ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

MICROSIMULATION-based ANALYSIS OF PEDESTRIAN OVERPASS
CASE STUDY: İSTANBUL ŞİRİNEVLER METROBUS STOP

M.Sc. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

YAYA ÜST GEÇİTLERİNİN MİKROSİMÜLASYON TABANLI ANALİZİ

VAKA ÇALIŞMASI: İSTANBUL ŞİRİNEVLER METROBÜS DURAĞI

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NİSAN 2023

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Date of Submission : 05 April 2023
Date of Defense   : 14 April 2023

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To my dear family, beloved friends,

FOREWORD

In the thesis process, I would like to thank my esteemed advisor Prof. Dr. Ali Osman ATAHAN who always answers my questions, allocates valuable time to me, and does not withhold his motivation and support.

Thanks to my father, mother and brother, for supporting and inspiring me throughout my life, accepting me as I am, and giving me a place where I can always come back.

Also, I would like to thank Doç. Dr. Murat ERGUN for the data and support he provided during the writing process of my thesis.

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ABBREVIATIONS

ANOVA	**:** Analysis of Variance
PTV	**:** Planung Transport Verkehr
RMSE	**:** Root Mean Square Error
VISSIM	**:** Verkehr In Städten – SIMulationsmodell
TUIK	**:** Turkish Statistical Institute

SYMBOLS

N   **:** Amount of data

At   **:** Actual data

Ft   **:** Simulation Data

τ   **:** Tau

λm   **:** Lambda_mean

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MICROSIMULATION-based ANALYSIS OF PEDESTRIAN OVERPASS CASE STUDY: İSTANBUL ŞİRİNEVLER METROBUS STOP

SUMMARY

Humanity strives to adapt its environment to its needs and desires. This effort of humanity and its developing needs have enabled it to reveal various highway structures. Overpasses, in other words, pedestrian bridges, are types of structures built from different materials to overcome different obstacles from past to present. Pedestrian bridges were first built-in order to cross the openings that are difficult to pass due to necessity, as stated in the sources. It has been attributed with different functions for different purposes in history and has preserved its importance in every period. Today, the gradual growth of cities and population growth have created different problems in big cities. New urban planning was made with the widespread use of motor vehicles. The complete separation of motor vehicles and pedestrians has created an obligation in this context. At this point, pedestrian overpasses were built to meet this need. Over time, more functions have been attributed in proportion to user needs. With the technological developments, more openings have been passed and simpler solutions have been introduced to meet the increasing demand. Pedestrian overpasses are structures built in metropolitan cities to allow pedestrians to cross wide vehicle roads, railways, tramlines, metro and metrobus roads, and streams. While creating the transition on these lines, priority was given to the built-in front of heavy areas such as schools, hospitals, city centers, and squares. Thus, vehicle and pedestrian traffic are separated from each other. Along with pedestrian overpasses, different solutions have been realized in vertical circulation in the form of stairs, escalators, elevators and ramps. With the increase in material diversity and quality, both the visual effect has been increased and the amount of comfort has been increased by creating different solutions. Pedestrian overpass plans were made out of the needs arising over

time rather than being a planned structure in the cities. In fact, with the increasing traffic and pedestrian density over time, some areas needed to be re-planned and rebuilt. In this study, the old and current condition of the Şirinevler overpass with the alternative overpass solution, which is one of the overpasses with the highest pedestrian density in the city of Istanbul and has been re-planned over the years, has been evaluated. The main reason why the Şirinevler overpass is handled is that it has been the subject of many news in the media over the years, as it is insufficient in the face of increasing passenger demand. Thus, as a result of the analysis of this inadequate bridge, the parameters that an overpass should have and that should be considered during its planning were revealed.

In particular, the Şirinevler overpass, which is integrated with the Aksaray-Atatürk Airport Metro and Metrobus line in terms of the rail system, has a special location in a metropolitan way like Istanbul, as it is integrated with bus and minibus lines in terms of rubber-wheeled transportation. Due to the importance and special location of this overpass, it is necessary to analyze the traffic effect and therefore the effect of pedestrian density on the bridge. PTV VISSIM is a micro-scale multi-modal traffic flow simulation widely used to evaluate traffic conditions. PTV VISSIM is a software that allows the designing of efficient traffic management strategies and testing different structures to achieve a sustainable city logistics and sustainable urban traffic system. One of the most necessary steps for traffic planning; is the evaluation of various traffic management scenarios and taking optimization measures before implementation in order to choose the best alternative. The aim of this study is to design the simulation model of the Şirinevler overpass using the PTV VISSIM microsimulation program in context, and as a result, to compare its old and current condition by presenting a new alternative solution. In line with the results obtained, the parameters that the overpass structures should have according to the location and traffic density were evaluated. Within the scope of the study, a simulation model was created with PTV VISSIM using the minimum parameters that the pedestrian overpass should have and the pedestrian data counted in the Şirinevler overpass in 2016, and different analyzes were made by adapting the same modeling to the current condition of the Şirinevler overpass. The analyzes that emerged through the results obtained with

PTV VISSIM were summarized as Network Performance, Pedestrian Density, Speed, Travel Times, and Area / Ramp Performance Measures.

As a result of this study, it is aimed to present improvement suggestions that can be a reference for similar stops on the Metrobus line in line with the data obtained and alternative solution suggestions.

YAYA ÜST GEÇİTLERİNİN VISSIM TABANLI SİMÜLASYON ANALİZİ VAKA ÇALIŞMASI: İSTANBUL ŞİRİNEVLER OTOBÜS DURAĞI

ÖZET

İnsanlık, içinde bulunduğu çevreyi zaman içerisinde gereksinimlerine ve isteklerine uyumlu hale getirme çabası içinde olmuştur. İnsanlığın bu çabası ve gelişen ihtiyaçları, çeşitli karayolu yapılarını meydana getirmesine sebep olmuştur. Üst geçitler diğer bir adıyla da yaya köprüleri, geçmişten günümüze farklı engelleri aşabilmek için, farklı malzemelerden inşa edilen yapı tipleridir. Yaya köprüleri kaynaklarda belirtilen ilk haliyle ihtiyaçtan kaynaklı geçilmesi zor olan açıklıkları aşabilmek amacıyla tasarlanmıştır. Zaman içerisinde farklı amaçlar doğrultusunda fonksiyonlar yüklenmiş ve önemini her dönemde korumuştur. Günümüzde ise şehirlerin giderek büyümesi ve sonucunda doğan hızlı nüfus artışı, özellikle de büyük şehirlerde farklı problemleri beraberinde getirmiştir. Motorlu taşıtların da artan bu nüfus ile yaygınlaşmasıyla da yeni şehir planlamalarına ihtiyaç duyulmuştur. Motorlu taşıtlarla, yayaların birbirinden tamamen ayrışması bu bağlamda mecburiyet oluşturmuştur. Bu noktada yaya üst geçitleri bu ihtiyaca cevap vermek adına inşa edilmiş en önemli karayolu yapılarındandır. Zaman içinde kullanıcı ihtiyaçlarıyla orantılı daha fazla fonksiyon yüklenmiş ve teknolojik gelişmelerle birlikte de daha fazla açıklıklar geçilmiş, daha basit ve artan talebi karşılamak üzere çözümler getirilmiştir. Yaya üst geçitleri büyükşehirlerde yayaların geniş araç yollarını, tren yollarını, tramvay yollarını, metro ve metrobüs yollarını, akarsuları geçişini sağlamak amacıyla inşa edilmiş yapılardır. Bu hatlarda geçiş oluştururken birincil olarak okul, hastane, şehir merkezleri ve meydanlar gibi yoğun kullanım alanları önüne inşa edilmesine öncelik verilmiştir. Yaya üst geçitleri ile birlikte merdiven, yürüyen merdiven, asansör, rampa şeklinde

düşey sirkülasyonda farklı çözümler gerçekleştirilmiştir. Malzeme çeşitliliği ve kalitesinin artması ile hem görsel etkinin artışı sağlanmış, hem de farklı çözümler oluşturularak konfor miktarı artırılmıştır. Yaya üst geçit planlamaları şehirlerde başlangıçta planlanan bir yapı olmaktan çok zaman içinde doğan ihtiyaçlardan kaynaklı yapılmıştır. Hatta zaman içerisinde artan trafik ve yaya yoğunluğu ile birlikte bazı bölgelerde tekrar planlanmaya ihtiyaç duyulmuş ve tekrar inşa edilmiştir. Bu çalışmada da İstanbul şehrinde yer alan ve en fazla yaya yoğunluğuna sahip üst geçitlerinden birine sahip olan ve yıllar içinde tekrar planlanarak inşa edilen Şirinevler metro ve metrobüs durağı bağlantısı üzerinde yer alan üst geçidin eski hali ve mevcut durumu PTV VISSIM programı ile simüle edilerek analizi yapılmış, alternatif bir üst geçit modeliyle de yeni bir çözüm önerisi sunulmuştur. Özellikle Şirinevler üst geçidinin ele alınmasının başlıca sebebi, artan yolcu talebi karşısında yetersiz kalması sebebiyle yıllar boyunca medyada da birçok habere konu olarak yaya trafiği konusunda yetersiz kalmasıdır. Böylece bu yetersiz kalan köprünün analiz edilmesi sonucunda aslında bir üst geçidin sahip olması gereken ve planlanması esnasında göz önünde bulundurulması gereken parametreler ortaya konmuş, yeni çözüm önerisiyle de yaya trafiğinin minimuma indirilebilmesi için alternatif sunulmulmuştur. Özellikle de raylı sistem anlamında Aksaray-Atatürk Havalimanı Metro ve Metrobüs hattı ile entegre olan Şirinevler üst geçidi, lastik tekerlekli ulaşım anlamında otobüs ve minibüs hatlarıyla entegre edilmiş olması nedeniyle İstanbul gibi metropol bir şekilde özel bir konuma sahiptir. Bu üst geçidin önemi ve özel konumu nedeniyle, trafik etkisinin ve dolayısıyla da yol açtığı yaya yoğunluğunun köprüye olan etkisinin analiz edilmesi gerekmektedir. PTV VISSIM, trafik koşullarını değerlendirmek için yaygın olarak kullanılan mikro ölçekli çok modlu trafik akış simülasyon olup, sürdürülebilir bir kentsel trafik sistemi ve sürdürülebilir bir şehir lojistiği elde etmek amacıyla, verimli trafik yönetimi stratejileri tasarlamaya ve farklı yapıları test etmeye olanak tanıyan bir yazılımdır. Bu çalışmanın amacı, Şirinevler otobüs durağının bulunduğu üst geçidin PTV VISSIM yazılımı kullanılarak simülasyon modelinin bağlam içinde tasarlanması, bunun sonucunda da eski ve mevcut halinin karşılaştırmasının yapılması, geliştirilen alternatif üst geçit modeliyle de yeni bir çözüm önerisinin sunulmasıdır. Elde edilen sonuçlar doğrultusunda üst geçit yapılarının bulunduğu konum ve trafik yoğunluğuna

göre sahip olması gereken parametreler değerlendirilmiştir. Çalışma kapsamında yaya üst geçidin sahip olması gereken minimum parametreler ile 2016 yılında Şirinevler üst geçidinde yapılan yaya sayımı verileri kullanılarak simülasyon modeli oluşturulmuştur. Aynı parametreler doğrultusunda geliştirilen simülasyon modelleri Şirinevler üst geçinin mevcut haline ve öneri olarak geliştirilen alternatif üst geçit modeline de uyarlanarak analizler yapılmıştır. PTV VISSIM yazılımı ile elde analiz sonuçları; yaya hızları ve yoğunluğu, seyahat süreleri, duraklamalar ve durma süreleri parametrelerine göre değerlendirilerek özetlenmiştir. Bu çalışma sonucu, elde edilen veriler ve alternatif çözüm önerileri doğrultusunda metrobüs hattı üzerinde bulunan benzer duraklar için de referans olabilecek iyileştirme önerileri sunmayı hedeflemiştir.

