.7	24.1	30.5
EUR8	34.8	32.8	22.3	23.4	22.3	27.3	25.0	31.8
EUR9	36.5	32.7	22.6	27.8	27.4	29.2	26.7	33.7

Table B.3: Generalized Costs of Mixed Mode for Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	75.7	80.3	38.8	28.6	31.5	44.8	47.1	52.3
EUR11	70.3	74.8	33.4	23.2	26.1	39.4	41.7	46.8
EUR12	68.7	73.3	31.8	21.6	24.5	37.8	40.1	45.3
EUR13	88.6	93.1	51.7	41.5	44.4	57.7	60.0	65.1
EUR14	103.2	107.7	66.3	56.1	58.9	72.3	74.6	79.7
EUR15	99.0	103.6	62.2	52.0	54.8	68.1	70.4	75.6
EUR16	95.2	99.7	58.3	48.1	51.0	64.3	66.6	71.7
EUR17	80.6	85.1	43.7	33.5	36.4	49.7	52.0	57.1
EUR18	98.1	102.6	61.2	51.0	53.9	67.2	69.5	74.7
EUR19	107.9	112.5	71.1	60.9	63.7	77.0	79.4	84.5
EUR20	104.4	108.9	67.5	57.3	60.2	73.5	75.8	80.9
EUR6	79.3	83.8	42.4	32.2	35.1	48.4	50.7	55.8
EUR7	70.0	74.5	33.1	22.9	25.8	39.1	41.4	46.5
EUR8	82.0	86.5	45.1	34.9	37.8	51.1	53.4	58.5
EUR9	88.9	93.4	52.0	41.8	44.7	58.0	60.3	65.5

Table B.4: Generalized Costs of PV for Off-Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	58.6	65.8	35.7	28.6	31.7	38.4	35.3	48.8
EUR11	65.9	74.5	45.0	36.6	40.3	47.6	44.5	55.8
EUR12	65.4	71.4	42.5	34.7	37.8	44.6	41.4	54.2
EUR13	68.1	74.2	37.1	36.1	40.5	47.3	43.8	57.0
EUR14	78.9	84.9	49.0	48.2	51.4	59.3	55.4	68.1
EUR15	76.8	83.2	51.9	49.9	49.5	56.8	54.8	65.7
EUR16	74.0	81.3	51.0	44.4	46.9	53.5	50.3	63.0
EUR17	69.9	77.6	48.4	41.2	43.7	50.3	47.2	59.9
EUR18	76.8	83.6	54.5	47.4	52.1	56.4	53.2	66.5
EUR19	84.0	92.1	59.7	54.5	57.6	64.3	60.3	74.1
EUR20	80.7	87.1	52.1	50.1	53.1	60.0	54.5	69.6
EUR6	50.3	58.3	23.5	20.0	23.1	31.0	26.2	40.3
EUR7	55.9	62.6	30.8	25.4	29.8	37.0	32.2	45.3
EUR8	53.0	59.7	28.7	21.4	24.4	31.1	28.2	41.3
EUR9	60.1	67.1	33.6	27.7	32.7	40.0	36.2	48.4

Table B.5: Generalized Costs of PT for Off-Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	28.4	30.5	20.7	17.8	17.6	20.4	19.6	25.3
EUR11	33.1	36.8	24.8	22.6	21.4	24.2	23.4	29.6
EUR12	31.7	33.8	24.1	21.0	20.7	23.5	22.7	28.2
EUR13	31.7	34.0	21.3	21.0	20.7	23.5	22.3	28.4
EUR14	35.9	38.0	25.5	25.0	24.8	27.7	26.5	32.4
EUR15	35.2	37.4	25.6	24.7	24.6	28.1	26.4	31.8
EUR16	35.8	37.5	28.9	27.0	25.6	28.2	27.2	32.6
EUR17	33.3	35.1	25.9	23.9	22.3	25.1	24.2	29.9
EUR18	37.3	38.2	29.4	27.7	25.9	28.7	27.6	34.2
EUR19	39.0	41.2	29.3	28.0	27.7	30.6	29.2	35.6
EUR20	34.5	36.9	24.6	23.7	23.5	27.2	25.6	31.3
EUR6	25.1	27.0	16.2	14.4	14.2	16.9	15.6	21.7
EUR7	29.1	31.2	22.0	18.5	18.4	21.1	20.3	25.7
EUR8	27.9	30.0	21.0	17.3	17.0	19.8	19.1	24.5
EUR9	28.6	30.7	19.7	17.7	17.6	20.1	19.1	25.3

