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A NOVEL TRUCK PARK DIFFERENTIATION MODEL BASED ON REST TIME REGULATIONS AND PARKING PERIODS

M.Sc. Thesis by

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M.Sc. THESIS EXAMINATION RESULT FORM

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An article with same title which is prepared from this thesis is under review for possible publication in Transportation Research Part A Journal.

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A NOVEL TRUCK PARK DIFFERENTIATION MODEL BASED ON REST TIME REGULATIONS AND PARKING PERIODS

ABSTRACT

This research focuses on a new facility model for truck parking areas with two new types of parking areas that are tailored to the duration of parking activities in compliance with work and rest time regulations. According to an analysis of related regulations, parking activities could be categorized as short breaks and long rests, with varying requirements for each parking activity. Currently, parking requests are fulfilled within the same "universal type" facility, resulting in inefficient capacity utilization. In this context, Short and Long Park Differentiation (SLPD) Model is proposed as an alternative model in which Long Park is only serving for long rest requests and Short Park is only for short break requests. The advantages of new models in terms of efficiency are tried to be presented by a mathematical model and Monte Carlo Simulation. The goal of a mathematical model is to maximize overall profit while minimizing opportunity and operating costs. Then, a simulation model is applied to compare the capacity utilization ratios and the number of unmet parking requests in a variety of scenarios that include varying levels of parking demand conveyed to both existing and proposed types of park spaces with the same total parking lot capacity. The study also points to the fact that the extra facilities offered in universal park areas of which the target group is long rest customers is a costly practice since a significant part of the capacity of parking areas are used by vehicles having a short break.

Keywords: Park area planning, resource allocation, mathematical modelling, Monte-Carlo simulation, international road transportation, road safety, driving ergonomics.

DİNLENME ZAMANI YÖNETMELİKLERİ VE PARK SÜRELERİNE GÖRE YENİ BİR TIR PARKI FARKLILAŞTIRMA MODELİ

ÖZ

Bu araştırma, çalışma ve dinlenme süresi düzenlemelerine uygun olarak park faaliyetlerinin sürelerine göre uyarlanmış iki yeni park alanı türü ile kamyon park alanları için yeni bir tesis modeline odaklanmaktadır. İlgili yönetmeliklerin analizine göre, park faaliyetleri kısa molalar ve uzun dinlenmeler olarak kategorize edilebilir ve her park faaliyeti için farklı gereklilikler söz konusudur. Mevcut durumda, park talepleri aynı "evrensel tip" tesis içerisinde karşılanmakta ve bu da verimsiz kapasite kullanımına neden olmaktadır. Bu bağlamda, Uzun Park'ın sadece uzun dinlenme talepleri için, Kısa Park'ın ise sadece kısa mola talepleri için hizmet verdiği alternatif bir model olarak Kısa ve Uzun Park Farklılaştırma (SLPD) Modeli önerilmektedir. Yeni modellerin verimlilik açısından avantajları matematiksel bir model ve Monte Carlo Simülasyonu ile ortaya konulmaya çalışılmıştır. Matematiksel modelin amacı, fırsat ve işletme maliyetlerini minimize ederken toplam kârı maksimize etmektir. Daha sonra, aynı toplam otopark kapasitesine sahip hem mevcut hem de önerilen park yeri türlerine iletilen park talebinin değişen seviyelerini içeren çeşitli senaryolarda kapasite kullanım oranlarını ve karşılanamayan park yeri taleplerinin sayısını karşılaştırmak için bir simülasyon modeli uygulanmıştır. Çalışma ayrıca, hedef kitlesi uzun süre dinlenen müşteriler olan evrensel park alanlarında sunulan ekstra olanakların, park alanlarının kapasitesinin önemli bir kısmının kısa mola veren araçlar tarafından kullanılması nedeniyle maliyetli bir uygulama olduğuna da işaret etmektedir.

Anahtar kelimeler: Park alanı planlaması, kaynak tahsisi, matematiksel modelleme, Monte-Carlo simülasyonu, uluslararası karayolu taşımacılığı, karayolu güvenliği, sürüş ergonomisi.

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NOMENCLATURE

Acronyms

MoTI	Ministry of Transport nd Infrastructure Republic of Türkiye
EU	The European Union
GDP	Gross Domestic Product
AETR	Accord Européen sur les Transports
UNECE	The United Nations Economic Commission for Europe
ITC	The Inland Transport Committee
UN	The United Nations
TEN-T	The Trans-European Transport Network
TEM	Trans-Europan Motorway
EEC	The European Economic Community
ATRI	American Transportation Research Institute
SLPD	Short and Long Park Differentiation
EC	The European Commission
SMEs	Small and Medium-Sized Businesses
IRU	International Road Transport Union
ITS	Intelligent Transport Systems
GPS	The Global Positioning System
KDOT	The Kansas Department of Transportation
UDOT	Utah Department of Transportation
NCST	National Center for Sustainable Transportation
TDSP	Truck Drivers Scheduling Problem
TDSPFM	The Truck Driver Scheduling Problem with Fatigue Monitoring
XGBoost	Extreme Gradient Boosting
LSTM	Long Short-Term Memory
TPIMS	Truck Parking Information and Management System
TPOP	Truck Parking Occupancy Prediction
MC	Monte Carlo
TL	Turkish Liras
CCTV	Closed Circuit Television
CM	Current Model

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CHAPTER 1

INTRODUCTION

In parallel with the globalization of trade, the competition in international markets has moved to unprecedented levels. This intense competition environment has reduced profit margins and made it difficult to achieve customer satisfaction. At this point, businesses understand logistics activities are vital to reach their objectives such as reducing costs and aligning delivery times with customer requests. With globalization, the free movements of products, raw materials, semi-finished products, products people, and transportation activities at the international level are increasing as well. Transportation has always been a significant issue considering the distance between production and consumption points. Transportation can be defined as an instrument that allows the movement of raw materials, materials, semi-finished products, products, or people from one point to another (Cascetta, 2001). From a broad perspective, transportation is the transfer of raw materials, materials, semi-finished products, and products in a timely, traceable, and customer-oriented manner at low cost without giving damage to the cargo. In the new global economy, transportation has become a central issue for most enterprises.

Transportation activities, which are the backbone of supply chains, are in context of both domestic and international commercial activities. Freight transportation is divided into types/modes according to the transport methods used during the activity, such as multimodal transport, maritime transport, rail transport, air transport, and inland waterway transport. Each of these modes of transport has advantages and disadvantages. It is important for businesses to carefully consider choosing the right mode of transport based on factors such as cost, speed, reliability, and environmental impacts. Additionally, disruptions in one mode of transport can have ripple effects throughout the entire supply chain, highlighting the need for contingency plans and risk management strategies.

Road transport is a transport mode that is the related mode of this study; provides door-to-door and non-stop delivery of goods between the sender and the carrier for a certain

price with contracts, procedures, and principles as well as supports other transport systems within the framework of international agreements. Road transport is advantageous since it provides capability of accessing anywhere by road (from the door), significant cost savings during packaging, has a widespread network as well as flexible scheduling opportunity for loading and unloading. Thanks to the widespread road network all over the world and appropriately sized transport vehicles, road freight transport is an issue that should be emphasized in terms of the commercial development of countries. On the basis of transportation planning studies with the objectives to contribute to the design, construction, maintenance, and operation activities of highways more rationally and scientifically; the road transportation studies gain increasing importance and focussing every year.

It has contributions such as decreasing in costs while increasing job opportunities,the total welfare level of the country, and the access of consumers to the domestic and imported products.. In this regard; road transport has an important contribution to the development of foreign trade activities of countries, increases their level of economic development and allows for the establishment of economic relations. The road transport data of Türkiye in Figure 1.1 reflects the importance of road transport (MoTI, 2022).

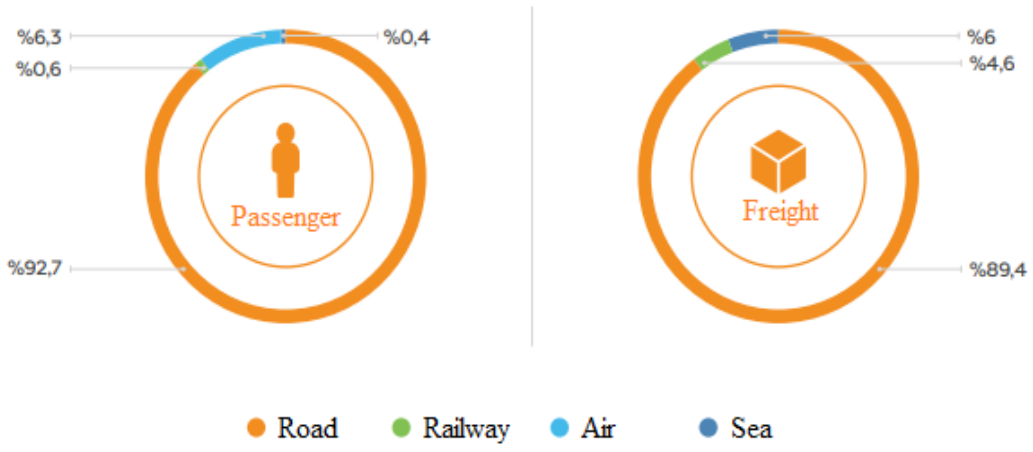

Figure 1.1 Domestic passenger and freight carrying rates by type of transportation in Türkiye (MoTI, 2022)

Türkiye is the largest of all of The European Union (EU) accession candidate countries, with 783,562 square km (including lakes and islands). The country has a population of 83.6 million people, with a growth rate of 1.35%, and half of those under the age of 30. With a gross domestic product (GDP) of $720 billion, it is the 19th largest economy in the world (GDP at purchasing power parties). In less than a decade, the country's per capita income has nearly tripled and now exceeds EUR 8,000 (WB, 2022).

Türkiye is located in three important geopolitical/geostrategic spheres of influence. This effect areas near land (Balkans-Middle East-Caucasus), sea (Black Sea-Adriatic-Eastern Mediterranean-Red Sea-Persian Gulf-Caspian Sea), and continental (Europe – Northern Africa - South, Central, and East Asia) basins bringing significant benefits to Türkiye (Çakar, 1998). Türkiye has borders with eight countries, including the EU Member States, and borders along the Black Sea, the Mediterranean Sea, and the Aegean Sea offering a gateway to growing markets in the Middle East and the Caucasus. Expanding transit demand with bordering countries is limited by inadequate internal transportation systems and missing linking routes to neighboring countries.

Handling 90% of domestic freight by volume by road transport, Türkiye owns the largest capacity truck fleet in Europe with more than 916,000 trucks across the country (TSI, 2022). Approximately 450.000 trucks of goods are carried as “full truckload” daily in Türkiye and the full truckload “ shipment volume is over 13.5 million trucks monthly. With 1.2 million professional competence certificated truck drivers Türkiye has the largest market in Europe considering both crew and vehicle capacities.

Road transport is the dominant transport mode in Türkiye in frame of both freight and passenger transport. In 2020, 89.4 % of freight and 92.7 % of passenger used road transport (MoTI, 2022). In a comparison, in the same year, the share of road transport for passenger and freight were respectively 94,6 % and 77.4 % in the EU-25 (EUROSTAT, 2022). Between 2010 and 2017, road freight transport in Türkiye increased by over 5% per year from 190 billion to 262 billion ton-km (MoTI, 2021). Road freight transport is operated predominantly by the private sector.

Since road transport is the leading mode of transportation, road safety is a very significant and difficult issue to be handled. Decent working conditions for drivers as well as a fair business environment for road transport undertakings have significant importance and require establishment of a safe, secure, efficient, and socially traceable road transport sector while ensuring a non-discriminative manner. Driver fatigue is one of the most important and frequently occurring risk factors that endanger road safety and security. Total working time is critical factor in terms of fatigue. The working hours of professional drivers of vehicles such as trucks, buses, or coaches are relatively longer which leaves inadequate time for fulfillment of the vital needs for recuperation and restorative sleep and prevents a satisfactory balance between work and private life. Crashes in which vehicles such as trucks and buses are involved constitute between 20 to 30 percent of total road traffic accidents and they are %50 more probable to result in serious injury or death as a consequence of the dimensions of the vehicles involved.

Drivers are aware when they are feeling sleepy due to fatigue naturally and they should decide a rest at their earliest convenience. However, one of the reasons which leads drivers to continue working although they are feeling sleepy is the underestimation of the risk of falling totally asleep and unconscious during the the driving activity.

Even though a “micro-sleep” only for a few seconds is quite long enough to lose the control of the road and result in an accident. These accidents tend to be the most severe in terms of injury or death, as the fatigued driver does not attempt to prevent or avoid fromthe crash.. Traffic accidents are also very important in terms of occupational health and safety because most traffic accidents are work-related. At the same time, road traffic accidents are the leading cause of work-related injury, disability, and death in the world. It is estimated that workers are involved in approximately 30% of traffic accidents. It is estimated that between 6 and 15 million workers suffer from work-related injuries due to traffic accidents annually. Although commuting accidents are excluded, work-related traffic fatalities account for up to 40% of work-related fatal injuries (Ekmekçi, 2012).

Road transportation sector contains workplaces with all hazard classes, including very dangerous, dangerous and less dangerous. In order to reduce occupational accidents,

injuries, diseases and deaths in road transport; it is necessary to determine the occupational risk factors in accordance with the requirements of the job and its hazard class in order to take the necessary precautions,inform the employees about occupational health and safety, working environment and conditions,receive training on the subject, establish a safety culture among the employees and the society as well. In this context; an international agreement named “European Agreement concerning the Work of Crews of Vehicles Engaged in International Road Transport (AETR)” came into force on 5th of January 1976. AETR was a result of a series of negotiations which lasted more than 15 years for elaboration of a first AETR Agreement and its advancement were performed under the auspices of The United Nations Economic Commission for Europe (UNECE) since 1962. UNECE still continues to reflect its expertise and serves with its organizational capacity to meet the needs of road transportation sector in specific with the working groups such as "Inland Transportation Committee, Road Traffic Safety, Transport of Perishables, Combined Transport and Transport of Dangerous Goods".

The AETR Agreement regulates the working and rest times of drivers and crews of commercial vehicles of more than 3.5 tons or transporting more than 9 people, engaged in international road transport. The control devices, which enable checks on mentioned working and rest times, are regulated with technical requirements for the production, testing, installation, and inspection of the mentioned devices so that an international standardization in this frame is achieved as well. Besides, the AETR Agreement also specifies the procedures to be followed by inspection authorities for the control of requirements defined in the Agreement regarding working time and recording equipment of the vehicles.

In addition to regulating working times and rest periods of drivers of commercial vehicles engaged in international transport increase the level of road safety and security, AETR also affects the road transport market by supporting fair competition by standardizing the working hours of employees and excessive working time has been eliminated as a factor for profit. The third pillar of the Agreement is introducing appropriate social rules which guarantee to provide decent working conditions for professional drivers.

In this context; the truck parks are the main infrastructure to making the mentioned rules applicable so that; UNECE sets by The Inland Transport Committee (ITC) Strategy until 2030 the mission for ITC to contribute to sustainable inland transport and mobility for achieving the sustainable development goals by the UNECE and the The United Nations (UN) Member States through “policy dialogue, harmonizing regulatory frameworks” and the Strategy also stipulates “road safety as the special priority” which are in parallel with the development of parking area infrastructure.

The main pillar of EU transport infrastructure policy, the Trans-European Transport Network (TEN-T) Regulation indtroduced similar policy with the objective of establishing networks that contain safe and secure parking areas are available at a maximum distance of 100 km from each other, providing sufficient parking space for commercial vehicles and complying with the requirements set out in Regulation (EU) 2020/1054 of First Mobility Package.

The parking areas are also linked with the Road Safety Strategy and Action Plan of Türkiye, which is prepared in line with the Stockholm Declaration 2020 and the EU Road Safety Policy Framework 2021-2030 and the Action contains significant outcomes which contribute road safety, with the priorities listed under:

- In accordance with the "Zero Loss of Life in Traffic (Vision Zero) Approach", the target is to reduce the loss of life as a result of traffic accidents by 50% by 2030 and zero by 2050.
- Increase necessary measures to prevent of parking of heavy goods vehicles on highways, intercity highways, and safety lanes/banks which is one of the main causes of accidents.

The main progress that has been made within the context of road transport infrastructure. Transport and communication sectors; not only provide the citizens with quality, comfortable and safe transportation and fast access but also at the same time, the contributions of our citizens to the economy and ensures an increase in welfare.

The Ministry of Transport and Infrastructure has invested 169.2 billion dollars including public private partnership (PPP) for the transport and communication infrastructure in Türkiye between 2003-2020. These investments have shown an effect on Gross Domestic Product is 409.7 billion USD, production is 869 billion USD, and employment of an average of 705 thousand people per year (MoTI, 2021). Türkiye has a widespread motorway network that provides transportation between Middle East Countries and Europe. The total length of the Trans-Europan Motorway (TEM) Highway was 24,931 km as of 1.1.2011, and approximately 6,940 km which correspond to 28% of the entire TEM network are located within the borders of Türkiye (KGM, 2019). The legal framework is also at a good level of preparation regarding the alignment with the EU acquis with the progress such as the adoption of the Road Safety Strategy and Action plan which is prepared based on the Stockholm Declaration 2020 and the EU Road Safety Policy Framework 2021-2030.

The legislative alignment to the EU acquis on technical, social, and safety conditions is still being continued to improve road traffic safety. The harmonization of relevant provisions of Council Regulation (EEC) No 3821/85 was completed with the By-law on Inspection and Sealing of Recording Equipment, which was published in the Official Gazette No. 28171 of 12 January 2012. In this context, the digital tachograph system became obligatory as of 1st of January 2011 for vehicles registered after June 16, 2010 carrying more than 9 people (for buses) with a mass of more than 3,5 tones (for trucks) in the scope of international transport. Besides, digital tachographs have been compulsory as of 30th June 2014 and the transition process for retrofitting been completed on October 1, 2021 for the vehicles engaged in domestic transport. The work for adaptation of relevant AETR provisions to By-law on Road Traffic still continues in context of road side inspections of working/rest times of professional drivers (EU Commission, 2021).

Parking areas are essential infrastructure to get under control of driver fatigue at secure levels. Trucks play a vital role the in economy and they are essential for delivering supplies to manufacturing and delivering products to our retail establishments. Truck parking capacity should be adjusted to meet the demand of total truck fleet using the routes in the territories of each country individually. Truck parking deficiency is a

global safety concern with additional risks because lack of truck parking supply can lead to fatigued truck drivers on the road and force them to park at unsecure places such as exit ramps, roadside, or vacant lots if they are unable to locate available dedicated areas for truck parking. Consequently;, unsafe locations along roads become alternative parking areas which result in dangerous occasions for other drives as well as preventing mobility on the bicycle and vehicle lanes or blocking sight lines at intersections and driveways.

Since communities have their own retail establishments, manufacturing, or other industries; trucks are necessary to support these businesses so that there is close relationship between planning of truck parking infrastructure and development. The lost time is spent searching for appropriate parking places consequently causes increased congestion levels on the road network. Looking for parking can also force drivers to drive through residential zones which can be unsafe as well as a nuisance for local residents. In addition, the negative effect on the environment is directly proportional to the extra time drivers use their vehicles.

As well as constituting the main infrastructure for the implementation of driving and rest times; truck parking areas are also providing service for the human needs of drivers, fuel delivery, and minor repairs of vehicles. Therefore, an adequate number of parking areas are a very significant part of the road transport system.

Studies show that the current capacity of truck parking infrastructure comes short to meet the demand and it is inevitable that parking area demand will also increase in correlation with the increase in trade and population. In this regard, it comes with an optimization problem with the objective to minimize construction costs and maximize the utilization of parking areas. Parking areas are planned at regional, governmental, and international context and optimal design and distribution of parking areas as well as location allocation have critical importance in order to fulfil such a huge demand.

Truck parks with decent safety, security and legal background is a diachronic issue so that transport undertakings and professional drivers have already surpassed a critical phase in terms of available capacity problems and increased awareness. Dependency on commercial vehicles in terms of freight transportation, purchasing behaviour of

consumers, and improving supply chains have effected their operational aspects and induced the need for freight transport infrastructure in vast urban areas. There are changes in regulatory policy likely to exacerbate existing truck parking challenges in addition to abovementioned capacity deficiency. The recent provisions of Mobility Package of European Commission affect driver operations and cause the need for additional safe and secure truck parking capacity. When the driving time is exhausted on a location where there is none truck park area available, it is possible to observe parked vehicles on unsafe or prohibited locations in order to meet the mentioned requirements. In order to solve the aforementioned problems, 2 types of parking areas are developed as a result ıfanalysis of requirements of working/rest time regulations in force and the quantitative outcomes of the implementation of these models are presented with a simulation in this study. First of all, root causes that affect parking area demand differentation is illustrated. After analysis of the parking area demand in detail, park area supply with an alternative designs is compared by using a model. Comparison of opportunity cost and number of unserved vehicles of proposed and current model will also assist to the mathematical model to underline the effect of alternative design.