1. INTRODUCTION

Pedestrians are among the most vulnerable to traffic injuries. In order to reduce the high rate of pedestrian fatal accidents, many solutions are being considered and some measures are implemented at the same time. Pedestrian underpasses and overpasses, which are expected to give the most successful results from these measures, eliminate the possibility of accidents by separating pedestrian traffic and vehicles.

Today, pedestrian bridges are very important structures in terms of facilitating the transportation of pedestrians in heavy traffic and providing safe pedestrian transportation. According to the definition in the Highway Traffic Regulation in Turkey, overpass; it is a structure that allows the highway to pass over another highway or railway.

In other words, pedestrian overpasses are engineering structures designed as a solution in the context of pedestrian safety and continuity of roads, especially in heavy traffic areas. The functional purpose of pedestrian overpasses; facilitating continuity or uninterruptedness in transportation, directing pedestrians to the locations they want to go safely. In addition to being transportation structures on roads open to vehicle traffic, they are urban reinforcement elements that can affect the view of the city with their aesthetic aspects.

Pedestrian overpasses have a symbolic value as well as a functional one. In developed countries, heavy vehicle traffic is solved by traffic signaling, not being allowed into the city. In our country, increasing vehicle traffic enters the city and intersects with pedestrian axes. As a result, it has become necessary to build many pedestrian overpasses in city centers (Sütiçen, 2008).

These overpasses are built to provide a comfortable passage for pedestrians without interfering with vehicle traffic. Pedestrian overpasses have become an important part of traffic in many cities of our country with various examples. However, it is observed that there are planning, technical implementation and aesthetic problems in many of these overpasses.

One of the biggest problems in the pedestrian overpass, which is also the subject of this study, is the planning and design problems. Site selection, problems encountered

as a result of incomplete or incorrect analyzes in terms of traffic and pedestrian transportation, problems arising from the approach of pedestrians to the overpass and usability can be counted among the main planning and design problems.

In addition to these design and planning errors, the high rate of population growth in and around Istanbul causes various problems, especially in the field of transportation. As the population increases, the mobility of the population's travel movements will increase, which will put a strain on the existing road network infrastructure. Since transportation is the economic pulse of a city, the presence of transportation is very important. Therefore, the efficiency of the performance of urban transport systems requires efforts to support the economic growth of a city or region.

Microscopic simulation models are admitted as the most suitable analytical tool to understand the capability problems of vehicle and pedestrian traffic and to evaluate the effectiveness of remedial measures accordingly. There are many studies on this subject in our country and in the world. In this article, analyzes were made for the old condition of Şirinevler overpass, which had the problems listed above, and the new condition, which was designed by taking remedial measures, using the microscopic simulation model.

According to Drew (1968), a simulation is defined as "a dynamic representation of some part of the real world achieved by building a computer model and moving it through time". The goal of a simulation study is typically to improve understanding of how a system proceeds, to evaluate the impact of changes in the system or in the values of the parameters that govern the system, or in decisions on the policies that control the system.

The use of traffic simulation systems started in 1955. In parallel with the development of computer hardware and software technologies, traffic simulation systems have also developed rapidly in the following years. Even though there are many various types and uses for microscopic simulation models, only a small number of these models are well developed with user-friendly interfaces and instructions. VISSIM is defined as a traffic microscopic simulation software extensively used to estimate current traffic conditions. It is especially useful to evaluate different traffic management scenarios to select the best alternative and optimization methods before implementation.

This article creates solutions with pedestrian overpass models in PTV VISSIM microsimulation. The continuation of this thesis, which was written to compare and evaluate the results obtained from different overpass models on the Şirinevler example,

is as follows: Chapter 2 reviews related studies on the pedestrian overpass and simulation methods; Chapter 3 presents a case study and simulation steps; Chapter 4 introduces the methodology used in this study. Chapter 5 presents an evaluation of the results; Chapter 6 includes an interpretation of the results and summarizes the thesis's primary conclusions as well as future study prospects.

2. LITERATURE REVIEW

In this section we are going to talk about the previous pedestrian overpass design and VISSIM simulation studies.

The first study on the pedestrian overpass was made in 1965 by Moore and Older. In this study, Moore and Older evaluated the use of overpasses in terms of time. The correlation they call the Consistency Ratio (R) is obtained by dividing the pedestrian crossing time over the overpass by the road crossing time. If the pedestrian overpass usage is R≥1.5, it is expected that the overpass usage will be very low; In case of R~1, the overpass utilization rate is expected to be quite high. (Moore R, Older S., 1965)

In addition to observations, survey studies were also included in the studies on the use of overpasses. Thus, it has been tried to reveal what kind of features affect the use of overpasses by pedestrians. Sisiopiku and Akın conducted research via electronic survey in order to examine the behaviors of pedestrians and to reveal the factors affecting these behaviors. 41% of the surveyed pedestrians cross the road from any suitable place; 61% stated that when any suitable gap occurs in the traffic, 46% stated that they sometimes do it from areas without pedestrian crossings. Pedestrians explained the reasons for illegal crossing from the road as 42% proximity to their target points, 27%-time savings and 30% no risk. (Sisiopiku V, Akin D., 2003)

In a study conducted in Colombia, data obtained from surveys showed that 48% of pedestrians found the traffic in the area dangerous and 14% found the overpass very dangerous. In the study, it was observed that pedestrians who were injured during their crossing at the road level and who found the overpass safe preferred to cross with rules. (Oviedo-Trespalacios O, Scott-Parker B, 2017)

In another study conducted in Bitola City, the second largest city of Macedonia, it was concluded that the crossing facilities available for pedestrians at the location were below the planned service level. The historical record of accidents near the location is a serious factor in demonstrating the need to provide transit assistance.

According to the results proposed by this research, the methodology for selecting a crosswalk is quite extensive. For this purpose, VISSIM microscopic simulation was

used to model alternatives under different pedestrian and vehicle volumes. The evaluation process of the alternatives was carried out by comparing the pairs of criteria by calculating the weights of the criteria and alternatives based on the survey results for different target groups such as citizens, professionals, the disabled and the healthy. As a result, it has been concluded that professionals give priority to traffic safety and overpasses.

It was underlined that the acceptance of sustainability concepts was influenced by the worsening of transportation issues and the requirement for a new strategy for mobility planning; consequently, a number of studies presenting various definitions came to be. (Talevska J.B., Ristov M., and Todorova M.M., 2019)

According to Campos (2005), the inclusion of sustainable mobility in a region's sustainability assessment can be viewed as a strategy to encourage land usage and the decline in the use of private vehicles in conjunction with transportation policies that improve access to land. Orientation of the public toward activities that emphasize walking and cycling more than other modes of transportation.

As sustainability concepts are discussed more and studies on this subject get deeper, there is a need for practical tools to support the process. In this context, attention has been drawn to the development of sustainability indicators, which are brought together in different forms and in different structures, and which assist politicians, planners and managers in dealing with the complexity of cities' current problems. (Gudmundsson, 2004).

In another article, Campos (2005) came to the conclusion that in order to achieve sustainable mobility in the social, economic, and environmental context, we can identify strategies aimed at: urban development toward transportation; promoting short-distance travel; enforcing vehicle use restrictions; an adequate supply of public transportation; an adequate tariff for the supply and demand of public transportation; safety for pedestrians, cyclists, and people with reduced mobility; safety in public transportation; and investments in public transportation.

In order to create a sustainable transportation system in line with all this main idea, the integration of public transportation systems and each other, therefore, pedestrians and pedestrian areas of use at the intersection of all these systems are of great importance. (Akyüz, B., Aydemir, K.P., Akdemir, Ç., Yılmazsoy, B., Güler, S., 2018) It has been emphasized that public transportation systems provide solutions to many urban problems in terms of improving environmental awareness, preventing urban sprawl

with clogged roads, population, size of the city, cost, need for accessibility and creating corridors.

The continuation of the study continues in this way; In megacity Istanbul, the success of public transportation in reducing urban systemic access and pedestrian vehicle usage is undeniable. In the integration of the Metrobus line with other modes of transportation, it is seen that it serves in integration with the highway and the rail system. The fact that the Metrobus line is completely separated from the traffic in terms of its holistic street design is also important in terms of transportation reliability. In addition, in most of the urban journeys, pedestrians reach the public transportation stops and stations on foot. It has been observed that 'pedestrian accessibility' at Metrobus stations is met with stairs, pavements, walking paths, pedestrianized areas, pedestrian bridges, and platform areas. Turnstiles are used at the entrances and exits to the station areas. Throughout the entire BRT line, pedestrian guardrails have been applied at the entrance of the platform areas and at the continuation of the stairs at almost every station. This is a positive development in terms of pedestrian safety (Akı, 2012).

In the road safety investigation study carried out in partnership with EMBARQ Turkey and CONSIA Consulting in 2014, critical points were determined along the metrobus line in terms of safety, capacity and operation, and recommendations were developed for these areas. In particular, features that need to be improved have been identified in order to make passenger boarding and alighting safer and more comfortable at the stations. The first of these is the direct and good design of passenger access to the station areas. In this context, three recommendations have been developed. These; Connecting the metrobus station areas with overpasses and IETT (Istanbul Electric Tramway and Tunnel Operations) bus lines, updating the locations of the IETT bus stops around the metrobus, expanding the pedestrian areas, sidewalks, and rearranging them to allow pedestrian movements. In this context, it was stated that corrections were made especially at the heavily used metrobus transfer points.

The second point stated in the EMBARQ report is to provide access to the stations via overpasses or underpasses, and in this sense, the implementation of elevators and ramps for disabled, baby carriage and elderly people to access the stations. The third regulation mentioned in the report is the expansion of the platform areas at the intensive use stations. In addition, passenger entry-exit directions are reserved at some stops in order to reduce the density at BRT stations (EMBARQ, 2014).

At the beginning of the 2000's, studies have gained importance in Turkey, especially in the context of the accessibility of the disabled. For example, in the planning of walking areas, care should be taken that the slope is not more than 1/12, platforms such as steps and paving stones and arrangements that prevent the passage of wheelchairs and prams should be avoided. Especially on corner turns, ramping increases accessibility (EMBARQ, 2015). Therefore, the quality of the pedestrian network is directly related to the physical design quality of the streets; In addition, for "Barrier-Free Movement", people of all ages and abilities should be provided with the opportunity to walk in the space uninterruptedly and unhindered (Akkar Ercan and Belge, 2017). For the pedestrian-oriented solution of the urban space, the pedestrian access network must be directly linked to different modes of transport. For this, non-motorized transportation vehicles, public transportation (bus, minibus, train, tramline, metro, etc.) and private vehicles are articulated; public transportation stops, parking lots, transfer centers such as train stations and bus terminals are integrated with the pedestrian transportation system; A holistic and comprehensive transportation plan is needed that puts the pedestrian at the center of the transportation strategy.