Table B.6: Generalized Costs of Mixed Mode for Off-Peak Hours.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	64.8	73.6	40.2	27.8	30.7	42.1	43.5	49.6
EUR11	59.9	68.7	35.3	22.8	25.8	37.2	38.6	44.7
EUR12	60.1	69.0	35.6	23.1	26.1	37.4	38.8	44.9
EUR13	81.8	90.6	57.2	44.7	47.7	59.0	60.5	66.5
EUR14	99.7	108.5	75.1	62.6	65.6	76.9	78.4	84.4
EUR15	90.0	98.8	65.4	52.9	55.9	67.2	68.7	74.8
EUR16	87.7	96.5	63.1	50.7	53.6	65.0	66.4	72.5
EUR17	73.4	82.2	48.8	36.3	39.3	50.6	52.1	58.1
EUR18	88.8	97.7	64.3	51.8	54.8	66.1	67.5	73.6
EUR19	102.5	111.3	77.9	65.5	68.4	79.8	81.2	87.3
EUR20	101.6	110.5	77.1	64.6	67.6	78.9	80.3	86.4
EUR6	73.7	82.5	49.1	36.7	39.6	51.0	52.4	58.5
EUR7	59.8	68.7	35.3	22.8	25.8	37.1	38.6	44.6
EUR8	72.3	81.1	47.7	35.2	38.2	49.5	51.0	57.0
EUR9	79.6	88.4	55.0	42.5	45.5	56.8	58.3	64.3

Table B.7: Generalized Costs of PV for Weekend.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	58.4	65.5	41.4	27.4	32.0	39.5	36.7	49.3
EUR11	67.9	75.3	51.1	37.2	41.5	49.2	46.5	58.9
EUR12	65.1	72.3	48.1	34.2	38.7	46.4	43.5	56.0
EUR13	69.4	72.5	38.3	35.1	39.4	48.2	40.7	60.3
EUR14	80.5	83.9	49.6	47.5	51.6	59.4	52.0	71.4
EUR15	80.6	84.2	49.9	45.3	49.6	59.6	52.0	71.6
EUR16	89.4	92.6	58.5	47.1	51.3	68.2	60.7	80.4
EUR17	71.4	78.9	53.0	40.8	45.3	52.7	50.0	62.4
EUR18	76.6	95.9	61.5	46.1	50.6	58.0	63.8	67.6
EUR19	88.5	92.0	57.5	52.8	57.1	67.4	59.9	79.4
EUR20	82.6	86.3	51.8	47.3	51.6	61.7	54.2	73.8
EUR6	47.5	54.8	31.3	16.8	21.1	28.8	26.1	38.4
EUR7	55.4	62.8	39.1	24.6	29.1	36.6	33.9	46.3
EUR8	51.0	58.2	32.7	20.2	24.7	32.2	29.5	41.9
EUR9	57.0	70.8	36.1	25.9	30.8	38.3	38.5	47.9

Table B.8: Generalized Costs of PT for Weekend.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	28.6	29.7	22.8	16.9	18.0	20.7	19.8	25.4
EUR11	32.9	34.3	27.2	21.5	22.3	25.1	24.2	29.7
EUR12	33.5	35.0	27.8	22.1	23.0	25.7	24.8	30.4
EUR13	29.5	29.2	21.1	20.4	21.3	21.7	19.2	26.3
EUR14	34.3	34.1	26.0	25.6	26.6	26.7	24.2	31.2
EUR15	32.8	32.6	24.7	24.4	25.2	25.2	22.7	29.7
EUR16	37.7	37.4	29.7	26.1	27.2	29.5	27.1	34.6
EUR17	36.7	38.4	31.2	25.4	26.3	29.0	28.1	33.6
EUR18	37.7	37.5	29.7	26.6	27.6	30.1	27.8	34.6
EUR19	37.3	37.1	29.2	28.6	29.5	29.7	27.3	34.2
EUR20	33.6	33.3	25.4	25.1	26.0	25.9	23.5	30.5
EUR6	24.6	25.9	20.4	13.1	14.1	16.9	16.0	21.3
EUR7	29.9	31.4	25.5	18.2	19.2	22.0	21.1	26.7
EUR8	28.1	29.2	22.9	16.4	17.4	20.2	19.3	24.9
EUR9	27.1	27.5	19.1	16.3	16.7	19.5	17.4	24.0

Table B.9: Generalized Costs of Mixed Mode for Weekend.

