PARKING MANAGEMENT IN SMART BUILT ENVIRONMENT:
EVALUATION OF METU CAMPUS

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EVALUATION OF METU CAMPUS

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ABSTRACT

PARKING MANAGEMENT IN SMART BUILT ENVIRONMENT: EVALUATION OF METU CAMPUS

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With the ever-increasing number of vehicles and technological advancements, transportation-related social problems are addressed with more systematic and smarter solutions, as a part of Intelligent Transportation Systems (ITS) services. Parking management is an ITS application area, where limited parking capacities can be efficiently and fairly utilized by more road users. However, detection of the true nature of parking demand and supply limits as well as the expected response to any policies and technology tools to be employed, is necessary prerequisite step.

Middle East Technical University (METU) campus is a built environment that suffers from parking-related problems due to limited parking supply capacity despite the increase in the demand. Thus, parking violations have been increasing lately due to high number of cars in the campus. Besides the negative environmental impacts, parking violations have started to threaten the flow and safety of the campus traffic due to traffic congestion and loss of road network capacity at critic locations.

This thesis focuses on estimation of the type and level of parking utilization and violations in METU Campus, so that smart parking management strategies can be recommended for development of a more sustainable campus transportation policies. Smart parking management requires an understanding of land use, parking supply and demand, driver needs, behaviors, and perception of the commuters, in the scope of parking management. Thus , within the study, parking space inventory, parking survey were conducted and a smart campus transportation survey was utilized. After this comprehensive evaluation, a campus-wide parking management strategy plan that promote smart mobility within the campus was proposed within the campus, in 7 stages . In addition, a regional strategy plan, including the locations, and application of the proposed parking pricing strategy, and the areas where parking should be prohibited, has been created.

Keywords: Smart Parking Management, Smart Built Environment, Smart Mobility, Parking Management, Smart Campus.

ÖZ

AKILLI ÇEVRE KAPSAMINDA PARK YÖNETİMİ: ODTÜ KAMPÜSÜ DEĞERLENDİRİLMESİ

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Giderek artan araç sayısı ve teknolojik gelişmelerle birlikte, ulaşımla ilgili sosyal problemler; Akıllı Ulaşım Sistemleri'nin bir parçası olan sistematik ve akıllı çözümlerle ele alınmalıdır. Park yönetimi, sınırlı otopark kapasitelerinin daha fazla yol kullanıcısı tarafından verimli ve adil bir şekilde kullanılabildiği Akıllı Ulaşım Sistemleri uygulama alanıdır. Ancak; otopark arzının ve parklanma talebinin kapsamının, ayrıca kullanılacak olan herhangi politika ve teknolojik ürüne verilmesi beklenen karşılığın belirlenmesi gerekli ön şarttır.

Yapılı çevre olan Orta Doğu Teknik Üniversitesi (ODTÜ) kampüsü parklanmaya olan talebin artmasına rağmen, içerisindeki park yeri kapasitesinin sınırlı olmasından dolayı, parklanma ile ilgili problemlerle yüzleşmektedir. Son zamanlarda park ihlalleri, kampüste araç sayısının fazlalığından dolayı artmaktadır. Olumsuz çevresel etkilerin yanı sıra park ihlalleri; kritik konumlarda trafik sıkışıklığı ve karayolu ağı kapasitesinin kaybı oluşturması nedeniyle. kampüs trafiğinin akışını ve güvenliğini azaltmaya başlamıştır.

Bu tez, ODTÜ Yerleşkesi'nde park kullanımının ve ihlallerinin, türünün ile seviyesinin belirlenmesine odaklanmaktadır, bu yüzden daha sürdürülebilir kampüs ulaşım politikalarının geliştirilmesi için, akıllı park yönetimi stratejileri önerilebilir. Ancak, akıllı park yönetimi, park yönetimi kapsamında; arazi kullanımını, park yeri arzı ve talebini, sürücü ihtiyaçlarını, davranışlarını ve kişilerin bakış açılarını anlamayı gerektirmektedir. Bu yüzden bu çalışma kapsamında park yeri sayımı, parklanma araştırması yapılmış ve bir akıllı kampüs ulaştırma anketinden faydalanılmıştır. Bu kapsamlı değerlendirmeler sonucunda, kampüs içinde akıllı mobiliteyi teşvik eden bir park yönetimi strateji planı kampüs genelinde 7 aşamalı olarak önerilmiştir. Ek olarak, önerilen park yeri ücretlendirme stratejisinin konumu, uygulama şeklini ve park etmenin yasak olması gereken bölgeleri içeren bölgesel strateji planı oluşturulmuştur.

Anahtar Kelimeler: Akıllı Park Yönetimi, Akıllı Yapılı Çevre, Akıllı Mobilite, Otopark Yönetimi, Akıllı Kampüs.

This thesis is dedicated to my parents Sezai Genel and Fehime Genel.

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ABBREVIATIONS

ICT: Information and Communications Technology

IoT: Internet of Things

RFID: Radio Frequency Identification

BIM: Building Information Modeling

CBD: Central Business District

IT: Information Technology

PLot: Parking Lot

PSpace: Parking Space

GIS: Geographical Information Systems

CHAPTER 1

INTRODUCTION

Universities with a campus resemble cities because of accommodating recreational areas like shops, theaters, restaurants or offices, companies, museums, hospital. (Shoup, 2007). Although the attractiveness of the area increases with these buildings, hosting that many building types come with a price. Thus, universities with a big campus usually have transportation-related problems.

Middle East Technical University (METU) campus is a perfect example of a campus that suffers from transportation-related problems. These problems are mostly originated from the limited number of parking spaces that don't meet the demand. According to Altıntaşı (2013), METU Campus has become more "automobile oriented" with the number of vehicles exceeding 15000 per day. According to Karatas (2015), high demand for using private car causes traffic congestion at peak hours and illegal parking behavior because of limited roadway capacity at METU campus. Increase in vehicle ownership started to affect efficiency of parking lots because search time for parking has increased. Therefore, traffic congestion and use of energy in traffic have increased accordingly.

In the last decade, the number of stickers increased drastically at METU campus. It indicates that automobile use at the campus increases day by day and thus, it makes use of parking lots ineffective and insufficient. Since increasing the parking supply at the METU campus will create new difficulties including traffic congestion, air pollution, it requires systematic evaluation before applying any strategy.

Instead of increasing the parking supply, applying smart parking management is a better way to cope with these problems as the goal is not to provide parking space to every automobile user in the concept of smart parking management. Nevertheless, parking management requires to accomplish some tasks, such as the reduction in traffic congestion by lowering cruising, reduction in time and energy consumption and providing reliable service to numerous users by considering sustainability the most. Therefore, smart parking management requires an understanding of land use, driver needs, behavior, and perception of commuters in the scope of parking management. So, it is essential to do a comprehensive evaluation of travel demand, mode choice, and parking needs.

It is crucial to get the perspectives of the commuters regarding parking experience, parking behavior, and expectations in order to deal with the mobility sourced problems. In light of the literature, potential solutions can be established after analyzing the behaviors, the status of transport modes, and parking lots.

In order to obtain information about the use of parking lots and the perception of people regarding METU campus mobility experience, the study includes surveys and evaluation of a parking space inventory. In this study, evaluation of METU campus parking management within a smart built environment was done, then mobility needs were discussed afterward.

1.1 METU Campus Built Environment

METU campus is located on the southwestern part of Ankara (Figure 1.1). Land use for METU campus consists of 4500ha campus area, which includes 3403ha forest. In addition, only 200 ha area is within the built environment. METU campus suffers from mobility sourced problems due to high demand to driving. Thus, at METU campus, mobility should be kept under control as there are approximately 35 thousand commuters per day. Furthermore, METU campus which locates on the southern side of the İnönü Boulevard also known as Ankara – Eskişehir highway, is approximately 10 km far away from the area called CBD of Ankara. Altıntaşı (2013) reported that approximately 15,000 vehicles entry to METU campus per day. The demand indicates the attractiveness of METU campus which is quite a lot.

At METU campus, there are 3 open gates (A1, A4, A7), where people can enter to campus. It should be noted that there are seven gates at METU Campus, some of which kept close for security and land-use purposes. The main gate for accessing to METU campus is A1 that is located near Ankara-Eskişehir highway. A1 is accessible for all types of public transport modes like metro, dolmuş, public buses, private buses (see Figure 1.1). Therefore, A1 gate is the busiest gate among METU commuters.

Moreover, public buses are being operated between METU campus and the CBD, parallel to the metro line. Also, dolmus is being operated to A1 and A4 gates. A4 gate is another busy gate for accessibility of the METU campus because there is a direct dolmus line to Yüzüncüyıl, where many students live in. On the other hand, A7 gate is used by private car owners, who lives in the western part of Ankara (Bilkent, Cayyolu regions, etc.).

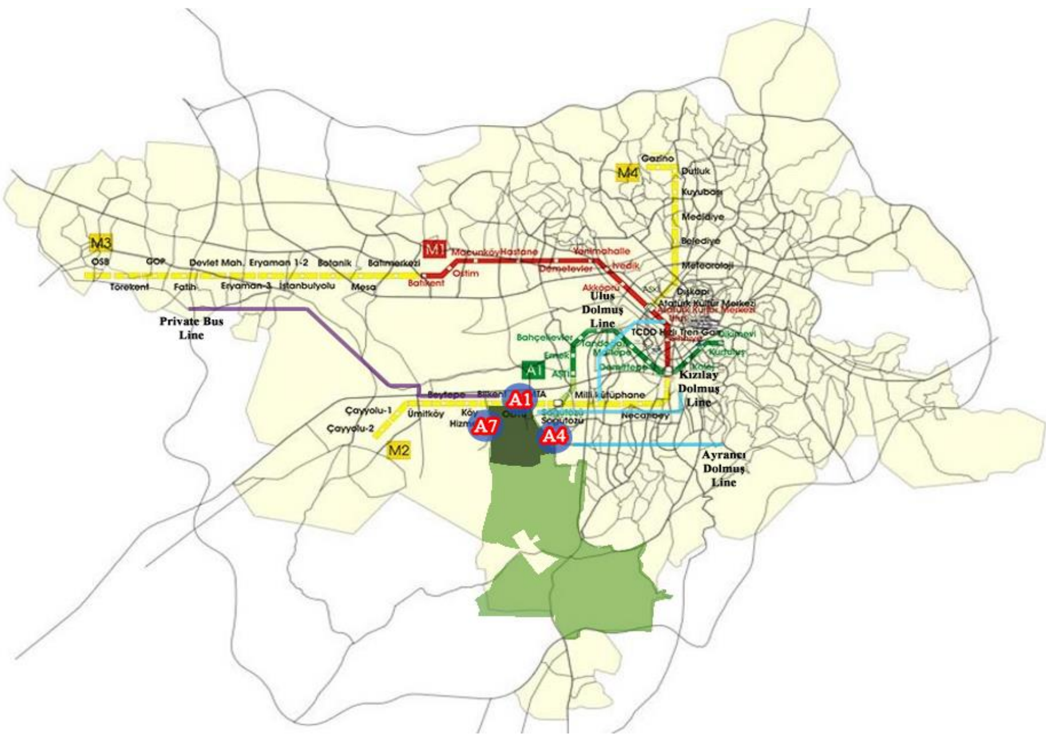


Figure 1.1 Location of METU Campus and Accessibility Options to METU campus (Ankara Development Agency Regional Plan, 2014; Middle East Technical University Website, 2016)

1.2 Current Parking Management at METU

At the study area which is a METU campus, there are 56 parking lots with different capacities. Evaluation of parking lots had been done by dividing the study area into 13 different regions (see Figure 1.2).

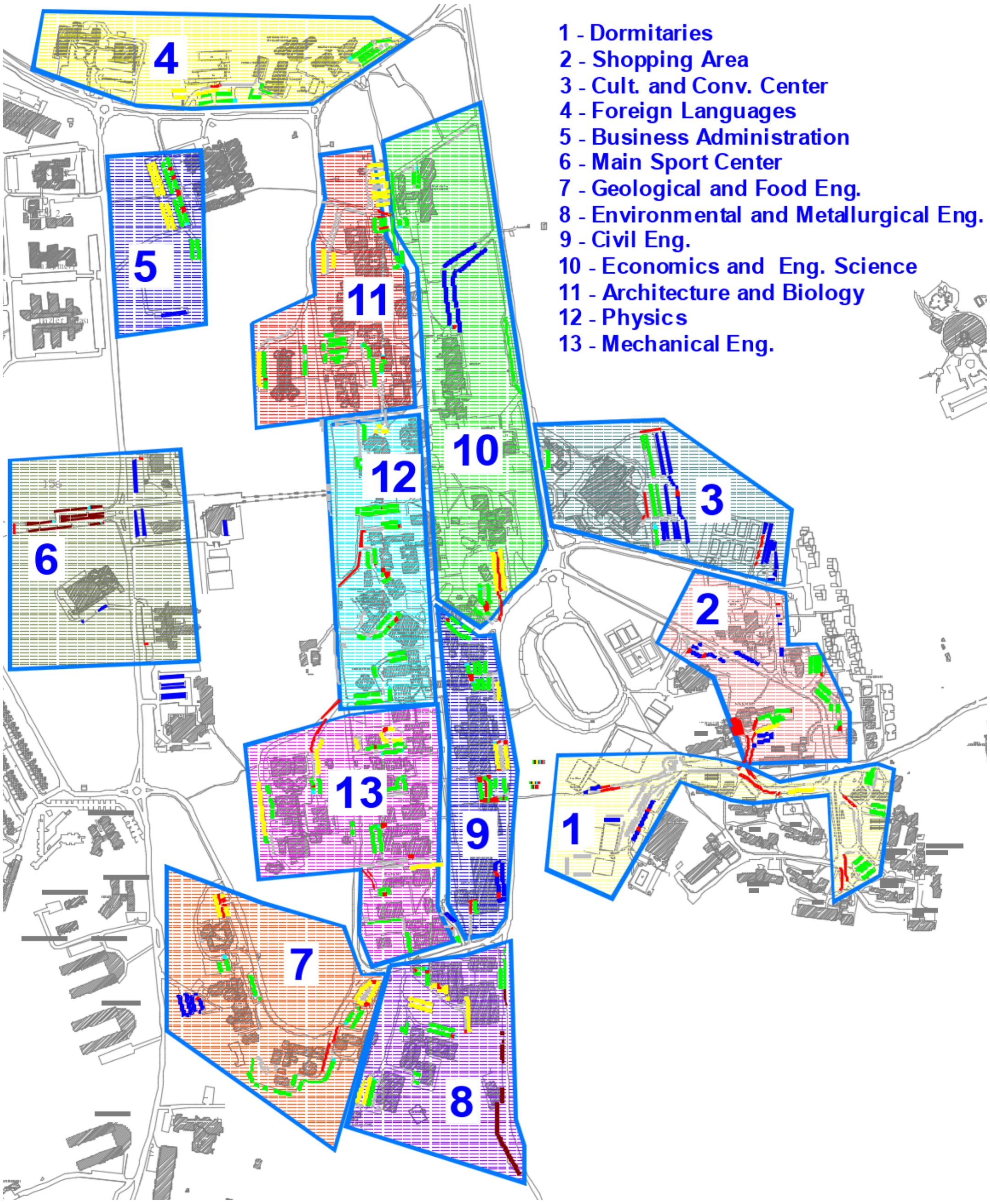


Figure 1.2 METU campus regions for parking management evaluations

According to Christiansen et al. (2017), compact neighborhoods are associated with less use of personal vehicle. On the other hand, automobile ownership increases the probability of the driving. At METU campus, the number of stickers can be resembled to the automobile ownership. Therefore, it is important to discuss the use of stickers at first.

METU stickers differ from the traditional parking passes because of their usage. At METU campus, vehicles with stickers are allowed to enter the campus. In case of the absence of the sticker, the drivers need to take a visitor card by dropping their identification cards to the gate security in order to enter the campus with their personal vehicle, unless they are current students at METU. Although all of the stickers give authorization to drivers to enter to campus, it does not ensure the availability of parking space.

Besides, not all user of parking stickers has access to all parking lots. The distinction between sticker types is illustrated by using color codes (see Figure 1.3). There are eleven types of stickers, that are being currently used at the campus. These sticker types can be listed as academic, personnel, resident, foundation, Technopolis, guest, guest type two, alumni, yellow, brown, and college.

The sticker owners are allowed to park their vehicles on specific parking lots according to their sticker type, so they can not park their vehicles to certain parking lots that belong to another community. In case of parking the vehicle to parking lot that is not allowed causes sticker violation which is a type of parking violation. At the entrance of the parking lots, there is a sign that indicates which sticker type user is allowed to use certain parking lot locates. Those signs contain color codes (see Figure 1.3). Certain sticker owners can park the vehicle if only the color code of sticker and sign matches. Otherwise, the driver might get a warning. Three times of getting warning owing to parking illegally results in cancellation of the sticker permanently or temporarily.

Figure 1.3 Sample of the Stickers and Authorization Sign of Parking Lots

1.3 Challenges of Parking Management at METU Campus

Designated parking spaces at METU campus locate at parking lots and roadside. Parking lots are being used by faculty members, personnel, students and guests. Moreover, at the campus some of these parking lots are remote parking lots where people can take shuttle services or walk, after parking their vehicles to these parking lots.

Roadside parking, can be considered as parking the vehicle near sidewalks. Roadside parking can be defined as both on-street parking and curbside parking. Nevertheless, the use of parking lots in the purpose of parking rather than roadsides, is more desirable. Decreasing the road width by providing on-street parking causes decreased traffic safety and operational capacity of road. It is more dangerous on campuses where pedestrian mobility is really high. Because of old campus architecture, the width of the roads at METU campus that are not large enough. In addition, roadside parking makes the traffic environment dangerous due to high pedestrian mobility at METU campus. Therefore, roadside parking is undesirable, although it is not forbidden at all of the roads.

Parking violation behavior is another obstacle for parking management at METU campus. Two types of parking violation has been observed at the campus. The first one is common type of parking violation that is parking the vehicle on the forbidden area is called No-parking violation. The second one is the sticker violation, in other words parking the vehicle to a parking lot which is reserved for another sticker type owners. Because parking violation is a common behavior among METU commuters, it is essential to mention about this behavior. Spiliopoulou (2012) found that illegal parking increases when the probability of finding available parking space decreases. Otherwise, the behavior of searching for available parking space causes traffic congestion. Therefore, cruising is needed to be eliminated at METU campus.

1.4 Scope of the study

The scope of the study is to understand parking behavior and user perception about parking at METU campus. In order to gather the perspective about the parking experience at METU campus, several studies were done:

- A campus-wide survey that included questions regarding parking behavior was conducted. The survey consists of two phases that are face-to-face and online.

In the purpose of analyzing the current parking behavior at METU campus, various studies were performed. These studies involved;

- A parking inventory study to determine campus parking capacity and types
- A parking survey that consists of counting parked vehicles at parking lots, was designated. It includes 3 time periods (morning, noon, evening) of a day, in order to observe the occupancy rate of parking lots and determine parking violations.

Within the scope of the study, research questions are:

1. What are the current occupancy rates of the parking lots at METU campus?
2. What is the extent of violations of parking lot/space allocations?
3. What do commuters consider about parking at METU campus and what have they experienced?

In the analyses of these questions, two approaches are used:

i) Statistical outputs indicated the behaviors and the perceptions regarding to parking experience at METU campus. These analyses revealed the current situation and guide to develop an applicable strategy.

ii) Spatial outputs are used for visualization of parking lots, capacities, parking violations. Besides, the variations in the occupancy rates, parking violations were visualized.

By following these studies, past parking related campus studies and other METU campus studies a parking evaluation had been done. Thus, challenges and problematic areas were defined at the campus. In sight of the evaluations and past studies, a framework was created. Then, applicable parking management strategies and systems that transform campus mobility into smart one, were defined. As a result of the study, a campus-wide parking management strategy plan was created step by step. Moreover, for problematic areas at required parking lots parking pricing strategy was offered. In addition, at areas with high pedestrian mobility and roadside parking were proposed as no parking areas.

1.5 Layout of the thesis

In chapter 2, the dimensions of parking management and the variations in parking management within the years were summarized based on the literature. This chapter also consisted smart parking management strategies and systems. In addition, potential reactions to parking-related problems were discussed at this chapter.

In Chapter 3, the dimensions of smart and sustainable campus concepts were discussed. The concept involved goals and policies. Moreover, smart and sustainable campus projects and activities at METU campus was overviewed. Chapter 4 discussed the methodology implemented in this study to understand the parking needs and behavior. It involved smart campus transportation surveys, parking space inventory and parking survey. Chapter 5 consisted of the results of the surveys and inventory. Accordingly, parking lots are divided into categories by analyzing the occupancy levels, parking violations.