The optimization problem mentioned here is a complex one that requires careful consideration of various factors. The first step towards minimizing construction costs and maximizing parking utilization is to conduct a thorough analysis of the parking demand in the area. This analysis should take into account not only the current demand but also the projected future demand. Once this analysis is complete, it is important to design parking areas that are efficient and effective in meeting this demand. This may involve considering alternative designs, such as multi-level parking structures or underground parking facilities. In addition, it is important to carefully consider the locational allocation of these parking areas in order to ensure that they are easily accessible and convenient for users. Finally, ongoing monitoring and evaluation of the effectiveness of these parking areas will be necessary in order to make any necessary adjustments and improvements over time.

In this study, parking areas are differentiated as short and long park areas considering the requirements of working/rest time regulations in force and the benefits of the model

is tested by a Monte Carlo simulation model in different demand rate scenarios. Capacity utilization ratios, examples of opportunity costs for different pricing options are provided in order to achieve a clear understanding and illustration of the feasibility of proposed Short and Long Park Differentiation (SLPD) Model. The Monte Carlo simulation model which is used to test the proposed SLPD Model provides valuable insights into the feasibility of different pricing options. By analyzing capacity utilization ratios in various demand rate scenarios, the model highlights opportunities for maximizing revenue while minimizing costs. The SLPD Model offers a flexible approach to parking management, allowing for dynamic pricing based on factors such as time of day and duration of stay. This approach can help increase revenue during peak demand periods while also encouraging longer stays during off-peak times. The model also considers opportunity costs associated with different pricing options, providing a comprehensive analysis of the potential benefits and drawbacks of each approach. Overall, the SLPD Model represents a promising solution for optimizing parking management in urban areas, with the potential to improve efficiency, reduce congestion, and enhance the overall user experience.

The rest of the study is constructed as follows: A literature review regarding the truck parking areas' regulation, management, and operation requirements is presented in Chapter 2. The proposed model is explained in Chapter 3. The experimental results and outcomes are presented in Chapter 4. Finally, this research is concluded with an explanation of the important results in terms of the managerial and practical implications and further work suggestions.

CHAPTER 2

LITERATURE REVIEW

2.1 Working and Driving Time Regulations

Scientific research and examinations of working hours of professional drivers reveal that night driving, irregular shift patterns and last but not least extended working hours cause their exhaustion as well as stress. All of these issues have a severe influence on not just road safety but also workplace safety, particularly when drivers are involved in loading and unloading procedures. The average duration of working hours has stayed constant over the years. Furthermore, laws on driving hours may allow for significant variations in the time when rest intervals are authorized on a daily basis in some circumstances (Stefaniec et. al.,2021).

Health and safety conditions of drivers are both at risk. It is also worth noting that when working hours are scheduled, working periods are shorter when divided into regular shifts. In contrast, the high volume of night driving may be explained by the fact that driving conditions are far better at night and by the fact that loading and unloading operators usually take place during the day. The amount of time spent by the drivers with the activities including examining their vehicles and loads should not be deemed free time as well because they are still engaged in job tasks. Drivers are not driving during these hours; instead, they are unloading or loading their vehicles as well as vehicle maintenance are performed. Custom procedures are also among waiting activities for drivers and require a significant amount of time for a daily duty of the driver engaged in international road transportation. The concept of time on duty, in which drivers undertake duties that benefit their employers, might potentially aid in the resolution of any issues that may occur. It would also assist to minimize misunderstanding over salary concerns, which all too frequently intrude on and obscure the argument over working hours definition (Lupova, 2018).

Effective regulatory instruction can assist to enhance the conditions of road transportation. In order to address all of these difficulties, a code of good practice must

be developed and extensively communicated and implemented. Taking advantage of the existing knowledge to produce such guidance is a reasonable goal. The EU has established social regulations in the realm of road transport since 1969. The main goal is improving working conditions for drivers, road safety while ensuring that transportation companies compete fairly.

Regulations on the use of mechanical and electro-mechanical tachographs; EEC Regulation No. 3820/85 11 on Harmonization of Certain Social Legislation Regarding Road Transport and EEC Regulation No. 3821/8512 on the Use of Recording Devices in Road Transport, which regulates the regulations regarding the use of tachographs and the technical specifications of the device were published in 1985. The mentioned regulations repealed the EEC Regulations No. 543/69 and 1463/70, respectively. EEC Regulations 3820/85 and 3821/85 entered into force together in EU countries on 29/9/1986. Council Directive 88/599/EEC on Standard Audit Procedures for the Implementation of EEC Regulation No. 3820/85 Concerning the Harmonization of Certain Social Legislation Concerning Road Transport and EEC Regulation No. 3821/85 Concerning the Use of Recorders in Road Transport was published in 1988.

Mechanical and electro-mechanical tachographs record operating times on a waxed paper disc called tachograph paper. Since tachograph papers cannot always be exchanged between different types of tachographs, safer devices have been sought since they are open to destruction and unauthorized intervention. Along with the developments in the field of digital electronics, the idea that the tachograph should also be digital has been put forward. With the proposal of the European Commission and the decision taken by the European Parliament and the Council, it is foreseen to replace the existing system with a digital tachograph system.. Figure 2.1 shows the development of the tachograph over time (Örs, 2013).



Figure 2.1 The evolution of the tachograph over time (Örs, 2013)

The application of the digital tachograph system is the EEC Regulation No. 3821/85 on the Use of Recording Devices in Road Transport and EEC Regulation No. 3820/85 and EEC No. 3821/85 published in 1998. It started with the EC Regulation No. 2135/98 on the Amendment to the Directive No. 88/599/EEC on the Implementation of the Regulation. In order to improve the technical features of the digital tachograph, the EEC Regulation No. 1360/2002, Adapting for the Seventh Time to the Technical Advancement of the EEC Regulation No. 3821/85 on the Use of Recording Devices in Road Transport was published in 2002 and entered into force.

In order to prevent unfair competition between enterprises and to increase road safety, the need to amend EEC Regulations 3820/85, 3821/85 and EC Regulation 2135/98 has arisen. Therefore, Amending the EEC Regulation No. 3821/85 and the EC Regulation No. 2135/98 Concerning the Harmonization of Certain Social Legislation Regarding Road Transport and EC Regulation No. 561/2006, which repealed the EEC Regulation No. 3820/85, came into force in 2007.

The EC Regulation No. 561/2006 establishes maximum allowable daily and weekly time limits of driving. The compulsory rest times day and week period of working are also determined in the mentioned regulation which is applied to all EU member states. The scope of the regulation is commercial truck drivers of trucks with maximum allowed mass of greater than 3.5 tonnes and of buses or coaches with a transporting more than nine people.

The diversity of national conditions and legislation in Member nations will eventually need harmonisation of driving and working hours for both paid and self-employed drivers through legislative measures.

2.2 Ergonomics of Driving

2.2.1 Fatigue

As a subject, fatigue is studied by various researcher in fields such as psychology, medical sciences, cognitive neuroscience, the exercise physiology and therefore definitions are vary accordingly. It can be defined as an overwhelming sense of cognitive and/or physical exhaustion or tiredness. "Fatigue" is sometimes used

interchangeably with "sleepiness," however the latter term refers to a more limited element of sustaining alertness. Sleepiness is described as a "tendency towards sleep" that may be measured using subjective judgments or neurophysiological indications of the onset of sleep that have a significant impact on driving (Gier et. al.,2023). In this regard, driver fatigue is one of the main issue that should be solved with appropriate measurements as aforementioned working/rest time regulations.

2.2.2 Night Work, Shift Work

In the transportation industry, night work has never been uncommon. Drivers are expected to work at night in "emergencies" or alter their schedules to accommodate for delays in the manufacture or loading of products. In long-distance transportation, such assumptions are much more widespread. Haulage enterprises must fulfill higher demands in terms of schedule compliance, delivery time, and reliability of service as a result of the widespread adoption of new logistics and transport concepts as well as the trend to consider transportation as part of the production process. Customers in commerce and industry are likely to use the option of having products delivered overnight more frequently. Express and courier services, as well as haulage businesses operating on defined routes, visibly publicize this sort of service by emphasizing its "special" nature (Perttula et. al., 2011).

For drivers, this implies more late-night driving. In road transport, regular shift patterns are not the norm; the quantity of night labour required varies according to the needs and demands of the transportation process. In general, night work is a significant cause of stress as well as a significant risk factor for road safety. According to statistics, single-vehicle accidents - those involving only one vehicle and no other road users - are more likely to occur late at night or early in the morning than during the day. Indeed, night employment is extremely stressful since drivers' physiological systems and mental processes must stay vigilant at a time when, according to the regular circadian cycle, they would ordinarily desire to sleep. As a result, the "driver" component of the driver-vehicle-environment system is unable to perform optimally. Fatigued drivers which are less able to anticipate circumstances and drive properly, increase the accident probability. Furthermore, their long-term health will definitely suffer as well (Ani et al., 2022).

2.2.3 Drivers' Work

Although driving appears to constitute the majority of a driver's overall working time, it is far from the sole duty they perform. In fact; even drivers tend to overestimate the amount of time spent behind the wheel, other responsibilities, including loading and unloading, waiting and on-call time, planning, and other administrative chores, as well as vehicle maintenance take up the majority of a driver's working time. While much progress has been achieved in the full automation of operations, machines have not yet been able to operate large freight vehicles. Nonetheless, the responsibilities placed on drivers have altered significantly as a result of the installation of automated, semi-automated, and other driving features in vehicles. Furthermore, in parallel with improvement of technology and mechanics in commercial vehicles, the know-how and understanding needed to remedy technical problems, which were formerly an important element of a driver's abilities, have lost much of their relevance (Tzamalouka et al., 2005).

Drivers are also required to be more cost-conscious in their driving style and more prompt in fulfilling deadlines, according to current logistics notions. Furthermore, the growing prevalence of information and communication technologies, as well as data processing in road transportation, necessitates the ability to use and handle this technology and fundamentally alters the way of organization of drivers' job. Increased traffic congestion has an impact on the demands and constraints that drivers face on a daily basis. Heavy vehicle producers, on the other hand, are working to automate additional vehicle steering operations to solve this problem (Higgins et al., 2017).

Nonetheless, a fundamental aspect of drivers' employment remains unchanged: it is still primarily a task involving the perception, processing, and production of driving task data. Such mental processes require different rates of efforts from drivers depending on the distance travelled. Driving in densely populated locations is certainly the most stressful task than driving on highways.. Driving in country lanes or secondary roads is in the middle of the stress scale. Driving under stressful situations, such as at night, on wet roads, or in the winter, was found to dramatically increase stress (Chung et al., 2019). Such circumstances would warrant a reduction in driver

miles or more frequent breaks. Such measures, however, are challenging to implement given modern logistical notions.

2.2.4 Breaks and Rest Periods

The distribution of breaks and rest intervals during a day's work is critical to drivers' recovery and consequently to road safety. As a result of analysis of 200 truck drivers over 1.000 workdays, it is found that despite the considerable length of their working day, they take too few breaks. The gradual but constant growth in their morning hours can be interpreted as occurring due to late arrival to their destination and prefer sleeping for several hours in their vehicle before unloading (Harris et al., 2023).

Further examination of their working hours indicates distinct disparities in the work rhythms of long and short-distance road drivers. Short-distance drivers have a relatively "normal" daily routine, as their work starts in the morning, have opportunity to take a break for breakfast and lunch, and their daily work finishes in the evening. On the contrary, this is not observed in the work of long-distance drivers, who have largely lost the traditional working time breakdown. To satisfy the needs of the transportation industry, drivers must change the allocation of their working hours. As a result of their schedule of parks and rests, drivers must put their personal needs aside in order to complete their tasks (Voss and Vitols, 2019).

2.3 Road Safety

Long-distance truck driving is unquestionably one of the most hazardous occupations. Any steering error, for example, might result in death: there is no "emergency button" to prevent a lorry that has begun sliding on the road. Apart from driving, drivers are usually required to do some loading and unloading. The fact that drivers are extremely vulnerable to accidents while completing or supervising this type of work is frequently overlooked. However, experts believe that the greatest risk to road safety comes from a combination of poor working conditions, driver weariness, sleepiness, and other fatigue-related disorders. Fatigue and fatigue-related moods are manifestations of a certain level of activation/arousal. There is a distinction to be made between tiredness and other states that are extremely similar in their presentation to exhaustion but have

a different cause and as a result, require different countermeasures if they are to be avoided or reduced. Monotony, boredom, a loss of working motivation, a loss of attention and some types of stress are all examples of this (Davidović et al., 2020).

Risk factors for fatigue-related accidents are; sleepy or tired drivers, driving for a long time without taking a break, driving at night, in the afternoon and during normal sleeping hours, drivers who take sleep-inducing drugs or alcohol (Hancı and Eşiyok, 2001).

2.4 Social Conditions and Employment

2.4.1 Scale of Social Problems in Road Transport

All types of transportation have social issues. There have been several confrontations and strikes involving railway workers, airline pilots, bargees, and other maritime workers. The severity of these issues is determined by a number of factors, including government social policy and support, the financial situation of the sector and its operators, the rate of unemployment, the sector's structure (firm concentration or dispersion), competition intensity, and strictness of regulations and working conditions. It is indeed difficult to say whether social conditions are much worse in road transport than in other modes of transportation, but the size of the road transport workforce would seem to indicate that, from the perspective of social policy in the transportation field, the scale of problems is the most significant challenge (Njå et al., 2012).

The nature of social issues in road transport is influenced both indirectly by the state of the industry and its economic importance, and directly by the organization and working conditions of this mode of transportation. It is impossible to picture a market economy without the ability to use the road for manufacturing and goods distribution. Small and medium-sized businesses (SMEs) would be unable to compete in today's market if only rail or inland waterway transportation were available. Demand for road transportation services is quite strong due to its advantages (flexibility, availability to any place, and inexpensive pricing). As a result, there are an increasing number of road

transport companies, resulting in sector fragmentation and strong competition (Pastori and Brambilla, 2017).

Road transportation is not only a mode of transportation that can not easily be replaced by environmentally friendly modes which are more efficient. On the other hand, it is also such a sector that supports the national economy by facilitating the distribution of goods, offering many job vacancies and assists tourism among many other aspects. The current function of road transportation in economic and social life can not be measured just in terms of external costs; losses resulting from the lack of a strong road transportation system must also be assessed.

The fragmentation of the road transport industry, as well as the presence of a large number of small operators and door-to-door services, demonstrate the sector's unique organizational structure. While a railwayman follows company-defined regulations when doing specialized operations, a lorry driver is frequently forced to perform a variety of tasks (driving, documentation, border formalities, and so on) and bear direct responsibility for the outcomes. However, truck drivers which have increased obligations do not ensure a better wage due to market principles (Mahajan et al., 2019).

2.4.2 Employment Conditions of Road Transport Sector

Mechanized activity leads to unemployment and societal difficulties from a macroeconomic standpoint. Those in charge of social policy are opposed to intensive automation, which is beneficial for solely economic reasons. They have few effective ideas for combating unemployment. Many industrial sectors have made significant technological advancement (robotisation, computerisation, etc.) as a result of technology breakthroughs, resulting in significant labour and cost reductions. The transportation sector is not uniform, and technological advancement varies by mode. For example; pipeline transportation is highly automated and requires a relatively little workforce, whereas road transport takes at least one person to convey even a tiny quantity of commodities. Despite the growing tendency in the number of tonne-kilometres generated per employee, road transport still supports a large number of employment (Zwanenburg and Bednarowicz, 2019). Although social difficulties are observed within the industry, road transportation has a highly favourable role in the

macroeconomic system by quickly absorbing labour. Last but not least; by improving working conditions of drivers, safe and adequate park areas are expected to be one of the factors that decrease driver shortage which is estimated to be approximately 600.000 and if the same trend continues it will reach almost 2 million by 2026 (IRU, 2022). On the other hand total truck park demand is 400.000 in EU but there are only 300.000 lots in service currently which means 100.000 lot of additional park area is already needed (The EU Commission, 2019).

2.4.3 Attractiveness of Working in Road Transport

From the outside, the road transportation industry appears to be both economically and socially appealing. It is considered as a field where becoming your own boss and starting a business have a lot of attraction and a decent possibility of succeeding. Despite all evidence to the contrary, the idea in the prospect of a greater social status and a better standard of life as a self-employed individual persists. Despite the numerous failures, examples of companies going bankrupt are dismissed as minor mishaps that do not jeopardize the core idea.

Freedom of action is a valuable advantage for people who want to provide transportation services. It would be counterproductive to discourage people who want to work in the field and instead urge them to work for a huge, well-organized road transport company. The issue is more about adjusting small and competitive positions of leading companies. Small enterprises are not capable of performing all of the operations of large operators, and it would be unreasonable to diminish the efficiency of the leading firms. However, better road transport environment might mitigate the mentioned disadvantages by teaching costs management to expand their companies (Fenelon, 2017).

2.5 Truck Park Areas

2.5.1 Truck Park Area Operations and Demand Analysis

In metropolitan areas where land demand for numerous facilities exceeds their limited capacity, difficulties are seen in allocating additional areas for truck parking. Although demand for truck parks is high and constant, this makes it more difficult for operators

to build and operate in certain areas. (Giuliano et al., 2018). Although wok time regulations stipulate strict and certain rules for the parking of trucks, decent infrastructure of park areas is not provided in many regions (Martin and Shaheen, 2012). However, it is hard to increase the capacity of parking areas. Most of 87 truck park areas were constructed before 1970 in California which demonstrate difficulty of increasing parking capacity (Caltran 2019). In the same a similar direction, a report compiled by the Arizona Department of Transportation identifies the usage of completely autonomous cars in the future as one of the most essential solutions to the problem. This conclusion was reached after taking into account the restrictions that prevent the development of more truck parking sites and the rising demand.(CPCS, 2019). In this regard, increasing efficiency of existing park infrastructures and limiting additional parking areas which is the objective of this study is a very important alternative solution which is not been studied with the same approach before.

Studies generally underline the importance of dissemination of real-time park area availability information between drivers by technological support of intelligent transport systems (ITS) integrated to smartphone applications in terms of efficiency. As a result of a survey of the American Transportation Research Institute, parking monitoring technologies, variable message signs, smartphone applications, embedded "information push" systems, and formalizing truck parking information system standards are recommended to increase the efficiency of park area utilization (Murray and Shirk, 2021). Utilization of truck information systems in terms of facility investment planning is emphasized while multi-linear regression analysis is found appropriate for the estimation of future truck parking demands (Gitau, 2021). In this regard, The Global Positioning System (GPS) data was utilized in order to analyse location of parking of trucks and it is found that 1.2% are parked at undesignated locations while 82.7% of parking periods are spent at industrial or commercial park areas. Besides, parking duration shows various amounts due to the parking location (WSP, 2021). This outcome supports the idea of this study which is criticizing the current approach of meeting various demands of park with a single uniform type of park areas. Therefore, this study suggests that it is essential to consider the location and specific needs of each park area to meet the diverse demands of truck drivers such

as long or short-term parking. By doing so, we can create more effective and efficient park management strategies.

On the other hand, the collection and utilization of data vary significantly, and the needs of each parking facility should be defined accordingly before the design of smart park information systems. There are 10 functional requirements, 3 organizational requirements that are advised for all park areas while 2 functional requirements and 1organisational requirement could be accepted as optional for smart park systems (EasyWay, 2012).

The Kansas Department of Transportation (KDOT) defines peak hours for truck parking as between 12 a.m. and 4 a.m. (KDOT, 2015). It can be interpreted as Kansas is located in a center point of long trips and drivers use park areas for short breaks. However, the study reveals that drivers search for an appropriate parking area for 30 minutes on average which is approximately equal to the duration of a short break. Peak parking demand, parking duration on average, as well as average duration per hour travelled, are the main components similar in Virginia Truck Parking Study for the demand estimation model (Kimley Horn, 2015). Driving and rest hours regulation is the critical factor affecting choices of park location due to the survey of the Utah Department of Transportation (UDOT, 2012). Field observation supplemented by wireless sensors located on the surface of park areas are beneficial for data collection for the occupancy prediction model (FDOT, 2012). There are three main types of ITS systems deployed for identifying the availability of truck parking. Video Detection Systems, In-Pavement Sensor Systems, and Light and Laser Detection Systems are the three main components in terms of ITS infrastructures that are capable of providing park area availability data. While Laser Detection Systems are highly accurate, In-Pavement Sensors have a cost advantage. Video detection also has installation and maintenance costs. On the other hand, accuracy problems in snow, rain and vulnerable to the wind, sun, etc. (NCDOT, 2017). Internet/Website information portals, Roadside Changeable Message Signs (CMS), and onboard geolocation applications are another sources of data for truck parking. After a study implemented data collection with a pilot, %66.7 of drivers answered that the truck parking information system has had a positive effect for finding an available place to park as well as complying with

compulsory rest times (Morris et al.,2017). Smart parking management systems are increasing the supply of parking spaces by matching supply and demand better in places that a parking shortage observed (Bayraktar et al., 2014).