	AS10	AS11	AS3	AS4	AS5	AS6	AS7	AS9
EUR10	67.2	76.0	45.9	31.0	33.8	43.8	47.6	52.8
EUR11	59.8	68.7	38.6	23.7	26.4	36.5	40.3	45.4
EUR12	60.8	69.7	39.6	24.7	27.4	37.5	41.3	46.4
EUR13	86.1	95.0	64.9	50.0	52.7	62.8	66.6	71.7
EUR14	99.5	108.3	78.3	63.3	66.1	76.1	80.0	85.1
EUR15	92.4	101.2	71.1	56.2	58.9	69.0	72.8	78.0
EUR16	96.8	105.7	75.6	60.7	63.4	73.5	77.3	82.4
EUR17	75.6	84.5	54.4	39.4	42.2	52.3	56.1	61.2
EUR18	90.0	98.8	68.7	53.8	56.5	66.6	70.4	75.6
EUR19	105.0	113.8	83.8	68.8	71.6	81.6	85.5	90.6
EUR20	95.9	104.7	74.7	59.7	62.5	72.5	76.4	81.5
EUR6	72.4	81.3	51.2	36.2	39.0	49.1	52.9	58.0
EUR7	58.8	67.7	37.6	22.7	25.4	35.5	39.3	44.4
EUR8	71.6	80.5	50.4	35.4	38.2	48.2	52.1	57.2
EUR9	77.6	86.5	56.4	41.5	44.2	54.3	58.1	63.3

APPENDIX C

Table C.1: Number of Expanding.

Origin	Dest.	Exp.	Origin	Dest.	Exp.	Origin	Dest.	Exp.
EUR6	AS3	76	EUR10	AS9	17	EUR11	AS9	17
EUR7	AS3	215	EUR16	AS5	44	EUR12	AS9	21
EUR8	AS3	246	EUR17	AS5	31	EUR13	AS9	7
EUR9	AS3	13	EUR18	AS5	31	EUR14	AS9	7
EUR10	AS3	38	EUR19	AS5	37	EUR15	AS9	10
EUR11	AS3	38	EUR20	AS5	28	EUR16	AS9	20
EUR12	AS3	24	EUR6	AS6	100	EUR17	AS9	15
EUR13	AS3	8	EUR7	AS6	245	EUR18	AS9	15
EUR14	AS3	8	EUR8	AS6	352	EUR19	AS9	17
EUR15	AS3	34	EUR9	AS6	12	EUR20	AS9	5
EUR16	AS3	42	EUR10	AS6	50	EUR6	AS10	20
EUR17	AS3	16	EUR11	AS6	50	EUR7	AS10	49
EUR18	AS3	16	EUR12	AS6	29	EUR8	AS10	67
EUR19	AS3	28	EUR13	AS6	18	EUR9	AS10	3
EUR20	AS3	15	EUR14	AS6	18	EUR10	AS10	11
EUR6	AS4	76	EUR15	AS6	30	EUR11	AS10	11
EUR7	AS4	215	EUR16	AS6	44	EUR12	AS10	17
EUR8	AS4	246	EUR17	AS6	31	EUR13	AS10	8
EUR9	AS4	13	EUR18	AS6	31	EUR14	AS10	8
EUR10	AS4	38	EUR19	AS6	37	EUR15	AS10	11
EUR11	AS4	38	EUR20	AS6	28	EUR16	AS10	8
EUR12	AS4	24	EUR6	AS7	97	EUR17	AS10	7
EUR13	AS4	8	EUR7	AS7	209	EUR18	AS10	7
EUR14	AS4	8	EUR8	AS7	469	EUR19	AS10	28
EUR15	AS4	34	EUR9	AS7	15	EUR20	AS10	1
EUR16	AS4	42	EUR10	AS7	30	EUR6	AS11	8
EUR17	AS4	16	EUR11	AS7	30	EUR7	AS11	7
EUR18	AS4	16	EUR12	AS7	42	EUR8	AS11	15
EUR19	AS4	28	EUR13	AS7	20	EUR9	AS11	2
EUR20	AS4	15	EUR14	AS7	20	EUR10	AS11	7
EUR6	AS5	100	EUR15	AS7	59	EUR11	AS11	7
EUR7	AS5	245	EUR16	AS7	44	EUR12	AS11	15
EUR8	AS5	352	EUR17	AS7	19	EUR13	AS11	3
EUR9	AS5	12	EUR18	AS7	19	EUR14	AS11	3
EUR10	AS5	50	EUR19	AS7	37	EUR15	AS11	3
EUR11	AS5	50	EUR20	AS7	8	EUR16	AS11	7
EUR12	AS5	29	EUR6	AS9	48	EUR17	AS11	5
EUR13	AS5	18	EUR7	AS9	155	EUR18	AS11	5
EUR14	AS5	18	EUR8	AS9	186	EUR19	AS11	8
EUR15	AS5	30	EUR9	AS9	13	EUR20	AS11	2