(Merve Akı, 2012) In the study titled Evaluation of Pedestrian Accessibility of the Istanbul Metrobus System, a survey study was conducted by selecting different parameters regarding the overpass, and as a result, a general evaluation was made.

The Şirinevler overpass, which is integrated with the Aksaray-Atatürk Airport Metro and Metrobus line in terms of rail system, is integrated with bus and minibus lines in terms of rubber wheeled transportation. As a result of the survey studies, the most basic problems of Şirinevler station and its close surroundings; It has emerged as the lack of access facilities suitable for the disabled and the pedestrian density experienced in the overpass area during peak hours. In this context, survey participants specifically stated that it is necessary to make arrangements for the disabled. However, it has been revealed that Şirinevler overpass is one of the highest passenger density, causing pedestrian congestion in the overpass and stop platform area.

Şirinevler station and its surroundings do not provide the basic features of pedestrian access, as they do not allow for ideal walking speed and cause especially heavy pedestrian queues. In addition, it has a positive quality with its convenient walking distances and the fact that the walking environment is lively as a result of the mixed function of the area due to the land use structure of the area. Routes used by pedestrians to access Şirinevler station comply with the criteria of continuity, clarity and

immediacy. While the bus stop and its surroundings create a pleasant environment in general, the increase in this density at peak hours turns into serious problems and elements that threaten the safety of pedestrians. It can be said that this situation seriously affects comfort level.

In this section, we are going to talk about the previous studies on pedestrian simulation with PTV VISSIM and the implemented methodologies.

(Qin and Xiong, 2006) chose VISSIM to evaluate some schemes in their scientific research on traffic rehabilitation in Kunming, southern China. With the simulation application of one-way plans, they introduced a new assessment to evaluate traffic management plans under complex traffic conditions. As a result, they have proven that VISSIM can offer some decision-making bases for traffic management departments.

(Muhammed and Robert, 2009) presented a method to include pedestrians in the VISSIM model. After defining pedestrians as vehicles, they calibrated different parameters in VISSIM to calibrate pedestrian behavior with pedestrian speed-flow models. Their study, using a real traffic network with high pedestrian traffic crossing, provides the feasibility of realistically modeling vehicle-pedestrian interactions.

(Gai, 2005) stated with his work that VISSIM is the most advanced and greatly used microscopic traffic simulation software. It proposes to expand its application in China by introducing the modules, function and application area of VISSIM.

(Kaveh and Jinwoo, 2011) explore possible conversion tools and integration alternatives, as well as a comprehensive set of traffic and network simulators. They state that microscopic traffic simulators such as VISSIM, AIMSUM, PARAMICS are extensively used as an analysis tool in transportation design as well as evaluation, and then explain some of the key features of VISSIM.

In summary, based on the literature review, there has been a good deal of research on sustainable transportation, including pedestrians, on road network analysis using microscopic software such as VISSIM, both in theory and in practice.

3. CASE STUDY: ŞİRİNEVLER OVERPASS

This thesis focuses on the simulation data obtained with VISSIM in order to reduce the density by planning the pedestrian traffic more accurately with the new alternative overpass model developed, while making a comparison for the old and new conditions of the Şirinevler overpass, which has the highest pedestrian density in Istanbul, Turkey. The Şirinevler overpass, which is integrated with the Aksaray-Atatürk Airport Metro and Beylikdüzü-Uzunçayır Metrobus line in terms of rail system, is integrated with the bus and minibus lines in terms of rubber-wheeled transportation. The most important problems of Şirinevler station and its surroundings; It was known as the lack of access facilities suitable for the disabled and the pedestrian density experienced in the overpass area, especially during rush hours. Şirinevler station and its surroundings did not provide the basic features of pedestrian access well, as they did not allow ideal walking speed and caused especially heavy pedestrian queues. This situation, which was caused by the density, was turning into serious problems and threatening the safety of pedestrians. It can be said that this situation seriously affects comfort level.

Figure 1 : Location of the Şirinevler overpass

The below diagrams show the Şirinevler square and the pedestrian stations near the Şirinevler pedestrian overpass, where it interacts heavily, such as the bus, metro, and metrobus line.

Figure 2 : Pedestrian access scheme for Şirinevler overpass

Figure 3 : Pedestrian stations and square where the overpass interacts

3.1 Framework of Pedestrian Analysis Steps

The framework of this study is given in Figure 4. This shows that the first stage of the analysis is the procedure of collecting data from the real world. The next step consists of defining the flow parameters for the data extraction procedure. In addition, a VISSIM model was created using these observed parameters. After the model development, the values of the parameters obtained as a result of the simulation of the three overpass models were compared with the pedestrian characteristics.
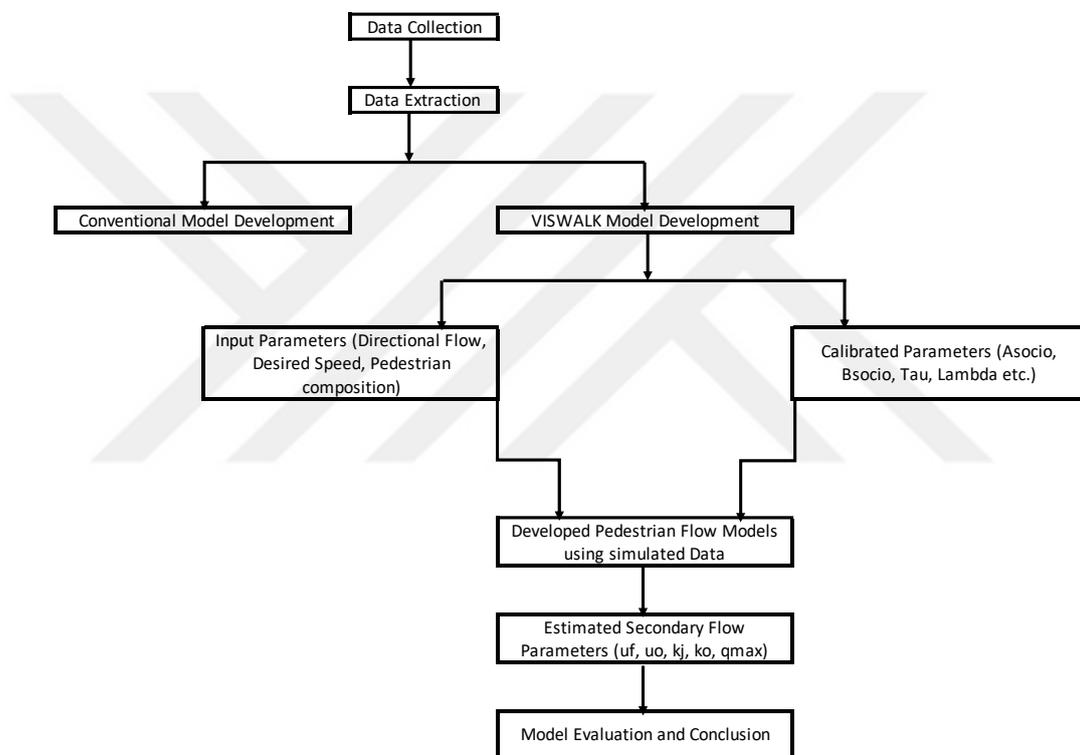
```
                    Data Collection
                          |
                    Data Extraction
                          |
         ┌────────────────┴────────────────┐
Conventional Model              VISWALK Model
  Development                     Development
                                      |
                        ┌─────────────┴─────────────┐
              Input Parameters (Directional    Calibrated Parameters
              Flow, Desired Speed,             (Asocio, Bsocio, Tau,
              Pedestrian composition)          Lambda etc.)
                        └─────────────┬─────────────┘
                        Developed Pedestrian Flow Models
                              using simulated Data
                                      |
                        Estimated Secondary Flow
                        Parameters (uf, uo, kj, ko, qmax)
                                      |
                        Model Evaluation and Conclusion
```

Figure 4 : Framework of Pedestrian Simulation Steps

3.2 Determination of Measures of Performance

The first stage in the calibration and verification procedure is to choose the right performance measures for the two processes. Both input factors that can be controlled and performance measures that cannot be controlled should be identified. The performance measure selected for the calibration and validation process for this study was the pedestrian travel time between two data collection points in the network. The objective behind selecting the performance measure was that it should be selected from the list of simulation results and that real system data may be measured and collected with high accuracy.

3.3 Data Collection (Traffic Counting)

The simulation program's input parameters and output performance measurements have to be measured in order to calibrate and validate the microscopic simulation model. The field was to be used to collect performance measurements and uncontrollable input parameters. The geometry of the current overpass and the number of pedestrians are uncontrollable input variables. Data were collected during peak hours to analyze the performance of pedestrians on the sidewalk at Şirinevler overpass.

Figure 5 : Şirinevler Metrobus station connection

Flow velocity values were estimated in terms of pedestrians per minute (P/min/m) per meter indicated below table as categorized all pedestrians, taking into account the effective walkway width. Effective walkway width can be defined as the width of a facility that can be used effectively by pedestrians after deducting the hesitant departure distance.

Table 1 : Şirinevler Overpass Pedestrian Number (max per day)

Time	Number of pedestrians
Morning time (max)	4150
Morning time (average)	3444
Nighttime (max)	4012
Nighttime (average)	3206

This pedestrian count, which is made during the peak hours of the Şirinevler overpass, is based on the selected gender, age, and load status shown as the below table. They were grouped in order to be able to determine the pedestrian speeds in a correct way in line with the selected criteria and to reflect them in the analysis.

Table 2 : Şirinevler Overpass - Age and Gender Distribution of Pedestrian Numbers

Age and Gender Distribution	Number of pedestrians
Woman	2282
Man	1868
Single	3901
≥ 2	249
10-19	872
20-64	2614
65+	664
With Load	3154
Without Load	996
Total	4150

In the graph below, the average crossing speed rates of pedestrians counted according to age, gender and load status were determined separately and evaluated in line with these parameters in the analysis.