Finally, by using results of surveys, and inventory, METU campus parking management evaluation was done at Chapter 6. Moreover, a framework, a campus-wide parking management strategy plan was developed. Furthermore, campus area was divided into Zones and parking pricing strategy was offered at some parking lots. Besides, at areas with high pedestrian mobility, parking lots alleys and roadsides are proposed as No-Parking areas.

CHAPTER 2

DIMENSIONS OF PARKING MANAGEMENT

As improvements in technology which led to decrease in vehicle prices, the increase in the income level, desire in the comfort and adding automobile-oriented transportation system, it promoted private vehicle ownership. According to TurkStat, vehicle ownership in Turkey was 7,093,964 in 2009. Today, in 2019 the number of vehicle ownership is 12,505,020. In other words, it increased by 76% in the last decade. This increase araises various problems like traffic congestion, parking-related issues etc. And all these problems are inter-related. For instance, Ibeas et al. (2018) declared that private vehicles stay in parked at ninety percent of a time. This indicated the importance of parking by means of transportation management.

In the past parking-related problems had been solved by increasing the parking supply (see Figure 2.1). Litman (2017) identifies this old paradigm as giving priority to the drivers at the transportation system. Related to this approach, providing excessive parking supply increased the use of automobiles. Thus, the demand for parking space also increased. According to Weinberger et al. (2010) with the old paradigm drivers cruise for an available parking space for a long time, developers are obligated to provide more parking lot than it requires, and traffic managers are struggling to deal with traffic congestion that is generated by new parking demand.

Lately, it was recognized that increasing the parking supply was not the solution to the problem, even it caused more chaotic situations like increased traffic congestion within high mobility areas. Sykes et al. (2010) discovered that cruising, in purpose of searching unoccupied parking space, causes 26% of the traffic in Brooklyn, 45% in Manhattan (Spiliopoulou, 2012). It makes the most attractive places suffering from traffic congestion and as a result of it, loss of attractiveness was faced. Moreover, Tafidis (2017) declares problems with the functioning of the transportation which involves urban areas that suffer from traffic congestion, air pollution, and destruction of the environment. According to Weinberger et al. (2010), increased automobile trips, which lead to traffic congestion, air pollution, and greenhouse gas emissions, are the sum of these unintended consequences.

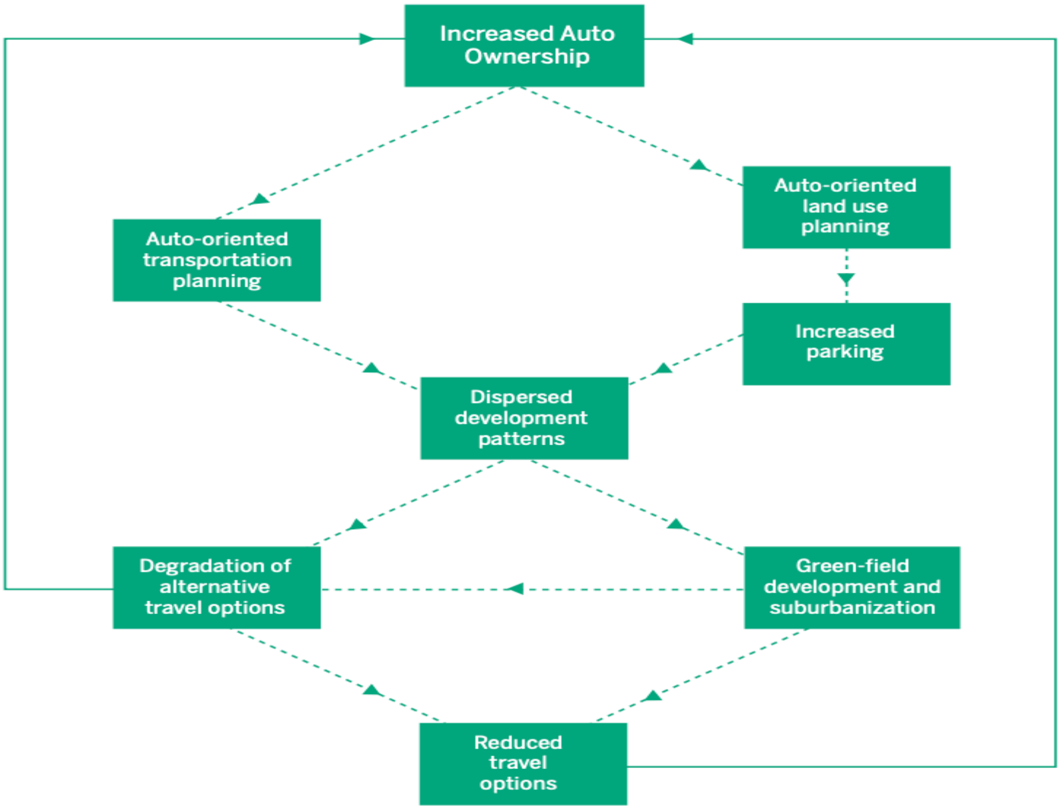


Figure 2.1 The Cycle of Automobile Dependency (Weinberger et al., 2010)

Authorities have started to question the approach of providing parking space to drivers and realized that traffic congestion can be mitigated by this approach. The situation had created the need to a paradigm shift in the planning process. Therefore, it was inevitable to change the attitude and gave priority to accessibility rather than private car use. In other words, the perception of automobile-oriented system has been changed in time. Then, the approach was transformed to parking maximum and effective use of parking spaces which is called parking management, instead of increasing the parking supply.

According to Litman (2006), parking management related to policies and programs can contribute to effective use of parking supply (see Table 2.1), and appropriately implemented parking management can decrease the number of parking spaces, presenting economic, social, and environmental benefits. In addition, Litman (2016) believes that parking management is the best option for ensuring user quality of service, helping to create more accessible patterns of land use and decreasing motor vehicle traffic, decreasing traffic congestion, accidents and gas emissions, building more attractive neighborhoods and increasing accessibility for non-drivers.

Table 2.1 Comparing Increased Supply and Management Solutions (Litman, 2006)

Problem	Increased Supply	Management Solutions
Response to demand for parking	Positive	Positive
Spillover. Problems from location that drivers are unwilling to park	Positive	Mixed. Some management strategies increase spillover problems, others reduce them.
Parking lot construction costs	Negative	Positive. Decreases parking requirements.
Traffic congestion.	Negative. Increases vehicle use.	Positive. Many management strategies decrease automobile use
Equity and fairness. Non-drivers forced to pay for parking that they do not use.	Negative	Positive. By charging drivers, decreases parking requirements.
Tax costs. Increased tax burden required to subsidize parking facilities.	Negative	Positive. By charging drivers, decreases parking requirements.
Environmental impacts. Loss of greenspace, stormwater management costs, air pollution, unattractive landscapes.	Negative	Positive. Decreases total parking requirements and vehicle use.
Sprawl. Encouraging dispersed, urban fringe development, and discouraging multi-modal, urban infill development.	Negative	Positive. Encourages smart growth development patterns.

Furthermore, it is important to identify potential solutions. Litman (2017) defines parking management principles which are needed to be followed before deciding applicable parking management solutions. Parking Management principles consist of 10 principles as following;

Parking Management Principles

1. *Consumer choice.* It requires to provide viable travel and parking option.
2. *User information.* It requires to inform the user regarding on their parking and travel options.
3. *Sharing.* Parking lots need to provide parking space to multiple destinations and users.
4. *Efficient utilization.* Management and size of the parking lots need to be defined in order to make parking spaces usually occupied.
5. *Flexibility.* Parking plans require to handle uncertainty and change.
6. *Prioritization.* The most demanded parking spaces should be managed according to higher priority uses.
7. *Pricing.* Collecting fee directly is more desirable.
8. *Peak management.* The parking supply should respond to peak demand.
9. *Quality vs. quantity.* Both quantity and quality of parking lots requires to be considered as, including aesthetics, security, accessibility and user information.
10. *Comprehensive analysis.* All significant costs and benefits should be considered in parking planning.

2.1 Smart Parking Management Concept

Lately, parking management concept transformed into smart parking management concept. Smart parking management, which is a branch of smart mobility consists of smart parking management strategies and systems that contribute to social, environmental, and economic subtitles in the view of the technology. According to Battarra et al. (2018), in order to make smart mobility index efficient, it is essential to improve the link between ICTs (Information and Communications Technologies), urban context, and parameters that rely on accessibility and sustainability. Moreover, it is important to mention policies that are linked with parking management. Battarra et al. (2018) claimed that with well-designed role of mobility which lets implementation of policies and supportive projects, it is possible to satisfy user and sustainability-oriented activities in the concept of the Smart City.

Nowadays, in the scope of campus mobility management, parking management is a great tool for preventing traffic congestion. Thus, the need for parking management strategies and systems becomes more crucial day by day. Nevertheless, these strategies and systems require to be designed and applied logically.

Smart parking management consists of both strategies and systems. Before mentioning the dimensions of parking management on campus, it is essential to clarify the distinction between parking management strategies and systems. Although both of them serve for economic, environmental and social improvements, the role of parking management systems and strategies distinguish from each other. Parking management systems are being improved accordingly to technological developments. Management systems are for increasing the efficiency of applied management strategy or parking lot. Yet, parking management systems are relatively new terms comparing to parking management strategies because technology has become indispensable lately. Thus, the concept of sustainability has started to be transformed to the concept of smartness that involves ICT.

2.2 Parking Management Strategies

The old perception was to build a new parking facility or increase the fields that provided for parking. That concept was not able to resolve the traffic congestion problem. In spite of the fact that available spaces were existed, reaching there was causing traffic congestion in the central business districts and urban areas. Because most of the parking problems occur in city centers, the old paradigm gave its place to a new one which is supporting parking management strategies.

In order to cope with problems sourced by parking, management strategies are required. Parking management strategies consist of policies and programs that make use of parking supply effectively. According to Litman (2017) implementing applicable parking management strategies is useful for descending necessity of parking supply.

Yet, parking management strategies should be identified by following principles that are mentioned at Section 2.1. Moreover, the recent condition of the area that is wanted to be applied to parking management strategies, is also important. De Wit (2008) has worked on a study that involves the evolution of parking solutions (see Figure 2.2). Below required reactions to parking problems by considering parking demand according to the complexity of the situation is provided.

1. At the first phase, any intervention is not needed. Parking the vehicle is convenient, as long as it doesn't affect the attractiveness of the area.

2. After the impact of the parking becoming to be observed, parking regulations and control should be applied. Curbside parking can be forbidden. Marks of the parking spaces require to be distinctive and parking spaces should be designed effectively.

3. The principle of a strategy of time limitation on the use of parking lots needs to be applied in case of lack of available parking space has been observed constantly. So, the parking space can be used more effectively. The idea behind the restrictions is, discouraging long term parking. Applying priced parking would make it to be achieved more effectively.

4. When an overflow occurs at parking lots at central districts, demands switches to residential areas. The problem is often overcome by the introduction of resident parking systems requiring people following a set of criteria or charging a permit fee.

5. At phase 5, it requires that increased demand is needed to be under control. The most irrevocable strategy is to set a parking fee by considering the availability of the parking space.

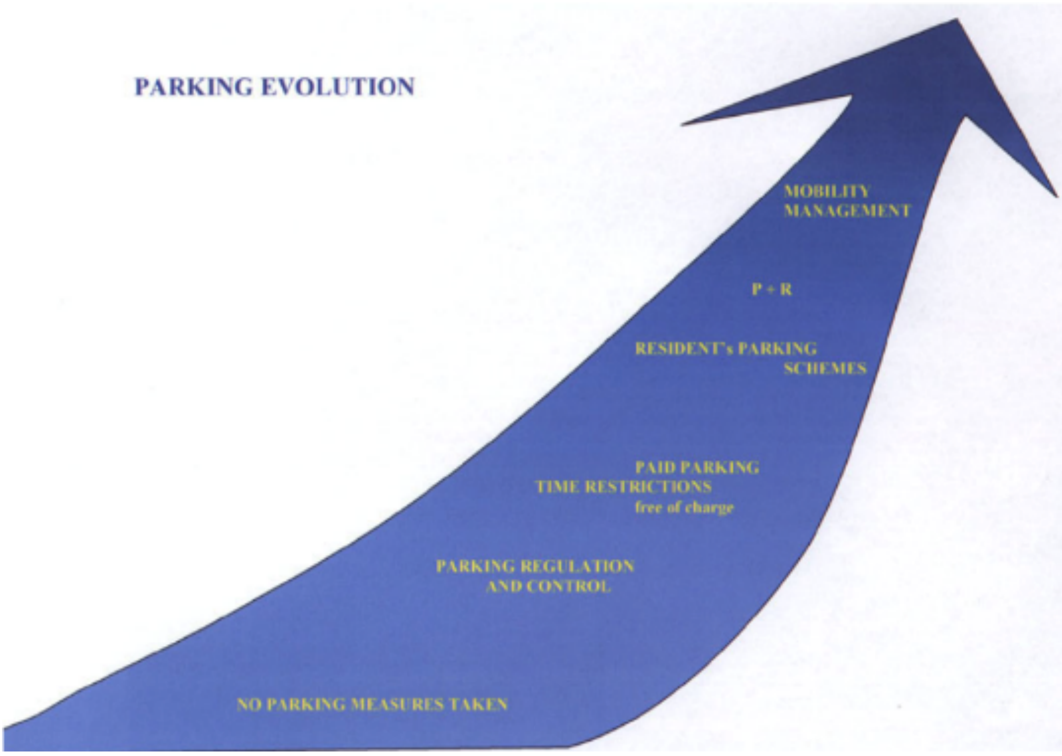


Figure 2.2 Parking Evolution (Source: De Wit, 2006)

6. It requires a reduction when the parking demand gets drastic. At that point, parking areas need to be moved away from the center of the city. Then, transportation should be handled by other transportation modes. The parking lots need to be supported by shuttle services, railroads or subway. In other words, park-and-ride parking lots require to be used. Park and ride sites are very useful in the purpose of relieving the traffic in the city center.

7. At the last phase, the final reaction requires to be mobility management. The concept is formed as a combination of both public and private vehicle use. A more improved version is park and ride sites. The main point is to increase the accessibility of the area.

Because the reactions are arranged for components of a city, they need to be converted to the climate of campuses. Because every campus has its own climate, reactions should be arranged accordingly. In the following section, the most effective parking management strategies are provided.

2.2.1 Parking Maximums

Parking maximum means that putting an upper limit on parking supply. It is essential for reducing automobile use at high demanded areas and encouraging drivers to use other modes such as public transportation, shuttle services, walking, or cycling. Christiansen et al. (2017) found that the reduction in the availability of parking space decreases personal vehicle use. In addition, Bond and Steiner (2006) claimed that reducing parking supply encourages people to use public transportation and supports people for walking or cycling when the destination point is close.

On the other hand, solely strategically decreasing parking supply would be not sufficient, it is needed to be supported by well-designed walking, cycling environment, and transportation services. Delaware Valley Regional Commission, (2004) claimed that in case of the existence of well-provided transportation services, cycling or walking paths, parking maximum strategy would be more effective.

Moreover, Christiansen et al. (2017) claimed that the abundant number of parking supply makes the strategy of parking pricing ineffective. Therefore, parking management strategies require to be considered together. In addition, according to Metropolitan Transportation Commission (2007) reducing the parking the supply may be able to reduce demand (10-15%), or reflect a lower demand, especially adjacent to transit or combined with shared parking and pricing.

According to U.S. Environmental Protection Agency (2006), both planners and developers benefit from restricting the number of parking spaces. From the city’s perspective, maximum limits:

- Parking maximums strategy is useful for improving the environment by providing open-space;
- Decreases traffic congestion and traffic-related costs;
- Provides attractive and pedestrian-friendly urban design
- Encourages public transportation
  - Decreases the construction, operations, and maintenance of parking lots;
  - Decrease parking requirements.

2.2.2 Parking Pricing

Parking pricing strategy is one of the most crucial parking management strategies. Parking pricing strategy is not only useful for decreasing traffic congestion that is sourced by the act of cruising, but also useful for generating additional revenue for the maintenance of parking facilities. Shoup (2011) justified that policy of parking pricing influences the user's preference by means of mode choice.

According to the Metropolitan Transportation Commission (2007), parking pricing has the greatest effect (5 to 30%) to decrease demand for parking. Likewise, Shoup (2006) indicated that parking pricing has the greatest effect to discourage people from driving. Besides, Christiansen et al. (2017) found that parking capacity restrictions at the workplace are more effective to discourage people from driving comparing to parking pricing strategy. Furthermore, it was found that it is possible to increase the effect of parking pricing strategy by decreasing parking capacity. In addition, Christiansen et al. (2017) found that free and available parking space causes quadrupling of the parking demand at workplaces. On the other hand, Fei (2016) discovered that free parking increases the use of automobiles for traveling. Besides, one of three people prefer public transportation, cycling, or walking if free parking is eliminated. Automobile use decreases with the high parking prices.

Furthermore, the fee of parking should be arranged, by considering the occupancy of the facility as %15 percent available for parking (Shoup, 2006). Thus, people will be able to find parking space near destination when it is required, or switch mode, or destination accordingly unless want to pay for parking. According to Shoup (2008), several reasons affect willingness to pay, if the person is tired or late, weather, scenery, safety, heavy packages, health, exercise.

For a smart campus, it is important to choose the location for the parking pricing according to the occupancy rates. Consequently, central spaces are needed to be allocated for priced parking. According to Shoup (2008), users of priced parking spaces at a campus area; will be short-term parkers, carpoolers because of splitting the parking fee, and people who place a high value on saving time. Yet, according to Litman (2020), parking pricing strategy has unintentional effect that drivers may park illegally or cause traffic congestion during the search of available free parking space. Moreover, Thanh and Friedrich (2017) believe that the reason why illegal parking is common in Vietnam Hanoi is because of lack of enforcements. Therefore, it is essential to improve parking regulations, provide user information, and apply enforcements effectively while thinking parking pricing strategy.

2.2.3 Remote Parking

Remote parking lots locate at far away from central districts. The idea behind the remote parking is to keep automobile use out of central areas and to limit the cruising. Kent (2007) found that in zones with limited car parks, although parking spaces are available for parking, drivers may prefer not to go to the area because of being pessimistic about the probability of finding available free parking space. The idea drags them to look for space at another zone with a high probability of unoccupied parking space.

Litman (2006) defines remote parking as off-site parking facilities. First and foremost, remote parking facilities are needed to be assisted by well-provided shuttle or public transportation services in order to encourage drivers to use these parking facilities. Today, park and ride parking facilities are accepted as the most common remote parking. Özen et al. (2016) considered that while estimating demand for park and rides parking lots, the relationship between land use, public transportation, and parking lots requires to be thought.

2.2.4 Parking Regulations

Litman (2017) suggests that in order to optimize parking use, parking regulations govern who can park at a certain parking space, when and how long vehicles can stay. It is essential to identify some criterias for parking regulations, some parking regulation types are provided (see Table 2.2). In addition, parking restrictions which would be an effective strategy for optimizing the use of parking supply, are one of the most important parking regulation types. Yet, Christiansen et al. (2017) defends that in case of constructing parking lot far away from the center of the district, parking restrictions are not as effective as in the center of the district. Therefore, it was concluded that parking restrictions are more effective in case of the existence of compact neighborhoods or cities. Also, Christiansen et al. (2017) found that a workplace nonexistence of reserved parking space influences the decision making of driving. Drivers tend to give up from driving in case of own dedicated parking space is removed.

Table 2.2 Common Parking Regulations (Litman, 2006)

Name	Description	Favored Activity
User or vehicle type	Spaces dedicated to loading, service, taxis, customers, rideshare vehicles, disabled users, buses and trucks.	As specified.
Duration.	Limit parking duration (5-minute loading zones, 30-minutes adjacent to shop entrances, 1- or 2-hour limits).	Short-term users, such as deliveries, customers and errands.
Time period restrictions	Prohibit occupancy at certain times, such as before 10 am, to discourage employee use, or between 10 pm and 5 am to discourage resident use.	Depends on restrictions.
Employee restrictions.	Require or encourage employees to use less convenient parking spaces.	Customers, deliveries and errands.
Special events	Have special parking regulations during special events.	Depends on restrictions.
Accommodate short-term users.	Provide options for vehicles that make numerous short stops, such as special parking passes.	Delivery and service vehicles.
Residential parking permits	Use Residential Parking Permits (RPPs) to give area residents priority use of parking near their homes.	Residents.
Options for special users.	Establish a system that allows specific parking spaces to be reserved for service and construction vehicles.	Vehicles used for special activities.
Restrict overnight parking	Prohibit overnight parking to discourage use by residents and campers.	Shorter-term parkers
Street cleaning restrictions	Regulations that prohibit parking on a particular street one day of the week to allow street sweeping.	Street cleaning. Insures motorists move their vehicles occasionally.
Large vehicle restrictions	Limit on-street parking of large vehicles, such as freight trucks and trailers.	Normal-size vehicles
Arterial lanes	Prohibit on-street parking on arterials during peak periods, to increase traffic lanes.	Vehicle traffic over parking.
abandoned vehicles	Have a system to identify and remove abandoned vehicles from public parking facilities.	Operating vehicles.