APPENDIX D

Table D.1: Travel Time Between O-D Pairs by Private Vehicle during Peak Hours (min).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	55.44	57.63	54.27	68.71	60.58	89.61	96.98	91.61
EUR7	73.13	66.31	65.19	82.47	72.74	96.71	104.19	107.52
EUR8	66.09	70.12	66.01	84.63	76.21	101.55	108.57	101.04
EUR9	67.39	86.70	85.10	91.91	82.54	108.81	114.97	100.52
EUR10	77.96	72.03	75.30	92.08	85.46	109.68	118.56	112.73
EUR11	87.38	83.32	79.62	96.06	93.51	111.42	119.74	120.93
EUR12	91.59	84.95	80.39	100.12	97.43	118.92	128.54	123.44
EUR13	79.95	81.33	76.58	97.62	92.23	117.29	126.16	113.30
EUR14	91.29	108.67	105.48	110.29	103.12	125.36	130.47	117.11
EUR15	97.43	95.88	96.17	112.51	110.02	132.22	138.90	128.12
EUR16	95.54	93.53	91.69	108.26	104.85	125.87	132.57	130.79
EUR17	96.73	91.89	91.18	107.42	104.75	126.41	132.58	128.18
EUR18	101.27	96.14	94.77	111.52	109.00	130.01	135.61	133.86
EUR19	101.07	101.65	101.43	116.92	112.71	129.91	131.29	129.89
EUR20	99.47	104.73	103.36	121.76	116.43	133.91	139.08	129.62

Table D.2: Travel Distance Between O-D Pairs by PrivateVehicle during Peak Hours (km).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	13.15	11.79	13.68	22.53	16.14	25.63	35.08	44.62
EUR7	17.26	13.31	16.57	21.24	22.69	26.76	36.69	43.65
EUR8	14.43	11.95	14.59	21.77	16.69	26.18	39.37	44.09
EUR9	19.15	19.26	21.67	29.44	25.53	33.31	47.58	52.98
EUR10	20.97	17.59	19.79	24.94	23.22	31.05	39.85	47.95
EUR11	21.93	19.95	21.83	26.39	25.53	33.31	42.75	48.80
EUR12	25.74	20.80	24.57	29.77	27.47	35.67	44.46	54.22
EUR13	22.90	20.27	25.42	28.37	29.07	36.32	44.13	55.78
EUR14	30.73	29.56	32.66	39.58	34.96	43.76	58.94	61.74
EUR15	33.03	28.75	31.49	37.17	39.95	42.11	52.08	64.57
EUR16	31.75	27.56	30.14	34.75	36.15	40.23	50.20	57.12
EUR17	30.73	25.79	29.12	33.68	36.20	40.23	49.67	60.13
EUR18	34.87	30.46	33.26	37.81	39.26	43.28	53.26	63.88
EUR19	39.85	33.84	37.70	42.27	43.72	48.27	60.39	71.81
EUR20	38.02	30.68	33.95	44.73	43.88	46.71	56.69	65.81