Table 3 : Şirinevler Overpass - Average Crossing Speeds (m/s)

Age and Gender Distribution	Speed of pedestrians (m/s)
Woman	1.50
Man	1.74
Single	1.72
≥ 2	1.45
10-19	2.06
20-64	1.67
65+	1.42
With Load	1.32
Without Load	1.64

Figure 6 : Şirinevler overpass
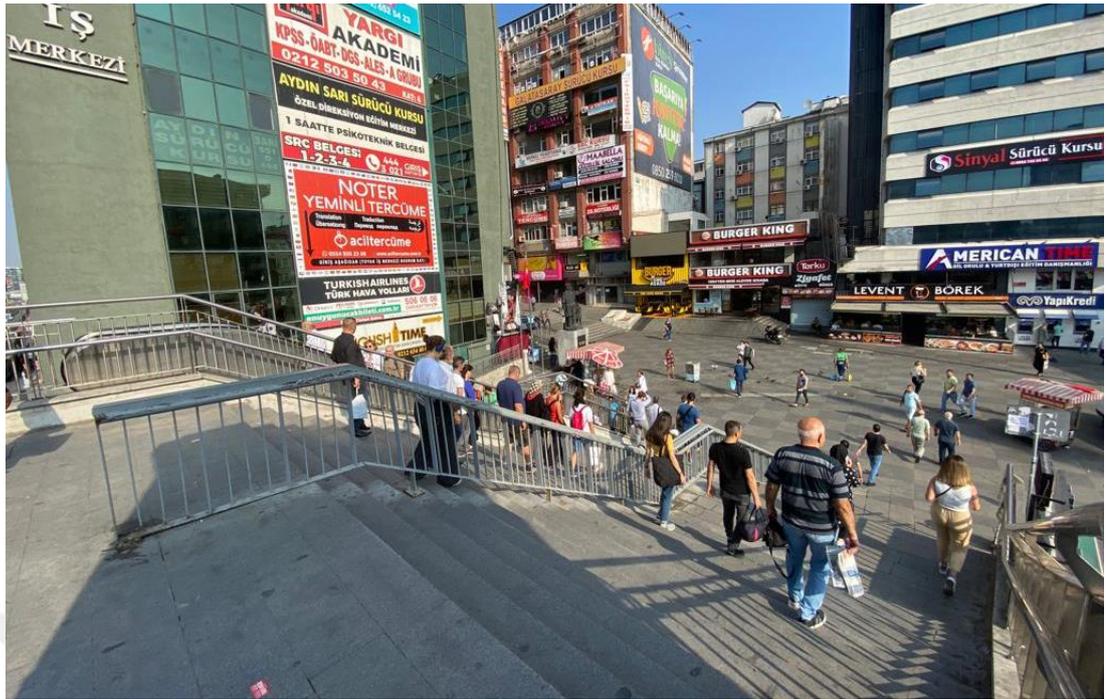
Figure 7 : Şirinevler square connection
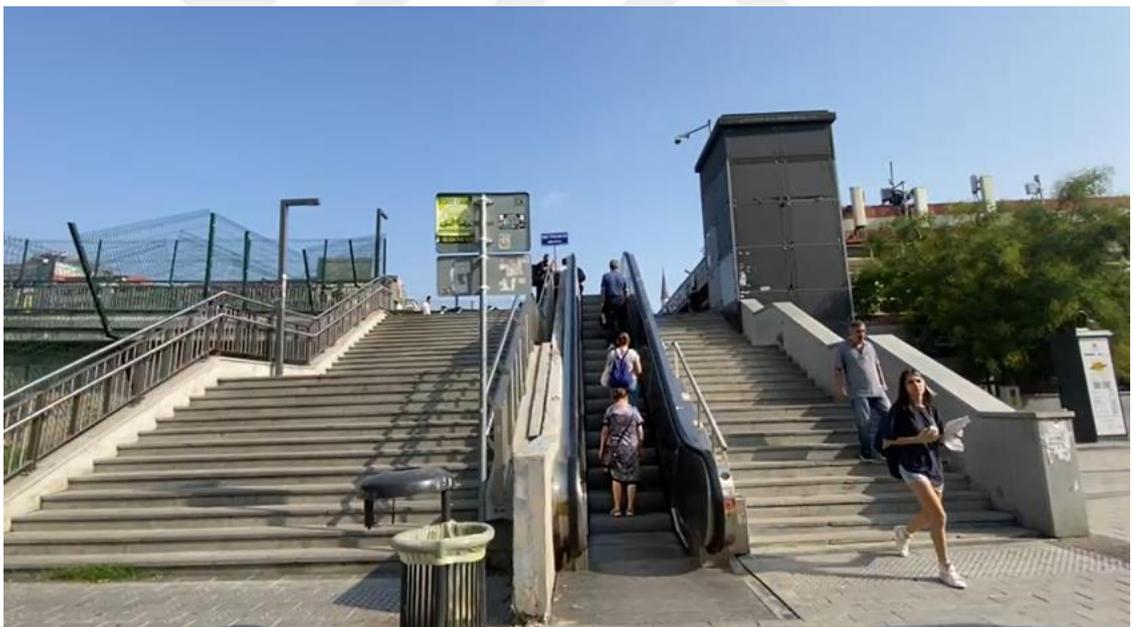
Figure 8 : Ataköy connection

Figure 9 : Ataköy Metro station connection

In order to examine the current condition of Şirinevler pedestrian overpass, the camera was put in order to measure pedestrian movements. As a result of the counts obtained as a result of the measurements, it was observed that the counts between 17:00-18:80 on Friday evening took the maximum values and reached the volumes specified below. In Figure 10, 11 pedestrian movement volumes in different sections of Şirinevler Pedestrian overpass are given.
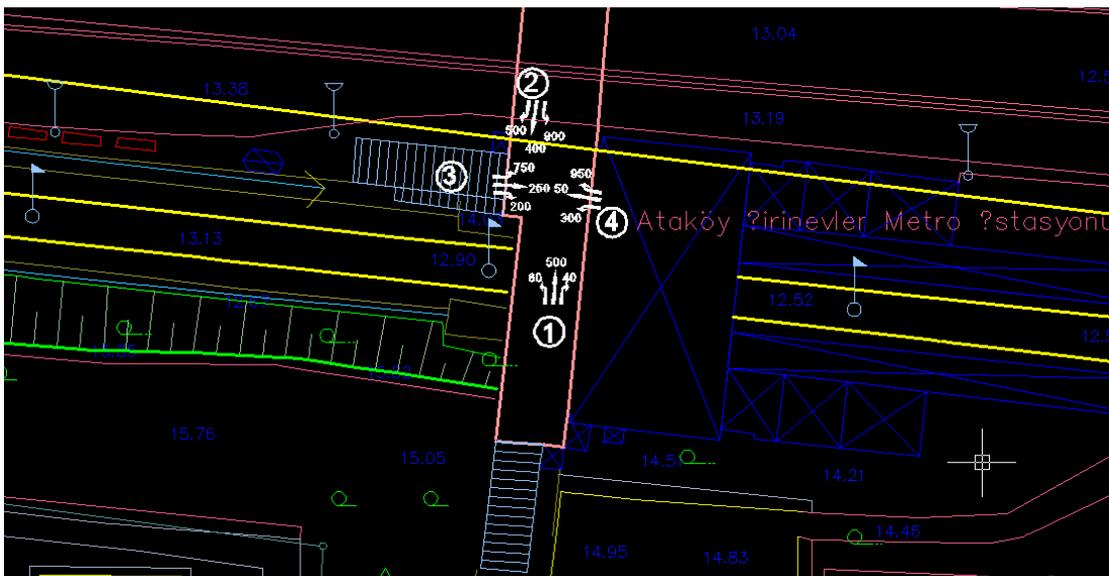
Figure 10 : Pedestrian movements in Ataköy section for old condition
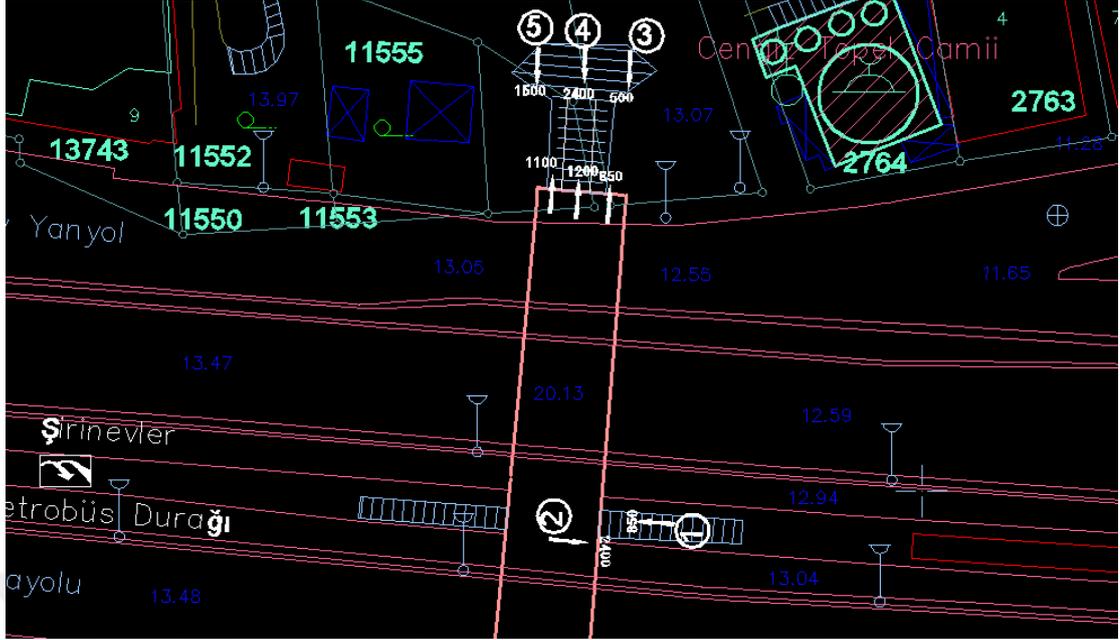
Figure 11 : Pedestrian Movements in Şirinevler Square Section of Şirinevler Pedestrian overpass for old condition

These pedestrian counts were made in 2016 for the analysis of the old state of the overpass, and these data were used to analyze the old condition in VISSIM.

Table 4 : Istanbul human population according to the years

Year	Istanbul Human Population
2022	16,228,610*
2021	15,840,900
2020	15,462,452
2019	15,519,267
2018	15,067,724
2017	15,029,231
2016	14,804,116

Prediction value regarding estimation of previous years

The population of Istanbul for the 2021 and earlier years was reached by using the data of TUIK "Provincial/District Center, Town/Village Population and Annual Population Growth Rate by Province and Districts". The average of these increase rates was accepted as 1,025 and the population of Istanbul was estimated for 2022. The table above summarizes the population of Istanbul by years.

Since the analysis of Şirineveler overpass was performed in VISSIM simulation in 2016 and 2022, the ratio for linear increase between these years was taken as 1.08 and adapted according to the current overpass.

Figure 12 : Sidewalk at Şirinevler overpass in 2016

Figure 13 : Sidewalk at Şirinevler overpass in 2022

3.4 Pedestrian Simulation Using Real Data

Ten walking behavior factors from the VISSIM microscale program are used to analyze how pedestrians move in relation to each other and the environment. (PTV AG, 2015), according to:

1) Tau (τ): This parameter, which relates the difference between the desired speed and direction with the current speed and direction for acceleration, reflects the relaxation time or inertia that can be related to response time.

2) Lambda_mean (λm): This variable controls the degree of anisotropy in the forces resulting from the fact that a pedestrian's psychological and social responses to events and occurrences are less affected when they are out of his line of sight.

3) A and B social isotropic: These variables, along with lambda, affect one of the two forces that makes up the repulsive force between two pedestrians.

4) A and B social mean: The strength of the force is determined by the parameter A social mean, and its range in meters is determined by the parameter B social mean.

5) Noise: The random force term's strength is controlled by this variable. The random force that is added to the forces that are consistently calculated when a pedestrian deviates from his desired speed for a predetermined period of time increases in strength with the parameter value.

6) React to n: The maximum number of pedestrians to be taken into account when calculating the social force is set by this parameter. Only the influence of the n closest pedestrians is taken into consideration when calculating the total force for a pedestrian.

7) VD: This parameter will define how much time a pedestrian needs to avoid other pedestrians walking in his direction, along with the A and B social means.

8) Side preference: This parameter determines whether competing pedestrian flows choose to pass each other on the right or left: The behavior is the same as before: pedestrians do not avoid one another. The values -1 stand for preference of the right side, 1 for preference of the left side, and default 0 is no preference.