2.3 Parking Management Systems

Parking management systems rely on technological improvements directly comparing to parking management strategies. In the past, parking management systems were used for getting a ticket when entering to the parking lot. The idea was to estimate how many hours did the customer leave the vehicle in the parking lot. Today, parking management systems became more complex because of high vehicle ownership. Kodransky (2011) stated that a typical driver can spend nearly 25% travel time by cruising in order to find available parking space. Parking search can be a significant contributor to central city traffic congestion during peak commute hours. In fact, many have estimated that such traffic composes between 25 to 50 percent of all peak period traffic (Shaheen, 2005). The major objective of these systems is to decrease travel time which emerges because of cruising. Yet, Ma et al. (2018) discovered that because the majority of the drivers are not familiar with parking applications, it was concluded that real-time parking apps are not common in Hong Kong. There is still doubt about the popularity of the concept of the smart city among the public.

2.3.1 Parking Guidance and Information Systems

The main goal of implementing Parking Guidance Information (PGI) systems is to decrease traffic that is sourced by parking search in central cities and in large parking facilities. A typical PGI system which is implemented on entrances and exits or in individual parking spaces is beneficial for gathering data of number of occupied parking spaces and provide available parking spaces in parking lots. Moreover, drivers are able to be directed to available parking space by using Parking Guidance Information System.

According to Shaheen (2005), the goal of Parking Guidance and Information Systems are to accomplish some advantages like travel time savings, reduced vehicle travel, less traffic congestion, driver frustration, lower fuel, energy, reduced air pollution, increased parking revenues. Yet, Ma et al. (2018) demonstrates that 72.8% of Hong Kong citizens are not aware of any parking applications and adds that real-time parking applications that are branches of smart mobility are not common yet.

2.3.2 Transit-Based Information Systems

Transit-Based Information (TBI) systems might be considered separately from parking management systems. Yet, it is integrated with parking management. At park and ride parking lots transit-based information systems are very useful in order to keep drivers away from central business districts.

TBI systems can be considered as an improved version of parking guidance and information systems in terms of use. Today a typical transit-based information system requires to provide real-time information to drivers regarding the number of available parking spaces in park-and-ride parking lots. According to its location or purpose, schedule of bus, shuttle services, train, or subway requires to be provided. Moreover, arrival and departure times of other modes are needed to be provided by using TBI Systems. The aim of these smart parking management systems is to accomplish the number of advantages; such as increasing bus use, decreased car transportation, reduced use of fuel; reducing air pollution, and higher revenues from transit (Shaheen 2005).

2.3.3 Smart Payment Systems

Advances in smart payment systems (e.g., smart meters, smart cards, mobile communications, and e-parking) improve parking payment convenience and reduce operation, maintenance, and enforcement costs (Shaheen, 2005). Throughout Turkey, the workplace or valet parking system generally collects parking fees. In parking areas, still, fees have been usually collected by a cashier in Turkey. In addition to the common worldwide use of parking meters, brand-new payment systems are emerged as an alternative to the old-style parking meters. Customers can pay quickly and accurately by using a smart card. Moreover, the customer can make a call and pay by using a credit card, or through the transfer of money to easily accessible cards. In other words, the fee can be collected via the Internet, mobile telephone. Ma et al. (2018) demonstrates that whether people use parking applications or not, system information security seems to be crucial in front of their sights. People want to be sure that their personal information is being protected. Moreover, according to Idris et al. (2009), smart payment systems provide methods of payment as well as they can be used for detection of the vehicles that violate parking spaces by taking photos.

2.3.4 Parking Reservation Systems

Parking Reservation Systems allow drivers to get information about parking availability at a given destination, reserve a parking space, and pay for parking upon departure using web-based tools, applications or calls (Shaheen, 2005). Also, with an improved version of the parking reservation system, drivers can be directed to the parking lot which is available. This improved version of the parking reservation system is called e-parking (Shaheen, 2005). Thus, it is possible to minimize time during cruising, and the driver might change destination unless the available parking space exists.

2.4 Highlights of Parking Management for METU Campus

After discussing the scope of smart parking management, parking management strategies, and systems, it is essential to extend it to smart and sustainable mobility management at the campus environment. Therefore, rather than focusing only on driving, other transportation modes are needed to be considered. Therefore, the following chapter includes walking, cycling, public transportation, and ride-sharing policies and programs.

In addition, for effective parking management, it requires an understanding of the environment, too. Thus, understanding of METU campus environment is indispensable. Accordingly, the next chapter also discusses the past studies regarding METU campus built environment, on-campus and off-campus (accessing to campus) transportation, mode choice, perception and behavior of METU commuters.

CHAPTER 3

SMART AND SUSTAINABLE CAMPUS (SSC) MANAGEMENT AT METU

The smartness concept typically used for the city scale. However, the concept of smartness does not include the city completely, yet it refers to many features of a city (Albino et al., 2013). Moreover, the concept of the smartness involves the scales from device to city. The focus of this study is the built environment, within the scope of the concept of the smartness. A built environment comprises structures that are made by people. Thus, the built environment comprises a big scale from buildings to cities. According to McClure and Bartuska (2007), the concept of the built environment is shaped by the needs, actions, and thoughts of people. McClure and Bartuska (2007) defined built environment components as products, interiors, structures, landscapes, cities, regions, and Earth. Kas et al. (2018) had adopted and categorized built environment components as product, interior, structure, neighborhood/campus, and city. At this point, university campuses may be assumed as small scaled cities as campuses have significant similarities with CBDs. Therefore, parking related problems and solutions liken.

3.1 Dimensions of Smart & Sustainable Mobility Concept within Campus

The smart campus concept is more likely to focus on technological improvements in addition to the sustainable campus concept, which takes the social, economic, and environmental improvements into account. Within the smart sustainable campus concept, mobility management takes an important role. Smart and sustainable mobility management involves smart and sustainable campus policies. According to smart and sustainable campus policies, the goal is to reduce automobile dependency and encourage people to use non-motorized transportation modes and public transportation. Also, parking management strategies are being identified in order to reduce automobile use because it causes traffic congestion. The idea behind this goal is to decrease traffic congestion which harms economically, environmentally, and socially.

According to Litman (2006), effective parking management policies and programs can improve user quality of service, create more accessible land use patterns and reduce motor vehicle traffic, reduce congestion, accidents and pollution, create more attractive communities and improve mobility for non-drivers. Parking management cannot be considered by itself as it is a part of a complex system, transportation. Moreover, it is essential to consider automobile use and its interactions with other modes. Thus, in order to create a mobility management strategy; parking management should be considered with policies on other modes rather than personal vehicle use. For instance, effective parking management cannot be considered without well-provided shuttle services and walkable environment. Altıntaşı (2013) gathered these policies under the concept of "Transportation Demand Management" which involves cycling, walking, public transit, ride-sharing, and parking management policies. The main idea of campus mobility management is to decrease automobile dependency and increase accessibility.

Cycling Policies

Universities with campuses are great environments to support cycling, which is an alternative mode of driving. In order to support mobility, environment and economy, it is essential to support cycling on campuses. Garau et al. (2016) suggested that procuring bicycle parking racks and lanes would increase cycling and discourage private vehicle use. For instance, University of Colorado found that providing the bike lanes and enhancing infrastructure resulted in an increase in bike use from 20 percent to 31 percent in one year (From Altıntaşı, 2013). Also, bike-sharing systems are useful for increasing cycling on campus. Garau et al. (2016) believes that every 300 meters putting bike-sharing stations, increases the demand.

According to Altıntaşı (2013), main policies for increasing cycling are as follows;

- Providing bicycle paths, racks, and lockers
- Implementing bike sharing system
- Providing bicycle storage rooms and shower facilities
- Establishing connectivity between various transportation modes
- Providing signs and markings that are recognizable
- Accommodating map of bicycle routes
- Providing bicycle repair and maintenance store

Walking Policies

For a campus, walking can be considered as the main transportation mode because campuses generally have compact infrastructures. It is crucial to provide an environment that is appropriate for walking. Yet, it is a complex process to measure the quality of walkability. Karatas (2018) offered a multi-dimensional evaluation technique addressing measures from four main categories that are traffic, land use, safety/comfort, and infrastructure for evaluation of the pedestrian level of service. Designing compact campuses for universities is better to encourage people to quit from driving and prefer walking or cycling instead. According to Christiansen et al. (2017), odds of driving decrease when the walking distance between the start and destinations of the trip is reduced. Besides, in order to not to increase walking distance, parking lots needed to be close to proximity or supported by shuttle services that provide connectivity. Christiansen et al. (2017) found that increase in the distance between the parking lot and the destination decreases the odds of driving. Moreover, Mohammed and Shakir (2013) stated that if precautions are taken against darkness, drains, and animals, these promote walking and cycling.

Ride-Sharing Programs

Stiglic et al. (2015) denoted that in ride-sharing, individuals with matching itineraries and schedules share a ride in a personal vehicle. The driver and rider(s) typically share the associated costs (e.g. fuel, tolls, parking fees) so that each can benefit from the shared ride. Ride-Sharing is also an alternative for decreasing the number of automobile use on campus. Lam (2012) suggested decreasing parking supply, introducing ride-sharing, putting limits on free parking and encouraging carpools and low-emission vehicles by supplying prioritized parking spaces. Carpooling is one of the ride-sharing policies. A good example can be given from University at Buffalo. Three drivers can get a carpool sticker by giving up their regular stickers. The idea behind ride-sharing is that preventing people from drive alone. Besides, carpooling sticker owners can park their vehicles to the nearest parking space that is reserved for them. Accordingly, Arizona State University has car-sharing programs that allowed its members to rent a low emission, fuel-efficient vehicle for an hourly fee, and this implementation resulted in 28.6 tons of carbon emission reduction in a year. (From Altıntaşı, 2013)

Public Transit Policies

In order to accomplish a smart parking management at a campus, it is important to pay attention to public transportation. In other words, both shuttle services and public transportation services are needed to be well provided for a campus. Bond and Steiner (2006) declared that abundant parking supply discourages people from the use of public transportation. In order to encourage drivers to quit driving and to use public transportation, parking supplies are needed to be limited. According to Christiansen et al. (2017), the greater outcome is possible with a combination of parking restrictions and qualified public transportation services. In addition, Christiansen et al. (2017) claimed that high quality of public transportation affects driver’s mode choice decisions and makes them quit from driving and select public transportation instead. On the other hand, Liu et al. (2017) stated that poor public transportation services encourage drive alone. For instance, Mohammed and Shakir

(2013) discovered that in case of 70% reduction on travel time by public transportation that leads to 84% decrease in the decision to travel by personal vehicle instead of using public transportation services. However, the reduction in the travel time is not the only parameter that encourages people to select public transportation. Moreover, with respect to Mohammed and Shakir (2013), factors like travel cost, fee of remote parking lot, waiting time in bus stations also increase the use of public transportation services.

3.2 Smart and Sustainable Campus Projects/Activities at METU

For better understanding of METU campus transportation, it is useful to benefit from past studies regarding campus transportation and built environment. Therefore, past studies about METU campus transportation and built environment were investigated. In this section, the previous transportation-related studies at METU campus were briefly summarized to understand travel behavior but also to understand infrastructure of the METU campus.

3.2.1 Assessment of Scenarios for Sustainable Transportation at METU Campus (2013)

A thesis titled as Assessment of Scenarios for Sustainable Transportation at METU Campus (Altıntaşı, 2013) analyzed the levels of mobility and vehicle emissions at METU Campus in detail. In the scope of the study; i) campus origin-destination matrix, ii) in-campus vehicle-km-travelled (vehicle-km), and iii) carbon emissions were studied. Besides, the study involves scenarios between mobility management strategies and reduction on personal vehicle use. Thus, travel data that involves the occupancy rates of parking lots, were also obtained. Findings of the study of Altıntaşı (2013) indicated that discouraging students to use personal vehicles, is the first and simplest step to encourage sustainable campus transportation. Within the scope of this thesis understanding of gate activities and stay time of the vehicles are crucial since these paremeters are directly related in parking lot demand.

<u>**Gate Activity Profiles**</u>

Entry and exit activities on campus could be examined by using varying methods. In this study, gate RFID (Radio Frequency Identification) data and video recording data was used for examination of the university community's travel behavior, and findings were presented in Table 3.1. First of all, the METU campus entry and exit profiles were analyzed by using weekly RFID info from all 3 gates (A1, A4, and A7), and calculating the sum of entries and exits.

Table 3.1 indicated the results of video recording revealed almost equal numbers of entrances and exits at the campus gates, while RFID traffic counts showed significantly fewer exits. Because there were missing data on RFID counts, video recording data was assumed to be more accurate . It was concluded that approximately 15000 vehicles enter to METU campus daily.

Table 3.1 Sticker types and distributions in RFID and video recording data (Altıntaşı, 2013)

	Nov 10, 2010	May 4, 2011	Nov 23, 2011	Oct 19, 2011
	Daily Total Activities (gate RFID data)			(Gate video recordings)
Entry	9522	10065	12191	15280
Exit	6034	6588	7117	14828
Entry Activity by Sticker Type				
Academic Personnel	1585	2466	2845	---
Administrative Personnel	954	992	998	
Students	2087	2661	3041	
Taxi	624	638	783	1147
Dolmuş	---	202	327	357
Bus	---	---	---	211
Exit Activity by Sticker Type				
Academic Personnel	1514	1594	1803	---
Administrative Personnel	549	563	600	
Students	1161	1474	1587	
Taxi	343	371	440	1000
Dolmus	---	68	112	330
Bus	---	---	---	200

*Total, entry and exit values belong to 3 main campus gates information.

Figure 3.1-a presents the total daily entry profiles of METU campus; while there was limited demand for entering to the campus from midnight to 6:00 a.m., majority of the demand (3000 vehicles) was observed in between 7:00 a.m. to 9:00 a.m. Then, the number of entries decreased until noon. During the afternoon, the entry to the campus remained at about a constant level. After 6:00 p.m., it started to decrease dramatically.

Figure 3.1-b indicates the total daily exit profile of METU campus. Likewise, there was few exits occurred from midnight to 07:00 a.m. Then, the number of exits (1500 vehicles) increased around 8:00 a.m. to 9 a.m. The second peak was observed at noon to 1:00 p.m. with 1200 vehicles. The highest number of exists was observed the timeline between 5:00 p.m. to 6:00 p.m.

Eventually, in Figure 3.1-c, the overall daily activities which are the number of all entries and exists was presented. The majority of the trips was observed between 7:00 a.m. to 10:00 p.m. The peak timeline was between 08:00 a.m. to 9:00 a.m. Then, the number of the trips decreased, though it made a relatively small peak between 11:00 a.m. to 2:00 p.m. With the increased demand for existing from the campus, the number of trips increases after 3:00 p.m. The peak hour in the evening was observed from 5:00 p.m. to 6:00 p.m. As a result, in-campus morning peak hour was selected as 08:15 - 09:15 and evening peak hour was selected as 17:15-18:15.

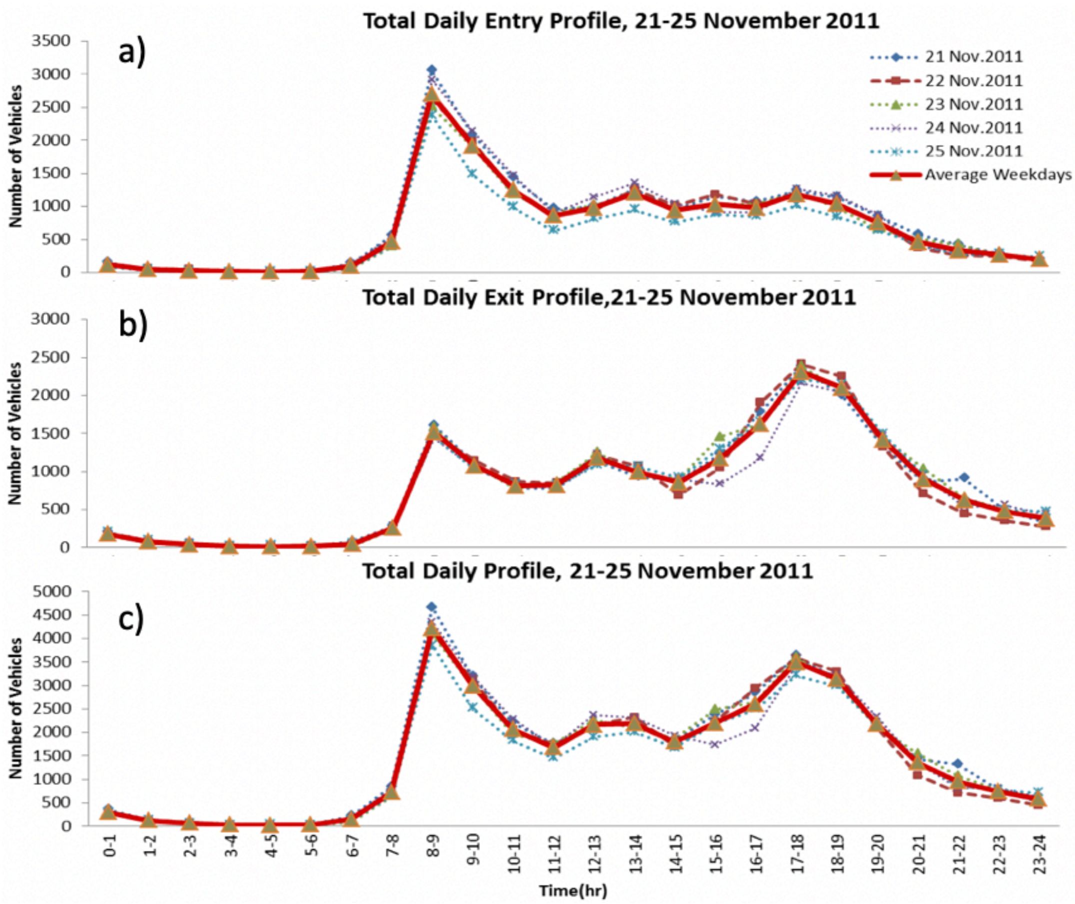


Figure 3.1 Total daily profile of METU campus including all entry-exit from three main gates (**(a)** entries, **(b)** exits, **(c)** entries-exits) (Altıntaşı, 2013)

<u>Gate-to-gate Mobility by Stay Time</u>

Although understanding the mobility of gate-to-gate activities is important, understanding of for how long the vehicles stay on campus is important, too. The calculation of stay time was done by matching entries and exists and taking the difference between the number of exists and entries. It was found that almost 45% of the vehicles stayed at the campus less than fifteen minutes which meant that people generally entered the campus for drop off and pick up (see Table 3.2). Moreover, 15% of the vehicles stayed at the campus for 15 minutes to 1 hour. In addition, the results indicated that approximately 22% of the drivers stayed at the campus from 1 hour to 5 hours which was approximately half workday time. Besides, approximately 13 % of the vehicles stayed in between 5 hours to 10 hours. Finally, the minority of the vehicles (almost 3%) stayed more than 10 hours.

Table 3.2 Campus stay time distribution (gate data only) (Altıntaşı, 2013)

	Number of Trips					
Campus Stay Time	**Nov 10, 2010**		**May 4, 2011**		**Nov 23, 2011***	
Total estimated trips	**8814**		**9223**		**10050**	
Total detected trips Stay Time	**5680**		**5997**		**6505**	
<15min	***2599***		***2635***		***2804***	
15-30min	*445*		*497*		*545*	
30min-1h	*420*		*452*		*489*	
1h-5h	***1301***		***1346***		***1465***	
5h-10h	***754***		***867***		***1029***	
10h +	*161*		*200*		*173*	
Trips with missing movements	**Entry**	**Exit**	**Entry**	**Exit**	**Entry**	**Exit**
	669	2465	643	2583	772	2773
	3134		**3226**		**3545**	

Moreover, the period of entries and stay time were also compared at the study. The results indicated that almost 30% of the vehicle entered to METU campus from 8:00 a.m. to 10:00 a.m. Moreover, all of the entries approximately 46% of them stayed no longer than 15 minutes. In addition, stays that was shorter than 15 minutes was 27% between 11:00 a.m. to noon and it was 30% from 2 p.m. to 3 p.m. The ratio of staying no longer than 15 minutes in the evening peak was 56%.