Table D.3: Travel Time Between O-D Pairs by Private Vehicle during Off-Peak Hours (min).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	32.62	27.34	26.89	34.47	30.84	47.93	54.19	59.61
EUR7	48.85	38.94	38.62	46.29	43.96	59.01	65.42	71.36
EUR8	45.91	35.70	34.86	42.63	40.54	55.85	62.09	67.94
EUR9	42.41	36.68	36.49	43.42	40.62	58.03	63.91	69.81
EUR10	45.04	36.89	36.44	44.23	42.06	57.96	63.44	69.36
EUR11	56.51	50.53	46.98	54.87	52.54	70.14	76.68	86.84
EUR12	54.59	45.89	45.03	52.89	50.70	66.15	72.76	78.52
EUR13	46.76	45.90	45.09	53.07	49.54	66.63	72.60	79.17
EUR14	55.44	54.02	53.48	61.47	58.02	74.78	81.11	87.03
EUR15	58.73	56.30	55.97	65.82	61.09	76.33	82.44	88.73
EUR16	68.04	62.61	58.71	66.06	63.43	78.38	84.12	88.91
EUR17	59.59	53.97	49.69	57.29	54.79	70.87	77.18	82.32
EUR18	69.56	64.59	59.66	67.45	64.40	82.96	88.44	90.82
EUR19	65.99	62.22	61.39	69.58	65.82	83.70	89.96	96.08
EUR20	55.91	53.48	52.93	63.33	58.77	74.82	80.61	87.28

Table D.4: Travel Distance Between O-D Pairs by Private Vehicle during Off-Peak Hours (km).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	14.11	11.70	14.64	20.71	16.85	27.03	35.19	41.67
EUR7	18.07	14.75	18.87	24.25	20.16	29.81	38.50	43.65
EUR8	16.62	11.63	14.53	19.42	17.06	26.60	36.36	41.51
EUR9	21.77	17.26	21.88	27.47	24.46	32.82	42.59	48.06
EUR10	23.22	18.02	21.03	25.86	23.38	33.15	41.30	46.93
EUR11	29.93	23.17	27.14	32.61	30.14	37.65	45.81	52.02
EUR12	27.95	22.20	25.21	30.14	27.56	36.80	46.02	50.57
EUR13	24.25	23.49	27.67	32.61	29.98	39.26	48.48	53.05
EUR14	33.74	33.31	36.32	42.20	39.21	48.16	57.01	61.62
EUR15	35.93	34.48	34.16	39.21	38.18	45.70	54.87	59.74
EUR16	33.52	28.32	31.33	36.15	33.68	42.91	52.02	57.97
EUR17	32.50	26.82	29.81	34.64	32.18	41.30	49.44	55.67
EUR18	36.52	30.78	35.93	38.62	36.15	45.33	53.95	59.74
EUR19	41.83	37.70	40.66	45.49	42.48	52.18	60.29	66.73
EUR20	36.52	35.08	37.97	42.59	38.29	49.56	58.78	63.60

Table D.5: Travel Time Between O-D Pairs by Private Vehicle during Weekend (min).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	44.28	23.78	26.70	34.57	31.90	46.83	52.70	56.35
EUR7	58.53	38.08	40.93	48.85	46.32	61.97	67.70	71.73
EUR8	51.40	33.00	35.82	43.75	41.12	56.83	62.57	65.67
EUR9	40.68	32.67	33.92	41.60	35.82	54.22	59.93	60.93
EUR10	51.02	34.40	37.55	45.12	42.53	58.17	63.93	67.15
EUR11	63.32	47.22	49.67	57.50	55.00	70.40	75.92	80.05
EUR12	65.07	49.07	51.57	59.18	56.65	72.22	77.72	81.85
EUR13	46.25	44.15	46.65	47.97	41.00	60.68	66.45	65.58
EUR14	56.72	55.63	58.38	58.67	51.72	71.25	76.73	76.10
EUR15	56.40	55.38	57.63	57.65	50.80	70.23	75.72	75.28
EUR16	70.23	60.27	63.23	69.83	63.13	84.10	89.42	88.62
EUR17	74.57	58.27	60.80	68.25	65.73	81.12	86.73	91.38
EUR18	70.23	61.73	64.30	71.38	64.85	84.03	89.38	88.90
EUR19	65.67	64.07	66.63	66.97	60.37	79.63	85.28	84.52
EUR20	58.20	57.48	59.90	59.75	52.97	72.47	77.98	77.25

Table D.6: Travel Distance Between O-D Pairs by Private Vehicle during Weekend (km).