9) Queue order: This parameter, which takes values between 0.0 and 1.0, describes how ordered the line of pedestrians is. The more pedestrians line up one behind another in line, the higher this value.

10) Queue straightness: With values ranging from 0.0 to 1.0, this option determines how the queue will look. The queue will appear more straight as the value increases.

The determination of the density value for each segment, the errors in the data presented for pedestrians on the overpass were evaluated using the VISSIM software, taking the values in the study for the Old Ottoman Pedestrian Bridge of Mostar as reference.

Table 5 : Specific pedestrian parameters of VISSIM tool

Viswalk Parameters	Default	Normal
tau (τ)	0.40	0.06
react_to_n parameter	8	4
ASocIso	2.72	1
BSocIso	0.20	0.10
Lambda (λ)	0.176	0.176
ASocMean	0.40	0.40
BSocMean	2.80	2.80
VD	3	9
Noise	1.2	1.2
PrefLato	nothing	nothing

To analyze the simulated walking speed and to control some social force model parameters, a sensitivity analysis was done. Sensitivity analysis seeks to enhance decision-making, particularly by assessing the accuracy of the chosen plan of action. It also draws attention to elements whose value merits a more accurate estimation and which should be strictly controlled during the research phase. In particular, the parameter values in the above table were altered one at a time in an effort to produce trustworthy outcomes that were comparable to the actual ones. As a result, the examined characteristics were chosen because they could influence the simulated walking speeds of the model's people. For every parameter, different modifications were done. Parameter values were examined, around the chosen values utilized for speed calibration and pedestrian type survey.

The comparison between the real value and the simulated one was carried out considering microscopically data and validated using Root Mean Square Error (RMSE) procedure to calibrate the model parameters and optimize the model like described in Equation (Adwitiya R.I., Sumabrata R.J., 2022)

$$RMSD = \sqrt{\frac{\sum_{t-1}^{T}(x_{1,t} - x_{2,t})^2}{T}} \qquad\qquad (3.1)$$

Therefore, the RMSE is a verification method in determining the accuracy of the estimation results by finding the average square of the error. It is important to note that a low RMSE value indicates the results are close to the real condition.

Where:

N = Amount of data

At = Actual data

Ft = Simulation Data

An RMSE value below 10% means the model is accepted, while the value above 10% indicates the model is rejected and needs to be reviewed.

3.5 Evaluation of Candidate Parameter Sets with Simulation

In this step, it was made to verify whether the parameter sets defined in the previous step produced statistically significant results and to compare and interpret the simulation models described in detail below according to the determined parameters such as pedestrian speed, travel time, and density. In line with all these collected data and optimization, the following models were created for the old and current conditions of the Sirinevler overpass with a new overpass alternative by using VISSIM.

Figure 14 : Old condition of the Şirinevler overpass in VISSIM simulation
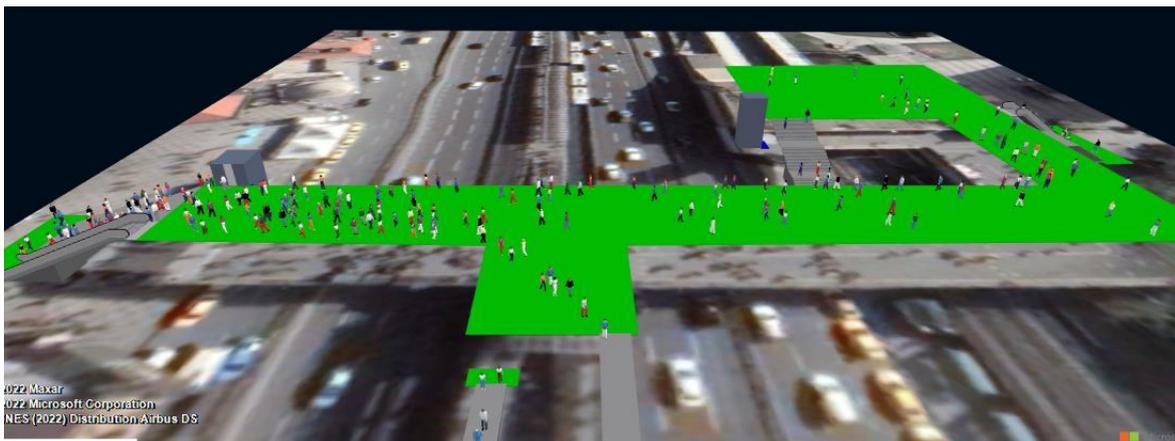
Figure 15 : Current condition of the Şirinevler overpass in VISSIM simulation
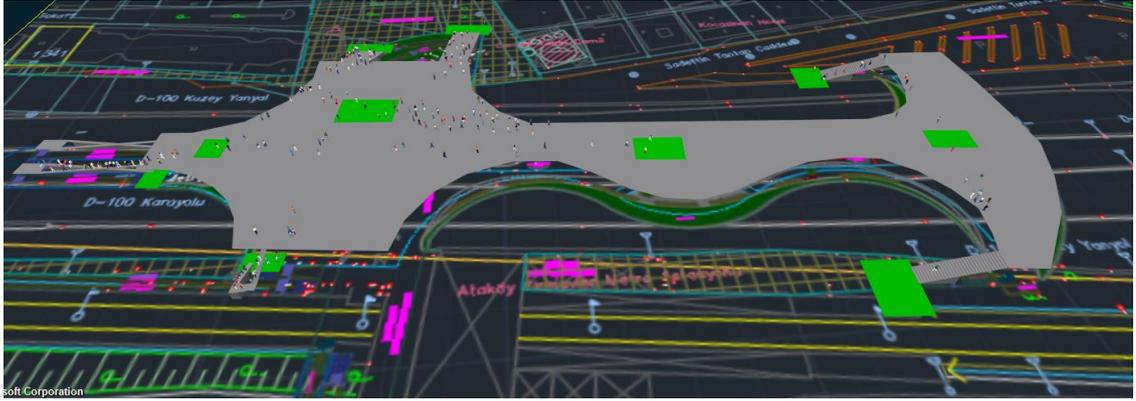
Figure 16 : Alternative solution of the Şirinevler overpass in VISSIM simulation

Figure 17 : Alternative solution of the Şirinevler overpass analysis

With this alternatively developed new solution, it has been tried to prevent pedestrian accumulation by making expansions on the platform in a way that will not cut the main axles in places where pedestrian density will be high. The combination of the exits that can be provided from both ends of the Metrobus stop on the upper platform will enable all these entrances and exits to be used actively.

4. DEVELOPMENT OF THE VISSIM SIMULATION MODELS

Network modeling is done using VISSIM microsimulation. The network modeling phase consists of four stages: network coding, calibration and validation of the old, current and alternative overpass models, model development, and comparison of performance measures in these models. Figures 18, 19 and 20 show a screenshot of the Şirinevler overpass models. The pedestrian simulation model was calibrated and validated before implementation to analyze the current condition and alternative solution.

Figure 18 : Current condition of the Şirinevler overpass in real and simulation

Figure 19 : Old condition of the Şirinevler overpass in real and simulation
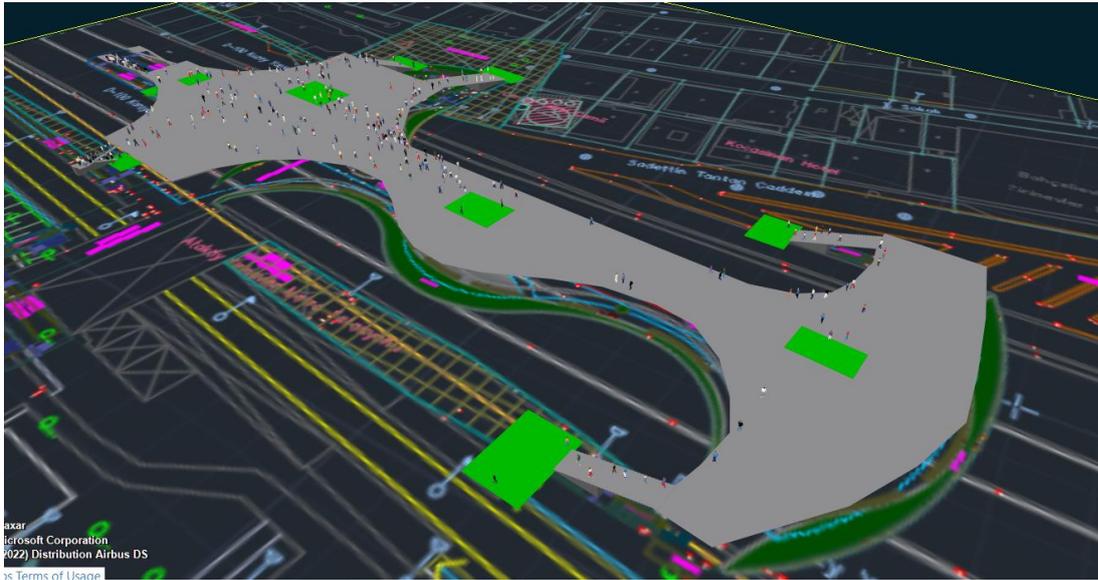
Figure 20 : Alternative solution of the Şirinevler overpass
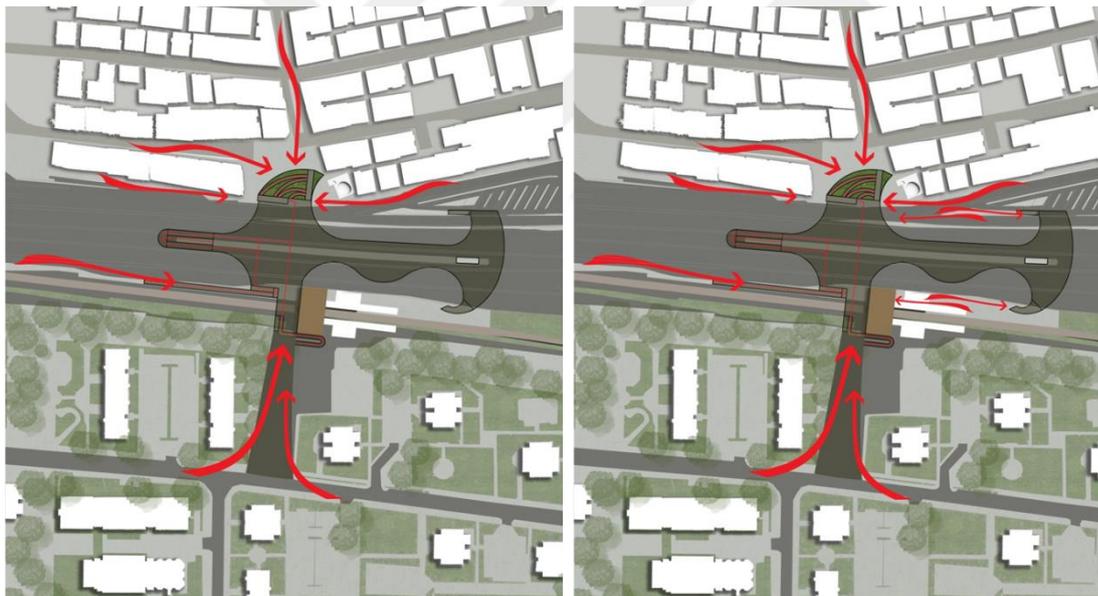
Figure 21 : Alternative solution of Şirinevler overpass showing pedestrian flows

By increasing the width of the platform up to 4 meters and increasing the number of ramps and stairs, the upper platform section will be greened on the platform, aiming for a more sustainable design, and a part of the active green area that Şirinevler needs will be provided. Thanks to this alternative model developed, it is aimed not only to prevent pedestrian queues by reducing traffic density, but also to create a small public space by creating a sustainable design.