The utilization ratio of parking areas varies across regions, from 48% to 97%, with the national average being 76% result of 311 park areas in England suitable for long parking with a total capacity of 15,012 parking lots according to a study of Department of Transport and Highways England (Masamvi, 2017). It could be interpreted as approximately %25 of the capacity is not used and requires additional efforts in terms of efficiency. Based on the views of drivers, 11 variables are defined to determine safe and adequate truck parking and less-than-truckload shipments, drivers between the ages 60–69, and weekdays are found as the factors which directly affect safe and adequate parking (Anderson et al., 2018).

There are contradictions between the tasks and personal needs of drivers for their parking decision. To meet the strict requirements such as delivery times of the transportation industry, drivers must change the allocation of their working hours. As a result of their schedule of parks and rests, people must put their personal needs aside to complete their tasks (Voss and Vitols, 2019).Traffic simulations play key role to understand park demand and forecast future trends. There are extensive aspects including establishing traffic networks and vehicle models which are very critical for the results of simulation should be considered to assess traffic simulation systems (Akkaya and Engin, 2022). As a consequence of the mentioned study; it gives idea to the researchers who seek information of traffic simulation software which have the potential to support the planning of truck park area and integrate truck park module to them as well.

The Research Report from the National Center for Sustainable Transportation (NCST) is elaborated on the effectiveness of the prices of parking. Results show that in the case of truck drivers keeping optimal schedules, parking fees would effectively help change the locations and time slots to be parked by drivers individually. However, price adjustments may sometimes cause change of demand in unexpected and not always beneficial directions, likely due to working time regulations (Vital and Ioannou, 2022). In this context, further investigations are needed to understand better the features of

the system and how these ondulation can be avoided or dampened. Additionally, due to customer demands and working time regulations, it may be impossible to sufficiently diverting of demand from locations and certain periods of time. Nevertheless, this model could contribute for the determination of the mentioned spots and the assessment of infrastructure investment requirements.

According to a study of the American Transportation Research Institute (ATRI) truck drivers consume an average of 56 minutes of their daily time of driving in order to find a park area. This spare driving time consequently reduces the productivity of each driver by 9.300 income-generating miles yearly – which is equal to loss of $4.600 of their wages of annually and approximately %10 of their total income (Boris and Brewster, 2018). It is expected to observe a decrease in these amounts after the application of efficient park area capacity utilization models and underlines the importance of this study in terms of economical aspects.

Most research under driver rest times subject could be associated with truck park demand analysis since each truck driver will require a parking lot in order to perform their rest activities. An example for such study is solving truck driver scheduling with interdependent routes while ensuring working time constraints. A two-stage algorithm minimizes delivery time under maximum continuous driving time, limited working hours, and break restrictions for a single working day (Sartori, et al., 2022). Parking demand could be derived from this model for the vehicles with determined routes. Another study (Goel - Irnich ,2014) is regarding the problem of unified vehicle routing and truck scheduling, which is trying to schedule compliant with working and rest hour constraints. To solve this problem, the authors proposed the branch and price algorithm, which is the first definitive algorithm to solve the combined vehicle routing problem with the time windows method with optimal results. (Prescott-Gagnon et al. 2010) discussed the European Driving Rules in the vehicle routing problem to create a routing in accordance with the European Regulations. To solve this problem, a Broad Neighborhood Search meta-heuristic was proposed, and the calculation results demonstrated the effectiveness of this method when compared to the branch and price heuristic and Tabu Search Column Generator.

Knust and Schumacher, (2011) process the Tank Truck Drivers Schedule with the purpose of this question assign a driver to each position while legal restrictions and security conditions are met. A mixed integer linear programming formulation and an optimization procedure are developed and the results indicated that the algorithm was capable of generating feasible charts without requiring long time. Non-preemption and pre-emption is another important factor for linear formulations addressing Truck Drivers Scheduling Problem (Arenas, 2022). Label setting algorithm for solving TDSP that minimizes the completion time and performs well in terms of both solution quality and uptime so that computation times are less as well. The Truck Driver Scheduling Problem with Fatigue Monitoring (TDSPFM) is an extended model which incorporates alertness score levels, sleep assumptions and hours of service regulations and it shows the extra time required by consideration of the mentioned constraints for the basic schedules (Bowden and Ragsdale, 2018).

In addition for the duration of parking, driving time of the extra distance to reach the park areas should be considered in order to make more accurate scheduling. The inclusion of additional constraint of parking availability forecasts at each park throughout the route to scheduling models for short and long trips does not result in extra delivery times (Ioannou-Vital, 2017). Machine learning is another approach in order for predicting park area availability which contributes to this study. A model which is based on the fusion of Extreme Gradient Boosting (XGBoost) and Long Short-Term Memory (LSTM) predicts park area availability successfully using only historic occupancy data (Gutmann et al., 2021). This prediction is expected to reduce the extra time spent by drivers in order to find an available lot in one of the parking areas. Acceleration by narrowing down searches, defining contraction hierarchies constraints and heuristics helps reduce run-times of time-dependent route planning for truck drivers (Kleff et al., 2017).

Another approach which is implementation of a central platform which collectively determines driving and rest times for a specific group of trucks with fixed routes and coordinates their allocation to a limited number of available parking lots for a given period is tested by a holistic optimization problem. It is solved by heuristic decomposition approach and results show that a booking platform which requires less

sophisticated management tasks than a central platform processing exact data of truck schedules performs similarly in terms of efficiency (Pilz et al., 2022).

Queuing models show that development of a better prediction algorithm for service time distribution models has a larger potential impact than a better arrival prediction algorithm. Besides, conventional model-free prediction algorithms could be utilized in order to develop probabilistic forecast models in field of park area planning (Tavafoghia et al., 2019). Utilization of data mining algorithms in order to find truck parking association patterns could be implemented with multi-day truck trajectory GPS data. This method enables easy management of handling of high-volume trajectory parking related data as well as improves tracking decisions for investments and related regulations (Yu et al., 2021).

Dynamic parking and route guidance system based on real time traffic data which proposes drivers to switch their park area and routes provides cost reduction for parking. Besides, this approach also allows a balanced demand for park area capacity of different operators so that under and over demand for different park areas are observed less (Chai et al., 2019). Capacity and demand imbalance is a significant issue since it is shown as a result of agent-based simulation modelling of park areas of Arkansas that overcrowding occurred at 26 of the 168 park areas in Arkansas (Mahmud, 2021). Wavelet neural network model which is a one of feed-forward neural network is also proven as an efficient system for forecasting short-term available parking. The model applied to parking guidance information systems surpasses the largest Lyapunov exponents (LEs) method in terms of efficiency, robustness and accuracy (Ji et al., 2014).

Improved complete ensemble empirical model decomposes time series of park periods and reduce its nonlinear and complex structure. Integration of gate recurrent unit (GRU) models for simultaneous learning methods provides prediction accuracy and stability by reducing the prediction errors. As a result; closest results for predicting parking demand are achieved (Li and Zhong, 2023). Choosing the right model for recurrent neural network is also important for the achievement of accurate predictions. For example, random forest regression model performs better than long short term memory model for predicting parking lot availability with a set of 5.500 parking lot

data which collected every 15 minutes and consists of 47.605 entries in 1 year period (Sadia et al., 2021). Similarly, Random Forest and K-Nearest Neighbours models outperforms computationally complex algorithms like Multilayer Perceptron, with higher prediction accuracy while comparable results are provided. It is also appropriate to process large datasets and 1.252.936 records are used for the model (Awan et al., 2020). However, a sequence-to-sequence deep learning model – Truck Parking Occupancy Prediction (TPOP) neural network makes more accurate prediction than random forest and long short-term memory models by the attribute feature extraction module which has better impact on the prediction sequence and extracts more beneficial representations of attribute. Truck Parking Information and Management System (TPIMS) which is integrated with Truck Parking Occupancy Prediction (TPOP) neural network for time-variant occupancy prediction by deep learning and embedded attributes have a proven outperformance compared to other state of art solutions (Yang et al., 2022).

The dynamic information services based on machine learning methods provides more effective route planning and thus fewer parking problems and compliance with compulsory rest time periods, service of more trucks in the park areas, and higher revenue for parking infrastructure owners with efficient utilization of capacity as well as cost reductions of construction and maintenance of truck park infrastructure (Slavova et al., 2022), which are similar outcomes of this study.

As a conclusion of this section, the literature regarding truck park areas and driving and rest times could be put into 3 categories:

I. Ergonomic, social and road safety aspects of driving and rest times

II. Estimation of parking place decision of drivers' location allocation of park areas

III. Analysis of parking demand and shortage of infrastructure in accordance with unserved vehicles. The mentioned studies are summarized in Table 2.1 as follows:

Table 2.1 Summary of related studies

Author(s)	Methodology	Results
Giuliano et al., (2018)	Impact analysis	Increasing the supply of truck parking would allow drivers better schedules of rest stops so increasing parking would increase safety.
Martin and Shaheen, (2012)	Clipboard survey	Average Annual Daily Five-Axle Truck Traffic data be used to profile the truck traffic on a corridor
Caltran, (2019)	Data analysis	Average annual daily traffic data analysis demonstrates the difficulty of increasing parking capacity
CPCS, (2019)	Survey and consultations with the trucking industry and drivers	Truck parking supply, demand, and needs analysis are performed based on answers of the survey.
ATRI, (2019)	Truck driver survey	The importance of park area information system is underlined and deficiencies of the current systems are detected
Gitau, (2021)	Multiple regression analysis	Future truck park demand is forecasted by the study in a specific region
WSP, (2021)	GPS data analysis	Relation of parking locations and durations is assessed
EasyWay, (2012)	Classification of data and technical infrastructure	Data collection and technical requirements are classified due to the defined service levels of parks.
KDOT, (2015)	Data collection method included an inventory assessment,	Peak hours and average time spent on park search are determined and improvement solutions are prepared.
Kimley Horn, (2015)	Demand estimation model	Model prepared based on peak parking demand, average parking duration, and average parking duration per hour of travel
UDOT, (2012)	Survey of drivers	Drivers' views of parking in the corridor, preferences for truck stop amenities, and real-time parking information are outlined.
FDOT, (2012)	Occupancy prediction model	Occupancy prediction model to predict available parking spaces at a date and time specified by the user is developed.
NCDOT, (2017)	SWOT analysis	SWOTt analyses were made for 3 ITS system infrastructures for parking availability data
Bayraktar et al., (2014)	Smart parking management system	Increasing the supply of parking spaces, and better matching supply and demand in areas where a parking shortage exists
Morris et al., (2017)	Survey and field test	A comprehensive ITS approach to deliver truck parking information to drivers and carriers was developed, tested, and demonstrated.
Masamvi and Reardon (2017)	Survey and consultation	Capacity utilization ratios of park areas are calculated.

Anderson et al., (2018)	Driver survey	LTL shipments, drivers between the ages 60–69, and weekdays are the factors that directly affect safe and adequate parking.
Voss and Vitols, (2019)	Survey of parking decisions of drivers	Drivers put their personal needs aside in order to complete their tasks
Akkaya and Engin, (2022)	Comparison of features of renowned traffic softwares	Pros and cons of traffic simulation models are explained
Boris and Brewster, (2018)	Detailed truck parking examination based on real data	Comparison of the effect of personal needs, obligatory rest, and location of park area on parking decisions
Sartori et al., (2022)	Mixed-integer linear programming	Scheduling problem with interdependent routes solved by two-stage algorithm ensure their feasibility with respect to rest time regulation
Goel and Irnich (2014)	Branch and price algorithm	The optimal solution achieved with vehicle routing problem with time windows method
Prescott andGagnon et al. (2010)	Large neighborhood search meta-heuristic	Efficiency compared to Tabu Search Column Generator and the branch and price heuristic
Knust andSchumacher, (2011)	Mixed integer linear programming	Algorithm was capable of generating feasible charts without requiring long time
Arenas, (2022)	Label setting algorithm and mixed integer linear programming	LS algorithm for solving TDSP minimizes completion time and performs well with fewer computation times
Bowdenand Ragsdale, (2018)	Linear programming	Calculation of extra time stems from alertness levels, sleep assumptions as well as hours of service regulations
Ioannou andVital, (2017)	Mixed integer linear programming	Models for short and long trips prepared provides parking availability forecasts at each park throughout the route
Gutmann et al., (2021)	Machine-learning	A model is based on the fusion of Extreme Gradient Boosting (XGBoost) and Long Short-Term Memory (LSTM) provide forecasts based on historic occupancy data.
Kleff et al., (2017)	Acceleration by contraction hierarchies and heuristic	Defined contraction hierarchies and calculated effect of park periods analyzed by a heuristic model
Pilz et al., 2022	Heuristic decomposition	Booking platforms perform similarly in terms of efficiency with central assignment platforms
Tavafoghia et al., 2019	Queuing model	Service time distribution models and probabilistic forecast models are offered for park area plans.
Yu et al., 2021	Data mining algorithms	Vehicle trajectory data
Mahmud, 2021	Agent-based simulation	26 of the 168 park areas in arkansas are overcrowded

Chai et al., 2019	Dynamic parking guidance	Switch their park area and routes based on real data decreases costs
Ji et al., 2014	Wavelet neural network model	More efficient system for forecasting short-term available parking than the largest lyapunov exponents
Li and Zhong, 2023	Gate recurrent unit	Gate recurrent unit models increase accuracy and stability of park area prediction
Sadia et al., 2021	Recurrent neural network	Random forest regression model performs better than long short term memory model for predicting parking lot availability
Awan et al., 2020	Machine/deep learning	Random forest and k-nearest neighbours models outperforms multilayer perceptron
Yang et al., 2022	Sequence-to-sequence deep learning model	Makes more accurate prediction than random forest and long short-term memory models
Slavova et al., 2022	Machine learning	The dynamic information services increase efficiency

2.6 Literature Gap and Research Objectives

Considering the literature and general implementation in the truck parking sector, the differentiation of parking areas and their potential advantages are underestimated. In this context, this study complements the mentioned approach by differentiating truck parks as short-duration and long-duration park areas. However, a counterexample to this approach could be that some truck drivers may require both short and long-duration parking in the same location, such as for overnight rest breaks and quick stops for meals or restocking supplies. In this case, the differentiation of parking areas may not be practical or beneficial for all truck drivers. The feasibility of the proposed park system is examined using a mathematical model and Monte Carlo simulation, and its contributions to efficiency and advantages are compared with tangible results. The novel approach is expected to make a significant contribution in order to meet park area demand, which is already not sufficient in many countries, and the necessity of additional park areas, an important topic with an increasing trend in parallel with transport activities and global trade, with a smart solution that allows providing parking service for more vehicles, cost reduction, and flexible pricing and location-allocation.

CHAPTER 3

METHODOLOGY

3.1 SLPD Model

The indices and notations which are used in mathematical modeling are shown in Table 3.1.

Table 2.1 Indices and Notation List

Parameters	Explanation
B_{st}	: Average time length of trucks for short break in rest area at time *t*
B_{lt}	: Average time length of trucks for long break in rest area at time *t*
c	: Capacity of rest area
c_s	: Capacity of short break rest area
c_l	: Capacity of long break rest area
N_t	: Number of trucks in rest area at time *t*
N_{lt}	: Number of long break trucks in rest area at time *t*
N_{st}	: Number of short break trucks in rest area at time *t*
T	: Time duration
TP	: Total profit
X_l^-	: Min length of long break time spent in rest area
X_l^+	: Max length of long break time spent in rest area
X_s^-	: Min length of short break time spent in rest area
X_s^+	: Max length of short break time spent in rest area
α	: Hourly profit for short break from each truck
β	: Hourly profit for long break from each truck
θ	: Hourly opportunity cost for each null parking lot
θ_l	: Hourly opportunity cost for null long parking lot
θ_s	: Hourly opportunity cost for null short parking lot
ζ	: Hourly operation cost of each parking lot
γ	: Threshold value for truck break time $\begin{cases}\gamma \leq 0.35, & short\ break \\ \gamma > 0.35, & long\ break\end{cases}$
ρ_s	: Threshold value for short break time $\begin{cases}0 \leq \rho_s \leq 0.33, & V_{s1} = 15\ mins \\ 0.33 < \rho_s \leq 0.66, & V_{s2} = 30\ mins \\ 0.66 < \rho_s \leq 1.00, & V_{s3} = 45\ mins\end{cases}$
ρ_l	: Threshold value for long break time $\begin{cases}0 \leq \rho_s \leq 0.43, & V_{l1} = 9\ hours \\ 0.43 < \rho_s \leq 0.86, & V_{l2} = 11\ hours \\ 0.86 < \rho_s \leq 1.00, & V_{l3} = 30\ hours\end{cases}$

The objective of this research is to determine the effect of the Short and Long Park Differentiation (SLPD) Model in rest area for truck drivers. A universal rest area in Fig. 3.1 where short- and long-term parking are accepted as two types of parking choice. The parking length for both short term and long term parking choices are divided in three categories 15, 30, and 45 mins for short-term parking, and 9, 11 and 30

hours for long-term parking. B_{st} and B_{lt} are average time length of trucks for short-break and long break driver spent in rest area at time t.

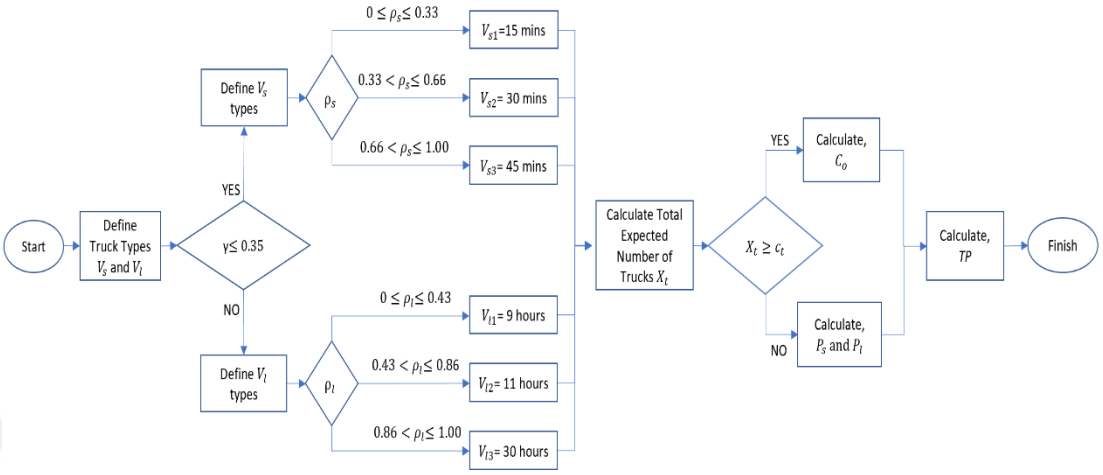

Figure 3.1 Universal type rest area parking planning simulation model

Fig. 3.2 illustrates that the SLPD lots in rest area. The proposed parking planning increase both total profit of rest area and the demand fulfilment rate of truck drives without drastically increasing operation cost of rest area or capacity utilization rate. The details of the proposed SLPD lots in rest area for truck drivers models are addressed in Eq (3.2) as below.