	AS3	AS4	AS5	AS6	AS7	AS9	AS10	AS11
EUR6	19.31	9.33	12.87	18.66	16.57	25.42	32.82	38.94
EUR7	24.14	14.16	17.86	23.49	21.40	30.25	37.65	43.76
EUR8	19.47	10.94	14.64	20.27	18.18	27.03	34.43	40.55
EUR9	24.30	16.25	20.60	26.23	27.35	32.98	40.39	52.94
EUR10	27.51	17.38	21.08	26.71	24.62	33.63	41.03	46.98
EUR11	34.43	24.30	27.84	33.63	31.54	40.39	47.79	53.90
EUR12	31.38	21.24	24.94	30.73	28.48	37.49	44.89	50.84
EUR13	25.42	22.85	26.39	34.27	28.48	43.28	50.68	53.74
EUR14	34.11	32.34	35.72	42.80	37.17	51.81	59.21	62.43
EUR15	34.43	30.41	33.95	43.12	37.33	52.13	59.53	62.91
EUR16	40.06	31.21	34.59	49.07	43.28	57.92	65.33	68.38
EUR17	34.27	25.74	29.44	35.08	32.98	41.83	49.24	55.35
EUR18	42.80	30.09	33.79	39.42	45.86	46.18	53.58	71.44
EUR19	39.90	35.88	39.42	48.75	42.96	57.76	65.16	68.54
EUR20	35.88	31.86	35.40	44.73	38.94	53.74	60.98	64.52

Table D.7: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Peak Hours (min).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	33.09	22.06	24.42	-	-
EUR7	24.08	13.49	15.04	-	-
EUR8	35.98	25.21	32.28	-	-
EUR9	24.29	23.66	31.81	-	-
EUR10	13.41	15.51	25.89	-	-
EUR11	9.05	11.99	24.17	-	-
EUR12	7.22	20.49	30.79	-	-
EUR13	29.06	28.61	36.54	-	-
EUR14	34.43	32.97	47.34	-	-
EUR15	34.86	32.76	47.13	-	-
EUR16	26.57	29.80	43.95	-	-
EUR17	15.89	23.47	33.15	-	-
EUR18	27.38	33.23	43.72	-	-
EUR19	32.26	34.67	48.73	-	-
EUR20	32.73	31.41	45.77	-	-
AS3	-	-	-	20.33	33.25
AS4	-	-	-	1.78	17.18
AS5	-	-	-	19.56	5.93
AS6	-	-	-	35.35	24.32
AS7	-	-	-	29.92	27.21
AS9	-	-	-	51.87	39.33
AS10	-	-	-	55.68	45.68
AS11	-	-	-	55.63	50.07

Table D.8: Travel Distance Between Origins or Destinations and Marmaray Stations by PrivateVehicle during Peak Hours (km).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	13.35	7.67	6.11	-	-
EUR7	8.85	3.54	2.25	-	-
EUR8	13.08	7.13	7.29	-	-
EUR9	12.12	10.73	10.78	-	-
EUR10	5.68	4.83	6.76	-	-
EUR11	2.41	2.78	5.95	-	-
EUR12	1.79	7.19	9.81	-	-
EUR13	9.93	10.14	11.38	-	-
EUR14	17.49	17.06	21.45	-	-
EUR15	15.98	15.01	18.46	-	-
EUR16	13.35	16.30	18.23	-	-
EUR17	6.97	11.26	14.05	-	-
EUR18	14.75	18.46	21.24	-	-
EUR19	19.26	22.48	24.73	-	-
EUR20	17.97	17.81	20.92	-	-
AS3	-	-	-	7.08	15.08
AS4	-	-	-	0.60	8.85
AS5	-	-	-	8.25	2.11
AS6	-	-	-	15.93	11.47
AS7	-	-	-	13.19	13.40
AS9	-	-	-	20.16	15.98
AS10	-	-	-	35.45	28.27
AS11	-	-	-	39.63	34.59