In addition, it was found that there was no correlation between staying up to 5 hours and entry time. 14% of the drivers who entered to campus from 8:00 a.m. to 10:00 a.m., stayed approximately 5 hours. Furthermore, as it was expected majority of the long stayers entered to the campus in the morning. It was found that almost 25% of the drivers who entered to campus between 8:00 a.m. to 10:00 a.m. stayed 5 hours to 10 hours, on the other hand just 5% to 7% of them had stayed more than 10 hours.

Average Daily Traffic Assignment

In the scope of the study, the number of vehicles which pass from certain road per day was estimated. For this thesis, the estimation is important in order to compare high occupied parking lots and roads. It is predicted that at some roads presence of traffic congestion is inevitable because of high parking demand on some parking lots which locate at the end of these roads.

The roads which attract more than 1500 vehicles per day were indicated at Figure 3.2. Findings of the study indicate that majority of the trips on the campus are actualized at roads that locate between main gates (A1, A4 and A7). Therefore, on corridors from A1-A4 gates and A1 gate to Technopolis, much of the traffic was observed. In addition, traffic congestion was observed less at Southern areas of the campus comparing to Northern areas.

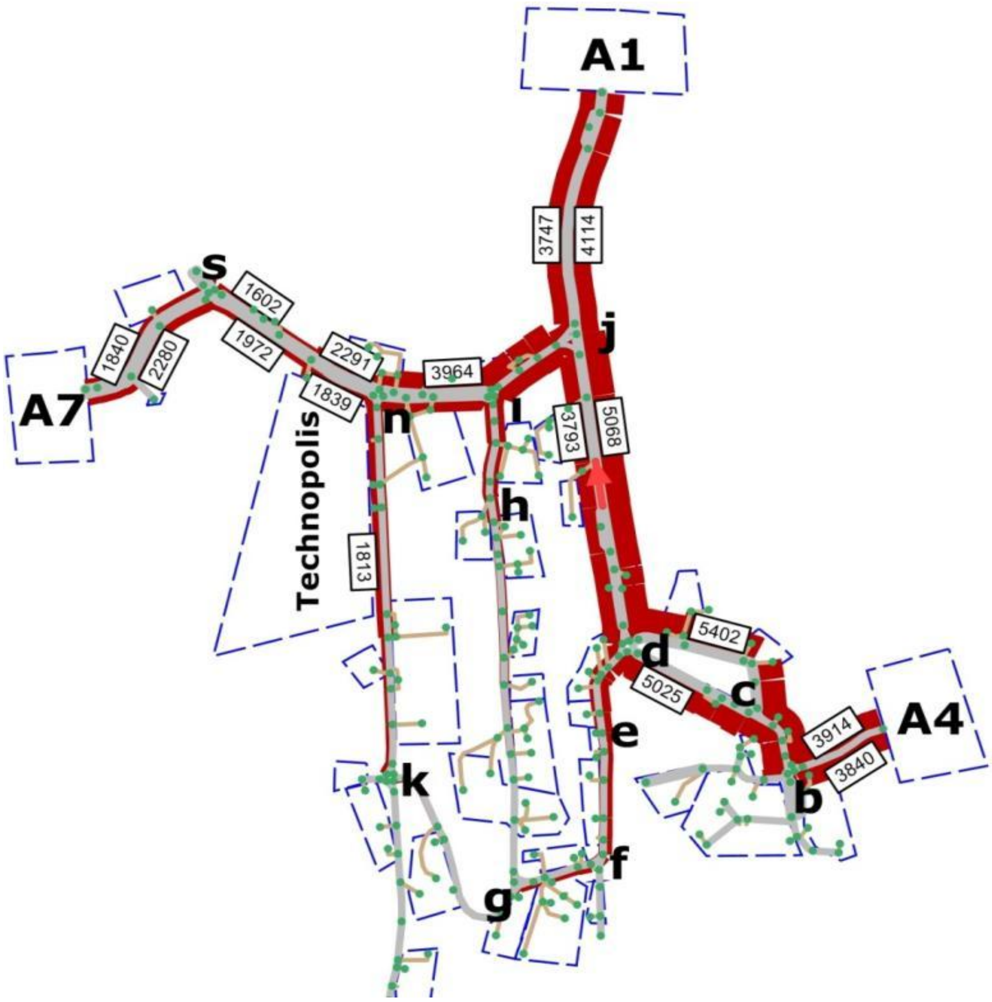


Figure 3.2 Daily campus traffic assignment result between 07:00-22:00 (Altıntaşı, 2013)

3.2.2 Determination of Pedestrian Level of Service for Walkways: METU Campus Example (2015) and Variability in Sidewalk Pedestrian Level of Service Measures and Rating (Karatas, 2018)

Study of Determination of Pedestrian Level of Service for Walkways: METU Campus Example involved pedestrian activity countings. The study was essential to determine the undesirable areas for parking that are with high pedestrian mobility. Therefore, the pedestrian volume counting study was important.

Figure 3.3 indicated that in the mornings and evenings, there was a lot of movement of pedestrians between the gates to the academic buildings. While more walking activity originated from the dormitories in the mornings, more activity was observed in the evenings around recreational areas.

Moreover, the study of Karatas and Tuydes (Variability in Sidewalk Pedestrian Level of Service Measures and Rating, 2018) evaluated the walkability at METU campus by utilizing three different methods. The purpose of the study was to understand the effectiveness of these three methods. According to Karatas (2018) a numerical example from the pedestrian level of service measures of 81 walkways indicated that all of the methods are beneficial, yet none of them reflected the whole aspects of walkability alone. Moreover, it was concluded that a description of the Pedestrian Level of Service which includes aspects of assessment regarding all factors effecting walkability (distance, time, comfort, health, etc.) as well as the trip purpose and infrastructure characteristics, would go beyond the current perspective. According to Karatas and Tuydes (2018), a successful walkability evaluation needs a multidimensional assessment process that involves four key categories that are traffic, land use, comfort/safety, and infrastructure.

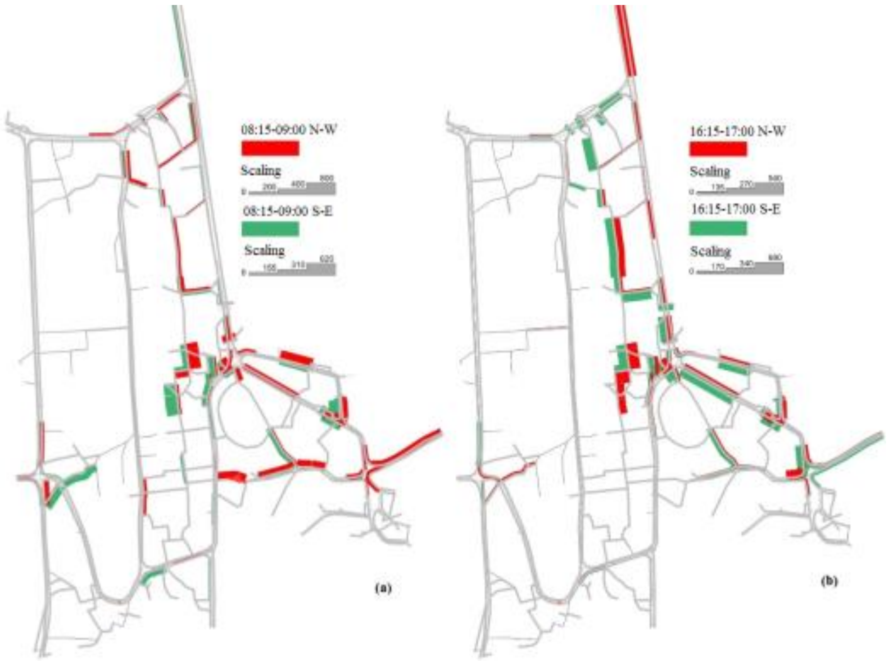


Figure 3.3 Mapping of Volumes and Directions of Pedestrian Flows for **a)** Morning (08:15- 09:00) and **b)** Evening (16:15-17:00) Hours (Karatas, 2018)

3.2.3 Perception of Parking Pricing and Willingness to Pay (2018)

The study of Perception of Parking Pricing and Willingness to Pay (Ipekyuz et al., 2018) consists of interviews regarding parking pricing strategy and willingness to pay for parking of METU commuters. A semi-structured interview study with 14 respondents was conducted for the purpose of understanding parking perception and willingness to pay for parking. Thus, the interview included questions to measure behaviors and attitudes of the respondents towards parking pricing, WTP for parking, reasons for parking-related problems, suggestions to cope with the problems, price recommendations for parking, and parking preferences at high-demanded locations at the campus (see Table 3.3).

Table 3.3 Scope of the Interview (Ipekyuz et al., 2018)

Part 1	Socio-Demographics (age, gender, income, etc.)
Part 2	Parking Pricing and WTP for METU Campus
	• Conditions to drive to Campus; Factors affecting private car preference • Parking problem experience • Preferred parking location (department parking lot, central parking lot, satellite parking lot, etc.) • Willingness to Pay (amounts and factors affecting WTP) • Recommendations for the parking problem
*Ethical permission for the interview was received from Ethical Committee of Department of Psychology in METU.	

Also, socio-demographic information was provided (see Table 3.4). The reason why obtaining socio-demographic information of the respondents is to understand the perception of the groups. For instance, the effect of the age, income level, towards willingness to pay, are analyzed. Volunteer automobile users including academics, students, staffs, and visitors who were METU commuters were selected randomly for the interview.

Table 3.4 Interview Respondent Profile (Ipekyuz et al., 2018)

	R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R 10*	*R 11*	*R 12*	*R 13*	*R 14*
Gender[a]	M	M	F	M	F	F	M	F	F	M	M	M	M	M
Age	23	29	22	29	26	34	33	28	27	24	22	22	28	22
Status[b]	U	A	U	E/G	G	A	O/G	E/G	G	U	U	U	E/G	U
Income[c]	II	IV	I	IV	V	IV	V	IV	V	V	I	I	IV	I

[a] Gender: Female (F), Male (M).
[b] Educational Status: Undergraduate (U), Graduated (G), Academic personnel (A), Employed (E), Other (O).
[c] Income levels as I: < (1000TL); II: (1000-2000TL); III: (2000-3500TL); IV (3500-5000TL); V: > (5000TL).

In order to provide objectiveness, the interviews were made face to face by three trained interviewers. The purpose of the research had been explained to the respondents at the beginning of the interviews. The respondents had been informed that any responses and identities would be kept confidential. Moreover, this study was started after getting ethical permission from Ethical Committee of the

Department of Psychology in METU. After all, the interviews were deciphered verbatim and analyzed to obtain the main factors affecting parking preferences, pricing and WTP for parking. Interviews took no longer than 30 minutes and were voice recorded. Verbatim deciphering enabled the determination of basic concepts and keywords regarding parking preferences, pricing, and WTP. Responses were saved anecdotally to fortify perspectives clearly.

Responses to the WTP interview considering METU campus parking policy indicate that most of the respondents consider that it is unacceptable and not ethical on campus to implement a parking pricing strategy. On the other hand, respondents denoted that they refrain from private car use due to the parking problem especially when the destination is around demanded areas like food courts, library, cafeteria. The respondents denied pricing strategy, although the campus is struggling with serious parking problems. Moreover, the respondents thought that the stickers for entering to campus also give the right of the parking. In other words, the respondents expect that the sticker requires to guarantee parking space at the same time. Besides, the respondents claimed that there is no investment or improvements on existing parking lots. The keywords, which are deduced from the statements of respondents for pricing and WTP on campus are provided (see Table 3.5).

Table 3.5. Perception of Drivers About Parking at METU Campus (Ipekyuz et al., 2018)

Parking Behaviors in METU
• Sticker-based parking • Limited capacity • Increasing demand • Old campus design • Limited on campus transportation services
WTP for parking* in METU
• Sticker price • At high demanded areas to provide turnover • Unacceptable in a campus • Limited Campus transportation (shuttle services)

Moreover, there is no applied parking pricing strategy at the METU campus. However, if it was, the pricing strategy that is recommended by the respondents requires to be on the high demanded areas (i.e. food court, cafeteria etc.).

In summary, they were asked for a pricing scheme for parking. The pricing scheme offered by the respondents for WTP and pricing at METU is provided (see Table 3.6).

Table 3.6 Recommended pricing scheme and prices (in TL) at METU (Ipekyuz et al., 2018)

WTP and Pricing	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*	*R11*	*R12*	*R13*	*R14*
<15m	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*x*	*x*	*f*	*f*
15m-30m	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*x*	*x*	*f*	*f*
30m-60m	*f*	*f*	*f*	*f*	*f*	1-2	*f*	1	*f*	*f*	*x*	*x*	---	*f*
1h-2h	*f*	*f*	*f*	*h*	5	3	1-2	1/h	*h*	---	*x*	*x*	---	5
3h-4h	1-2/h	*f*	---	*h*	10	4-6	5	1/h	*h*	---	*x*	*x*	---	7
>4h	1-2/h	---	---	*h*	15	10	6	1/h	*h*	---	*x*	*x*	---	10
"f" stands for free, while "x" stands for exactly against pricing in a campus. "h" represents people who prefer hourly pricing, while "/h" stands for "per hour". "m" stands for "minute".														

The importance of the WTP interview is that it provided background for creating Smart Campus Transportation Survey. According to interviews, the following statements were drawn:

- Related to income level, at METU campus students are opposed to paid parking more comparing to academics.
- Some of the academics suggest that places that are highly demanded should be controlled frequently to prevent parking violations.
- It is suggested that the initial price should be relatively high and the rate should be lowered according to elongation of the parking duration.

- A few of the respondents suggested that parking pricing should be set by considering the economic condition of users.
- Pricing for the parking spaces would be a solution to traffic congestion.
- Results indicated that relatively higher-income respondents were more willing to pay for parking both on-campus and off-campus.
- Some of the students complained that inefficient public transport or shuttle services force them to use private car.

3.2.4 USTDA (United States Trade and Development Agency) Project (2017)

USTDA METU Smart Campus Project (2017) was a collaboration study between of METU, WILLDAN, and EPRA. The project consisted of five main categories that are energy/ICT, transportation, water, buildings, and finance. METU campus was evaluated under these categories. Then, the potential strategies and ICT technologies were offered taking infrastructure and budget constraints into account. The transportation part of the study is going to be discussed further in the following chapters of this thesis, as the author and advisors were part of this research group. Within the project, a survey was conducted under the transportation section.

3.2.5 Integration of Dolmuş as a Paratransit Mode to The Existing Public Transport Network: Ankara Example (2016)

The study of Özbilen (Integration of Dolmuş as a Paratransit Mode to The Existing Public Transport Network: Ankara Example, 2016) is focused on minibus (Dolmuş) use that is a type of public transportation service. For better understanding the user's point of view and to evaluate the user satisfaction, a survey that involves questions regarding mode choice and dolmuş use, was conducted to METU commuters, which was called as METU Campus and Transportation Survey.

From November 2014 to May 2015, 623 students responded to the survey, which evaluated the sustainability and sustainable transportation (experience and perception) at the campus, accessibility to campus, on-campus accessibility, and campus traffic safety. While the total student number of METU is 28,000, the number of survey participants is 623 students, making the participants/total students ratio about 2.5%, which is a considerable amount.

Then, the survey results were analyzed in order to understand the use of dolmuş and its role in campus accessibility. Moreover, a comparison between dolmuş and other modes was done. Furthermore, analyze of the survey results was examined to integrate dolmuş into the rest of the public transportation services network by taking both road and fare integration into account. The aim of this study was to investigate the perception of users regarding dolmuş and to propose possible scenarios for the future of dolmuş in the transportation network.

Within the scope of the study mode choices of the students in the purpose of accessing to the campus was understood and analyses of modes were done. It was found that the use of dolmuş is quite common. Yet, the mode choice of the students was asked with the origin of their trip So, the study consists of both on-campus mode and off-campus mode choices. Besides, questions were also asked to students (234 students) who lived at the dorms, too. It was found that the use of private vehicles comes as second choice which is much lower than dolmuş which is only 17.7% in total (See Table 3.7).

Table 3.7 First Mode Preferred from the Trip Origin of the Participants (N= 622) (Özbilen, 2016)

Transportation Mode	Frequency	Valid (%)
Dolmuş (Minibus - Jitney)	**259**	**41.6**
Private Car	110	17.7
Private Bus	63	10.1
Metro (Kızılay – Çayyolu Line)	44	7.1
Municipality (EGO) Bus	41	6.6
Walking + Bicycle	40	6.5
Metro (Bilkent – Sincan Line)	23	3.7
Hitchhiking	29	4.7
Private Services	4	0.6
Others (Taxi – Motorcycle - Cablecar)	9	1.5
Total	**622**	**100**

From the public vehicle users of 622 participants, 176 of them use single vehicle, 50 of them use two transfers, 4 of them use three transfers (see Table 3.8). Comparing the modes as first transfer, the use of Dolmuş and Metro come into prominence. Moreover, the rate of hitchhiking is high because it is a common behavior among commuters at METU campus environment. As the second transfer, it was found that the dominant transport choice is hitchhiking. Finally , walking is the dominant mode for the third transfer.

As considering the dominant modes from different neighborhoods of Ankara to METU campus. Distances to METU campus and travel time of modes were analyzed. For access to the campus entrance, 44 different travel choices were identified. Those travel choices were categorized into zones. In total 20 different zones were identified (Actually it was 21 zones one of them was determined as an outlier). These zones were decided according to neighborhoods and modes. Then, these zones were enumerated by their distances to the METU campus (See Table 3.9).

Table 3.8 Transfers from the Firstly Preferred Mode (Özbilen, 2016)

Mode	Frequency (1st Transfer)	Valid (%)	Frequency (2nd Transfer)	Valid (%)	Frequency (3rd Transfer)	Valid (%)
Municipality (EGO) Bus	3	1.7	0	0	0	0
Private Bus	4	2.3	0	0	0	0
Metro	15	8.5	0	0	0	0
Metro (Kızılay – Çayyolu Line)	51	29.0	7	14.0	0	0
Dolmuş (Minibus - Jitney)	**54**	**10.7**	**6**	**12.0**	**1**	**25.0**
Private Services	3	1.7	4	8.0	0	0
Private Car	1	0.6	0	0	0	0
Walking	12	6.8	9	18.0	2	50.0
Hitchhiking	32	18.2	24	48.0	1	25.0
Taxi	1	0.6	0	0	0	0
Total	**176**	100	**50**	100	**4**	100

Moreover, while some zones are quite far from the campus, some zones are very close to the campus (almost within walking distance). Therefore, grouping close neighborhoods in the same Zone was assumed to be better. Overall, 20 different zones were determined as given in Figure 3.4. Moreover, these 44 travel pattern variations were separated into eight different combinations of modes. Those combinations are as following: "bus", "dolmuş" and "metro" seperately, "bus+bus", "dolmuş+dolmuş", "metro+metro", "bus+metro", dolmuş+metro".

For this thesis, the analysis of mode choice variations and duration of the trips was essential to encourage people to quit from driving and alternative modes could be evaluated. Therefore, mode choice of the respondents according to start point (neighborhoods) while coming to campus was evaluated. Those neighborhoods were indicated in the see Figure 3.5.

Table 3.9 Zone Names and Distances of These Zones from METU Campus (Özbilen, 2016)

#	Zone Name (Distance)	#2	Zone Name (Distance)3
1	Yuzuncuyil, Cigdem, Isci Bloklari (1 km)	11	Cayyolu, Umitkoy (12 km)
2	Sogutozu, Cukurambar (2 km)	12	Mamak (14 km)
3	Balgat, Ovecler, Cevizlidere (4 km)	13	Altindag (15 km)
4	Bahcelievler, Emek (5 km)	14	Yasamkent, Baglica (15 km)
5	Cankaya, Ayranci (6 km)	15	Kecioren, Etlik (16 km)
6	Kizilay, Kolej, Tandogan (8 km)	16	Oran, Yildiz, Birlik, Tinaztepe (16 km)
7	GOP, Seyranbaglari, Esat (9 km)	17	Batikent, Eryaman (17 km)
8	Dikmen, Keklik (10 km)	18	Golbasi (18 km)
9	Yenimahalle, Demetevler (11 km)	19	Etimesgut, Sincan (22 km)
10	Kurtulus, Dikimevi, Cebeci (12 km)	20	Pursaklar, Fatih (26 km)

In general travel time is less on single modes. Yet, all of the modes are not available for all origins. Moreover, it was found that people chose to travel with single mode, up to 8 kilometers. Bus and metro travel time is less compared to dolmuş, when those services are available. But for Ayrancı (6 km) zone, direct transportation by bus or metro is impossible. Therefore, it is not surprising that there are significant differences in the time of travel between patterns in some zones.