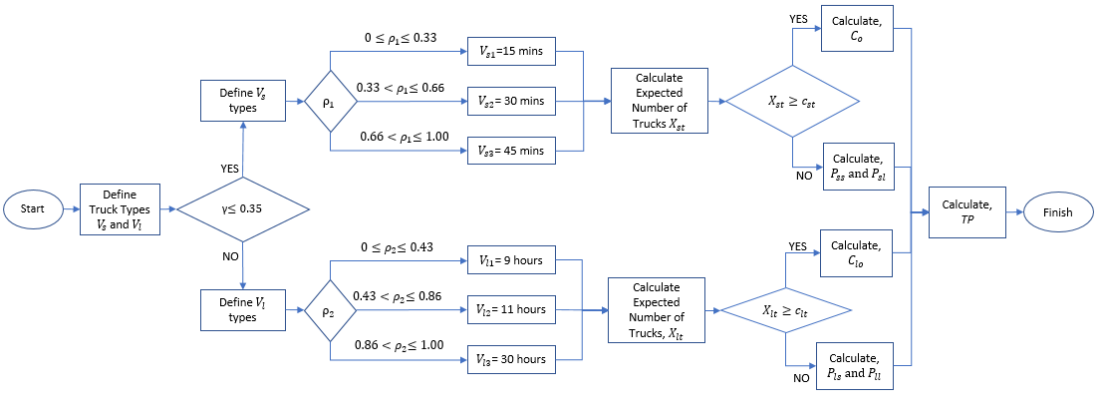

Figure 3.2 SLPD type rest area parking planning simulation model

Mathematical Model

For ease of use, it was assumed that the mathematical model's representation of the appointment length is a uniform distribution. By accounting for both the opportunity cost and the operating cost, the model was created to determine a better way to design rest areas, which could be used to reduce the overall cost. The expected total profit is made up of the expected number of vehicles served over both short- and long-term periods, which are defined for universal and proposed SLPD types in Eq. (3.1) and Eq. (3.2), respectively as follows:

$$E[TP] = \alpha \sum_{t=1}^{T} N_{st} P(\gamma \leq 0.35) + \beta \sum_{t=1}^{T} N_{lt} P(\gamma > 0.35) - \zeta \sum_{t=1}^{T} N_t - \theta \sum_{t=1}^{T} (c - N_t) \tag{3.1}$$

where $N_t = \sum_{t=1}^{T} N_{st} + \sum_{t=1}^{T} N_{lt}$.

$$E[TP] = \alpha \sum_{t=1}^{T} N_{st} P(\gamma \leq 0.35) + \beta \sum_{t=1}^{T} N_{lt} P(\gamma > 0.35) - \zeta \sum_{t=1}^{T} (N_{st} + N_{lt}) - \theta_l \sum_{t=1}^{T} (c_l - N_{st}) - \theta_s \sum_{t=1}^{T} (c_s - N_{st}) \tag{3.2}$$

Uniform distributions are the distributions applied for continuous random variables. In this regard, $P(\gamma \leq 0.35)$ is assumed on the cumulative distribution function, which for the uniform distribution is $\frac{B_{st} - x_{st}^{-}}{x_{st}^{+} - x_{st}^{-}}$ and $\frac{B_{lt} - x_{lt}^{-}}{x_{lt}^{+} - x_{lt}^{-}}$. Therefore, Eq. (3.1) and Eq. (3.2) can be revised as

$$E[TP] = (\alpha - \zeta + \theta)\sum_{t=1}^{T} N_{st}\frac{B_{st} - x_{st}^{-}}{x_{st}^{+} - x_{st}^{-}} + (\beta - \zeta + \theta)\sum_{t=1}^{T} N_{lt}\frac{B_{lt} - x_{lt}^{-}}{x_{lt}^{+} - x_{lt}^{-}} - \theta\sum_{t=1}^{T}(c) \tag{3.3}$$

$$E[TP] = (\alpha - \zeta + \theta_s)\sum_{t=1}^{T} N_{st}\frac{B_{st} - x_{st}^{-}}{x_{st}^{+} - x_{st}^{-}} + (\beta - \zeta + \theta_l)\sum_{t=1}^{T} N_{lt}\frac{B_{lt} - x_{lt}^{-}}{x_{lt}^{+} - x_{lt}^{-}} - \theta_l\sum_{t=1}^{T}(c_l) - \theta_s\sum_{t=1}^{T}(c_s) \tag{3.4}$$

By using the uniform distribution, the first and second derivatives of Eq. (3.3) based on the short and long-term parking variable shown in Eq. (3.5-3.6) and Eqs. (3.7-3.8,) respectively can be calculated as follows:

$$\frac{d}{dB_{st}} = \frac{N_{st}(\alpha - \zeta + \theta)}{x_{st}^{+} - x_{st}^{-}} \tag{3.5}$$

$$\frac{d}{dB_{lt}} = \frac{N_{lt}(\beta - \zeta + \theta)}{x_{lt}^{+} - x_{lt}^{-}} \tag{3.6}$$

$$\frac{d^2}{d^2B_{st}}\left[\frac{N_{st}(\alpha - \zeta + \theta)}{x_{st}^{+} - x_{st}^{-}}\right] = 0 \tag{3.7}$$

$$\frac{d^2}{d^2B_{lt}}\left[\frac{N_{lt}(\beta - \zeta + \theta)}{x_{lt}^{+} - x_{lt}^{-}}\right] = 0 \tag{3.8}$$

As shown in Eqs. (3.5-3.6), the optimal value *E[TC]* could be affected by relationship between α, ζ and θ. Because, it is know that $N_{st}, N_{lt} \geq 0$ and $x_{st}^{+} \geq x_{st}^{-}$ and $x_{lt}^{+} \geq x_{lt}^{-}$.

However, the second derivative Eq. (3.3) equals to zero are shown in Eqs(3.6-3.7). These results imply that relationship between α, ζ and θ could not granteed to confirm the results of the first derivivatives are local or glabol maximum points.

Also, the first and second derivatives of Eq. (3.4) are taken based on the short and long-term parkings variable shown in Eqs. 3.9-3.10 and Eqs. 3.11-3.12, respectively and can be calculated as follows:

$$\frac{d}{dB_{st}} = \frac{N_{st}(\alpha - \zeta + \theta_s)}{x_{st}^{+} - x_{st}^{-}} \tag{3.9}$$

$$\frac{d}{dB_{lt}} = \frac{N_{lt}(\beta - \zeta + \theta_s)}{x_{lt}^{+} - x_{lt}^{-}} \tag{3.10}$$

$$\frac{d^2}{d^2B_{st}}\left[\frac{N_{st}(\alpha - \zeta + \theta_l)}{x_{st}^{+} - x_{st}^{-}}\right] = 0 \tag{3.11}$$

$$\frac{d^2}{d^2B_{lt}}\left[\frac{N_{lt}(\beta - \zeta + \theta_l)}{x_{lt}^{+} - x_{lt}^{-}}\right] = 0 \tag{3.12}$$

The results of Eqs. (3.9- 3.12) imply similar outcomes of the first and second derivatives of Eq. (3.3), even if The differences are appear in θ_s and θ_l. The complexity of Eq. (3.3) and Eq. (3.4) are accepted has same. By calculation of second derivations of both of them, existence of local and global optimal at a stationary point is tested. In case of second derivative is less than 0, it would be possible to obtain the global or local maximum at a stationary point. However, second derivatives of both Eq. (3.3) and Eq. (3.4) are equal to 0 which means that the test is inconclusive. Therefore, they could not help to confirm local or global optimal points. For these reasons, another optimization method, Monte Carlo simulation is applied to analyse the proposed SLPD model and compare its results with the universal parking planning model.

Derivative of Eq. (3.3) for B_{st} as follows:

$$\frac{d}{dB_{st}} = \frac{N_{st}(\alpha-\zeta+\theta)(B_{st}-x_{st}^{-})}{x_{st}^{+}-x_{st}^{-}} + \frac{N_{lt}(\alpha-\zeta+\theta)(B_{lt}-x_{lt}^{-})}{x_{lt}^{+}-x_{lt}^{-}} + c\theta$$

$$= \frac{N_{st}(\alpha-\zeta+\theta)}{x_{st}^{+}-x_{st}^{-}}\left(\frac{d}{dB_{st}}[B_{st}] + \frac{d}{dB_{st}}[x_{st}^{-}]\right) + \frac{d}{dB_{st}}\left[\frac{N_{lt}(\alpha-\zeta+\theta)(B_{lt}-x_{lt}^{-})}{x_{lt}^{+}-x_{lt}^{-}}\right] + \frac{d}{dB_{st}}[\,c\theta] \quad (3.13)$$

$$= \frac{N_{st}(\alpha-\zeta+\theta)}{x_{st}^{+}-x_{st}^{-}}(1+0) + 0 + 0$$

$$= \frac{N_{st}(\alpha-\zeta+\theta)}{x_{st}^{+}-x_{st}^{-}}$$

Derivative of Eq (3.4) for B_{lt} as follows:

$$\frac{d}{dB_{lt}} = \frac{N_{st}(\alpha-\zeta+\theta)(B_{st}-x_{st}^{-})}{x_{st}^{+}-x_{st}^{-}} + \frac{N_{lt}(\alpha-\zeta+\theta)(B_{lt}-x_{lt}^{-})}{x_{lt}^{+}-x_{lt}^{-}} + c\theta$$

$$= \frac{d}{dB_{lt}}\left[\frac{N_{st}(\alpha-\zeta+\theta)(B_{st}-x_{st}^{-})}{x_{st}^{+}-x_{st}^{-}}\right] + \frac{N_{lt}(\alpha-\zeta+\theta)}{x_{lt}^{+}-x_{lt}^{-}}\left(\frac{d}{dB_{lt}}[B_{lt}] + \frac{d}{dB_{lt}}[x_{lt}^{-}]\right) + \frac{d}{dB_{lt}}[\,c\theta] \quad (3.14)$$

$$= 0 + \frac{N_{lt}(\alpha-\zeta+\theta)}{x_{lt}^{+}-x_{lt}^{-}}(1+0) + 0$$

$$= \frac{N_{lt}(\alpha-\zeta+\theta)}{x_{lt}^{+}-x_{lt}^{-}}$$

Derivative of Eq (3.4) for B_{st} as follows:

$$\frac{d}{dB_{st}} = \frac{N_{st}(\alpha-\zeta+\theta_s)(B_{st}-x_{st}^-)}{x_{st}^+-x_{st}^-} + \frac{N_{lt}(\alpha-\zeta+\theta_l)(B_{lt}-x_{lt}^-)}{x_{lt}^+-x_{lt}^-} + c_s\theta_s + c_l\theta_l$$

$$= \frac{N_{st}(\alpha-\zeta+\theta_s)}{x_{st}^+-x_{st}^-}\left(\frac{d}{dB_{st}}[B_{st}] + \frac{d}{dB_{st}}[x_{st}^-]\right) + \frac{d}{dB_{st}}\left[\frac{N_{lt}(\alpha-\zeta+\theta_l)(B_{lt}-x_{lt}^-)}{x_{lt}^+-x_{lt}^-}\right] + \frac{d}{dB_{st}}[c_s\theta_s] + \frac{d}{dB_{st}}[c_l\theta_l] \quad (3.15)$$

$$= \frac{N_{st}(\alpha-\zeta+\theta)}{x_{st}^+-x_{st}^-}(1+0)+0+0+0$$

$$= \frac{N_{st}(\alpha-\zeta+\theta)}{x_{st}^+-x_{st}^-}$$

Derivative of Eq (3.4) for B_{lt} as follows:

$$\frac{d}{dB_{lt}} = \frac{N_{st}(\alpha-\zeta+\theta_s)(B_{st}-x_{st}^-)}{x_{st}^+-x_{st}^-} + \frac{N_{lt}(\alpha-\zeta+\theta_l)(B_{lt}-x_{lt}^-)}{x_{lt}^+-x_{lt}^-} + c_s\theta_s + c_l\theta_l$$

$$= \frac{d}{dB_{lt}}\left[\frac{N_{st}(\alpha-\zeta+\theta_s)(B_{st}-x_{st}^-)}{x_{st}^+-x_{st}^-}\right] + \frac{N_{lt}(\alpha-\zeta+\theta_l)}{x_{lt}^+-x_{lt}^-}\left(\frac{d}{dB_{lt}}[B_{lt}] + \frac{d}{dB_{lt}}[x_{lt}^-]\right) + \frac{d}{dB_{lt}}[c_s\theta_l] + \frac{d}{dB_{lt}}[c_l\theta_l] \quad (3.16)$$

$$= 0 + \frac{N_{lt}(\alpha-\zeta+\theta)}{x_{lt}^+-x_{lt}^-}(1+0)+0+0$$

$$= \frac{N_{lt}(\alpha-\zeta+\theta)}{x_{lt}^+-x_{lt}^-}$$

According to results of Eqs (3.14-3.16), the results could not confirm local or global optimal points. For these reasons, Monte Carlo simulation is applied to analyse the proposed SLPD model and compare with the universal parking planning model.

3.2 Simulation

Simulation in its broadest sense means the representation (similarity) of reality. Simulation; verbal, formal or is represented symbolically. Simulation, as it is used today, is one of the problems encountered in the field of business management. Modelling an experiment or a physical phenomenon with the help of computers is called simulation. The model established is sometimes an equation, a group of equations, or it can sometimes contain a random group.

A real study through mathematical models, which envisages the use of computers to solve problems. It is a technique for representing the system. Simulation is an easy way to solve the problems faced by businesses and they are designed to ensure the smooth operation of the system. These designed models have the opportunity to experiment on them and as a consequence it prevents mistakes from causing a great harm (Tekin, 2010). Observing a simulated system offers more advantages than collecting information. The simulation is beyond the executed processes and it also offers the advantages of developing detailed analysis of processes by providing the opportunity to implement different scenarios (Aktepe et al.,2009). Simulation is a way of modelling the merits of an activity or system. The models enable to conduct experiments to evaluate the behaviour or response of the systems. Like linear programming it is not an optimizing method, but it provides the opportunity to solve the problems which are not suitable for optimal solution.

Literally, simulation is a technique that is frequently used in solving business problems (Düzakın, 2005). The purpose of simulation is to emulate a real world system with its inputs and outputs mathematically. As a concept, it is ability for recognizing and researching through the established model, trying different decisions and options, without requirement of any changes in the real system. The success of a simulation is determined by its reflection capability of real systems. In order to maintain the model to show similar behaviour with the real system, it is necessary to prepare the model

with accurate description of the purpose and existing problems, collection of decent data necessary for the preparation of the model simulation and selection of the appropriate simulation program.

3.2.1 The Role of Simulation in Increasing Efficiency

In the competitive environment of today, success of enterprises depends on their ability to make right decisions. In order to make the right decisions, collection and processing of data, as well as use of improved decision making techniques are significant factors. Simulating a system is establishment of a model that can represent that system process. The simulation method is a flexible solution method and changes can be made when necessary. Most complex, real-world systems with stochastic components cannot be accurately represented by models that can be solved analytically.

The simplification required for analytical solutions to complex problems significantly affects the results of the analysis. However, conditions and constraints that can not be examined in any other method can be modelled with the simulation method, and the simulation method can reflect the complexity of the system without losing its simplicity. For systems or processes that take a long time, it may be necessary to change the time period. In such cases, simulation is an approach that can provide complete control over time so that the event can be accelerated or slowed down as desired. In this way, in cases where the results can only be obtained after a long time, the system can be analysed in a very short time with the simulation method.

The simulation process is an iterative process and often reveals important information and new perspectives. New views and policies can be easily applied on the model without changing the modelled system. With the simulation method, by making a trial on the model of the system provides more control over the system when it is compared to implementation on real system.

The simulation method can be used both as an analysis tool to determine the impact of possible changes in the existing system and as a design tool to determine the performance of a new defined system under changing conditions. The information obtained during the simulation process helps to improve the system and simulation

method can be used as a learning tool to strengthen analytical solutions. Simulation is a tool that allows managers to understand the behaviour of the system in depth and concentrate on the core activities of the business such as product development, customer acquisition, customer satisfaction and sustainability.

3.2.2 Disadvantages of Simulation

Developing a good simulation model becomes more complex as the system becomes more complex results costly and more time consuming modelling process. Reducing the expenditures For modelling and analysis may cause the simulation to be insufficient to reflect critical aspects of the system. Simulation models are not as successful as optimization. It is not guaranteed to produce optimal results, it is a kind of trial and error method. Each simulation model is unique and solutions and results generally cannot be used to solve other problems since a simulation model is prepared according to the each system to be examined individually

The stochastic nature of the simulation method requires many experiments to perform a statistical analysis. In this regard; a mistake in modelling and analysis of findings lead to incorrect results. It may be impossible to simulate every alternative. However, the best result can be found among alternatives which are not simulated. It is not possible to detect whether a better outcome will emerge from among the other alternatives.

3.2.3 Monte Carlo Simulation

Monte Carlo (MC) is mathematical simulation with random variables and it is a numerical method used to solve problems. The MC method, a common numerical technique, is a widely used method for modelling from numerical integration problems in mathematics to probabilistic interest rates in economics. It has developed in parallel with the widespread use of computers and its area of use has expanded with the production of new generation computers. It is very useful for solving real reliability problems. Monte Carlo (MC) modelling technique is used when physical measurements are either very difficult or commonly used when it is impossible,

usually an event or an experiment that tries to describe the experiment numerically using various statistical techniques.

The MC method estimates reliability indices in simulations of random behaviour of the system and real processes. In the MC method, random numbers are generated for each element and results for the system can be provided from the examination and analysis of the generated random numbers. Various mathematical methods can be used for the generation of random numbers, as well as practical applications that can be implemented by ready prepared tables can also be used. Due to the requirements of the system to be analysed, one of the appropriate random number generation methods is used (Çavuş et al., 2003).

Aktan (2007) stated in his study that MC problems can be modelled with probability distributions due to the fact that the system data is very complex and random, which makes the analysis of the systems quite difficult. For this reason, the simulation has taken the form of a probability-based simulation more frequently.

Random variables from the uniform distribution are gathered and moved to the distribution of interest appropriately by MC method. A uniform distribution indicates that variable values are confined to a particular field and have equal chances or in other words, they have the same probabilities. Often these regular random variables are called random numbers.

MC sampling is a method used in combination with probabilistic simulation models. Using the MC method in order to establish a stochastic model of a real situation, relies on sampling experiments are performed on this model.. This type of simulation is based on a large number of interrelated variables in a stochastic structure. They are used in the studies of system outputs (Öztürk 2004).

The feature that distinguishes this method from other numerical analysis methods is that it uses random sampling method to solve the problem with appropriate probability. It establishes a stochastic model on the variables based on their distributions.

3.2.4 Problem Solving with Monte Carlo Simulation Method

Monte Carlo Simulation (MCS) starts with determining the probability distributions of the variables in the system. Based on these distributions made by sampling using probabilistic numbers, it is possible to determine the behaviour of the system.. Events established by random numbers are artificial, but reflect the real situation.

In MCS, a random model reflecting the real situation is established and sampling experiments are performed on the model. A large amount of data can be compiled through the technique, which would take a very long time to compile in the real case. Following this, analytical operations can be performed and results related to problem can be derived.

3.2.5 Phases of Monte Carlo Simulation Method

The first step is to define the problemand determine the characteristics of the system to be modelled in order to understand the logic of operation. First of all, the definition of the research is made, the boundaries are set and the dependent-independent variables and the relationships between these variables are determined for problem correctly. The definitions will directly affect the success of the simulation study to be performed. In order to make a good definition, data on the elements of the system are collected, analysed and converted into applicable measures in the model. Data collection has two main purposes:

1- To determine the distributions and parameters of the random processes in the system, and the compatibility of the observed distributions with known or expected probability distributions.
2- To determine adequacy of analysis of the real system of simulation during the validation phase.

Before trying the Monte Carlo simulation, it is important to clearly determine the inputs in the model first. Not well-defined or undefined inputs can cause waste of time and additional cost in the trial phase.

This both situation causes prolongation of the process and may cause confusions between inputs. Therefore, depth, content and diversity of the data to be used in the system should be determined at this stage. Defining the system's limits, assumptions, variable, and constant values will play an accelerating role in the execution of the model in the following stages.

A simulation development process includes establishment of an appropriate model of the system, identifying the input variables and their statistical changes, practicing the model to act as the system it represents and evaluating the results.

After the determination of inputs, the model is planned and built in the second stage. The second stage is the formulation of the model. At this stage, experimental design is made for the model of the system. With the experimental design, the alternatives to be simulated are determined. In order to be able to evaluate the various decision options that will enable the realization of the identified problems and the objectives for their solution, a model that can represent the system to be examined should be formulated. The model to be formulated consists of mathematical and logical expressions. The format of these expressions varies according to the system examined. However, the mathematical and logical expressions that will form the model must represent the operation of the real system.

Examination of ability of the model to reflect the real system is important at this stage. A realistically simulated model will increase the validity of the results of the research. However, establishment of a model that will reflect the reality will be challenging for the researcher due to reasons such as cost, time, and the existence of unmeasurable values. Therefore, it is necessary to be aware of such limitations while constructing models. After the necessary planning is made to establish the model, the model runs in line with the target.

In order for a model to represent the real system, determination of the operation of the whole system is not required. Since the model will be developed for a specific purpose, it will be formulated in this context. Therefore, the model can also be formulated to represent the operation of only a certain subsystem or subsystems of the system, depending on its purpose. It is preferred to develop a model that will cover only one

or more subsystems of the system for the purpose, unless otherwise necessary. Because a model that represent the operation of the system will inevitably be more complex and therefore it will be difficult to understand and use.

The third step is to determine the validity of the model. At this stage, it is evaluated how properly the data of the system is included in the model and the model represents the real system. Various statistical tests and methods are used here. In case of detection of the model not reflecting the system correctly, it cannot be passed to the next stages without eliminating its deficiencies.

At this stage, it is returned to the beginning to identify the factors or relationships that were unnoticed. Otherwise, results that are not related to the real system will be obtained with an illogical model. For this reason, this stage is one of the most important stages in the simulation model development process.

In order to solve a situation or problem in Monte Carlo simulation, it is necessary to generate random numbers that can be reproduced with a computer program. There are many programs that help to generate these numbers with the developing technology and the valuation of time (Öztürk, 2004). In this study, the RAND function was used in the Microsoft Excel program to generate random numbers. Increasing the number to be entered due to technology may make the simulation closer to reality.