Table D.9: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Off-Peak Hours (min).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	33.15	21.30	32.56	-	-
EUR7	19.66	10.96	13.54	-	-
EUR8	31.51	21.41	31.46	-	-
EUR9	24.25	22.62	33.83	-	-
EUR10	13.26	13.57	28.08	-	-
EUR11	7.72	11.49	27.71	-	-
EUR12	7.57	19.72	33.61	-	-
EUR13	27.61	27.98	41.88	-	-
EUR14	34.86	37.69	51.16	-	-
EUR15	31.93	35.59	48.38	-	-
EUR16	26.09	29.76	46.38	-	-
EUR17	15.03	22.15	35.89	-	-
EUR18	23.32	30.26	44.96	-	-
EUR19	32.31	35.90	52.72	-	-
EUR20	31.75	37.15	48.44	-	-
AS3	-	-	-	26.71	34.38
AS4	-	-	-	3.51	17.13
AS5	-	-	-	17.69	7.87
AS6	-	-	-	27.86	19.79
AS7	-	-	-	24.38	20.66
AS9	-	-	-	35.21	27.22
AS10	-	-	-	42.16	33.49
AS11	-	-	-	51.92	42.48

Table D.10: Travel Distance Between Origins or Destinations and Marmaray Stations by Private Vehicle during Off-Peak Hours (km).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	16.14	7.88	9.33	-	-
EUR7	9.98	4.10	1.88	-	-
EUR8	12.28	7.16	7.40	-	-
EUR9	11.86	10.70	11.58	-	-
EUR10	5.91	4.10	7.29	-	-
EUR11	1.88	2.65	6.28	-	-
EUR12	2.01	7.32	10.62	-	-
EUR13	13.15	11.34	15.45	-	-
EUR14	19.52	19.47	23.44	-	-
EUR15	16.30	14.80	19.10	-	-
EUR16	14.21	17.30	18.94	-	-
EUR17	8.00	10.78	14.53	-	-
EUR18	15.01	17.22	21.13	-	-
EUR19	21.08	21.80	25.90	-	-
EUR20	20.71	21.08	25.10	-	-
AS3	-	-	-	9.01	20.64
AS4	-	-	-	1.17	6.65
AS5	-	-	-	8.42	2.75
AS6	-	-	-	15.61	11.31
AS7	-	-	-	12.39	14.21
AS9	-	-	-	21.03	17.06
AS10	-	-	-	29.17	25.42
AS11	-	-	-	35.77	32.66

Table D.11: Travel Time Between Origins or Destinations and Marmaray Stations by Private Vehicle during Weekend (min).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	32.92	20.70	29.18	-	-
EUR7	23.17	14.48	9.85	-	-
EUR8	29.82	17.62	28.87	-	-
EUR9	23.57	19.07	30.32	-	-
EUR10	14.80	14.28	31.92	-	-
EUR11	7.85	10.95	29.60	-	-
EUR12	8.07	20.45	39.63	-	-
EUR13	30.92	29.20	42.38	-	-
EUR14	35.55	33.90	51.07	-	-
EUR15	31.55	29.85	47.02	-	-
EUR16	28.55	35.35	51.55	-	-
EUR17	15.50	21.87	41.05	-	-
EUR18	26.00	32.15	51.28	-	-
EUR19	32.25	37.85	55.15	-	-
EUR20	33.33	31.68	48.83	-	-
AS3	-	-	-	34.78	38.52
AS4	-	-	-	5.62	14.60
AS5	-	-	-	16.68	8.52
AS6	-	-	-	27.00	20.33
AS7	-	-	-	24.27	19.40
AS9	-	-	-	36.13	27.77
AS10	-	-	-	42.32	34.02
AS11	-	-	-	49.13	41.05

Table D.12: Travel Distance Between Origins or Destinations and Marmaray Stations by Private Vehicle during Weekend (km).