It is essential to mention Kızılay, Kolej, and Tandoğan (8 km) zone because this zone is part of the main transportation network of Ankara. Especially, Kızılay can be considered as Central Business District (CBD) of Ankara and there are various mode options. If the destination was accepted as any entrance of METU campus, it changes the mode according to the lowest travel time.. In this case, metro has the lowest travel time which is from Kızılay, Kolej, and Tandoğan Zone. On the other hand, dolmuş has the lowest travel time if the inside access to the campus is considered.

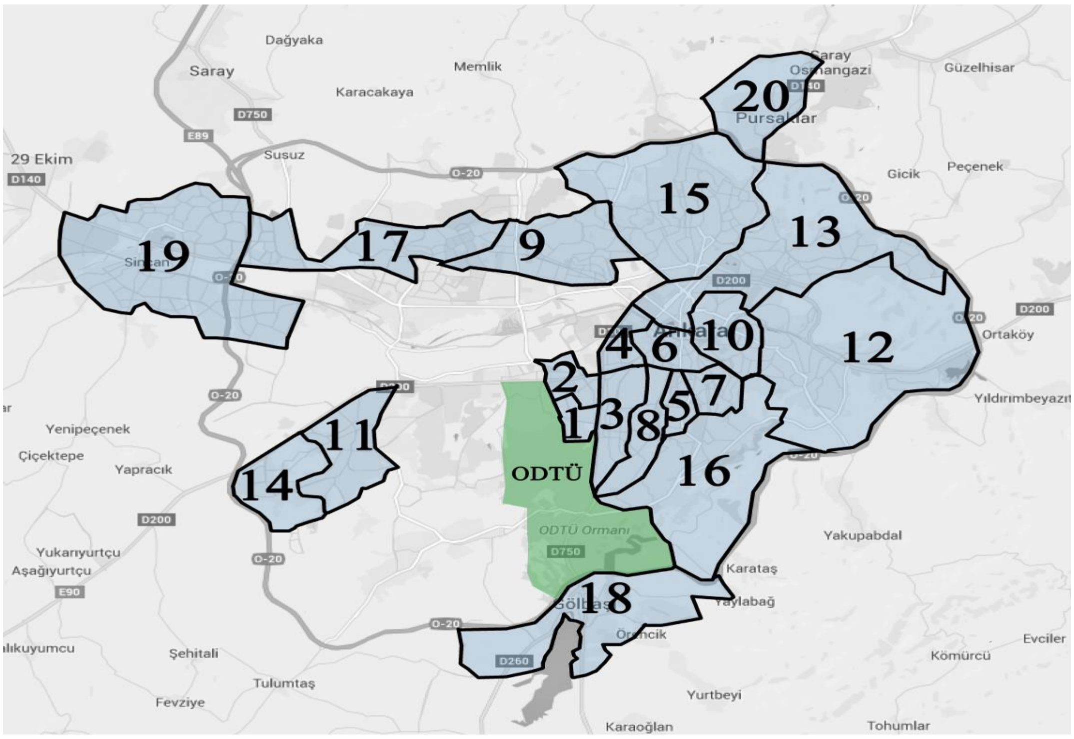


Figure 3.4 Zone Locations in the City with Respect to METU Campus (Özbilen, 2016)

It was found that after 8 kilometers combinations with dolmuş have the lowest travel time but in three Zones (Kurtulus, Dikimevi, Cebeci (12 km), Mamak (14 km) and Yasamkent, Baglica (15 km)) metro has the lowest travel time. In addition, Yenimahalle, Demetevler (11 km), Batikent, Eryaman (17 km), are the zones with good metro connectivity (see Figure 3.5).

It is obvious that the availability of transportation services is important. Metro works radially from the city center (Kızılay). On the other hand, dolmuş doesn't work radially. Moreover, there are dolmuş networks between zones, therefore, from some Zones, dolmuş services are more convenient.

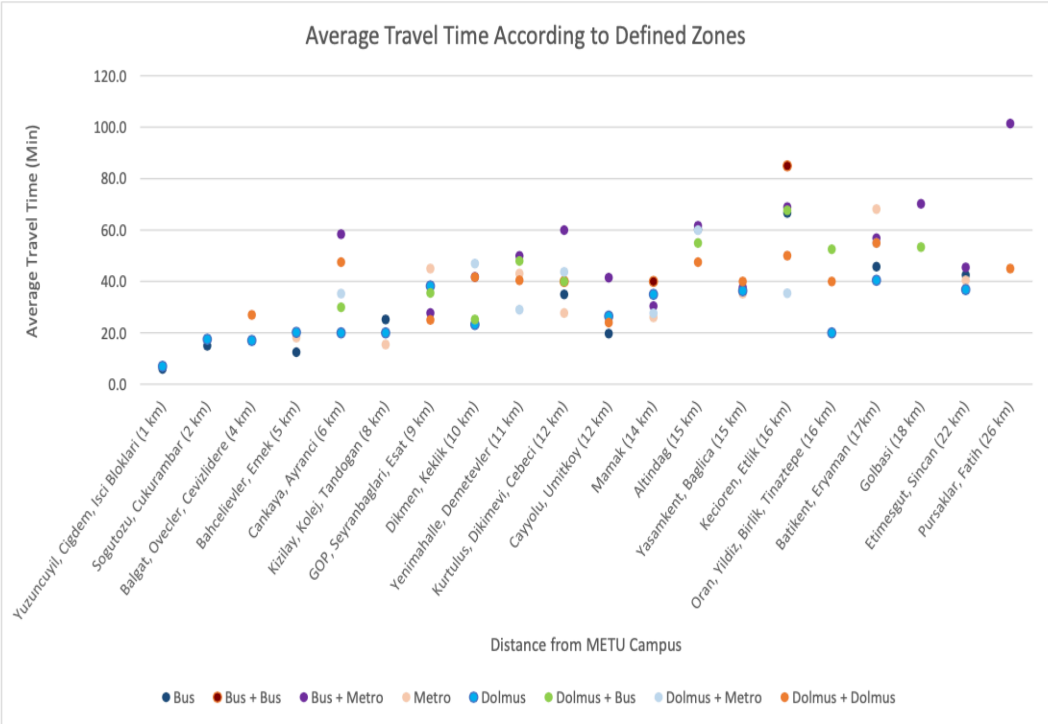


Figure 3.5 Average Travel Time According to Defined Zones (Özbilen, 2016)

3.2.6 Evaluating Public Transportation Alternatives in the METU Campus with the Aid of GIS (Gulluoglu, 2005)

The goal of this study was to create a new mode of public transport and a route in METU campus with the support of GIS by considering metro route stations. It was also intended to demonstrate that GIS can be a beneficial method for building a transport planning database, exploring and evaluating planning data. In the scope of the study land use, topography, population demographics, and transport system of the campus were analyzed. Also, the demand for travel and pedestrian volumes were evaluated. Thereafter, eight alternate public transport routes were proposed with stops or stations for three different modes, such as: guided light transit, modern trolleybus, and monorail.

Distribution of the campus population had been defined as building oriented for the 67 zones by standardizing the population of the buildings within those zones. The spatial illustration of the campus population, composed of both students and staff, was provided in Figure 3.6. Population distribution was done for 38,322 people that consist of people living in dorms, guesthouses, residential areas, students and staffs.

Population density of the zones can be used as a supplementary indicator together with the population of the zones in order to determine the zones with higher priority in public transport service planning. Especially, zones having populations and population density values higher than the average were considered as transport zones generating higher trip demands. The spatial distribution of these zones affects the locations of the public transit stops and the proposed routes of different modes. These zones which generate high trip demand were listed in Figure 3.7. By the way, it is expected that buildings with high populations would generate more demand for driving too.

For this thesis identification of population density of the zones is necessary to understand the trip generations of the buildings. Thus, the zones with higher priority can be understood. According to Gulluoglu (2005), the zones with higher populations and population density values can be considered as transport zones that generate more trip demands.

According to Gulluoglu (2005), the zones with highest trip demand are as following: METU Foundation School (zone 0) on the northwest; Faculty of Education on the north and northwest (zones 4 and 3); Department of Basic English on the north (zone 5); METU Technopolis on the west and northwest (zone 6); Faculties of Economic & Administrative Sciences and Architecture (zones 12 and 27); central zones 28, 34 and 35, respectively identical with Faculty of Social Sciences, Departments of Chemistry and Electric & Electronic Engineering; Department of Civil Engineering on south (zone 36) and southwestern and southeastern dormitories (respectively zones 20 and 43, 44, 45).

In this way, Gulluoglu (2005) proposed public transport service routing according to population and population density of the buildings. Zones to be considered with first and second-degree significance for public transport service routing was listed as;

METU Foundation School (zone 0); Department of Basic English (prep. school zone 5); METU Technopolis (zone 6); Faculties of Economic & Administrative Sciences, Architecture and Social Sciences (respectively zones 12, 27 and 28); Departments of Chemistry, Electric & Electronic Engineering and Civil Engineering (respectively zones 34, 35 and 36); finally dormitories and student guesthouses, zone 20 on the southwest and zones 43, 45 on the southeast.

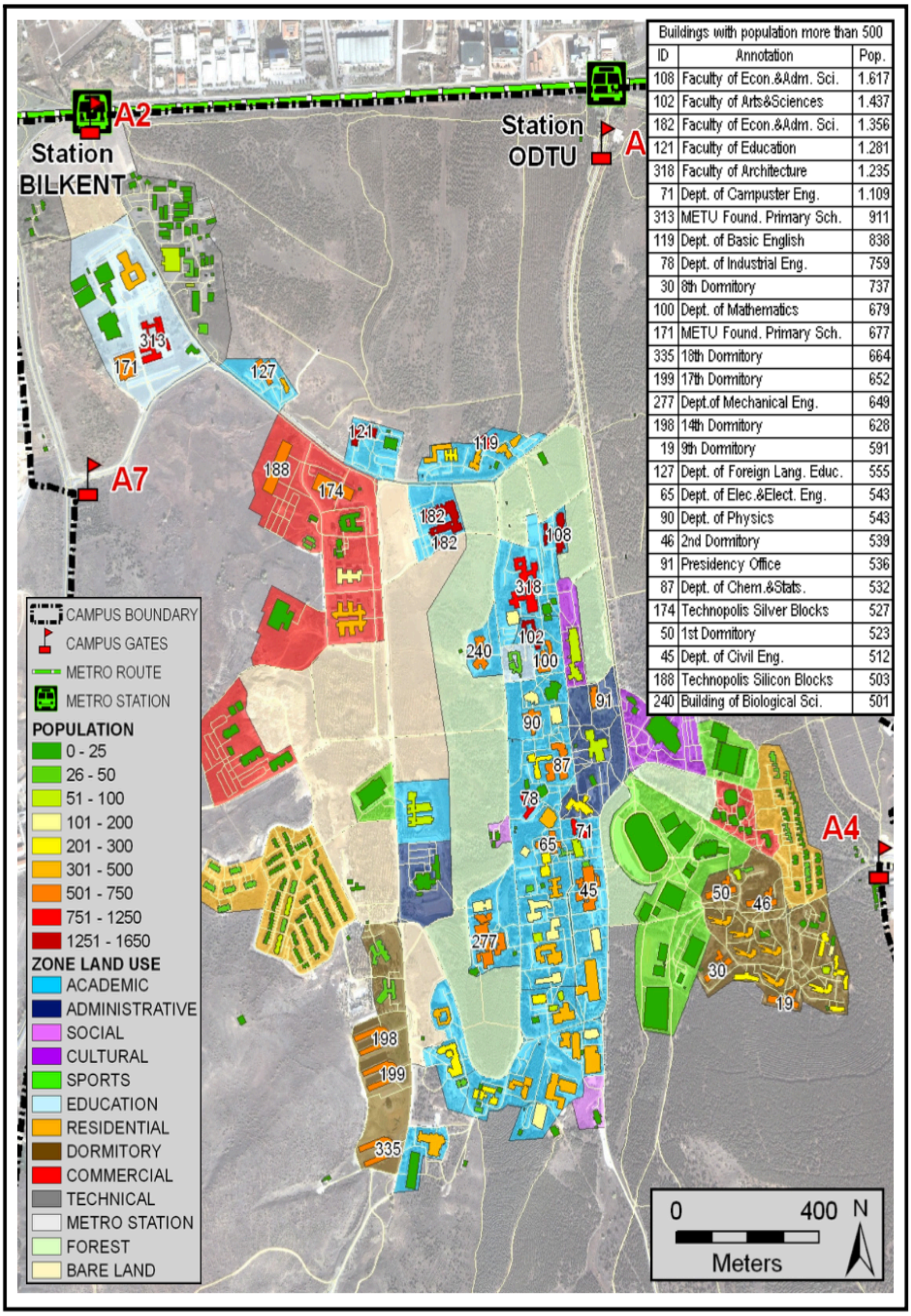
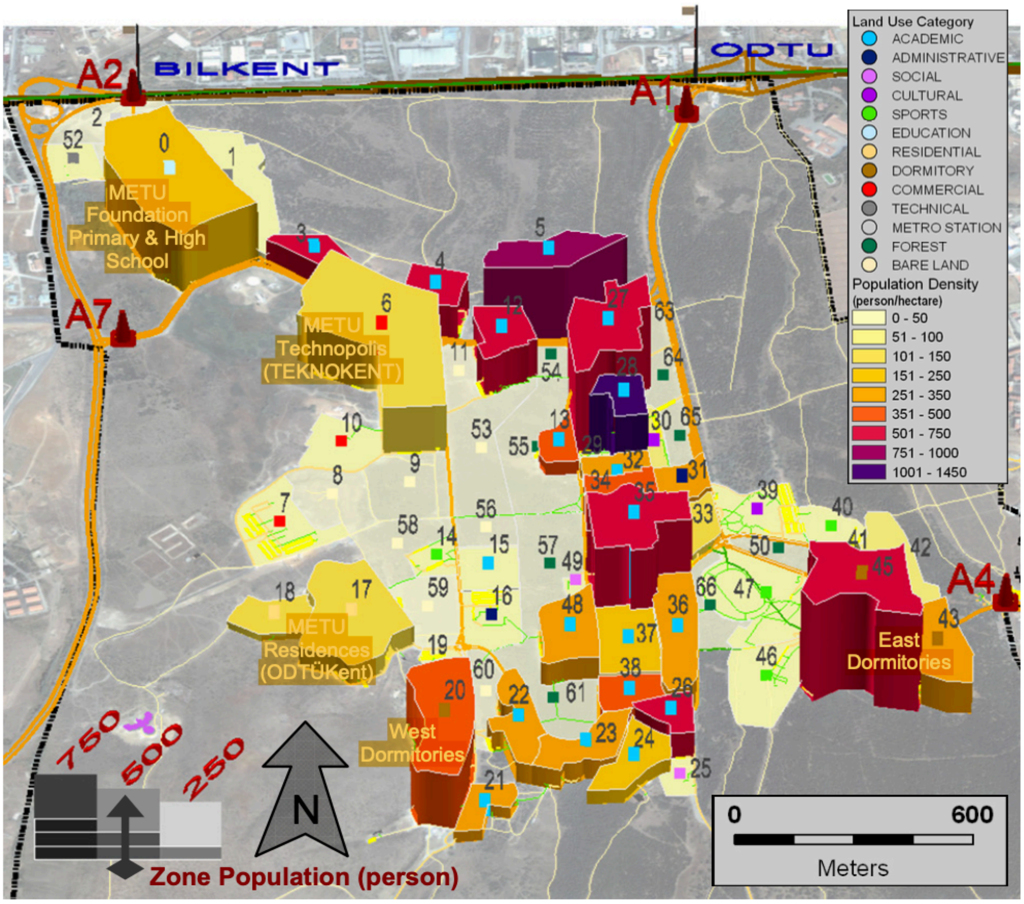


Figure 3.6 Distribution of the campus population according to the campus buildings (Gulluoğlu, 2005)



Zones with Population>650 persons (~avg.) & Pop. Density>200 per./hect. (~avg.)			
ID	**Annotation**	**ID**	**Annotation**
0	METU Foundation Primary&High Sch.	**32**	Dept. of Physics and Dept. of Biology
3	Faculty of Education (Build. 2)	**34**	Dept. of Chem. & Stats. and Ind. Eng.
4	Faculty of Education (Build. 1)	**35**	Dept. of Elec.&Elect. and Comp. Eng.
5	Department of Basic English	**36**	Dept. of Civil Eng.
12	Faculty of Econ.&Admin. Sci. (New)	**37**	Dept. of Mech. Eng. and Metal. Eng.
20	West Dormitories Zone	**38**	Dept. of Chemistry Eng.
22	Department of Food Enginnering	**43**	East Dorm. Zone Std. Guesthouses
23	Dept. of Mining Eng. and Geo. Eng.	**44**	East Dorm. Zone and Medical Serv.
26	Dept. of Envi. Eng & Civil Eng. (K4-K5)	**45**	East Dormitories Zone
27	Faculty of Arch. and Econ.&Adm.Sci.	**48**	Dept. of Mechanical Engineering
28	Social Sci. Building & Dept of Math.		Totally 21 analysis zones.

Figure 3.7 Zonal distribution of the overall campus population overlaid with the zones' population densities (Gulluoğlu,2005)

3.2.7 Smart Built-Environment Transformation Project: METU Campus Pilot Study

Aim of the project is that evaluating the smart built environment, smart mobility, smart buildings both integrated and individually. Moreover, the goal is to define necessities, parameters, and required data in order to alter a built environment into a smart built environment. For this purpose, METU research center was selected as a case study. Accordingly, the study involved evaluation of the research center by defining parameters of the smart built environment. Thus, the smart parking management necessities of METU campus were evaluated to provide users budget-wise and time-wise service. Moreover, instead of providing parking space to certain community, a smart parking lot requires serving as many people as possible. Furthermore, and most importantly, a smart parking lot requires to serve in order to decrease traffic congestion and energy wasting (Litman, 2006).

3.2.8 Categorization of Smartness in Smart Built Environments (Kas et al., 2018)

The study of Categorization of Smartness in Smart Built Environments made an initial attempt to systematically review of the literature in order to determine the scope and dimensions of the Smart Built Environment. It was found that most of the studies regarding smart built environment are around 2000s. It was revealed that most of the studies are based on conceptually definition of smart built environment or perform of case studies in order find most useful application during operational phase. It was understood that the scope of smart built environment varies from product to city scale. Moreover, most of the studies were about bringing smartness in structure scale, and effect of it in city, neighborhood or built environment level. The reason why smart built environment is considered as meshed with technology is that, the most of the studies in terms of technology which focusses on IoT, RFID, BIM or ICT.

3.3 Highlights of Sustainable Transportation at the METU Campus

According to smart and sustainable campus policies, the goal is to reduce automobile dependency and encourage people to use non-motorized transportation modes and public transportation. Before examining parking management on METU campus, it is essential to understand the behavior of drivers and needs of METU campus in terms of parking management; and also alternative modes, land use, transport demand and traffic (peak hours, stay time, etc.) at METU campus.

Therefore, at the beginning of this chapter, cycling, walking, public transit policies and ride-sharing programs were introduced in order introduce the alternative modes to private car use. Then, the previous studies completed specifically for METU regarding non-motorized transportation modes, smart campus concept, transport demand, and current traffic were summarized.

First of all, from the thesis of Gulluoglu (2005) buildings with the highest trip demand were understood by looking population and population density of the buildings. It is also useful for understanding the demand for parking lots at the campus. Results indicated that trip demand is higher at northern part of METU campus built-environment comparing to other parts of the campus. The buildings with high trip demand are as followings: METU Foundation School, Faculty of Education, Department of Basic English, Technopolis, Faculties of Economic & Administrative Sciences and Architecture, Faculty of Social Sciences, Departments of Chemistry and Electric & Electronic Engineering, Department of Civil Engineering and Dormitories.