A random number can be defined as a series of steps in which consecutive steps are completely independent of each other and each digit has the same probability of occurrence. A mathematical method is required for generating random numbers without relying on a random number table. In mathematical methods, after the initial value is determined, other random numbers are determined by the algorithm.

All the data expressed by the probability distribution enable the model to work by using random numbers. Thus, the decision maker will be able to make stronger decisions by considering the amount of required random numbers and runs vary due to the structure of the simulation model of each research area.

The fourth stage is the implementation stage. At this stage, experiments are made on the model and it is tried to obtain the necessary results in order to make comparison of

the alternatives. The success of the implementation phase depends on the previous phases.

In the fifth stage, the results obtained from the trials are collected and arranged to be used in the decision phase. If it is believed that the model is operated in accordance with the determined conditions and that all the desired conditions of the model have been examined, the final stage, the decision-making stage, can be implemented.

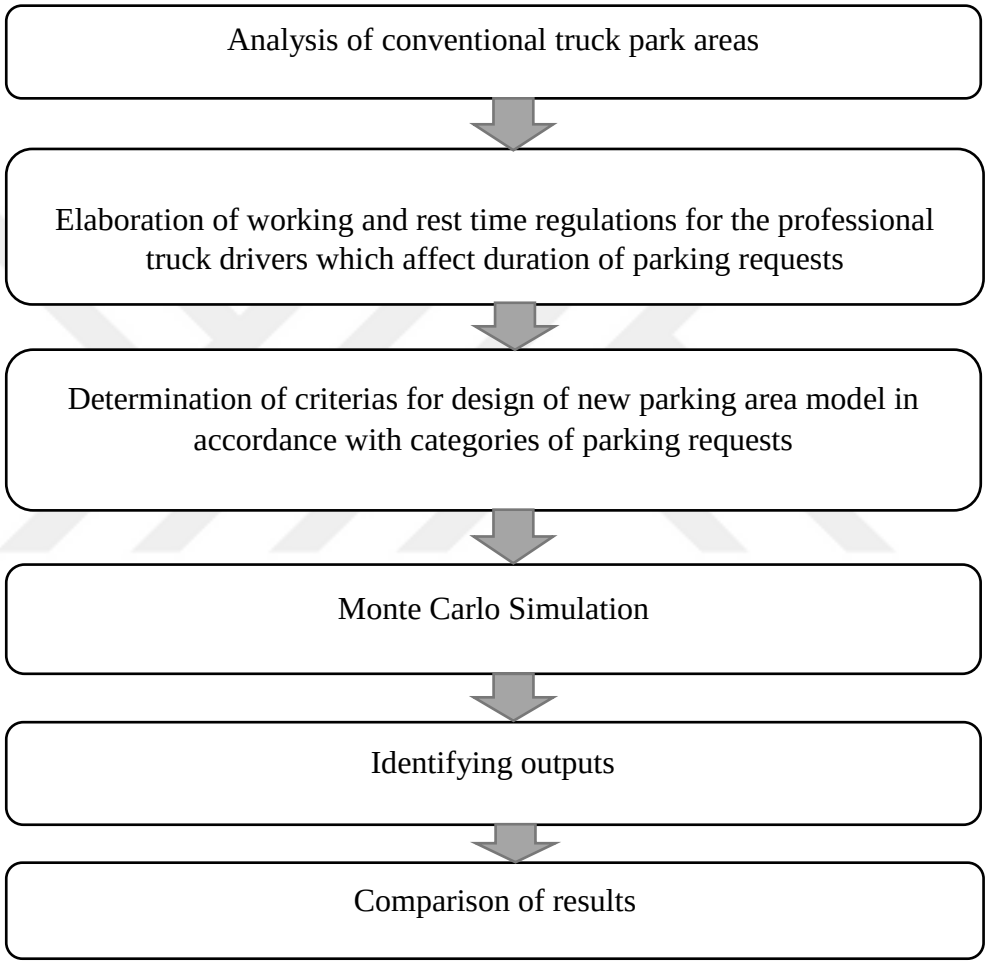

Figure 3.1 Methodological flow of study

In the final stage of decision making, the data obtained as a result of the trials are analysed, evaluated, and a decision is made about the functioning of the real system, taking into account the objectives which are determined at the beginning.

In terms of simulation, it is possible to say that almost all models consist of components, variables, parameters, relationships, assumptions, and constraints.These

elements that make up a simulation model are briefly defined as follows. Components are the parts that constitute the system. Variables are elements that allow us to assign arbitrary values to them at any time and determine the response of the model according to these value changes.

Parameters are values that are determined before the analysis and remain constant throughout the analysis. Relationships are the links between system and the subsystems of the system, the components of the system, the variables and the parameters. Assumptions are the assumptions required for the solution of the model and constraints are the constraints on the values of the variables.

Consequently a good simulation model should be;

- easily understood by the user,
- strong enough not to give meaningless results,
- easy to control and operate by the user,
- easily adaptable for model change and updates

3.3 The Simulation of SLPD Model

A certain number of simulations will be required to obtain the desired efficiency from a Monte Carlo simulation model. Since the aim is to observe the model with a minimum error rate, it will be more appropriate to make long-term trials to achieve the desired result. Although there is no optimum number for these trials; studies show that the probability of error will decrease as attempts are increased. For this reason, 2.464 random numbers are produced for this study.

A Monte-Carlo simulation model is developed to illustrate the operation of a 24-hour period for both the universal model and the proposed model of park areas. The capacity of rest area is assumed 100 parking lots for universal park area which is equal to total parking lots of type 1 and type 2 park areas which consist of 60 and 40 parking lots subsequently. The capacity distribution ratio could be adjusted due to the parking trends of a specific region. For example, in case of planning of park area for a region which is located in the intersection of main routes, park demands would yield more

for short breaks therefore capacity of type 2 parks should be increased. When park area planning is made for the regions contains departure/arrival points or loading/unloading points, park demands for long rests would be observed more frequently and capacity increase of type 1 park areas should be adjusted accordingly.

3 Scenarios are applied in this study and only the quantity of hourly parking demands is changed in each Scenario and rest of the conditions are remained the same. In the first scenario, 0-100 vehicles are generated as new park demand per hour of which maximum demand is equal to %100 of the total park capacity, in the second Scenario 0-50 vehicles as new park demand per hour of which maximum demand is equal to %50 of total park capacity and in the third Scenario 0-200 vehicles as new park demand per hour of which maximum demand is equal to %200 of total park capacity are simulated for both universal and the proposed model of park areas.

First of all, parking types are defined for each new park requesting vehicle in the beginning of each hour. Probabilities of 0,35 for short parks and 0,65 for long parks are determined based on the results of parking duration distributions of Truck Stop Locations in Europe report of Fraunhofer Institute for Systems and Innovation Research (Plötz and Speth, 2021) in which data of 170.000 trucks operating within a 200 km radius of their premises of undertaking and 230.000 trucks engaged in long-haul operations are analysed. In this regard, the mentioned probabilities could be changed according to different datasets of park demand distributions.

After defining park types for each vehicle, types of short breaks and long rests are assigned subsequently. 15 minutes (min)= 0,25 hour (h), 30 min.= 0,50 h and 45 min. =0,75 h are the options for short breaks whereas 9 h, 11 h, and 30 h are options for long rest and the mentioned durations are adjusted in accordance with relevant provisions of AETR. The 3 options for short breaks are assumed to have an equal probability of occurrence since there are not any substantive differences between them in terms of operational aspects and rest time regulations. Probabilities for the occurrence of each 3 long rest periods are 0,43 probability for 9h as well as 11 h period and 0,14 probability for 30 h period which are also assigned in coherence with ratio of number of daily and weekly rests in a week in accordance with provisions of rest time regulation.

For the universal model park areas, both short and long park-requesting vehicles are accepted and distributed to empty parking lots from 1 to 100. Vehicles that could not enter the parking area because of lack of empty lots are also recorded in order to calculate the opportunity cost. Same approach is also applied in the simulation of proposed park area model. The difference is short break requesting vehicles are only accepted in lot no 1-40 which are allocated for type-2 park area and long rests are conveyed to lots 41-100 which are allocated for type-1 park area . Unmet requests are also calculated individually for each types of parking areas. The results are compared and interpreted in terms of capacity utilization ratios and efficiency as well as opportunity cost. Comparisons of the effect of different pricing for short breaks are also performed by this study. Parametter settings are summarized in Table 3.2 as follows:

Table 3.2 Summary of parameter settings

Parameters	Values Units
c	= [min, max] = [0, 100]
c_s	= [min, max] = [0, 40]
c_l	= [min, max] = [0, 60]
T	= [min, max] =[15 min, 30 hr] = [15, 1800]
x_l^-	=N~(μ,σ)= $\begin{cases}0.00 \le \rho_l \le 0.43,\ 0.75 \le x_{l1}^l < 9\ hours \\ 0.43 \le \rho_l \le 0.86,\quad 9 \le x_{l2}^l < 30\ hours \\ 0.86 < \rho_l \le 1.00,\ 30 \le x_{l3}^l < 45\ hours\end{cases}$
x_l^+	=N~(μ,σ)= $\begin{cases}0.00 \le \rho_l \le 0.43,\ 0.75 \le x_{l1}^+ < 9\ hours \\ 0.43 \le \rho_l \le 0.86,\quad 9 \le x_{l2}^+ < 30\ hours \\ 0.86 < \rho_l \le 1.00,\ 30 \le x_{l3}^+ < 45\ hours\end{cases}$
x_s^-	=N~(μ,σ)= $\begin{cases}0.00 \le \rho_s \le 0.33,\ 0 \le x_{s1}^- < 15\ mins \\ 0.33 \le \rho_s \le 0.66,\ 15 \le x_{s2}^- < 30\ mins \\ 0.66 < \rho_s \le 1.00,\ 30 \le x_{s3}^- < 45\ mins\end{cases}$
x_s^+	=N~(μ,σ)= $\begin{cases}0.00 \le \rho_s \le 0.33,\ 0 \le x_{s1}^+ < 15\ mins \\ 0.33 \le \rho_s \le 0.66,\ 15 \le x_{s2}^+ < 30\ mins \\ 0.66 < \rho_s \le 1.00,\ 30 \le x_{s3}^+ < 45\ mins\end{cases}$
α	= [min, max] = [0, 200]
β	= [min, max] = [0, 15]
θ	= [min, max] = [0, 200]
θ_l	= [min, max] = [0, 15]
θ_s	= [min, max] = [0, 200]
ζ	= [min, max]
γ	: N~(μ,σ)= $\begin{cases}\gamma \le 0.35,\ \ short\ break \\ \gamma > 0.35,\ \ long\ break\end{cases}$
ρ_s	: N~(μ,σ)= $\begin{cases}0 \le \rho_s \le 0.33,\ V_{s1} = 15\ mins \\ 0.33 < \rho_s \le 0.66,\ V_{s2} = 30\ mins \\ 0.66 < \rho_s \le 1.00,\ V_{s3} = 45\ mins\end{cases}$
ρ_l	: N~(μ,σ)= $\begin{cases}0 \le \rho_s \le 0.43,\ V_{s1} = 9\ hours \\ 0.43 < \rho_s \le 0.86,\ V_{s2} = 11\ hours \\ 0.86 < \rho_s \le 1.00,\ V_{s3} = 30\ hours\end{cases}$

CHAPTER 4

PARKING AREA DESIGN IN COMPLIANCE WITH SOCIAL RULES

4.1 Difference of Parking Area Requirement Considering Specific Rules of Working and Rest Time Regulation

Social rules consist of working and rest time regulation and they are explained in Chapter 2 in detail. Rest times are basically comprise long rests (daily and weekly rests) and short breaks. Parking area requirements for long rests and short breaks differ in two aspects. First, locations to park are different for long rests and short breaks. Drivers generally park for long rest at arrival and departure points of their route. On the other hand, due to the working and rest time regulation (Article 7 of AETR), drivers may take an uninterrupted break after a driving period of four and a half hours or they may take a break of at least 15 minutes followed by a break of at least 30 minutes each distributed over the driving period or immediately after this period. The afore-mentioned options for drivers to take their breaks enables them to have the flexibility for location to park. That means, they may use any parking area located in their route during their driving periods of four and a half hours. In this regard, instead of limited number of park areas with high capacities in certain locations which are appropriate for long park demands; more frequent distribution of park areas with smaller capacities throughout the route would be more harmonized way of providing supply for short break demand.

Second aspect is that requirements of parking area infrastructure differs for long rests and short breaks. Parking areas for long rests should be more complicated facilities which meet minimum security standards because vehicles and the goods they carried are vulnerable for thefts since drivers may leave their vehicles for long hours to rest in a hotel or they may sleep in their vehicles. In this context, EU Commission has approved "Commission Delegated Regulation (EU) 2022/1012 of 7 April 2022 Supplementing Regulation (EC) No 561/2006 of the European Parliament and of the

Council with regard to the establishment of standards detailing the level of service and security of safe and secure parking areas nd to the procedures for their certification".

4.2 Facilities and Cost of Parking Areas

Parking areas are designed to serve both vehicles for short breaks and long rests and facilities are generally more extensive to meet the requirements of drivers of long rests such as high security standards, restaurants, showers. Eventually, drivers which are having short break in the parking areas enjoy less of those facilities relatively.

Table 4.1 Approximate investment cost of Gürbulak Border Crossing Point Truck Park (Ağrı Local Government, 2012)

No	Type of Structure	Area (m^2)	Unit Cost	Total Cost (₺)	Ratio in Total Cost
1	Administrative Building	2.400	560	1.344.000	3%
2	Motel	3.600	651	2.343.600	5%
3	Shopping Area and Restaurants	4.000	1.015	4.060.000	9%
4	Water Tank	400	140	56.000	0%
5	Roof of Parking Area	20.000	360	7.200.000	16%
6	Storage	6.000	360	2.160.000	5%
7	Fuel and Maintenance Station	4.000	475	1.900.000	4%
8	Lounge	120	475	57.000	0,1%
9	Retaining Wall	2.400	225	540.000	1%
10	Surface of Parking Area and On-site Roads	110.000	140	15.400.000	35%
11	Landscaping	70.000	60	4.200.000	10%
12	Infrastructure System	120.000	20	2.400.000	5%
13	Automation-Security System	500.000	-	500.000	1%
14	Tructor and Truck Scale	1.500.000	-	1.500.000	3%
Total Investment Cost			**43.660.600 ₺**		

Thera are several studies which list the facilities of the parking areas with cost analysis accordingly. For example, Ağrı Local Government prepared a feasibility report for Truck Park of Doğubeyazıt-Gürbulak Border Crossing Point including a cost analysis (Ağrı Local Government, 2012).

The European Commission also published a cost benefit analysis of a safe and secure parkıng areas for trucks during the preparation period of the draft regulation of safe and secure parking areas which is mentioned above. The objective of this case study is to ease the understanding and the practical application of CBA to the sector of Safe

and Secure Parking areas (EU Commission, 2019). The case study was envisaged as a worked example and essentially expands the “Guide to Cost Benefit Analysis of Investment Projects – Economic Appraisal tool for Cohesion Policy 2014-2020” to specific features of projects in this sector applying to the Connecting Europe Facility programme.

Although the project example may have drawn some inspiration from actual data, it has been greatly simplified and altered to highlight the CBA's sector-specific elements, such as typical economic costs and benefits, evaluation techniques, reference periods, etc. In addition, a number of CBA-specific recommendations included in the CEF Guide for Applicants and Frequently Asked Questions published in connection with previous CEF Calls for Proposals are being gathered for this case study.

The example provided should not be viewed as a typical project for the industry. It merely serves as an example and does not encompass the range of potential initiatives that are eligible for the CEF call for proposals' safe and secure parking priority. Similar to that, none of the premises presented here are meant to be taken as typical or indicative, but rather as illustrative examples. The company “CEF Safe and Secure Parkings” (CSSP), which operates safe and secure parking areas in several Countries of the EU, plans to upgrade its non-secure parking area in EasternLand (a fictional country and all parameters and values are realistic but do not correspond to any specific country of the EU) at km 328.1 of motorway A3. This section of the motorway is part of the TEN-T Core Network linking a TEN-T core port “Main Sea Port” with the Capital city of this Cohesion Country. The scope of the analysis includes the parking space itself as well as any supporting operations that enhance the activity's total service offering and any additional activities (or business lines) that gain from or are negatively impacted by the existence and operation of the anticipated investment. For this reason, the gas station and the snack bar are also featured.

The level of security that is targeted by the promoters for the parking area corresponds to the level “Silver” of the common EU standard for the required levels of security and service as methodized in the draft SSTPA regulation. In this context; Closed Circuit Television (CCTV) will be used to monitor the perimeter, which will also be 20 Lux-lit. Visibility is maximized across the parking lot, both outside and within. Between

the fence and the parking space, there will be a clear zone of one meter. The entrance gate will have a barrier and a CCTV that records the cars as they enter the parking space. Additionally, only authorized and freight vehicles will be permitted entry. A turnstile will ensure access for pedestrians.

Table 4.2 Approximate investment cost of silver level SSTPA (The EU Commisision, 2019)

Planning/design fees	135,000
Land purchase	75,000
Plot preparation and utilities (sewage, wiring, electric cabin)	221,000
Pavement renovation and new driveway	920,000
Relocation of two self-service fuel stations	73,000
Construction toilets, shower and washing rooms	249,000
Control room	171,000
Barriers and gates	245,000
Camera systems	135,000
Light towers	65,000
Construction of snack bar	490,000
Equipment and furniture for the snack bar	235,000
TOTAL	**3,014,000 EUR**

When the two investment cost table is compared, it is seen that both parking areas contain approximately same extensive facilities and are appropriate to serve to the vehicles which request long rest.

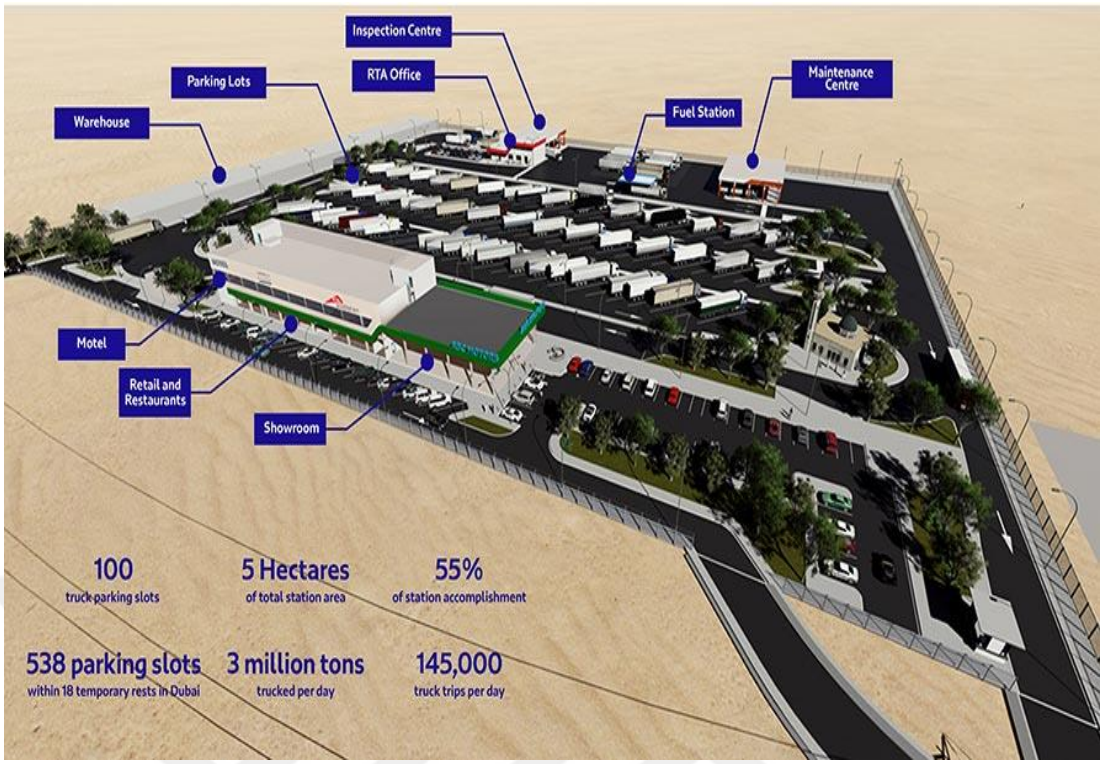

Figure 4.1 A Parking Area Model Which is Appropriate for Long Rests (Khaleji Times, 2022)

4.3 Alternative Parking Area Design for Short Breaks

The current and general implementation regarding truck parking areas is that they are designed in one form with extensive facilities to fulfil the requirements of long rest. In the meantime, they also accept and serve for vehicles which have short breaks.