	MRT1	MRT2	MRT3	MRT4	MRT5
EUR6	13.35	8.21	6.76	-	-
EUR7	10.30	4.34	1.61	-	-
EUR8	12.07	7.08	7.40	-	-
EUR9	11.75	9.98	10.30	-	-
EUR10	6.11	5.15	8.21	-	-
EUR11	1.77	2.57	6.11	-	-
EUR12	2.25	6.76	10.30	-	-
EUR13	14.32	13.35	17.54	-	-
EUR14	20.43	19.63	22.53	-	-
EUR15	17.38	16.41	19.47	-	-
EUR16	18.50	21.40	20.27	-	-
EUR17	9.01	11.91	15.45	-	-
EUR18	15.29	18.34	21.72	-	-
EUR19	22.53	22.04	25.10	-	-
EUR20	18.99	18.02	20.92	-	-
AS3	-	-	-	10.94	21.56
AS4	-	-	-	1.77	4.51
AS5	-	-	-	7.40	3.38
AS6	-	-	-	16.25	10.78
AS7	-	-	-	14.16	15.45
AS9	-	-	-	21.88	17.86
AS10	-	-	-	29.28	25.26
AS11	-	-	-	36.36	34.27

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Curriculum Vitae

Tests Taken:

High School Entrance Exam of Turkey (LGS): top 1% among 800,000 students
University Entrance Exam of Turkey (OSS): in top 1% among 1,600,000 students
Abitur (German "Reifeprüfung", Durchschnittsnote: 3.9)
YDS (80 Points)
ALES (84 Points)

Schools Attended:

High School: Istanbul Erkek Lisesi (2004–2009)
License: Istanbul Technical University, Control Engineering, Faculty ofElectrical and Electronics Engineering (2009-2014)
Master: Istanbul Technical University, Railway Systems Engineering, GraduateSchool of Science, Engineering and Technology (2014-Present)

International Experiences:

Concern and Location	Date
Hannover to improve language skills	2005
Manchester to improve language skills	2006
New York to improve language skills and for touristic visitation	2008
Copenhagen, Participant at European Union Contest for Young Scientist	2008
Boston to improve language skills and for touristic visitation	2013
Zurich for university visitation	2014
Erfurt/Germany for thesis study	2016

Woking Experiences:

Help Computer[1], Technician, 2004-summer
Istanbul Host[2], Webmaster, 2007-summer
Divit R&D[3], Intern, 2011-summer
Mercedes-Benz Turk A.S. R&D Center, PEP Intern[4], 2012-2014
Ford-Otosan, R&D Center, Product Development Engineer[5], 2014-2014
Turkish-German University, Research Assistant, Engineering Faculty, 2014-Present

[1] Located in Basaksehir/Istanbul/Turkey
[2] http://www.istanbulhost.com/
[3] http://www.divit.com.tr/(Worked as student Intern in an image-processing project.)
[4] Worked as intern in the R&D department of Mercedes Benz Turkey in two different groups. Achieved a control system design project, which is founded by me and supported by my team.
[5] Working on hardware, software development of a control module and its communication in the truck.

Language Skills:

German (fluent)
English (fluent)
Turkish (mother)

Interests:

R&D
Project-Management
Railway Investments
Neuroscience
Mathematics
Cognitive-Science
Control Theory

Skills:

Control Theory
Feedback Control Systems
Transportation Economics
C
C++
MATLAB
Simulink
SciLAB
Artificial Intelligence Algorithms
Social Skills

Honors and Awards:

Title	Issuer	Date
Young Researcher of the Year	Tubitak	2008
1st Place in Project Contest for Young Scientist	Tubitak	2008
Represented Turkey in an International Project Contest	EUCYS	2008
Elected participant to an Entrepreneurship and Innovation Education for Students	Tubitak	2013
Project Founder at R&D Center of Mercedes-Benz Turkey	Merc-Benz Turk.	2013
Finalist at a Contest of Tubitak for License Graduation Projects	Tubitak	2014

Summary:

Interest, knowledge and experience about scientific projects and management of them merged with social skills and a hard mathematics and scientific background from a German high school and a technical university. Special talent to learn about railway investments and management.

References:

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Ali Fuat Ergenç	Assistant Professor ITU	+905326581898 ali.ergenc@itu.edu.tr	Project Supervisor and Lecturer
Hakan Temeltaş	Professor ITU	hakan.temeltas@itu.edu.tr	Lecturer
Hans Werner Müller Poteloin	Retiree Gymnasium Teacher İstanbul Erkek Lisesi	muepot@gmx.net	Supervisor