Secondly, it is crucial to understand on-campus traffic, number of the vehicles which enter to METU campus and stay time of the vehicles. Those analyses provided information about parking demand and vulnerable areas in terms of traffic congestion. Altıntaşı (2013) concluded that in order to achieve sustainable campus requirements, the first step should be discouraging students to drive at the campus. Findings were as followings:

- Approximately 15000 vehicles entry to METU campus per day.
- Majority of the entries was observed at 07:00 a.m. to 9:00 a.m.
- Majority of the exits was observed at the timeline between 5 p.m. to 6 p.m.
- In terms of trip demand, peak hours are as 08:15 – 09:15 and 17:15 – 18:15.
- Almost 46% of the vehicles stays at the campus up to 15 minutes.
- 8% of the entries results in 15-30 minutes stay time and 7% of the vehicles stay 30 minutes to 1 hour.
- 23% of the vehicles stays at the campus 1 to 5 hours.
- 13 % of the vehicles stays at the campus 5 hours to 10 hours.
- 3% of the vehicles stay at the campus more than 10 hours.
- At northern areas of the campus traffic congestion occurs more comparing to southern areas of the campus.
- Most of the traffic congestion was observed on corridor A1 gate to A4 gate and A1 gate to Technopolis direction.

Parking management also requires an understanding of mode choice. In order to decrease driving, mode choice for the purpose of accessing to campus were studied. The mode chose selection depends to the origin . By considering travel time, findings were as followings:

- Within the transportation network, dolmuş services are more attractive, comparing other modes (bus, metro).
- Metro network is far from responding to expectations because of radially distributing and being city center oriented.
- Buses are unable to operate in high speeds because of traffic congestion.

- Dolmuş services averagely take one kilometer in 4 minutes in areas more than 8 km away from campus.
- Dolmuş related combinations of modes are faster modes almost from all of the zones that are further to METU campus more than 8 kilometers.
- During WTP Interview some of the students complained about efficiency of public transport and shuttle services. Therefore, they stated that they prefer driving instead.

Willingness-to-Pay Interview provided background information for conducting Smart Campus Transportation Survey. The findings of the interview were as followings;

- Parking pricing strategy is not welcomed among students comparing to academics.
- Some of the academics told that highly demanded places should be frequently controlled to avoid parking violations.
- It was recommended that the initial price requires to be relatively high, and that the rate should be lowered depending on the duration of parking.
- A few of the respondents suggested that parking fee should be budget-wise.
- Parking pricing strategy was considered as solution to traffic congestion.
- Willingness to pay for parking both on-campus and off campus is higher among wealthier respondents.

Before evaluating parking behavior and level of parking problem at METU campus, it was essential to understand both on-campus and off-campus transportation, land use, population density of the buildings at the campus, travel behavior, land use, problematic areas by means of traffic congestion. Therefore, by utilizing past studies, METU campus transportation habits, situation, and built environment were understood.

The findings indicate that there is a need for effective parking management at METU campus. Moreover, evaluation of parking lots at the campus were done by considering the findings of past studies. Moreover, parking management recommendations were done by utilizing both parking lot evaluations and past studies in sight of the literature.

CHAPTER 4

METHODOLOGY FOR EVALUATING METU PARKING MANAGEMENT NEEDS

In this study, a series of analyses were performed to better detect the level and situation of campus parking problems at METU campus. This chapter involves the details of surveys, and collected inventory (see Figure 4.1 for the framework), including the used methodologies and aims for performing these steps

Briefly to summarize this study, the following steps were followed. A detailed smart campus transportation survey was developed and performed face-to-face and online (USTDA SURVEY- see Section 3.2.4). Moreover, a parking space inventory was performed to quantify the parking supply at the campus. Then, the parking occupancy rate of parking lots, parking violations, and parking behavior were analyzed by utilizing a separate parking survey.

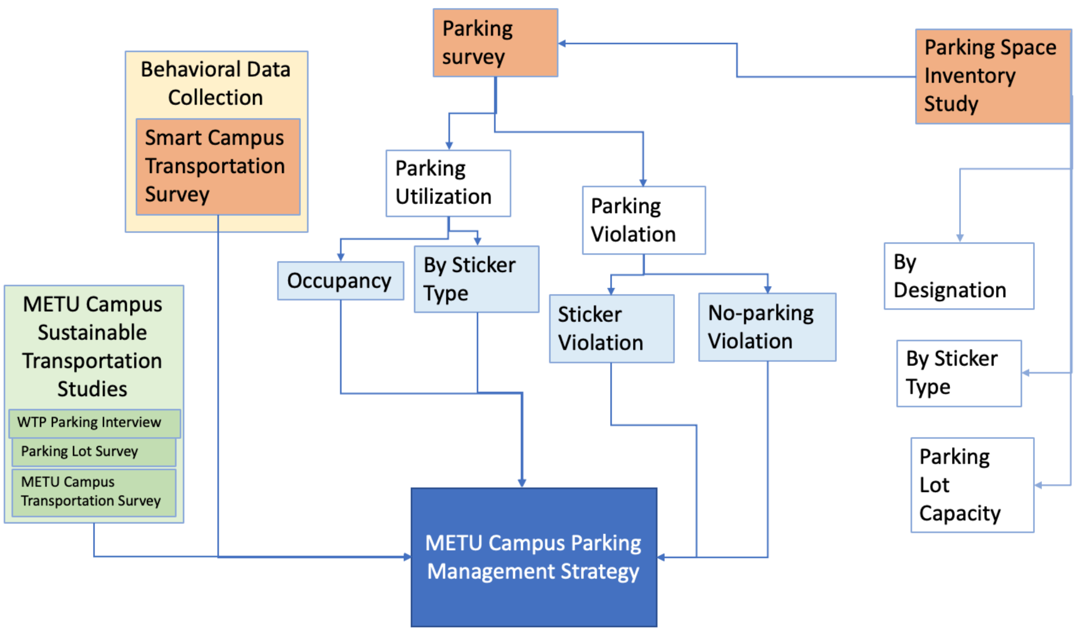


Figure 4.1 Framework for the study

4.1 Behavioral Data Collection

Behavioral data collection consists of smart campus transportation surveys to understand the perception of METU campus commuters regarding on-campus transportation, on-campus traffic, and the transportation modes which are being used on campus (USTDA, 2017). Therefore, face-to-face and online surveys were conducted. The total number of students who participated to the face-to-face survey is 320 and the survey was carried out in May 2019. The online survey was carried out in June 2019 with 865 respondents.

Although the coverage of this survey was broad, only parking-related questions were discussed in this thesis in detail. Accordingly, the questions asked in both surveys were given (see Table 4.1).

Table 4.1 Scope of the Surveys

Online/ Face-to-Face	Q1. What do you think about the number of cars in the campus?
Online/ Face-to-Face	Q2. What do you think about the parking lot capacity in the campus?
Online/ Face-to-Face	Q3 Do you use private car for in campus transportation?
Online	Q4. Which parking lot(s) do you generally use?
Online/ Face-to-Face	Q5. What do you do, if the parking lot you want to park in is full?
Online/ Face-to-Face	Q6. How often do you park illegally on campus?
Online/ Face-to-Face	Q7. What kind of enforcement have you experienced for illegal parking within campus?
Online/ Face-to-Face	Q8. What can be improved at the remote parking lots to make them more desirable places?
Face to Face	Q.9. What can be other locations for remote parking lot?

The most critical part was to determine the sample size for surveys to represent the perspective of the majority of the commuters METU campus population is around 35,000, the total number of participants who responded to surveys face to face or online is 1185 which is 3.4% of the population. (see Table 4.2). 531 male and 334 female respondents participated to the online survey. On the other hand, 177 male and 138 female respondents participated in the face-to-face survey. Moreover, the majority of the respondents are under 35 years old. Furthermore, demographic information involves income level, residence status and status in METU.

Table 4.2 Demographic Information

ONLINE			**FACE TO FACE**		
	Frequency	**%**		**Frequency**	**%**
Gender (N=865)			**Gender (N=315)**		
Female	334	38.6	Female	138	43.8
Male	531	61.4	Male	177	56.2
Age (N=854)			**Age (N=320)**		
<22	403	47.2	<22	182	56.9
22-35	351	41.1	22-35	136	42.5
36-44	62	7.3	36-44	2	0.6
45-54	25	2.9	45-54	0	0
55-64	11	1.3	55-64	0	0
65+	2	0.2	65+	0	0
Income TL (N=865)			**Income TL (N=316)**		
<1000	325	37.6	<1000	115	36.4
1000-2000	245	28.3	1000-2000	144	45.6
2000-4000	86	9.9	2000-4000	32	10.1
4000-6000	106	12.3	4000-6000	16	5.1
6000+	103	11.9	6000+	9	2.9
Residence Status (N=865)			**Residence Status (N=320)**		
METU Campus	301	34.8	METU Campus	132	41.3
Outside of Campus	564	65.2	Outside of Campus	188	58.8
Status in METU (N=858)			**Status in METU (N=316)**		
Academic personnel	55	6.4	Academic personnel		
Administrative personnel	39	4.6	Administrative personnel	1	0.3
Undergraduate student	579	67.5	Undergraduate student	263	83.2
Graduate student	139	16.2	Graduate student	42	13.3
Research assistant	40	4.7	Research assistant	10	3.2
Researcher	3	0.4	Researcher	0	0
Technical personnel	3	0.4	Technical personnel	0	0

4.2 Parking Space Inventory Study

A parking space inventory study was conducted in order to understand the structural design of parking lots, the total number of parking spaces, and parking restrictions (permitted users to park). The parking space inventory study consisted of three phases. The first phase consisted of the process of gathering information about parking lots as how many parking lots and parking spaces exist in the study area (see Figure 1.2 for the study area). The parking space inventory was completed on two Sundays that were on 20th and 27th of October 2019. For the study, early Sunday mornings were chosen because the occupancy rate of parking lots was expected to be low at 6 a.m. on Sundays. So, it was possible to get detailed information regarding parking spaces when the occupancy rate of parking lots is at a minimum.

Every parking space on parking lots was counted. Besides, designated, undesignated parking spaces and areas with no-parking signs were identified. Undesignated areas were defined according to the parking structure at the campus. For instance, if the vehicle is detected in the alley area of the parking lot, it is defined as undesignated parking (see Figure 4.2)

Figure 4.2 Undesignated Parking at METU campus

Moreover, roadside parking was accepted undesignated parking. In addition, no-parking places were defined by following no-parking signs and delineator studs (see Figure 4.3).

Figure 4.3 No-parking signs located at METU campus

Then, the data which was gathered during the inventory study was visualized by transferring to spatial data using AutoCAD. All of the parking lots, parking spaces, forbidden areas for parking, parking spaces for handicapped drivers, and authorization to use of parking lots were indicated with color-coding. Moreover, all of the information was also transferred to an excel file for further analysis.

4.3 Parking Survey

Parking Survey not only indicated the occupancy rate of the parking lots but also help to identify the sticker type of the vehicles which occupied the parking space. The parking survey was conducted in order to understand the level of parking problems within the study area. The results of the parking survey allowed to detect the problematic areas and parking behavior at the campus. The parking survey provides information about occupancy rates of the parking lots, no-parking violations, sticker violations, and blockings. Insight of the parking survey, vulnerable regions at the campus, and parking behavior of the communities were detected.

On 16th May 2019, the parking survey was conducted on three different times of the day in order to detect the occupancy rate of the parking lots. The first count was from 9:30 to 10:30, the second count was from 12:30 to 13:30 and the final one was 15:30 to 16:30. The reason why these hours were selected was to predict parking demand. The best time range to analyze the current parking demand and necessities is when the circulation of parking lots is greater. Bezerra et al. (2019) claimed that parking demand increases during office hours which is from 8:00 to 18:00. As aforementioned earlier, at METU campus, it is obligated to keep the stickers at the front window of the vehicles. Thus, the counts were also included the sticker types.

During the field study, the data was noted to CAD sheet prepared for each lot at the end of the parking space inventory study (Figure 4.4). Each rectangle box in the sheets represented a parking space and the letters (A,P,R,Y,B,M,G, T,C,Na) written in the box represented the parked vehicle's sticker type. Then, all of the data was transferred to the AutoCAD file (Figure 4.5). The data on the AutoCAD file involves all three counts at the same sheet. It was represented by dividing each rectangular box to three. Thus, the amount of data is excessive and needed to be simplified. Only major sticker types (Academics, Personnel, and Student (yellow and brown), which were about 75% of all, were clearly identified in the AutoCAD file. On the other hand, the vehicles without stickers were identified as not applicable (N.a.). The rest (alumni, guest, guest 2, Technopolis, foundation, resident, and college) was represented as "Others".

Besides, these data were also transferred to the excel file to calculate the occupancy rate. Thus, by comparing the capacity of parking lots and a real-time number of vehicles, the occupancy rates were estimated. As well, several parking violations were identified.

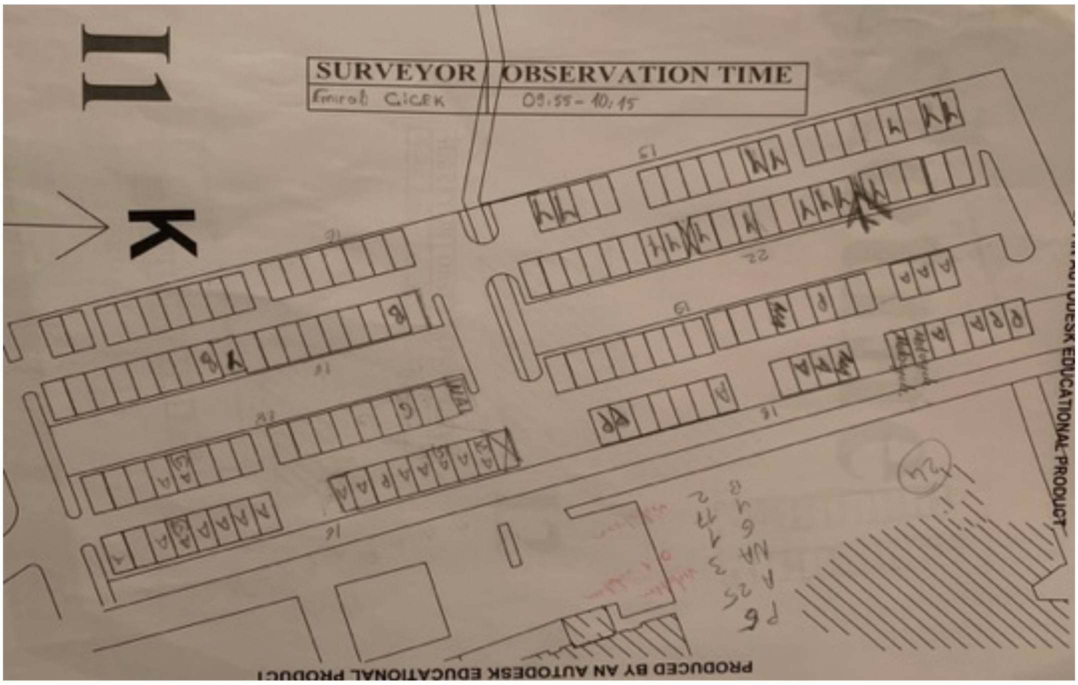


Figure 4.4 Visualization of Business Administration Plot in the Morning which is Filled on a Sheet During the Parking Survey.

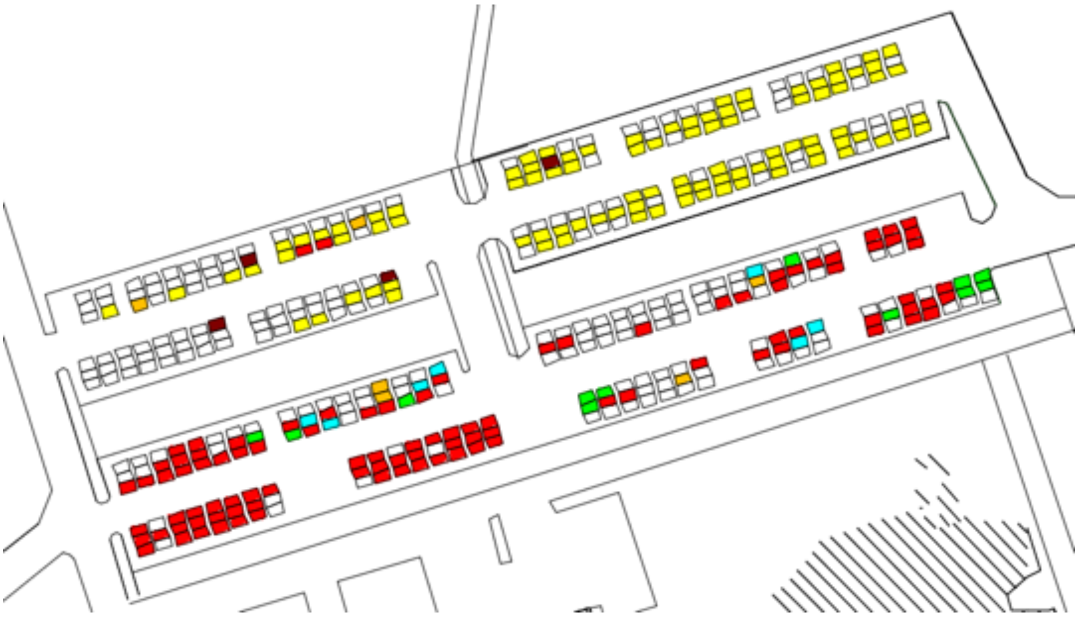


Figure 4.5 Visualization of Business Administration Plot which is Filled on AutoCAD File.

4.4 Spatio-Temporal Visualization of Parking Supply and Demand

Parking space reserved for which community is illustrated on the AutoCAD file (see Figure 4.6-a). First of all, red hatches are defined as forbidden areas. Parking in these areas causes parking violations. Second, the green hatches indicate parking places that are reserved for academics and staff. Third, yellow hatches demonstrate parking spaces that are allowed for students who own yellow stickers. Fourth, blue hatches represent parking lots (general parking lots) that everyone can park except brown sticker type holders. Fifth, which is not indicated in the figure is brown hatches. Parking spaces that are hatched by using brown color are allowed for everyone without exception. Sixth, the cyan hatches on the figure indicate parking spaces that are reserved for disabled drivers, no matter which sticker type that driver owns. Finally, gray hatches denote areas that are not identified as parking spaces. Those spaces are generally curbsides or flow alleys on parking lots.

Moreover, visualization of the Health Center Parking Lot is provided for a better understanding of the use of color codes (see Figure 4.7). For instance, at the figure, the reason of why no-parking violation is identified at the specific area is explained.

For visualization of parking space inventory, 7 different color codes were used in order to indicate sticker type owner who is authorized to park on a certain parking lot (Figure 4.6-b). For parking survey, in order to illustrate the parked vehicle's sticker type on the AutoCAD file, sticker types were visualized by color-coding system (see Figure 4.6-b). Academics were defined by red color. On the other hand, personnel were identified by using green color code. Moreover, the yellow and brown student sticker types were indicated by their colors. On the other hand, for conditions like an unavailable sticker on the front window of the vehicle cyan color code was used, and remaining stickers (others) were represented by orange color code.