This leads an use of over sophisticated infrastructure by the vehicles having short breaks and inefficiency of investment budgets. Vehicles having short breaks have simpler requirements than vehicles having long rest. A parking area designed to contain basic infrastructure and facilities such as WC and beverage/coffee automats will be adequate to serve for vehicles having short breaks comfortably. High security standards are also not necessary for short breaks since drivers do not leave their vehicle for long hours to stay in hotel or go to restaurants or sleep in their vehicles.

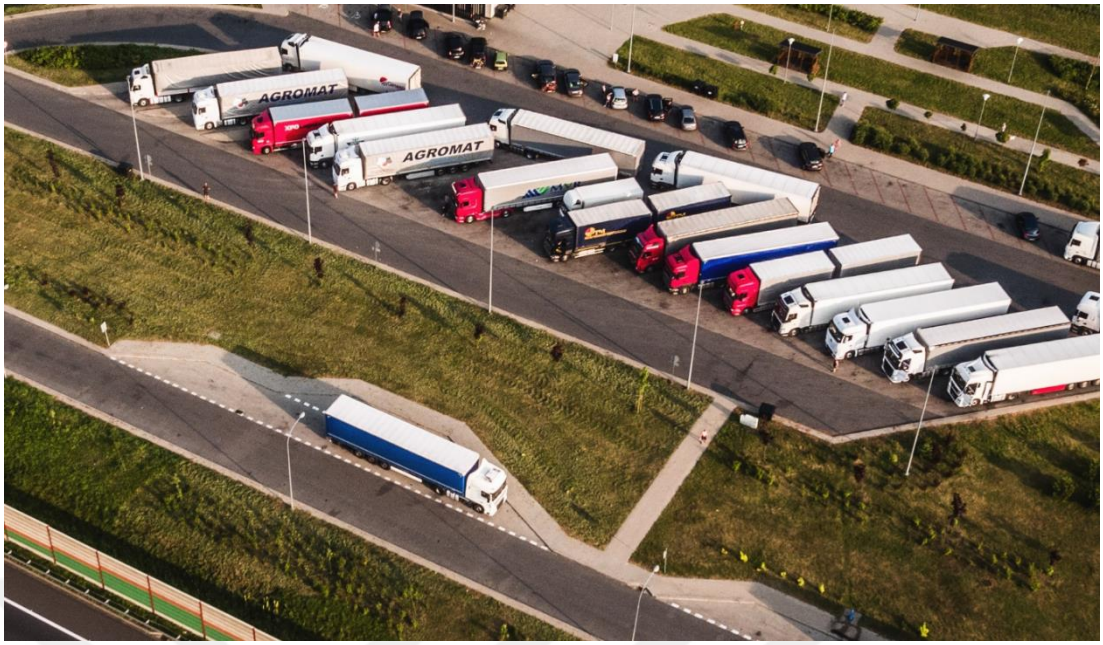

Figure 4.2 A Parking Area Model Which is Appropriate For Short Breaks (Wielgus, 2018)

In addition to its advantage on investment costs, parking areas for short breaks with this simple design is appropriate to be constructed in smaller areas. Drives which are searching parking areas will be able to find a small parking area frequently enough throughout their route by application of the mentioned design.

4.3. Cost Advantages of New Parking Area Design

In order to meet driving and rest time provisions of AETR, the average required daily parking time is calculated as shown in Eq 4.1 as follows:

Average parking time: = Average daily rest+daily break

(11x4+3x9)/6=10 +45/60 = 10+ 0,75= 10,75 hours (4.1)

0,75/10,75= %6,98 of the capacity of truck park areas are occupied for breaks.

Cost of an average truck park for 70 vehicles is 43.660.600 ₺as it detailed with a cost brakdown in Table 4.1.

Surface of Parking Area and On-site Roads is enough in terms of infrastructure for parking only for breaks which cost 15.400.000 ₺. Consequently parking area which is for only breaks with 70 vehicle could be constructed with the lower cost up to 43.660.600 - 15.400.000= 28.260.600 ₺.

Cost advantage of construction of specific parking areas for short breaks is calculated by following formula as shown in Eq 4.2:

N x 0,0698x28.260.600 / 70 ₺ (4.2)

N= total number of vehicles requiring parking area

4.4. Calculation of Required Parking Area Capacity for a Specific Region

The number of parking spaces required in a certain area depends transport intensity as well as the length of stay of vehicles in the car park. Ordinary daily rest in EU and contracting states of AETR (e.g., Russia) is at least 11 h, as well as at least one break of a duration of 45 min after 4.5 h of driving. This means that a vehicle can only drive for 12 hours and 15 minutes in a 24-hour period. According to research, the speed of freight transport vehicles is between 60 and 80 km per hour, and this affects how many parking places are available (Gašparík et al., 2018). The number of required parking places in a specified section of highway or road is possible to be defined by relation. Equation 4.3 is used to calculate parking spaces regardless of the type of park area

$$\mathrm{PP} = \frac{\mathrm{R}}{24} . \frac{\mathrm{D}}{\mathrm{T_d}} \tag{4.3}$$

where *PP* isthe needed number of parking places, *I* showstraffic intensity in solved section, *R/24* displaysdriver's rest in hours/24, *D* represntslength of the solved section, *S* isthe average speed of truck in solved section, and T_d showsthe average driving time of a vehicle per 24 hours (Poliak et al., 2020).

The number of parking places is quantitatively defined by the proposed equation. The validity of the data used as input determines its reliability. It considers the amount of

traffic in the section being handled, its length, the average speed of trucks, as well as some fundamental information on rest period of truck drivers.

After the application of the introduced relationship into selected sections of highways in Izmir, it is possible to claim that only 2 of truck parks achieve to meet the demand.

Table 4.3 The needed number of parking places in selected sections of the road network. Source: Processed by author

Road	Section	Intensity (Trucks/24 h)	Speed (km/h)	Length (km)	Existing Number of Places	Needed Number of Places
O-32	Şehitlik - Seferihisar	3.961	80	12,5	10	52
O-32	Seferihisar - Urla	2.336	80	9,3	25	23
O-32	Alaçati - Çeşme	957	80	11,3	40	11
O-30	Balçova - Gaziemir	6.012	80	9	60	57
O-30	Üniversite Ayr. - Karşıyaka	26.628	80	10	14	281
O-31	Germencik - Şevketiye	6.323	80	21,7	10	145
O-31	Belevi - Germencik	7.326	80	21,8	20	168
O-31	Torbali - Belevi	7.517	80	21,5	20	170

Consequently, the results in Table 4.3 show that %22 of parking area demand could be fulfilled by the existing capacity of the truck parking areas in the above mentioned section region.

4.5 Simulation Results for Comparison of SLPD and CM

The current and general implementation regarding truck parking areas is that they are designed in one form with extensive facilities to fulfil the requirements of long rest. In the meantime, they also accept and serve for vehicles which have short breaks. This leads a use of over sophisticated infrastructure by the vehicles having short breaks and inefficiency of investment budgets. Vehicles having short breaks have simpler requirements than vehicles having long rest. A parking area designed to contain basic infrastructure and facilities such as WC and beverage/coffee automats will be adequate to serve for vehicles having short breaks comfortably. High security standards are also not necessary for short breaks since drivers do not leave their vehicle for long hours to stay in hotel or go to restaurants and they do not sleep in their vehicles as well.

In addition to its advantage on investment costs, parking areas for short breaks with this simple design is appropriate to be constructed in smaller areas. Drives which are searching parking areas will be able to find a small parking area frequently enough throughout their route.

As a result of the application of simulation model in order to compare CM of parking areas and SLPD which separates parking areas as short break and long rest areas, meaningful results have been gathered.

3 different scenarios are prepared due to a number of requests and scrutinized individually as a first phase. Subsequently, the scenarios compared with each other and advantages and relative advantages and disadvantages of each model are described as well. In order to show the efficiency of SLPD and proper comparison of each parking models, total capacities are assumed to consist of same number of parking lots. In this regard, the capacity of universal park area assumed as 100 lots in total and capacity of SLPD is 100 lots in total consisting of 40 lots for type 2 park area and 60 lots for type 1 park area. Total capacity remains constant for all 3 scenarios. In all of the following figures which illustrate the results of simulations for all scenarios simulated; results of type 2 park areas are shown in first 40 lots and results shown in lot 41 to 100 correspond to results of type 1 park areas.

Table 4.4 Number of requests per hour in Scenario 1

Time	**00:000**	**01:000**	**02:000**	**03:000**	**04:000**	**05:000**	**06:000**	**07:000**	**08:000**	**09:000**	**10:000**	**11:000**	**12:000**	**13:000**	**14:000**	**15:000**	**16:000**	**17:000**	**18:000**	**19:000**	**20:000**	**21:000**	**22:000**	**23:000**
Vehicles	**60**	**22**	**15**	**88**	**98**	**32**	**0**	**50**	**25**	**37**	**18**	**4**	**37**	**89**	**67**	**28**	**62**	**44**	**98**	**74**	**99**	**41**	**28**	**32**

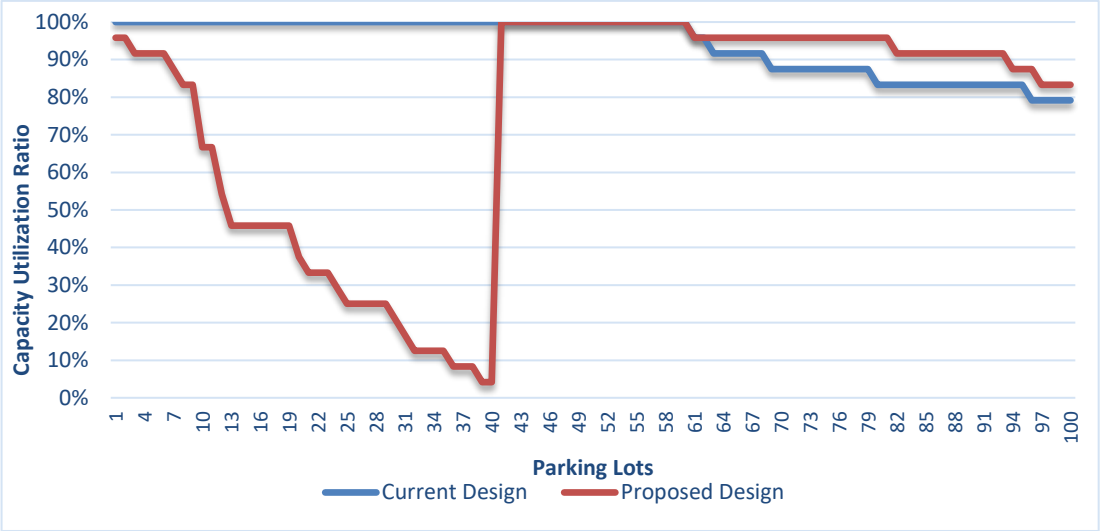

Figure 4.3 The capacity utilization ratio in Scenario 1 total number of vehicles visiting parking area per hour equal to total lot number

In the Vehicle Number Visiting Parking Area Per Hour Equal Lot Number Scenario, it is observed that parking lots that SLPD a lower rate of capacity utilization ratio which is %74 while it is %94 for CM becasuse of lower utilization of short break park area. On the other hand long rest area of SLPD performs better than CM. The overall capacity utilization ratio could also surpass the CM by adjusting capacity of short park area which means 40 vehicle capacity of short park area should be decreased for such park demand trend is experienced.

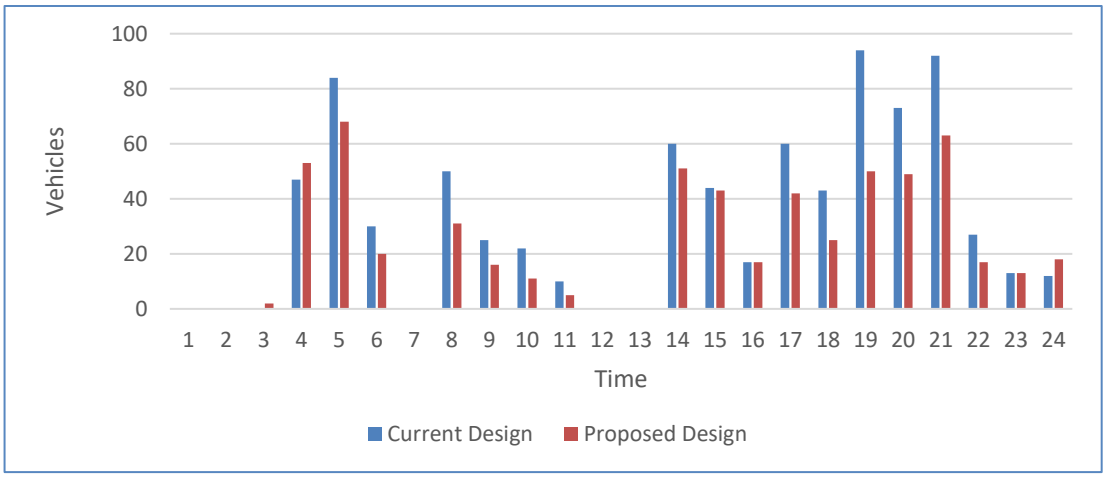

Figure 4.4 The number of vehicles which could not parked in Scenario 1: total number of vehicles visiting parking area per hour equal to total lot number

On the contrary, the number of vehicles which are not served due to lack of free parking lots is more in the CM than the SLPD as shown in Figure 4.4. This could be interpreted as in case of application of SLPD, the vehicles would seek less for new parking areas as a consequence of overcapacity.

In Figure 4.5 opportunity costs are calculated with the assumption of 15 ₺ for both short and long rests. The total opportunity cost of current design is observed 106.200₺ while proposed design 118.410 ₺. %11 increase in the opportunity cost occurs from unmet long rests due to %40 decrease in the long park lots.

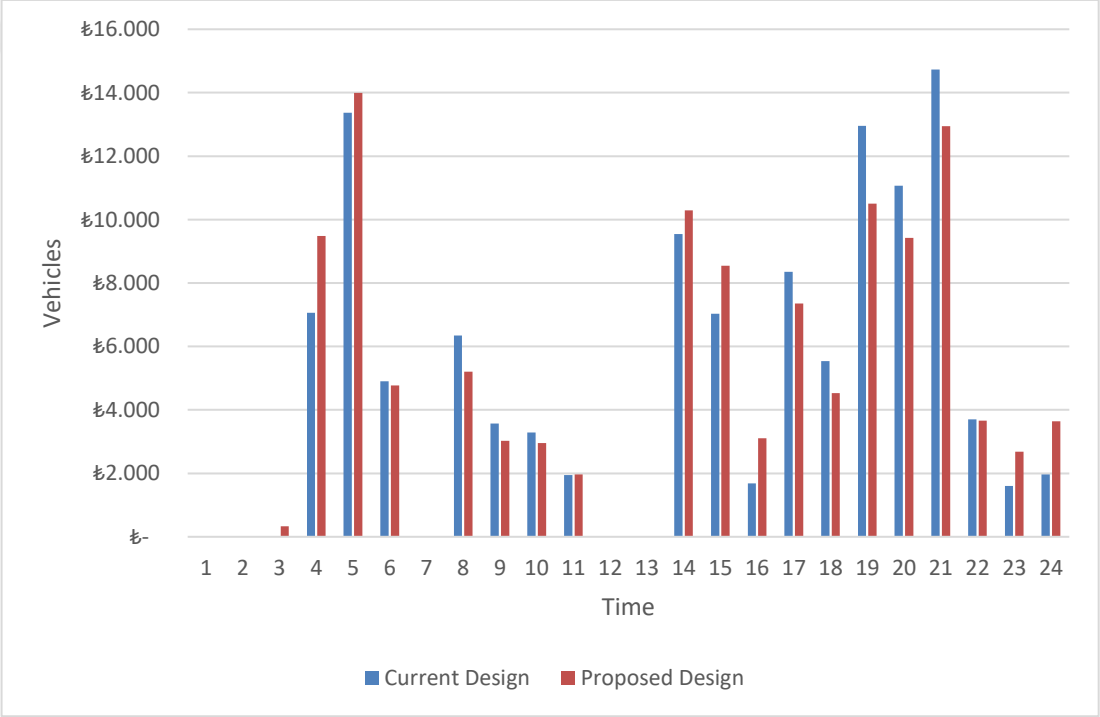

Figure 4.5 The opportunity cost of parking model when hourly income is 15 ₺ for both long and short rest in Scenario 1

In Figure 4.6 it is assumed that the opportunity cost of short breaks is 25 ₺ while the opportunity cost of long rest still remains 15 ₺.

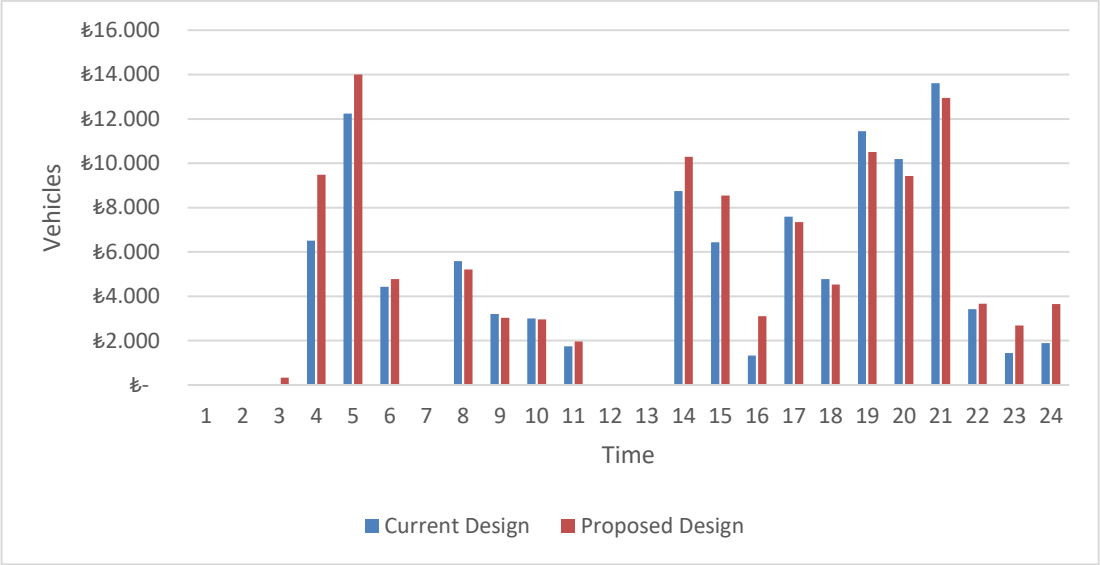

Figure 4.6 The opportunity cost of parking model when hourly income is 15 ₺ for long and 25 ₺ short rest in Scenario 1

The graphic shows that if the price of short rest is increased from 15 ₺ to 25 ₺, opportunity cost of current design increases to 108.970 from 106.200 ₺. However, the opportunity cost of SLPD is insensitive to increases in the price increase of short rest since there are not any fulfilled demand for short rests in the proposed design in Scenario 1 which is 118.410 ₺ in total.

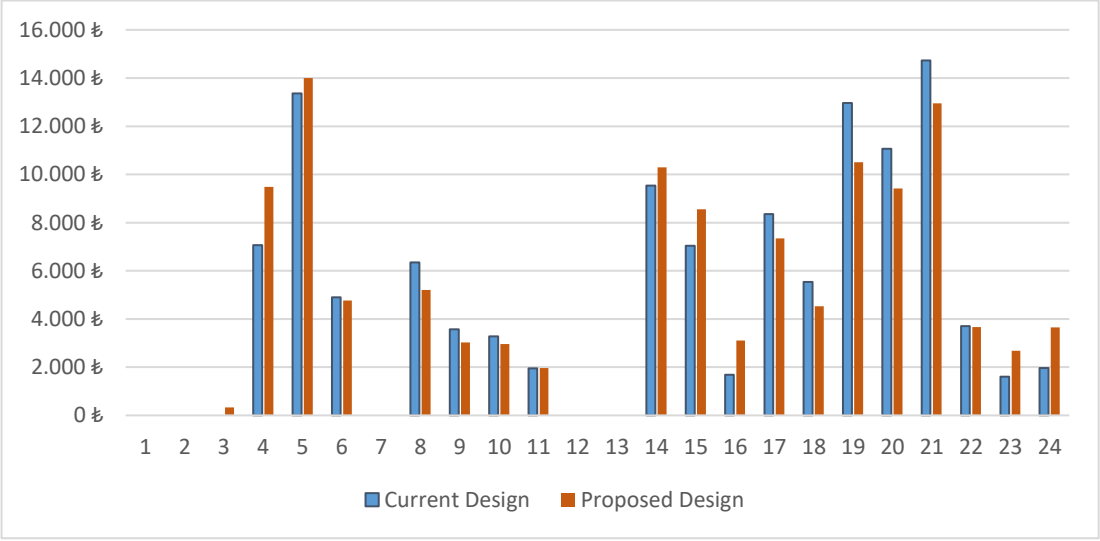

Figure 4.7 The opportunity cost of parking model when hourly income is 15 ₺ for long and 60 ₺ short rest in Scenario 1

In Figure 4.7, it is shown that in case of hourly profit of long rest is 15 ₺ and short breaks is greater than or equal to 60 ₺, opportunity cost of SLPD becomes less than current model. However, such a difference in incomes is not considered probable because it is not applicable such relatively high prices for short parks than long rests and cost of parking area for short and long rest also does not support such a difference in income as well.