Theoretical Background of the PTV VISSIM Software

PTV VISSIM is the microscopic simulation program for modelling multimodal transport operations and belongs to the vision traffic suite software. PTV VISSIM creates the conditions for testing various operating scenarios before their implementation for realistic and accurate in every detail. PTV VISSIM is now used worldwide by the public sector, consulting firms and universities.

(Tomáš Kučera, Jan Chocholác, 2020) summarized the According to PTV Group (2020), PTV VISSIM software is the standard microscopic traffic and transport planning software that is based on modeling and simulation. According to PTV Group (2020), this software can be applied in the following areas:

- Traffic Flow Simulation – Software facilitates decision-making for developing sustainable transportation systems (e.g. Muchlisin et al. (2019))
- Advanced Traffic Management Systems – Software aids in minimizing the negative impacts of the transportation system (e.g. Yang et al. (2013), Xing et al. (2014))
- Multimodal Systems – Software contributes in the analysis of various forms of transportation, including pedestrian traffic (e.g. Wu et al. (2018))
- Autonomous Vehicles and New Mobility – Software is used to simulate and model the effects of autonomous driving (e.g. Songchitruksa et al. (2017))
- Virtual Reality Traffic Simulation – Software enables the creation of micro traffic simulations.

5. EVALUATION OF THE RESULTS

The widths and numbers of stairs, elevators, and ramps for different entry and exit points have been changed for the Şirinevler overpass models for old, current, and alternative models, shown in the screenshots of the VISSIM simulation below in all cases with the same entrances.

Figure 22 : Şirinevler square connection in VISSIM simulation for current condition

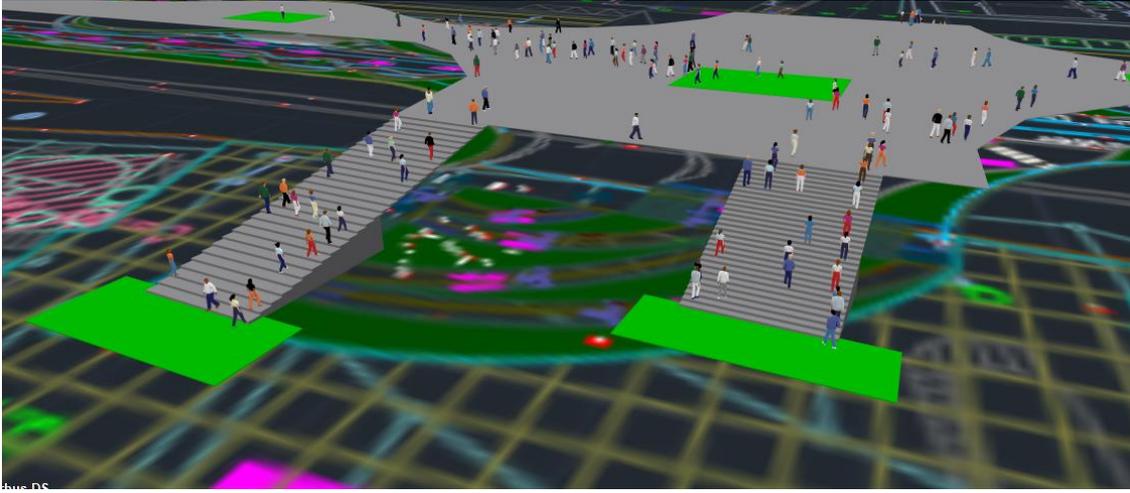**Figure 23 :** Şirinevler square connection in VISSIM simulation for old condition

Figure 24 : Şirinevler square connection in VISSIM simulation for alternative solution

The VISSIM screenshots below are of another connection point, Ataköy metro direction. The biggest difference between these two overpasses was the addition of a new connecting ramp and elevator.
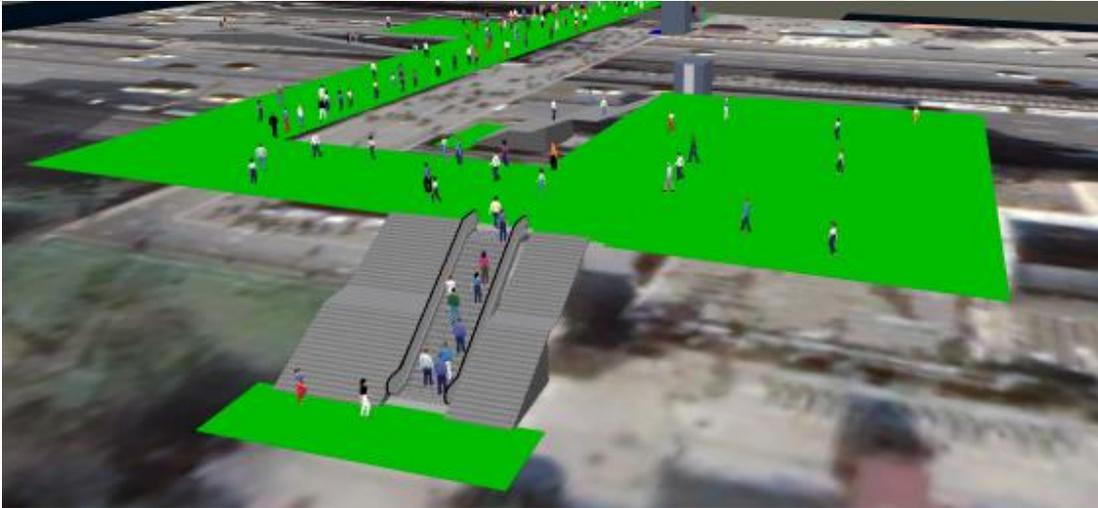
Figure 25 : Ataköy metro station connection in VISSIM simulation for current condition
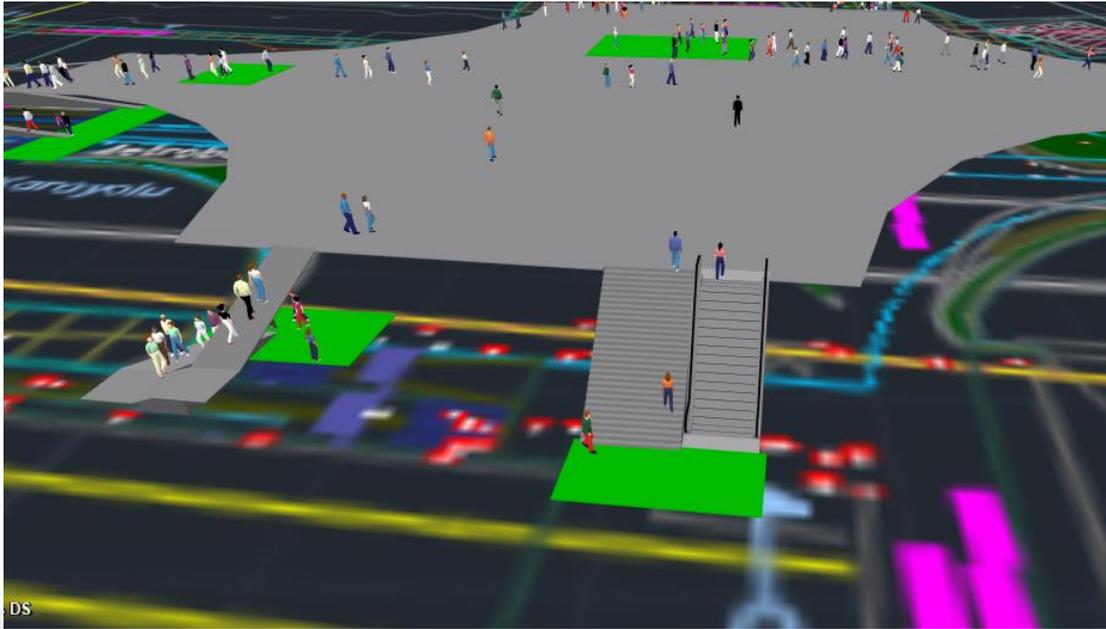
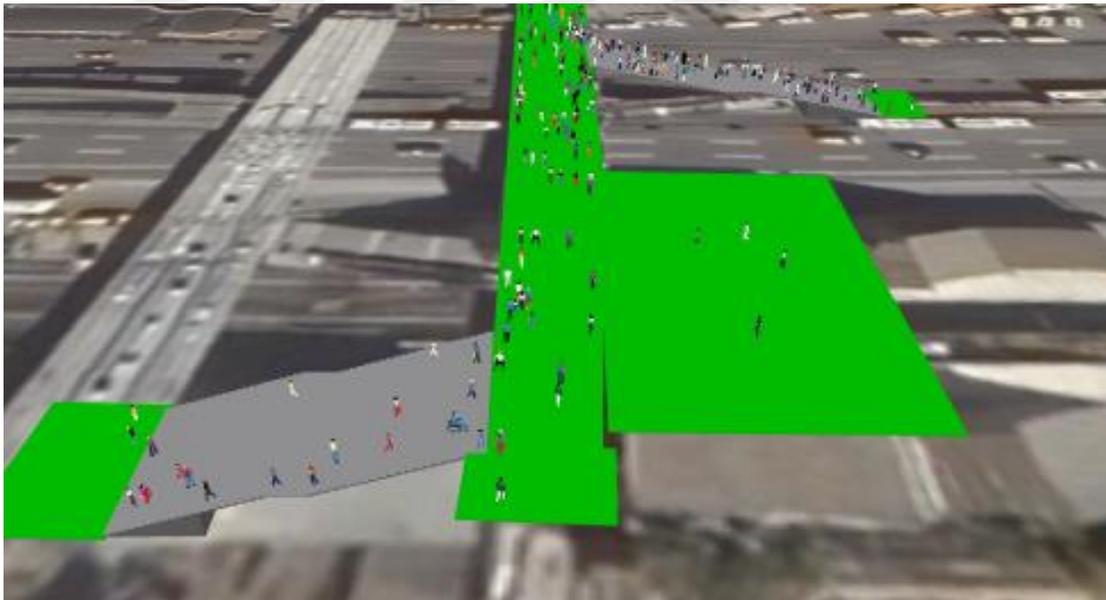**Figure 26 :** Ataköy metro station connection in VISSIM simulation for alternative solution

Figure 27 : Ataköy metro station connection in VISSIM simulation for old condition