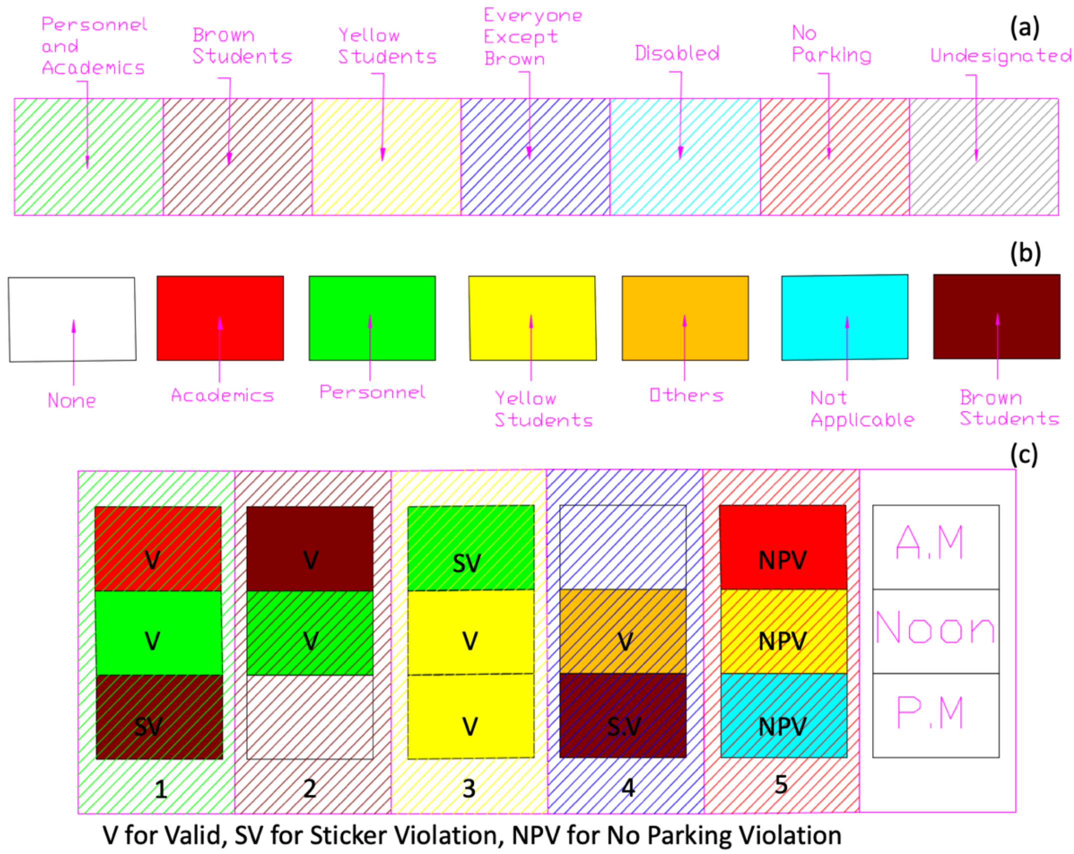


Figure 4.6 (a) Spatio-temporal visualization approach for the Parking Survey with sticker-type color coding, **(b)** temporal coding of time-dependent survey data, **(c)** examples of parking violations.

The results of the parking survey and parking space inventory were merged for visualization. The parked vehicle's sticker type according to time was shown in order to detect the change in parked vehicles' sticker type with respect to time on the parking space (see Figure 4.6-c).

Every vehicle was indicated by a block which is divided into three smaller blocks. These smaller blocks represent timelines. The top block refers to the timeline from 9:30 to 10:30, the middle block represents the timeline from 12:30 to 13:30. Lastly, the bottom block indicates the timeline from 15:30 to 16:30 (see Figure 4.6-c). Because not all the parking spaces are in the same direction, the left block identifies timeline from 9:30 to 10:30, the middle block represents timeline that is from 12:30

to 13:30, and finally the right block indicates timeline from15:30 to 16:30 (see Figure 4.8).

At Figure 4.6-c, the first diagram indicates parking space that is dedicated to personnel and academics. It can be observed that in the morning slot, an academic's vehicle is parked there, which is valid. Moreover, at noon, a vehicle of personnel stays parked which is valid too. On the other hand, it observed that a brown sticker owner parked the vehicle which causes sticker violation. Furthermore, at the second diagram, a parking space that is dedicated to brown sticker owners is illustrated. Because parking those parking spaces is allowed for everyone. All of the parking behaviors are valid. At the third diagram, sticker violation is observed in the morning by the personnel vehicle owner. Also, at the fourth diagram, parking space allowed for everyone except brown sticker owners. Therefore, sticker violation is observed in the afternoon by brown sticker. Finally, the fifth diagram indicates no-parking area. Without looking sticker type, all of the parking behavior activity at there, results in no-parking violation which requires penalty.

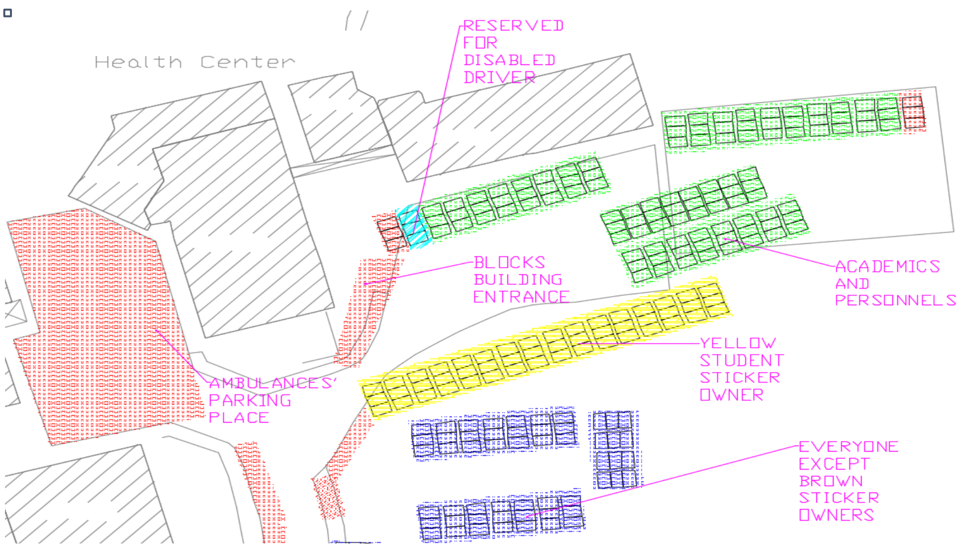


Figure 4.7 a Spatial Visualization of Parking Supply at Health Center Parking Lot

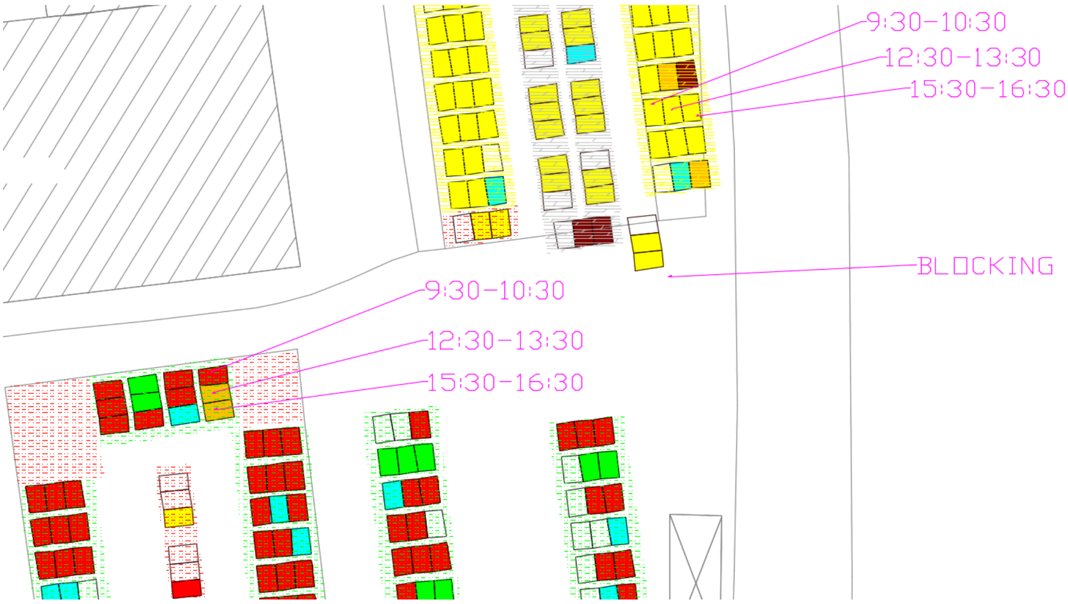


Figure 4.8 a Spatio-Temporal Visualization of Parking Demand and Supply at Civil Engineering Parking Lot

4.5 Summary of Data Collection

In the chapter, the data collection part of the study was discussed. The goal was to understand the level of the parking problem at the campus, and the perception of METU commuters. The study involves a survey of behavioral data collection to understand the perception of METU commuters regarding parking lot use, experiences during parking behavior and recommendations for overcoming the parking related problems. Moreover, in this chapter, the parking space inventory and parking survey were discussed in detail. This data was essential to estimate the level of parking problems like parking violations, overflows, and areas that face traffic congestion because of the high demand for parking.

The following chapter consists of the evaluations of those studies. Within the scope of the analysis, behavioral data, parking supply and demand, occupancy rates of parking lots, recommendations, level of parking, and parking violations were evaluated in order to come up with a campus-wide parking management plan.

CHAPTER 5

EVALUATION OF PARKING MANAGEMENT NEEDS ON METU CAMPUS

In order to create a parking management strategy for METU campus, it is crucial to analyze the parking supply and the demand. So, it is required to characterize the infrastructure overflows, parking violations, and level of the parking problems and parking behavior of the METU campus commuters. In this chapter parking supply and demand are evaluated in the light of the parking space inventory, parking survey, and smart campus transportation survey (USTDA). The goal is to determine the parking needs of METU campus. Thus, it will be possible to create METU campus parking management strategy plan.

5.1 Evaluation of Parking Demand

At METU campus there are 11 types of stickers that exist. Detailed information and the percentage of the sticker distribution is provided in Figure 5.1. Remaining parking stickers is approximately 25% percent of the overall. These are college, alumni, guest, guest type two, Technopolis, foundation and resident. As an aforementioned earlier, visitors need take a visitor's card at the entrance of the university.

- **Academic Stickers:** There are two types of academic stickers that vary as temporary and permanent. These stickers can be provided to faculty members, research assistants, and retired faculty members. Academic stickers are 24% of all.
- **Student Sticker:** 35% of the stickers are owned by students. Student stickers vary according to the use. These stickers are classified as yellow and brown.

- **Yellow Sticker:** 16% of the stickers are yellow type. These stickers are more expensive compared to the brown ones. The owners can park on parking lots with yellow student sign, which are located close to the departments.
- **Brown Sticker:** %19 of the stickers are brown. This type stickers are cheaper as compared to yellow ones. However, the owners are only authorized to park the satellite parking lots.

- **Personnel Sticker:** It is also one of the major parking stickers that cover %16 of all. Staff can take personnel stickers.

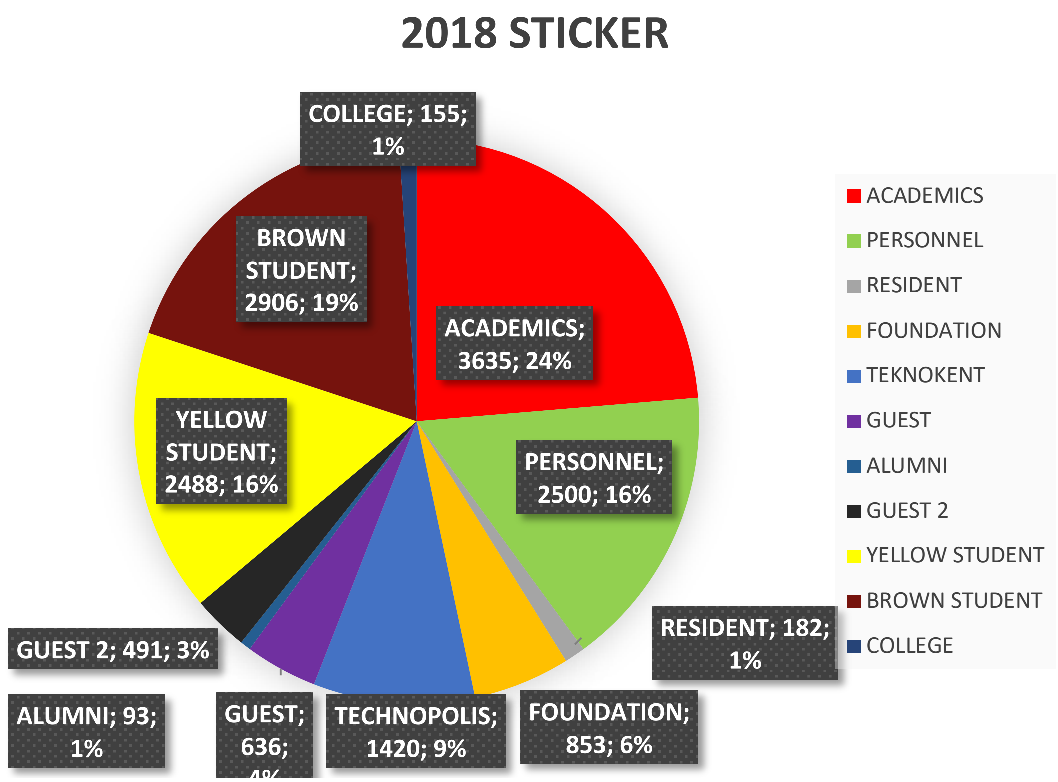


Figure 5.1 Distribution of METU Campus Stickers

In the last decade, the number of stickers given at METU campus has been increased by 60 percent. It has been reached up to 15359 in 2018 (Figure 5.2). It means that the use of automobile increases day by day. Thus, the parking supply has become insufficient. On the other hand, as an option, increasing parking supply might also create new challenges including traffic congestion, air pollution. That's why a systematic evaluation is needed. When sticker type distribution in years is observed, it is clearly observed that the number of brown student, personnel stickers has increased. Technopolis stickers has increased rapidly over the years. Moreover, the number of the academic stickers has been doubled over the years. On the other hand, the number of the alumni stickers has decreased over the years (see Figure 5.2).

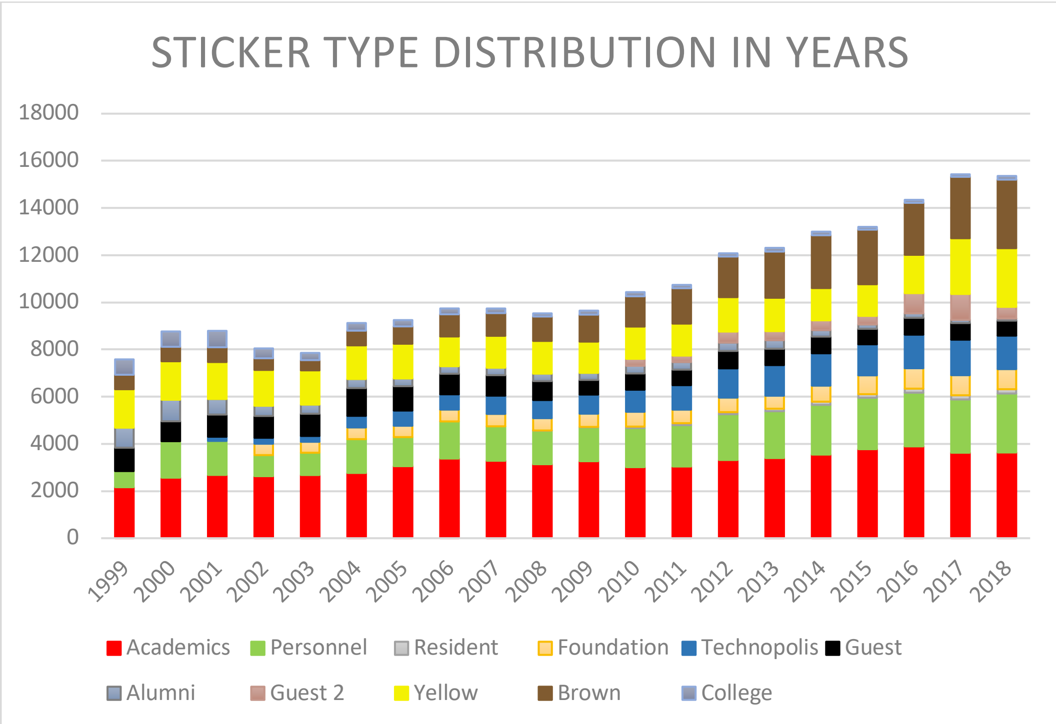


Figure 5.2 Sticker type distribution over the years

5.2 Evaluation of Parking Supply

The study area consists of 56 parking lots located at METU campus. Therefore, to simplify the analysis, the study area was divided into 13 regions compromising all 56 lots (see Figure 1.2). In addition, all of the parking lots were visualized according to the number of parking spaces that they contain. The Parking lots were separated into 6 categories according to their capacities (see Figure 5.3). There are 3 large parking lots which involve more than 150 parking spaces. 6 parking lot contains parking spaces between 100 to 150. 2 of the parking lots involve parking spaces in the range of 75 to 100. And, most of the parking lots (44) contain less than 75 parking spaces. By the way, for parking supply analysis, the close proximity parking lots (for instance, parking lot 10 and 11) were associated in this study. However, the exact capacities of parking lots were also provided (see Table 5.1). Numbers that are between parentheses indicate parking spaces that are illustrated with road markings. In other words, 2235 parking spaces at parking lots are indicated by road markings. On the other hand, 1073 parking spaces are not indicated by road markings, although they are designated parking spaces. In total, there are total 3308 designated parking spaces. At the table, bold numbers demonstrate the total designated capacity of parking lots. In order to avoid vagueness, road markings that indicate parking spaces should be marked.

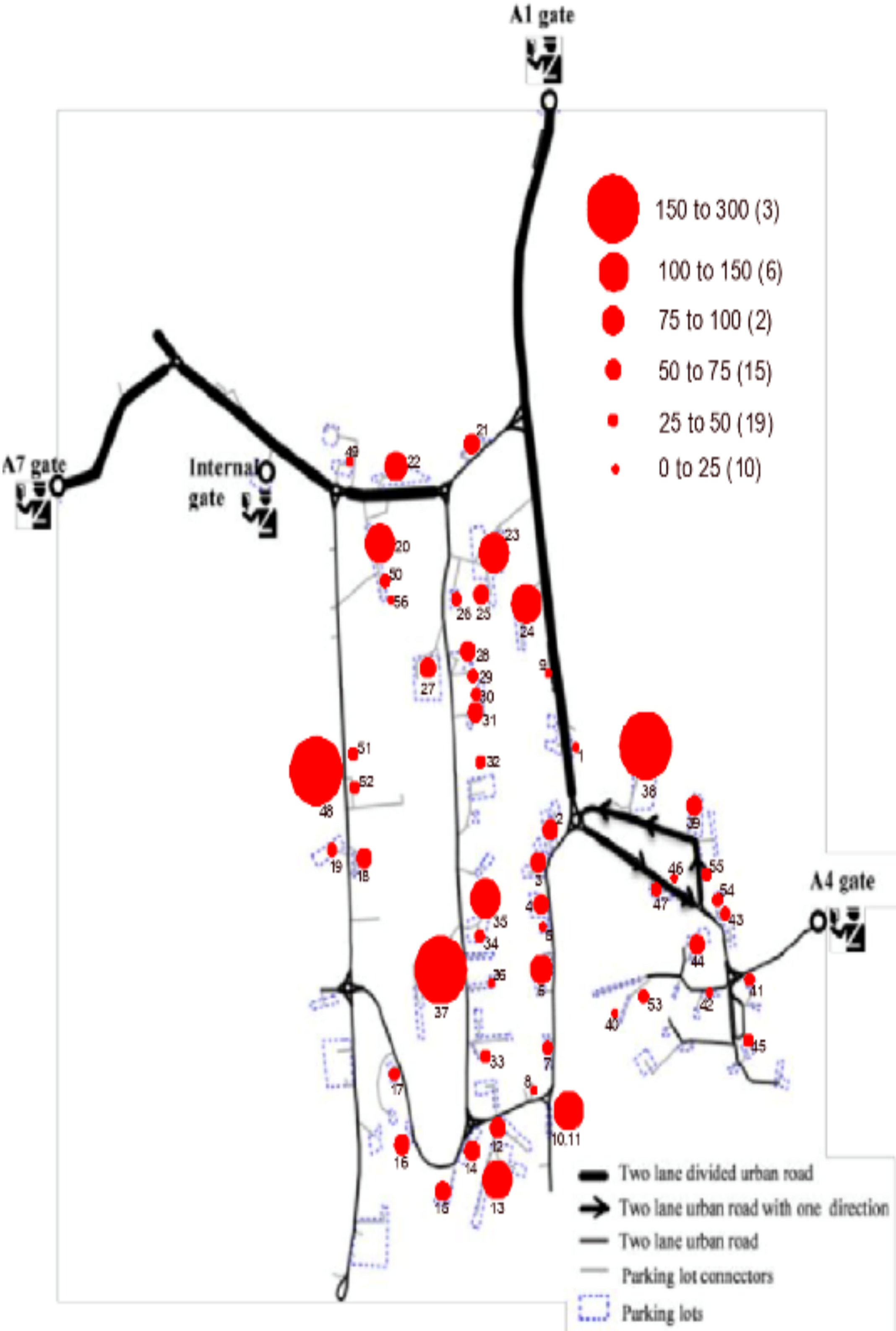


Figure 5.3 Visualization of Capacity of Parking Lots

Table 5.1 Capacity of Parking Lots

Plot No	Plot Name	No PSpc (Nd)	Plot No	Plot Name	No PSpc (Nd)
Dormitory Territory (1)			Environmental and Metallurgical Eng. (8)		
40	Sport Center and Courts	**18** (10)	10	Coastal And Harbor Eng.	**76** (0)
41	Guest House	**34** (34)	11	Mosque	**68** (0)
42	2,3,4 Dorm. Territory	**16** (0)	12	Dept. of Environmental Eng.	**57** (54)
45	Dormitory 3	**33** (0)	13	Dept. of Metal & Mat. Eng.	**129** (78)
53	Swimming Pool	**25** (0)	Civil Eng. (9)		
Shopping Area (2)			3	Engineering Science	**70** (43)
43	Housing Territory	**36** (15)	4	Computer Center	**69** (55)
44	Health Center	**72** (51)	5	Civil Engineering Storage	**0**
46	Bank Territory	**18** (18)	6	Civil Engineering	**83** (32)
47	Gymnasium	**42** (42)	7	Hydromechanics Lab.	**46** (46)
54	Housing Territory 2	**33** (0)	8	Hydromechanics Back	**8** (8)
55	Shopping Center	**31** (0)	Economics – Eng. Science (10)		
Culture and Convention Center (3)			2	Cafeteria	**54** (54)
1	Social Building	**12** (12)	9	Presidency Roadside	**20** (20)
38	Cult. And Conv. Center	**294** (294)	23	Fac. of Econ. & Admin. Sci.	**105** (105)
39	Tennis Courts	**73** (0)	24	Library	**120** (87)
Foreign Languages (4)			Architecture – Biology (11)		
21	Sch. of For. Lang. Build. A, B	**57** (57)	25	Fac. of Arch. 2	**57** (57)
22	School of Foreign Lang. Lab.	**93** (93)	26	Fac. of Arch. 1	**25** (0)
49	School of Foreign Lang. Basic	-	27	Dept. of Biology	**60** (60)
Business Administration (5)			28	Human Sciences	**67** (67)
20	Dep. of B. Administration	**142** (0)	29	Dep. of Math.	**37** (29)
50	Dep. of Business Adm. 2	**26** (0)	Physics (12)		
56	Dep. of Business Adm. 3	**21** (0)	30	Department of Physics Front	**28** (28)
Main Sport Center (6)			31	Department of Physics Back	**71** (71)
18	Informatic Institute	**54** (54)	32	Department of Statistics	**30** (30)
19	Technopolis Gymnasium	**44** (38)	34	Industrial Engineering	**37** (35)
48	Technopolis Satellite	**158** (81)	35	Dep. of Elect.& Electr. Eng.	**131** (107)
51	Modsimmer	**40** (40)	Mechanical Eng. (13)		
52	Cryptology	**34** (0)	33	Chemical Engineering	**46** (11)
Geological and Food Eng. (7)			36	Central Laboratory	**22** (0)
14	Geological Eng.	**57** (57)	37	Mechanical Engineering	**163** (117)
15	Mining Eng.	**62** (41)	TOTAL		**3308** (2235)
16	Dept. of Petrol and Nat. Gas	**64** (64)			
17	Dept. of Food Eng.	**40** (40)			