In Scenario 2, it is simulated that hourly parking request is between 0 and 50 which is equal to half of capacity of parking lots modelled and illustrated in Table 4.5.

Table 4.5 Number of requests per hour in Scenario 2

Time	00:000	01:000	02:000	03:000	04:000	05:000	06:000	07:000	08:000	09:000	10:000	11:000	12:000	13:000	14:000	15:000	16:000	17:000	18:000	19:000	20:000	21:000	22:000	23:000
Vehicles	30	48	10	48	15	26	13	15	37	46	20	8	4	42	5	43	31	47	44	0	28	25	10	32

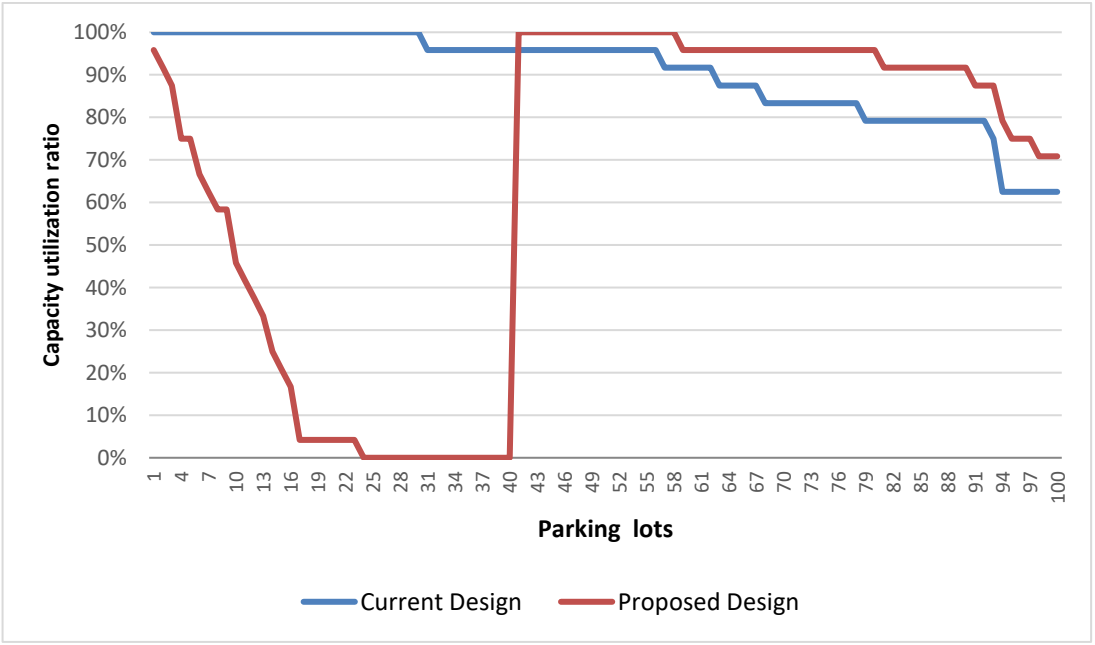

Figure 4.8 The capacity utilization ratio in Scenario 2: total number of vehicles visiting parking area per hour %50 less than total lot number

In the vehicle number visiting parking area per hour equal %50 of lot number scenario as shown in Figure 4.8, it is observed that parking lots which are allocated for short breaks have lower rate of capacity utilization ratio. On the other hand, the decrease of capacity utilization ratio for parking lots are observed more in the current model (CM) which supports the SLPD is performed more efficiently for long parks. It is observed %90 in the SLPD while average of CM is only % 65.

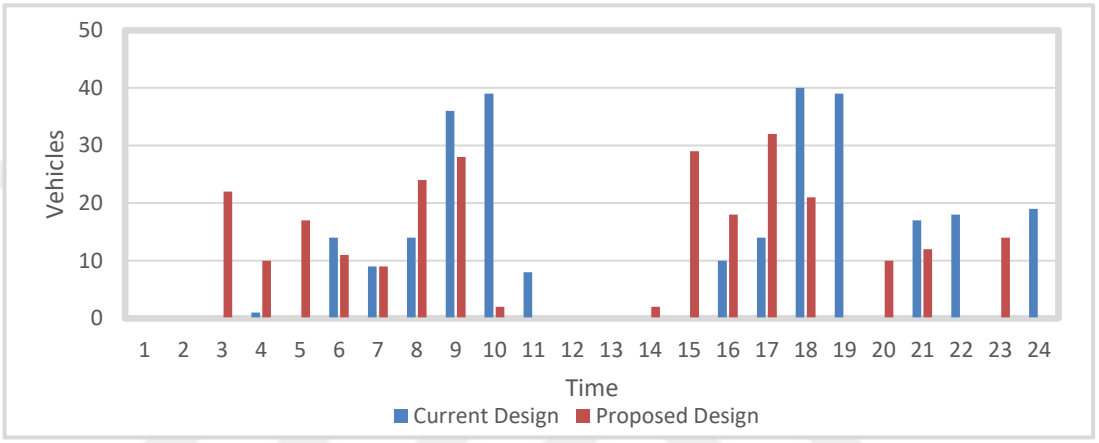

Figure 4.9 The number of vehicles which could not parked Scenario 2 : total number of vehicles visiting parking area per hour %50 of total lot number

Furthermore, 278 vehicles could not be served due to lack of free parking lots is in the CM while it is 261 vehicles in the SLPD. This could be interpreted as in case of application of SLPD, the vehicles would seek less for new parking areas as a consequence of overcapacity as shown in Figure 4.9.

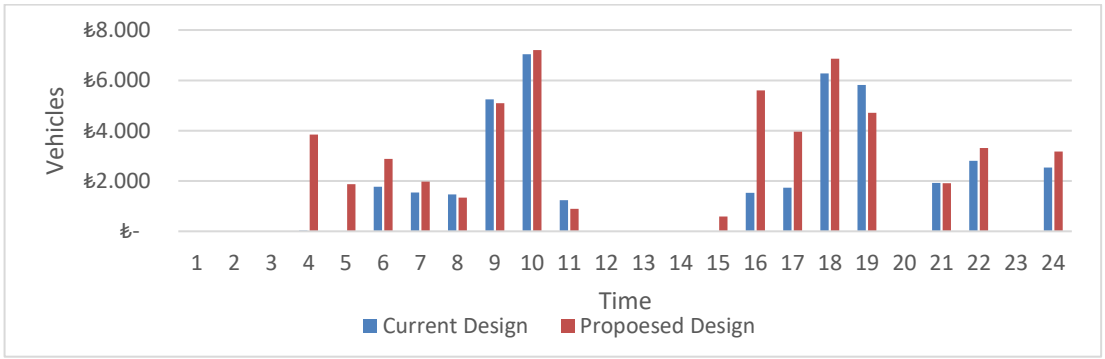

Figure 4.10 The opportunity cost of parking model when hourly income is 15 ₺ for both long and short rest in Scenario 2

In Figure 4.10 opportunity costs are calculated with the assumption of is 15 ₺ for both short and long rests. The opportunity cost of the proposed design is 55.185 ₺ while it is observed 40.080 for the current design.

In Figure 4.11 it is assumed that opportunity cost of short breaks is 25 ₺ while opportunity cost of long rest is still remains 15 ₺. As it is observed in Scenario 1, Price increase for the short break effects only SLPD negatively in Scenario 2 because unmet short park demand is only observed in the CM.

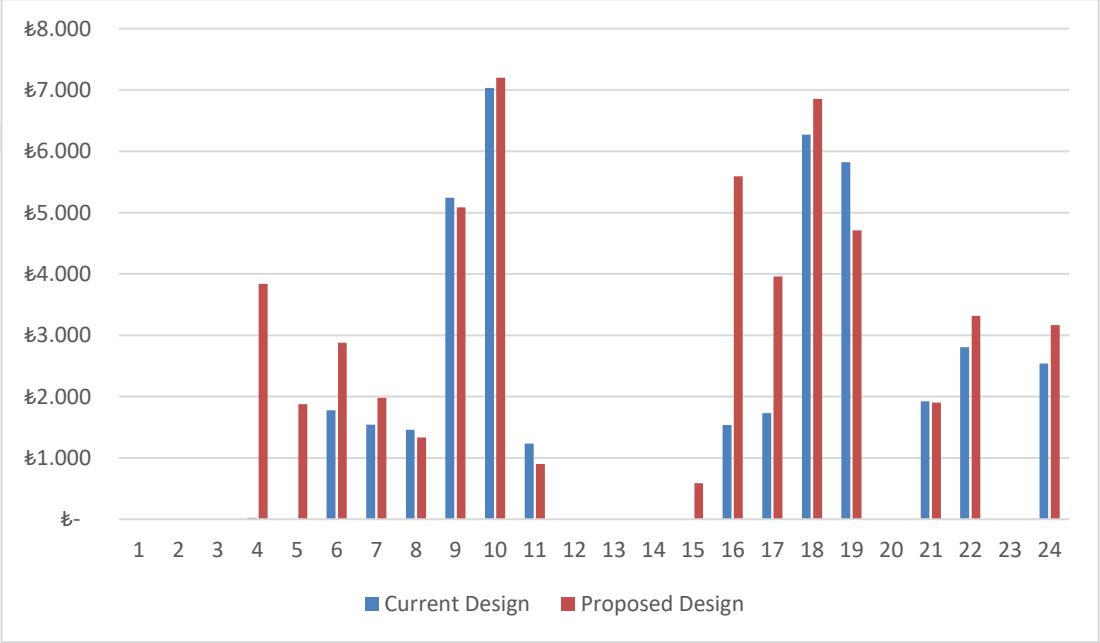

Figure 4.11 The opportunity cost of parking model when hourly income is 15 ₺ for long and 25 ₺ short rest in Scenario 2

Figure 4.11 shows that if the price of short rest is increased from 15 ₺ to 25 ₺, opportunity cost of current design increases to 40.940 from 40.080 ₺. However, the opportunity cost of SLPD is insensitive to increases in the price increase of short rest since there are not any fulfilled demand for short rests in the proposed design in Scenario 1 which is 55.185 ₺ in total.

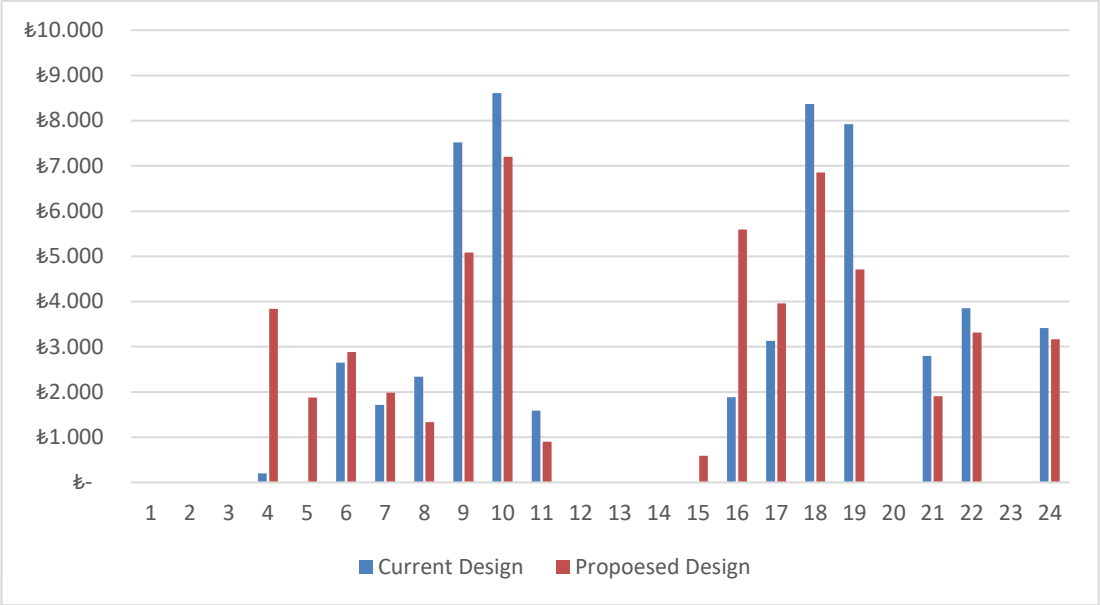

Figure 4.12 The opportunity cost of parking model when hourly income is 15 ₺ for long and 200 ₺ short rest in Scenario 2

In Figure 4.12, it is shown that in case of hourly profit of long rest is 15 ₺ and short breaks is greater than or equal to 200, opportunity cost of SLPD becomes less than current model. However, such a difference in incomes is not considered probable because it is not applicable such relatively high prices for short parks than long rests and cost of parking area for short and long rest also does not support such a difference in income as well.

In Scenario 3, it is simulated that hourly parking request is between 0 and 200 which is equal to twice of capacity of parking lots modelled and illustrated in Table 4.6.

Table 4.6 Number of requests per hour in Scenario 3

Time	**00:00**	**01:00**	**02:00**	**03:00**	**04:00**	**05:00**	**06:00**	**07:00**	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Vehicles	**128**	**155**	**95**	**93**	**186**	**35**	**169**	**102**	**9**	**114**	**1**	**179**	**126**	**67**	**61**	**6**	**59**	**37**	**141**	**72**	**28**	**188**	**94**	**178**

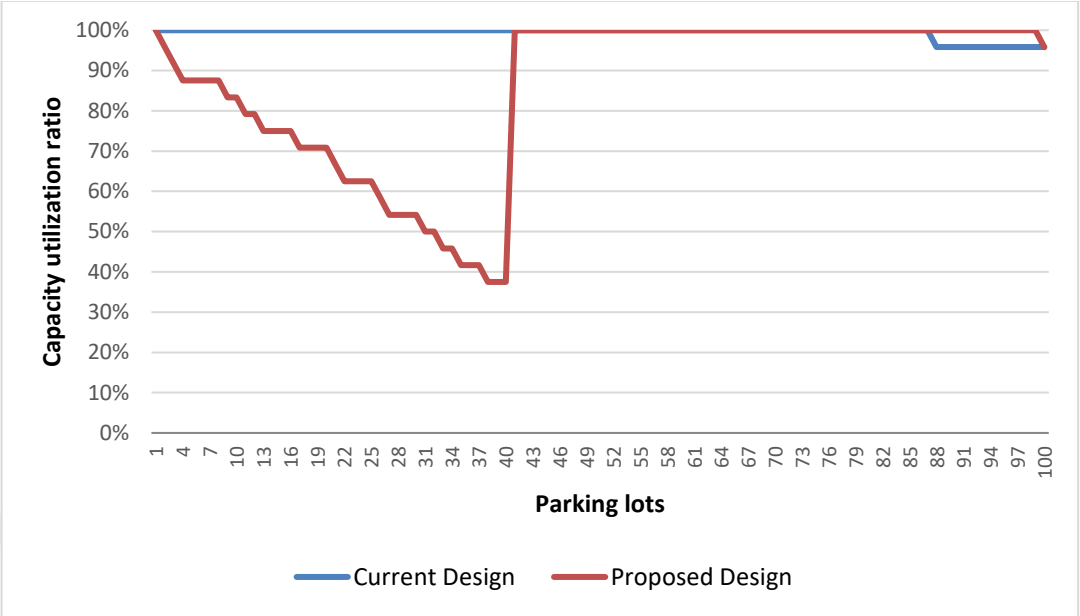

Figure 4.13 The capacity utilization ratio in Scenario 3: total number of vehicles visiting parking area per hour %200 more than total lot number

In the Vehicle Number Visiting Parking Area Per Hour Equal %200 of Lot Number Scenario as shown in Figure 4.13, it is observed that parking lots which are allocated for short breaks have lower rate of capacity utilization. However, the SLPD again performs better for long rests with %95 while it is %87 in CM as it is observed in Scenario 1 and 2.

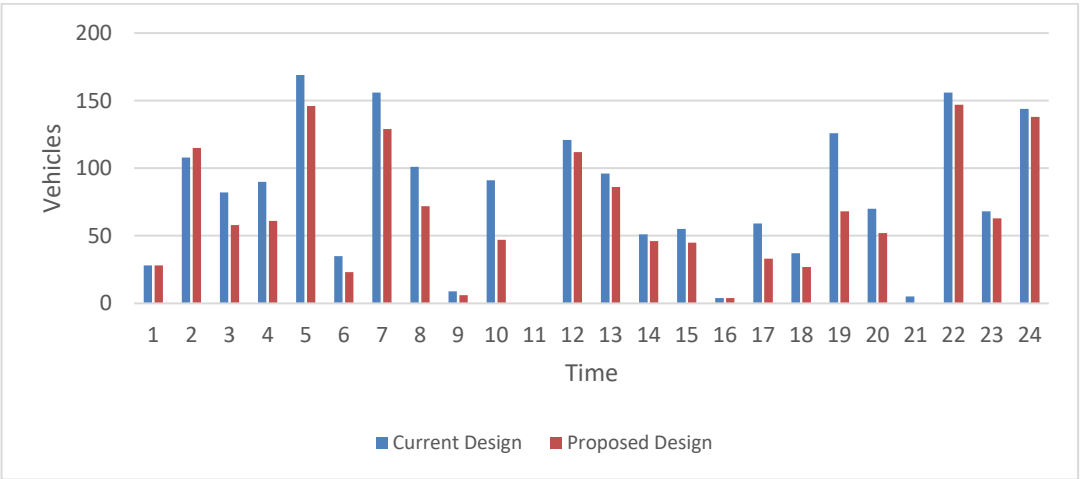

Figure 4.14 The number of vehicles which could not parked Scenario 3 : total number of vehicles visiting parking area per hour %200 more than total lot number

Besides, 1881 vehicles could not be served due to lack of free parking lots in the CM while it is only 1506 in the SLPD. This could be interpreted as in case of application of SLPD, the vehicles would seek less for new parking areas as a consequence of overcapacity as shown in Figue 4.14.

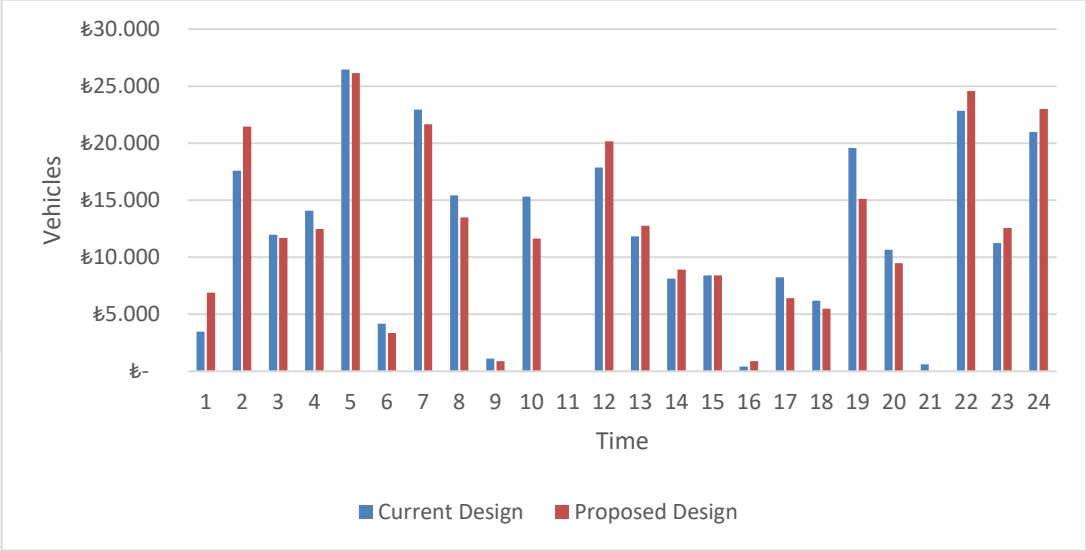

Figure 4.15 The opportunity cost of parking model when hourly income is 15 ₺ for both long and short rest in Scenario 3

In Figure 4.15 opportunity costs are calculated with assumption of is 15 ₺ for both short and long rests. The opportunity cost of proposed design is 268.275 ₺ while it is observed 243.225 ₺ for the current design.