When the metrobus connection, which is another connection point that can be considered the most important due to the fact that the pedestrian flow is the most intense, is examined, it is seen that the stairs system has been completely switched to the ramp system.
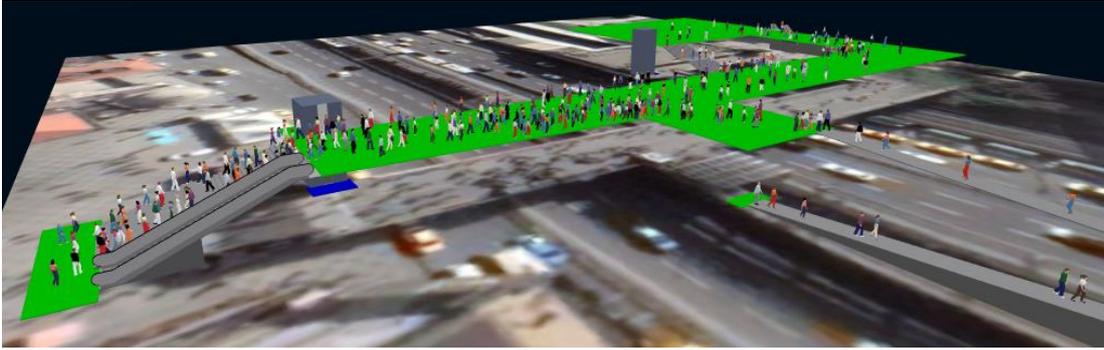
Figure 28 : Şirinevler metrobus connection in VISSIM simulation for current condition

Figure 29 : Şirinevler metrobus connection in VISSIM simulation for alternative solution
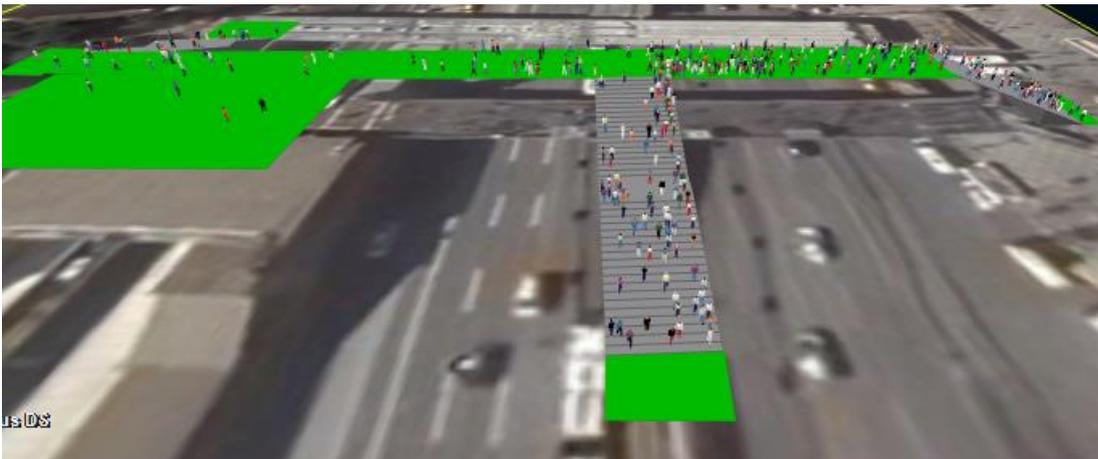

Figure 30 : Şirinevler metrobus connection in VISSIM simulation for old condition

All this modifications overpass system was redesigned on the PTV VISSIM, and as a result of entering the pedestrian data, which was mentioned in detail in the data collection part of the study, into the simulation: total number of stops, total stop time, speed, average density and average travel time parameters were examined, and the following data were obtained for each simulation models.

The analysis made for each case in line with the selected parameters is as follows:

The blue dots on the graph show the old condition, the orange dots show the current condition, and the values shown with the green dots show the alternative model.

The average speed is the total distance per total travel time that the value for the old overpass was calculated as 3.64 km/h, and it was analyzed that the pedestrian speed reached 3.86 km/h in the new case and increased. For the alternative solution average speed was calculated as 4.00 km/h. As a result of, the average pedestrian speed value increased by approximately %9.
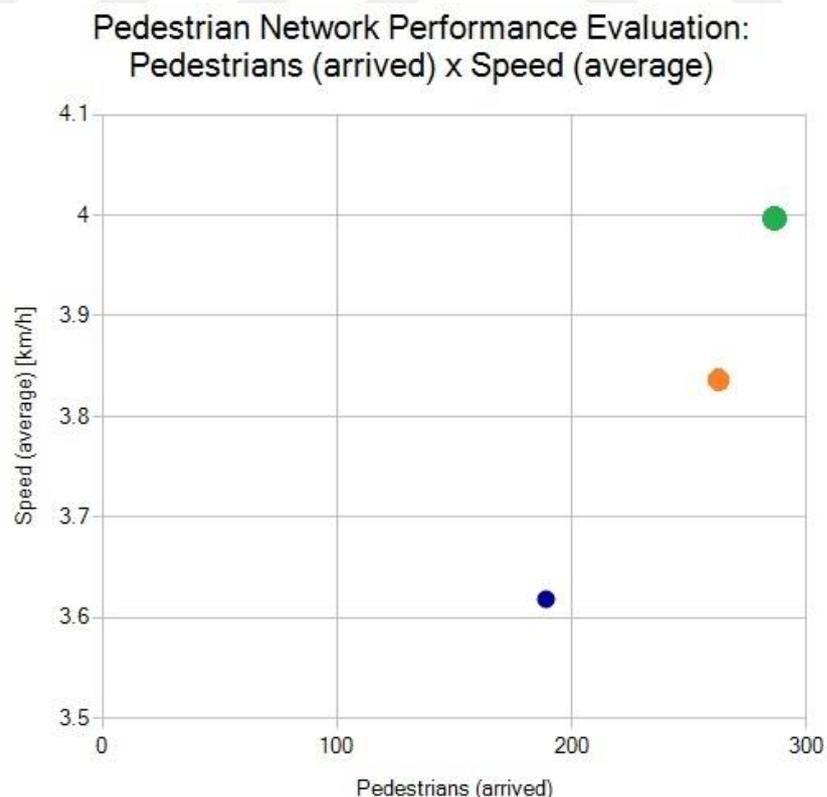

Figure 31 : Average speed results for all overpass models

Another measurement parameter is the average pedestrian density, which expresses the ratio of pedestrians in the network to walkable areas. The result obtained in the analysis for the old overpass was 0.0104 ped/m², and 0.0101 ped/m² according to the new condition. For the alternative solution average pedestrian density was calculated as 0.005 ped/m²

As a result of the values in the point graphs below, it is concluded that the average pedestrian density on the overpass has decreased. The simulation concluded that pedestrian density has decreased by 52% based on these data.
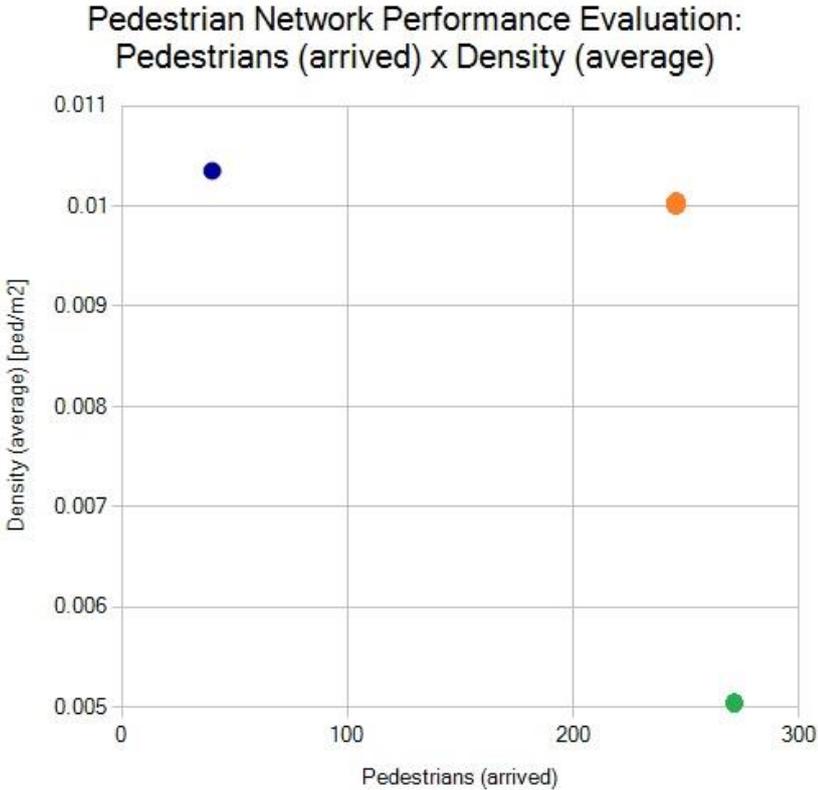

Figure 32 : Average density results for all overpass models

The third parameter analyzed is total travel time. This parameter represents vehicles traveling within the network or that have already left the network. It has been analyzed that while the average travel time of pedestrians on the overpass was calculated as 75.36 seconds in the old condition, it decreased to 67.24 seconds in the new condition with the effect of decreasing pedestrian density. For the alternative solution average

travel time was calculated as 61.82 seconds. The simulation concluded that the travel time decreases by 18.6% between the same two selected points in both models based on these results.
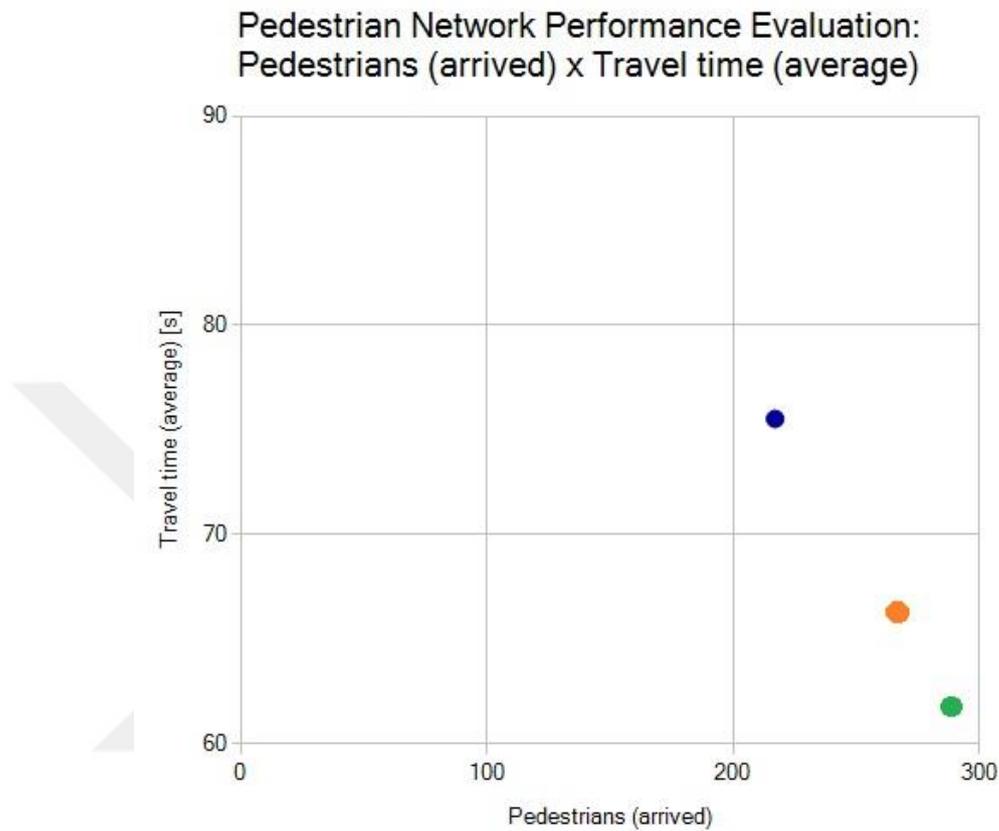

Figure 33 : Total travel time results for all overpass models

When the other parameters regarding the stops and stop times are analyzed for both overpasses, the following results are obtained: In the current condition of overpass, while the stops value is average number of stops per pedestrian during the evaluation interval that is 0.07 on average, the stop time is average stop time per pedestrian during the evaluation interval that is calculated as 0.013 seconds on average. When the old condition of the overpass is analyzed, the average stop value is 0.12, while the stop time is calculated as 0.014 seconds. For the alternative model, the average stop value is 0.10, while the stop time is calculated as 0.02 seconds.