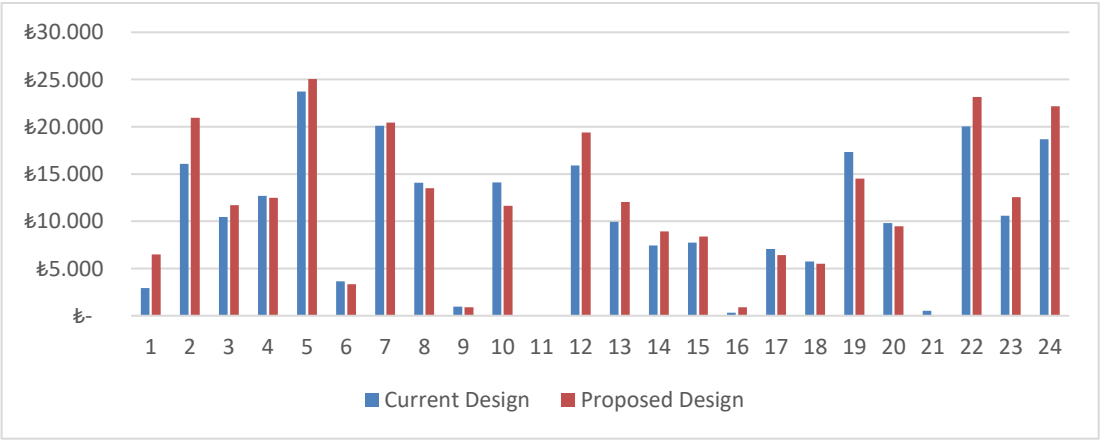

Figure 4.16 The opportunity cost of parking model when hourly income is 15 ₺ for long and 25 ₺ short rest in Scenario 2

Figure 4.16 shows that if the price of short rest is increased from 15 ₺ to 25 ₺, opportunity cost of current design increases to 249.815 from 243.225 ₺. In this case, opportunity cost of proposed design is also increases to 269.935 from 268.275. SLPD still is more advantageous for the price increase for short breaks but in this Scenario the opportunity cost is also slightly increased for the SLPD. This increase shows that unmet short break demand is observed for the first time in the SLPD in Scienario 3.

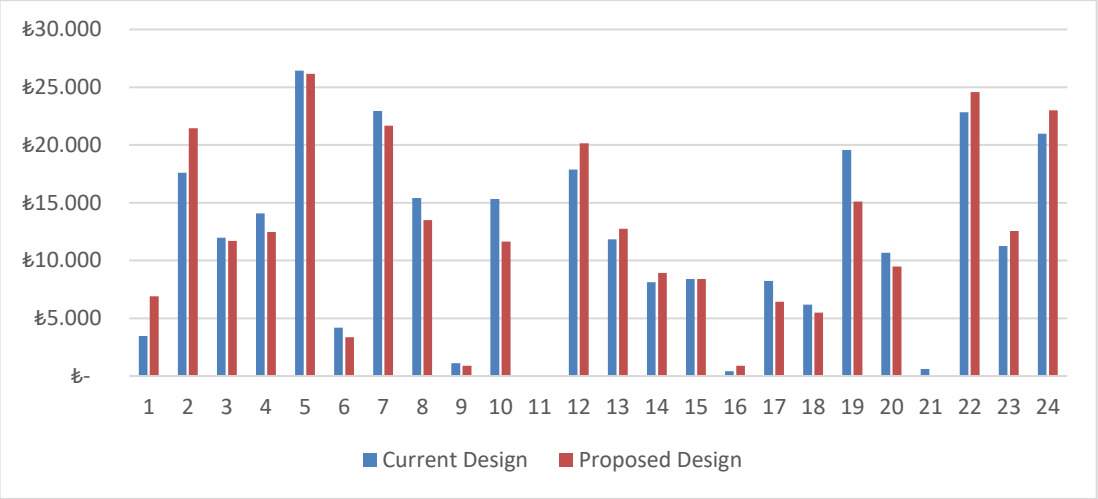

Figure 4.17 The opportunity cost of parking model when hourly income is 15 ₺ for long and 70 ₺ short rest in Scenario 3

In Figure 4.17, it is shown that in case of hourly profit of long rest is 15 ₺ and short breaks is greater than or equal to 70, opportunity cost of SLPD becomes less than current model. However, such a difference in incomes is not considered probable because it is not applicable such relatively high prices for short parks than long rests and cost of parking area for short and long rest also does not support such a difference in income as well.

In case of comparison of 3 scenarios with holistic approach, following statements and comments could be made.

In the comparison of capacity utilization ratios, when intervals of hourly requests increase as 0-50, 0-100 and 0-200; capacity utilization ratio of current model occurs %90, %94, and %95 consecutively as shown in Figure 4.18. First %100 increase in demand results %4 increase oin the capacity utilization ratio. However, in case of

increase of one more %100 increase of demand, only %1 of increase is observed in capacity utilization ratio. Consequetly, it can be interpreted that best performance of CM is observed in Scienario 1.

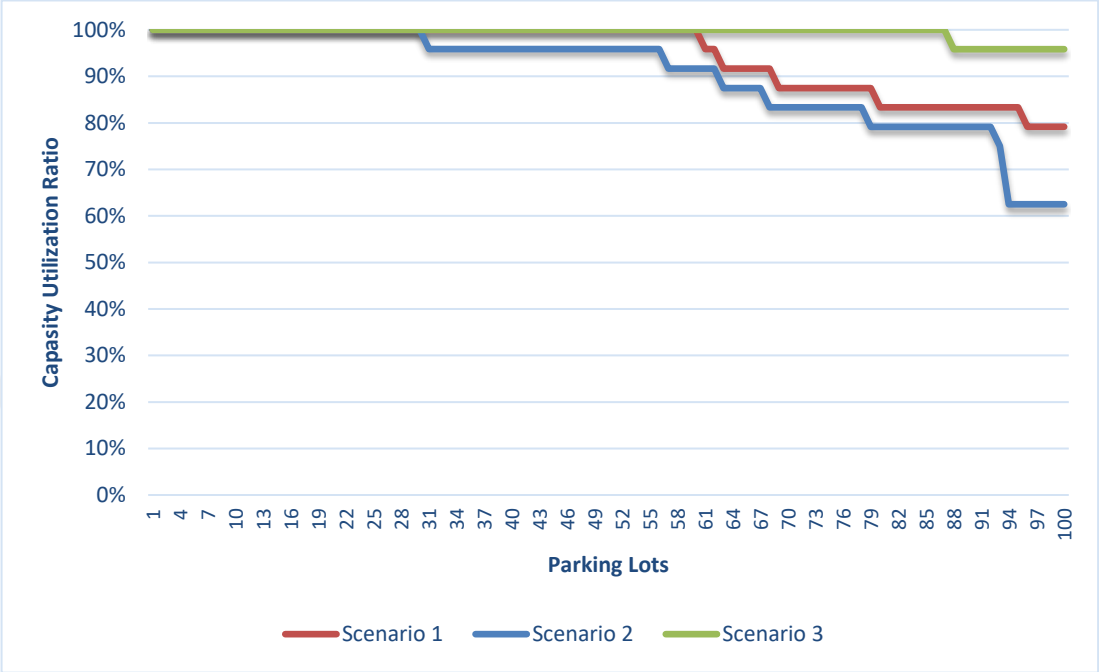

Figure 4.18 Comparison of capacity utilization ratio of current model of park area due to 3 scenarios

Overlapping of new long park request and current short breaking vehicles in case of park area serving with full capacity which result as an unmet service for long park request is observed in the current model of park areas and illustrated in Figure 4.19.



Figure 4.19 Illustration of occurence of unmet long rest demand and unused capacity subsequently in the CM

The comparison of durations of long rests and short breaks also underlines the importance of serving more long rest demand vehicles and decreasing number of unmet long break requests. Equation 4.4 is used for the comparison:

Minimum ratio of long rest-short break duration= Minimum long park period / Maximum short break period (4.4)

Minimum long park period = 9h =540 min

Maximum short break period= 45 min

540/45= 12

Consequenly, a long rest customer is equal to minimum 12 short break customer. The results of SLPD supports the mentioned the strategy of providing priority for long park vehicles.

On the other hand,; %65, %74 and %87 are observed consecutively as the overall capacity utilization ratio of the SLPD as shown in Figure 4.20. In case of the application of breakdown on the SLPD model, the type-1 long rest park area has %93, %95 and %99.93 of capacity utilization ratios consecutively for each scenarios. It can be interpreted that proposed type 1 park area which is designed for long rests outperforms the current model of park areas in all 3 scenarios.

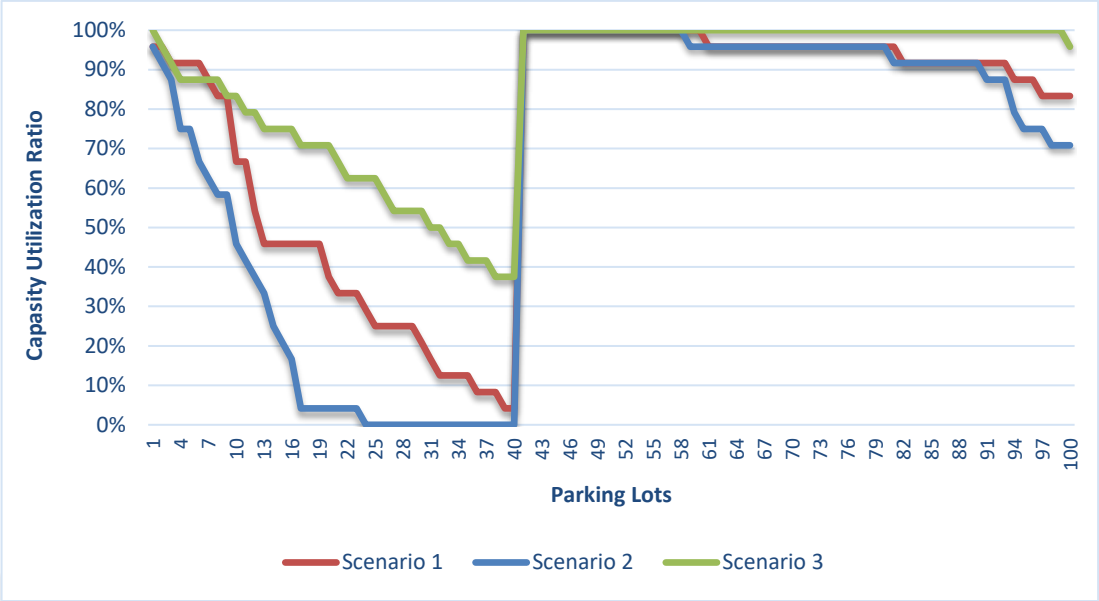

Figure 4.20 Comparison of capacity utilization ratio of SLPD park area due to 3 different scenarios

These results can be interpreted as current parking areas are less sensitive than the SLPD of parking areas to the increase of requests. Consequently, the SLPD would be more effective and beneficial in the spots where park area demand is observed high. Since, the idle capacity is observed more in all 3 scenarios in type 2 park areas which are designed for short breaks, capacity adjustments in the implementation phase such as decreasing the capacity of type 2 park areas and increasing type 1 areas will also effect the capacity utilization ratios of them in a positive way.

In comparison of number of unserved vehicles, when intervals of hourly requests increase as 0-50, 0-100 and 0-200; number of unserved vehicles hourly in CM occurs 278, 803 and 1861 consecutively. On the other hand; 261,594 and 1506 vehicles could not park in the SLPD consecutively. This means that vehicle circulation occurs more in the SLPD. It is achieved by allocation of constant capacity for vehicles which have short breaks so that they could park without being effected occupied capacity of vehicles which have long rest from previous hours as it is in the CM.

In comparison of profits, in case of assumption of hourly profit of long rest is constant and 15 ₺, when intervals of hourly requests increase as 0-50, 0-100 and 0-200; profit of hourly park should be 200, 60 and 70 consecutively in order to maintain less

opportunity total costs with the SLPD. However, such a difference in incomes or profits is not considered probable since it is not applicable such relatively high prices for short breaks compared to long rests and unit cost of park area for short and long rest also does not support such a difference in income as well. Therefore, opportunity cost advantage is not expected in all 3 scenarios for the SLPD but it will not diminish feasibility of SLPD if they are implemented in parking areas with free of charge such as truck park areas of Turkish highways.

CHAPTER 5

CONCLUSION

Truck Parking is an open, hard-surfaced area, other than a parking structure, street or public way, to be used for the transient parking of operable tractor-trucks or similar heavy commercial vehicles, whether for compensation or free. The shortage of truck parks is a critical issue for both professional drivers and the transportation industry worldwide.

In order to meet requirements of legal provisions of daily/weekly rest times and short breaks as well as humanitarian needs of the drivers and/or technical requirements of vehicles such as minor repairs, controls or fuel delivery, parking places for heavy goods vehicles (HGV) are needed. The professional drivers engaged in HGV's are the clients of truck parking areas. Drivers themselves or planners of their transport undertakings decide where to park.

The drivers of HGV's just drive in the parking areas, stop their vehicles in the designated areas and rest inside of their vehicles or disembark and leave them in park. Drivers are able to use parking areas which are located throughout or nearby their route including destination and arrival points. Truck parks offer service 7 days 24 hours naturally since road transportation is a continuous operation.

The main objective is minimize construction and operation costs of required parking areas by maximizing rate of capacity utilisation and maximize profit of parking area operators. The demand for truck parking area is sorted and separated as demand for long rests and demand for short breaks.

Parking areas are re-organized in 2 types due to the duration of park demand as type 1 is only accepting HGV's which will take long rest and type 2 is accepting HGV's which will take short break. Truck parks are needed to meet legal, humanitarian, and technical requirements for HGV drivers, providing service 7 days 24 hours. Thus, the simulation model aims to minimize opportunity costs of required parking areas by

maximizing capacity utilization and maximizing profit for parking area operators. It can be used as a standard model for all of the parking areas in a region or country.

In order to implement the mentioned types of parking areas sustainably, prohibition or checks are not only option for preventing wrong use of parking areas by the drivers such as entering into type 1- long rest areas for short breaks or vice versa. Instead, tariffs of parking should be set accordingly and will be deterrent for inappropriate usage. For example, a standard fee can be determined for 0 to 11 hours parking in type 1-long rest areas so that drivers using them for the purposes of short breaks, which is out of favour, will have to pay quite high amounts of fees compared to fees of type 2-short break parking areas. On the other side, parking fees of type-2 short break parking areas are applied due to the duration of parking so that drivers using them for the purposes of long rests, which is out of favour, will have to pay multiplied amounts of short breaks fees which will be much more expensive in total compared to the fees of type 1-long rest areas for the drivers taking long rests. The idea of charging higher fees for long rest parking areas is not a new. In fact, it has been implemented in some countries already. The reasoning behind this approach is to discourage drivers from using these areas for extended periods of time, which can lead to congestion and safety issues. By making the fees much more expensive than short break fees, drivers will be incentivized to only use these areas for their intended purpose - taking a long rest. This will also free up space for other drivers who need to take short breaks and reduce the overall demand for parking spaces. However, it's important to ensure that these fees are reasonable and not overly burdensome for drivers who genuinely need to take a long rest. Additionally, proper enforcement measures must be put in place to prevent abuse of the system by those who try to avoid paying the higher fees.

In current situation, there is not such a differentiation and drivers of HGV’s having long and short rests are using the same parking areas. When the parking areas are servicing in their full capacity and there are no parking place available, drivers which will take long rests will have to pass those parking areas. However, in a period of1-45 minutes, drivers which are using the parking area for short breaks will leave the parking place subsequently. This will cause empty parking places and reduce rate of capacity utilisation of parking areas.

In this study, new requests to park is calculated for 1 hour intervals and entry into the park area is assumed to be in the beginning of each hours. As a consequence, unserved long rest request due to occupation of lots by vehicles which have short break could not calculated since all short breaks which are 15, 30 and 45 minutes whichare smaller than 1 hour and in the beginning of each hour they are assumed to leave already the parking area before the long rest requesting vehicles enter into the park area. Further studies which will be based on real time model also provide opportunity to measure and illustrate how short break vehicles prevents the service for long rest requesting vehicles... SLPD offers a solution to this problem and short breaking vehicles will be excluded and use type 2- short parking areas and not effect and decrease empty parking lots allocated for the vehicles which will park for long rests in type 1 park areas. The problem of unserved park demands has been a concern for many years, but the SLPD has come up with a solution. By excluding short breaking vehicles and using type 2-short parking areas, the empty parking lots allocated for long-resting vehicles in type-1 park areas will not be affected or decreased. This approach ensures that all types of vehicles have access to adequate parking space, and it also helps to reduce congestion in the parking area. The SLPD's innovative solution is an excellent example of how technology can be used to solve real-world problems. With this new approach, park areas can be better managed, and visitors can enjoy a more pleasant experience. As we continue to face new challenges in our cities, it is essential to have organizations like the SLPD that are dedicated to finding creative solutions that benefit everyone.

It will be easier to collect real field data with the increase of smart parking areas in near future and data of the utilization of lots will provide more accurate results for the future studies in this field. In this study, allocated capacity of type 1 is assumed %60 of conventional type park areas and %40 for type 2 short park areas due to the data of research of Plötz and Speth. However, details of data including hourly distribution of the mentioned requests could not be obtained and the scenarios were prepared as requests range of 0 to %50, %100 and %200 of capacity which are not corresponding the of the referred study. Therefore, capacity utilization rates of type 2 short park areas occurred few and more idle capacity is observed than the current universal park model. A future capacity distribution study for short and long parks in relation with park

demand in a specific region will provide tangible results in terms of optimization of park area resources.

By the virtue of new models for parking areas, it will not occur that drivers which are parked for short breaks in type 1- long rest areas lead to turning away of the drivers which are searching parking areas for long rests. On the other side, the circulation and the number of vehicles served in the type 2-short rest areas will be increased by exempting the drivers for long rests. By the increase of rate of capacity utilisation of parking areas by this method, the parking area demand will be met by less parking area capacity and investment costs will be decreased in significant amounts.

From manegerial implications aspects, managers can use the SLPD model to optimize the truck parking areas' capacity utilization ratio. The capacity utilization ratio can be evaluated using the model to determine how different design parameters will affect it. Managers can use this information to make well-informed decisions about the layout and management of truck parking areas. The effective transport of goods across the nation depends on truck parking areas. However, these areas frequently experience capacity issues, which cause traffic jams and delays. Managers can use a model to optimize the capacity utilization ratio of truck parking areas to solve this problem. The model can determine the ideal number of trucks that can be accommodated at any given time by taking data on variables like truck arrival rates and parking spot availability. The model can also be used to assess how various design factors, like parking space size and arrangement, may affect capacity utilization. With this knowledge, managers can decide how to operate and design truck parking lots in a way that maximizes productivity and reduces delays. Different pricing strategies including dynamic pricing appropriate for differentiated park demand could be more easily and effectively implemented by this model as well. In the end, this strategy can ensure that goods are transported across the nation quickly and dependably while lowering costs and having a smaller negative impact on the environment.

In addition to the managerial implications, the practical implications of SLDP model are discussed as follows. A mathematical tool that can be used to maximize the capacity utilization ratio of truck parking areas is called the SLPD model. The capacity utilization ratio can be evaluated using the model to determine how different design

parameters will affect it.. A statistical technique that can be used to assess the effectiveness of the SLPD model is the Monte Carlo Simulation. Strategies for organizing traffic flow in and around truck parking lots are referred to as traffic organization strategies. In order to ensure effective and secure cargo transportation, it is essential to make well-informed decisions about the layout and management of truck parking areas. The Monte Carlo Simulation, which employs statistical techniques to produce a range of potential outcomes based on various variables, is one helpful tool for assessing the performance of the SLPD model. This enables decision-makers to evaluate the effects of various factors, such as location, capacity, and demand, on the performance of truck parking areas. Strategies for organizing traffic are another crucial factor to take into account because they can help to improve traffic flow in and around truck parking areas. Dedicated entry and exit points, wayfinding systems, and traffic-control devices like roundabouts or traffic lights are a few examples of these tactics. Stakeholders can design truck parking areas that are secure, effective, and satisfy the requirements of both drivers and businesses by carefully taking into account these elements and putting forth practical strategies.

Furthermore, since the construction costs of long rest areas are expensive due to security and safety levels of area and extra facilities offered, exempting the drivers for short breaks from those areas and harbor them at type-2 short break areas with cheaper infrastructure will decrease the construction costs of parking area network and also decrease the prices for short breaks in direct proportion. Parking areas will be a subject with increasing significance because they have the potential to be one of the main infrastructure for charging stations of electric vehicles. Parking lots are important because they have the potential to be one of the main infrastructures for charging stations as the world continues to move toward electric vehicles. Less expensive infrastructure will significantly lower the cost of building parking area networks, which will ultimately result in lower prices for quick breaks. Drivers who simply need a place to park will also benefit from this, in addition to those who need to charge their electric cars. More parking spaces can be constructed and maintained with less expensive infrastructure, improving accessibility and convenience for drivers. Additionally, this drop in construction costs might spur the development of new technology and innovations in the parking sector, like smart parking systems that make

it simple and quick for drivers to locate open spaces. In the end, more affordable parking infrastructure has the potential to transform the way we view transportation and open the door to a more sustainable future.

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