In light of these data, it is concluded that the stops and stop times in the alternative overpass model are greatly reduced, approximately 70%.
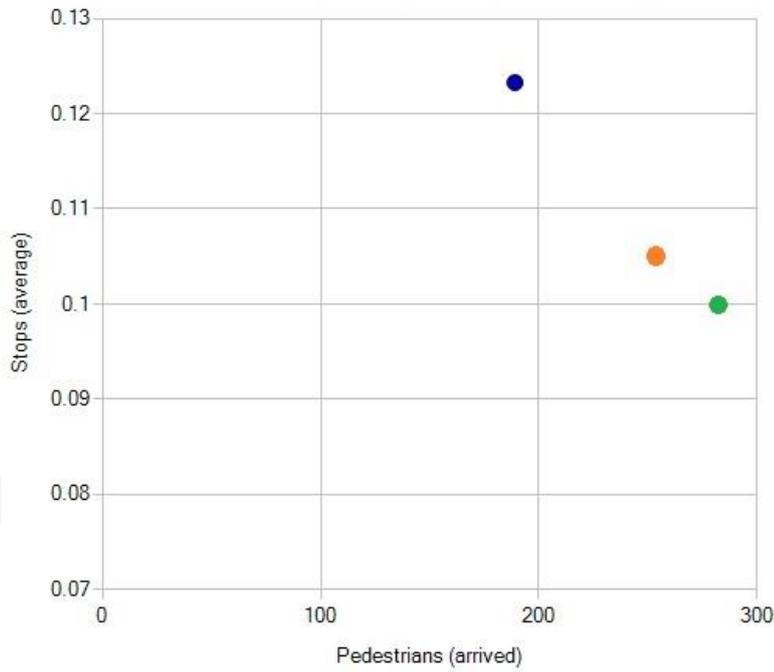
Figure 34 : Average stop values for all overpass models

Figure 35 : Stop time values for all overpass models
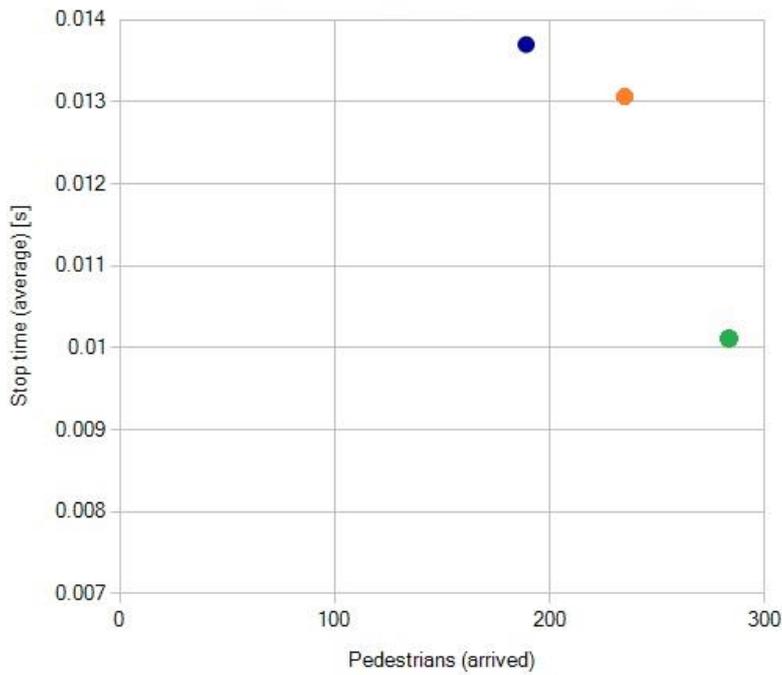
In the summary graphics below, average travel time and average speed values for both the old and the current condition and the alternative model of the overpass are presented as a graphic summary.
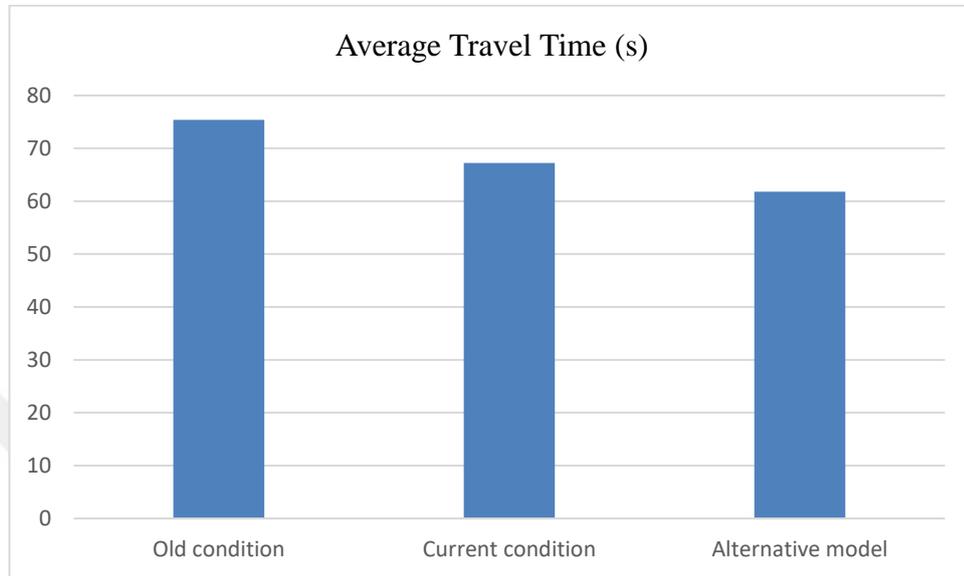

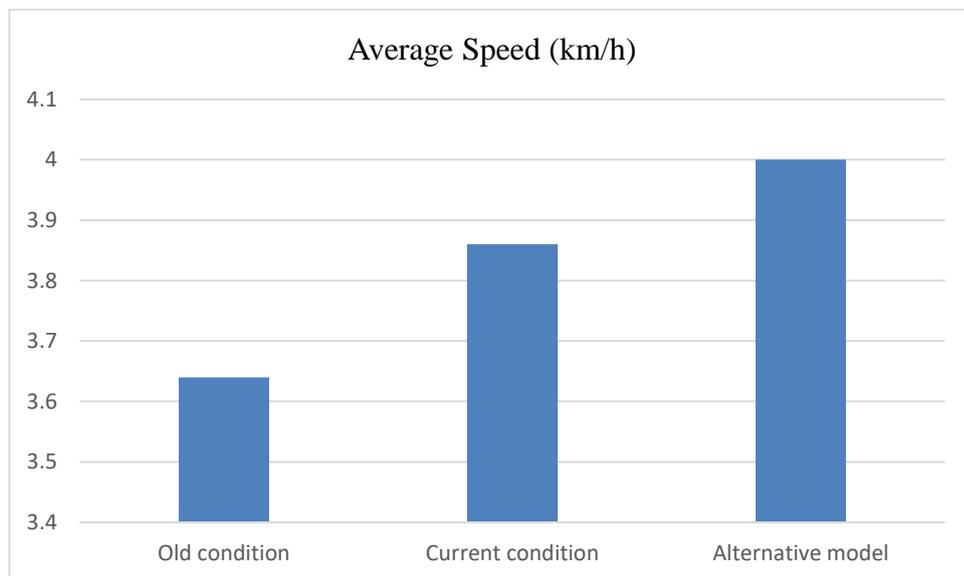**Figure 36 :** Travel time graphic for all models

Figure 37 : Average speed graphic for all models

6. CONCLUSION AND RECOMMENDATION

Pedestrian movements are inherently more complex than vehicle movements, and because of this complexity, pedestrian behavior is not always properly explained in traffic simulations. Taking such behaviors into account will lead to a better understanding of pedestrian interactions and help improve multimodal transportation planning and simulation.

The main difficulty in pedestrian flow in metropolitan areas such as Istanbul, especially in the common areas where the transfer to the Metro and Metrobus lines is made, is the excessive pedestrian density experienced especially in the morning and evening peak hours, and as a result, the queues formed on the overpasses. This situation becomes more challenging with the blockages occurring at the entrances and exits to the station and crossings and the decrease in pedestrian crossing capacity. More informed decisions can be made regarding pedestrian activity in the urban environment, especially when designing or developing systems with large numbers of pedestrians seeking to achieve goals such as pedestrian intersections or pedestrian-focused central business districts.

In order to provide a better understanding of pedestrian interactions at Şirinevler overpass and to analyze its old and current condition, the presented research tried to represent realistic pedestrian behavior in VISSIM, a microscopic traffic simulation program for a particular overpass.

In addition to these two model analyses, an alternative overpass model was created, and a new solution was presented. In both cases, pedestrian densities, speeds, and average pedestrian waiting time estimates were obtained as a result of the counts made during the peak hours of the pedestrian flow, and the changes in these parameters were observed for the alternative overpass model. For the simulation analysis, pedestrian count which is made during the peak hours of the Şirinevler overpass is based on the selected gender, age, and load status. They were grouped in order to be able to

determine the pedestrian speeds in a correct way in line with the selected criteria and to reflect them in the analysis.

As a result, with the simulation models created in line with the collected pedestrian data, it was concluded that the travel time between the same two selected points decreases by 18.6%, pedestrian density has decreased by 52%, the average pedestrian speed value increased by approximately %9, stops and stop times in the alternative overpass model are greatly reduced approximately 70%.

In line with these parameters obtained, it has been concluded that factors such as increasing the width of the pedestrian walkways, adding new entrances-exits, ramps, and elevators for access to the overpass, and providing correct redirection for pedestrians are directly related to the decreased pedestrian density and increase in average speed.

Another issue that this study also wants to emphasize is that urban standards and developments in infrastructure in the 21st century have increased the importance given to the quality of urban space. In this context, various policies are being developed for the concept of "sustainable urban transportation" all over the world in order to meet the transportation and access needs in urban areas in the most economical and environmentally sensitive way. For this reason, it is possible to analyze pedestrian priority planning/design in urban transportation in metropolitan cities such as Istanbul, and to analyze the results closest to reality beforehand and to contribute to feasibility studies in this direction with simulation programs such as VISSIM.

If we make a general evaluation, a good examination of traffic solutions in cities reveals the necessity of technological applications such as on-site traffic counts, camera shots and the analysis of data by experts with smart programs. At the same time, being able to make cost comparisons will enable us to realize the theory of providing the most benefit with the least cost, since it helps us to decide on the right investment. Especially as it is revealed in this study, it is very important that the simulation studies are carried out at the preliminary stage of the design process of the projects, so that the projects can be successful in terms of both time and cost.

As research in this area continues, it is likely that policy analysis and resulting traffic planning will flourish, utilizing simulation models based on pedestrian travel times.

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