Results of Parking Space Inventory Study

Parking Space inventory study is useful for evaluating the parking supply. It is important to understand how many parking spaces are dedicated to which community. Yet, it would be proper to start with the areas with No-Parking Sign where nobody is not allowed to park a vehicle. Parking on these areas causes No-Parking Violation and requires a penalty. No-parking signs at METU campus were detected and those areas were identified as No-Parking violation areas. It was observed that these forbidden areas are used frequently by drivers. The reason why these areas are not allowed for parking is that the width of the road might be narrow, parking there might block building entrances, or the parking place might be reserved for ambulances. From parking lots that were studied, it was revealed that there are 357 spots where the drivers park their vehicles, although these spots are defined as no-parking areas. Moreover, how many parking spaces dedicated to which community and distribution of parking spaces is provided (see Figure 5.4).

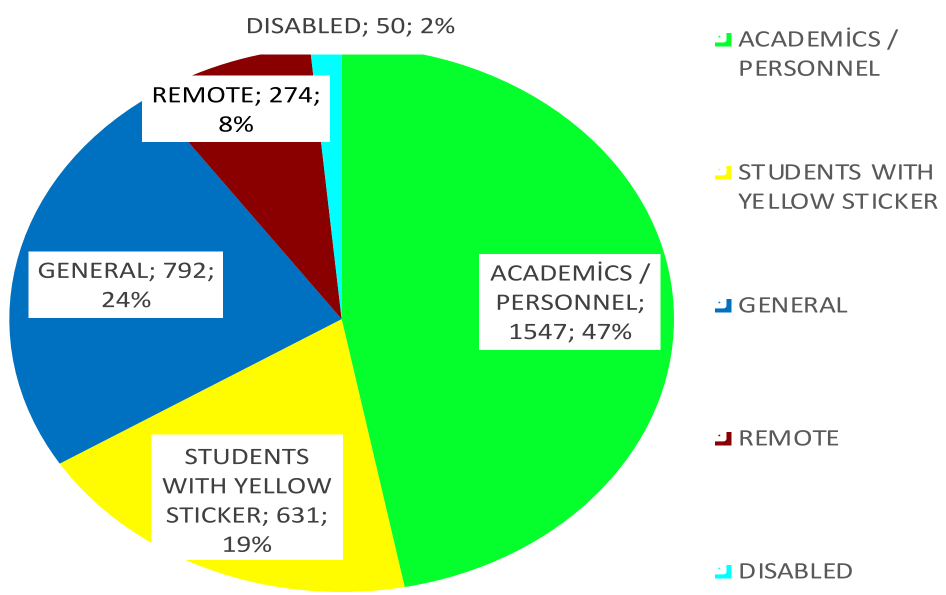


Figure 5.4 Distribution of Parking Spaces

Parking lots that are allowed for academics and personnel; parking on these parking lots without owning academic or personnel stickers causes a violation, therefore it requires a penalty. These sticker types cover 40% of all the stickers (see Figure 5.1). Thus, the majority of parking spaces are reserved for personnel and academics. Out of 3308 parking spaces at METU campus, 1561 parking spaces that cover 47% are for academics and personnel. Furthermore, these sticker holders are also allowed to park their vehicles in general and remote parking lots. This covers 79% of the parking spaces at METU campus.

The yellow sign at the entrance of parking lots demonstrates parking spaces that are allowed for students who own yellow sticker type. 631 parking spaces, which makes 19% of all, are reserved only for these sticker type holders. Adding to these reserved parking spaces yellow sticker owners are allowed to use both general and satellite parking lots, too. Thus, 1691 parking spaces (51%) serve for yellow sticker holders.

At METU campus, there are parking lots (general parking lots) that everyone can park except brown sticker type holders. General Parking Lots involve 792 parking spaces, 24% of all of the parking spaces at METU campus. Those parking lots are generally located close to recreational areas, shopping area, and dormitory regions like Bank Territory (46), Gymnasium (47), and Tennis Courts (39) parking lots. In addition, there are some general parking lots like Technopolis Gymnasium (19) and Modsimmer (51) parking lots that are located in less attractive regions and far away from the center of METU campus.

There are also remote parking lots. Parking Lots with code 10, 11 and 48 are considered as Remote parking lot, but still only Technopolis Satellite parking lot (48) has features of Remote parking lot (See Figure 5.3). These parking lots are allowed for everyone without exception. Although there is a remote parking lot locates at A2 gate with 228 parking spaces capacity, it is not included in the inventory as they are not used frequently. In this case, out of 56 parking lots, only 8% (274 parking spaces) of all of the parking spaces are available for use of brown sticker holders. Nevertheless, those parking spaces can be used by other communities, too. Because

2906 parking stickers out of all 15359 parking stickers are given to brown sticker type holders, 274 parking spaces with the shared use make remote parking lots insufficient. If these parking spaces were dedicated to only brown sticker holders, sticker violations would have decreased.

It is also important to mention parking spaces that are reserved for disabled drivers, Although the study involves 56 parking lots with 3308 parking spaces, there are only 50 parking spaces (2% of the overall) that are only dedicated to disabled drivers. Considering that at some parking lots, there are 2 disabled parking spaces. It is observed that many parking lots do not contain disabled parking spaces. In addition, at many parking lots reserved parking spaces for disabled drivers are not located at the nearest place to the entrance of buildings. It is obvious that disabled parking spaces are quite insufficient and ineffective.

Finally, undesignated areas are needed to be identified. Although These spaces are generally curbsides or flow alleys on parking lots, as parking on these spots is assumed normal at METU campus, as these areas do not block the way. In addition to the 3308 designated parking spaces, there are 732 undesignated spaces. Undesignated spaces were also identified during parking space inventory. During the inventory, if a vehicle was parked on a space rather than designated parking space and wasn't blocking the way, that space was identified as undesignated parking space. Moreover, it is found that 18% of spaces are identified as undesignated spaces.

5.3 Parking Occupancy Evaluation

At METU campus, the occupancy rate of parking lots seems reasonable in the current condition. Since 15% of a parking lot is unoccupied, as this level is the suggested limit in the literature (Shoup, 2008). However, the unoccupied spaces are not homogenously distributed. In other words, every region's and parking lot's occupancy rate is different. The occupancy rate of each parking lot is presented at Appendix B. By considering the number of the stickers that are distributed over years and comparing occupancy overall occupancy rate of the parking lots in 2013 and today, it can be concluded that parking demand increases. Moreover, in the future, the situation may become more drastic.

- In the morning;
    - at 09:30-10:30, parking lot occupancy rate was estimated as 60.88%
- At noontime;
    - at 12:30-13:30, parking lot occupancy rate estimated 85.85 %
- In the afternoon;
    - at 15:30-16:30, parking lot occupancy rate was estimated as 83.92 %

On the other hand, Altıntaşı (2013) had estimated the occupancy rate on November 2010 and May 2011 METU campus as follows;

- For the morning time;
  at 08:30-09:30, parking lot occupancy rate was found as 38.1% (spring)
  at 10:30-11:30, parking lot occupancy rate was 70.4% (spring),
  at 10: 30- 11:30 parking lot occupancy rate was 73.2% (winter)
- For the noontime;
  at 12:30-13:30, 74.6 % (spring),
  at 13:30-14:30, 78.5 % (winter)
- For the afternoon time;
  at 15:30-16:30, 75.2 % (spring)
  at 16:30-17:30, 61 % for spring survey

It is possible to predict the behavior of vehicle owners by looking at the number of parked vehicles. Therefore, vehicle frequency was estimated by counting stickers, then the number of vehicles which belong to which community was estimated. The total number of the parked vehicles was assigned as 100% at certain time (see Figure 5.5-a). For instance, the number of stickers that are used by students indicates that students tend to come to campus at noon times and keep increasing in the afternoon.

Moreover, the number of personnel vehicles is approximately constant during the day. For improving a METU campus strategy, it is important to understand the behavior of the different user groups. Also, sticker type rates were estimated by comparing parked vehicles at the specified timeline (Figure 5.5-b).

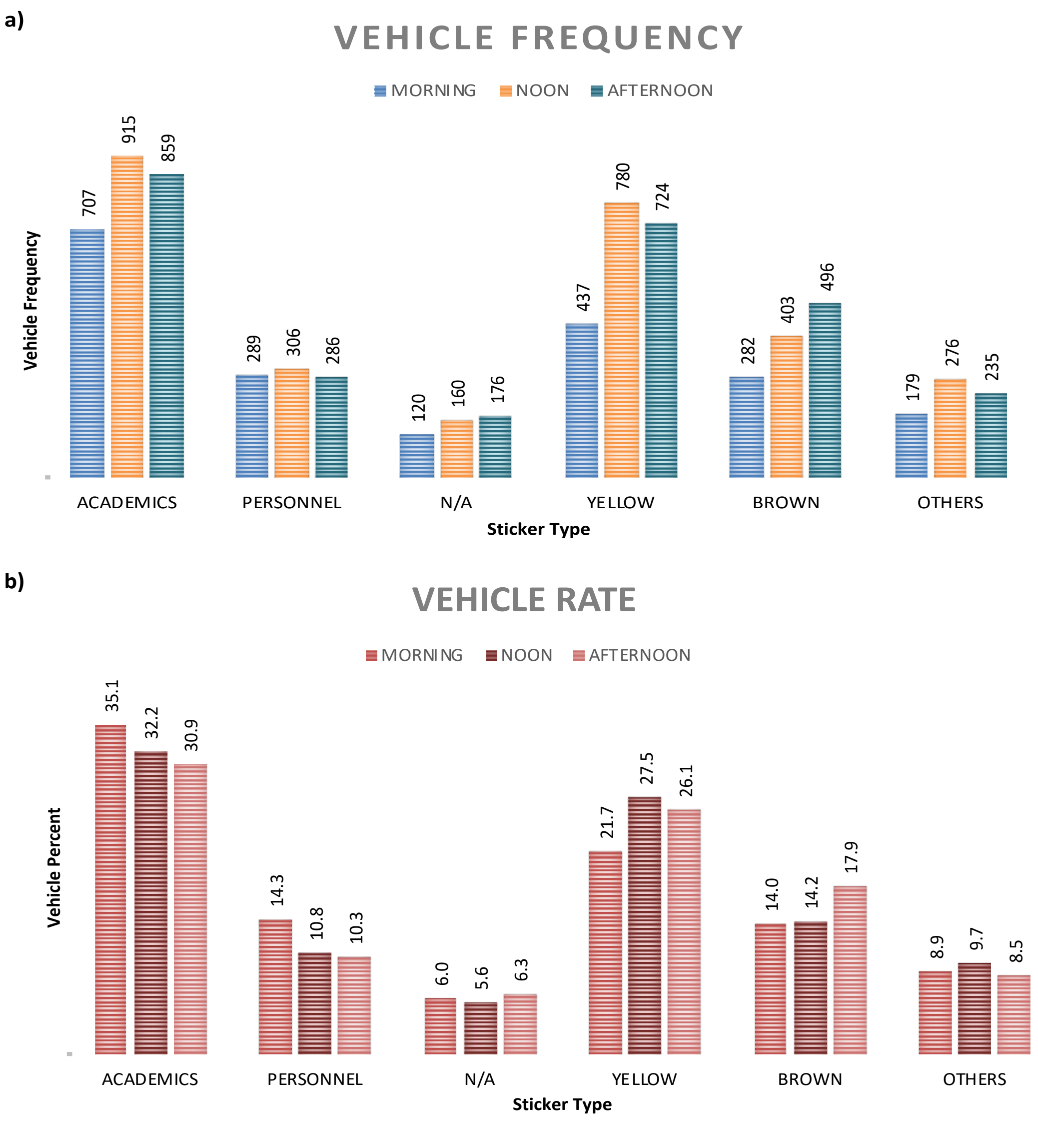


Figure 5.5 (a) Vehicle Frequency **(b)** Vehicle Rate from Parking Survey Number of Parked Vehicles by Sticker Type

It is found that approximately 60% of the vehicles are approximately yellow and academic sticker owners. By looking number of the stickers that are distributed to

METU commuters, it is possible to make the comparison. For instance, most of the owner of the vehicles are academics, that ranges from 31% to 35% (Figure 5.5-b). However, only 24% of the stickers involves academics sticker type (Figure 5.1).

Because 15% of availability is important at a parking lot in terms of effectiveness, as upper limit 85% of fullness was selected for the evaluation. Moreover, for the lower limit, 50% was selected in the purpose of indicating available parking lots. The comparison of occupancy rates between parking lots had been done.

It is revealed that 22 parking lots are with more than 85% occupancy rate in the mornings (see Figure 5.6). Moreover, the occupancy rate of 18 parking lots has ranged from 50% to 85% and 16 parking lots have been observed as less then 50%. At noon, 10 more parking lots have been reached more than 85% occupancy rate (see Figure 5.7). Besides, the occupancy rate of 14 parking lots ranges between 50% to 85% and 10 parking lots is under 50%. Finally, the number of over 85% occupied parking lots has been 31 in the afternoon (see Figure 5.8). It was explored that 16 parking lots have been working with a capacity of 50% to 85% in the afternoon and 9 parking lots were under 50% capacity. Moreover, it was detected that 20 of the parking lots work over the 85% capacity all the time.

When locations of high occupied parking lots were examined, it is possible to determine that parking supply at METU campus is not well distributed. It is found that critical regions are around shopping area (region no 2, see Figure 1.2), faculties (region no 9,10,11,12, 13), and foreign languages (region no 5). Occupancy rates of the parking lots were provided (Table 5.2 and 5.3). Parking lots with code 1,2,3,4,5,6,14,21,26,27,29,30,31,32,40,43,45,47,53,55 are those occupied more than 85% all the time. Because they are close to each other, it might increase traffic congestion accordingly. Parking management strategies require to be determined by considering the situation of these parking lots majorly. In addition, parking management systems should be implemented to those parking lots firstly.

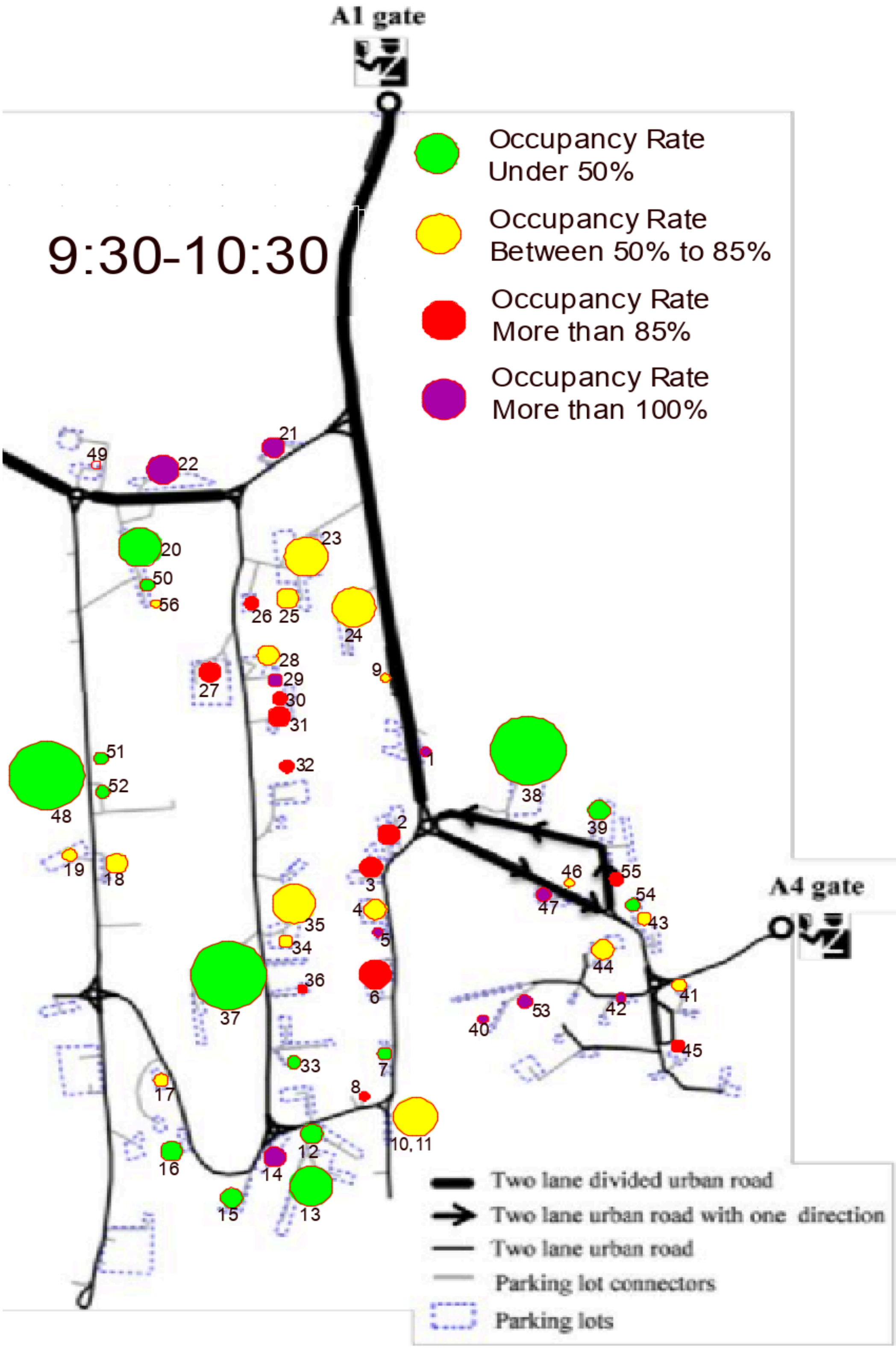


Figure 5.6 Occupancy Rate of Parking Lots in the Morning

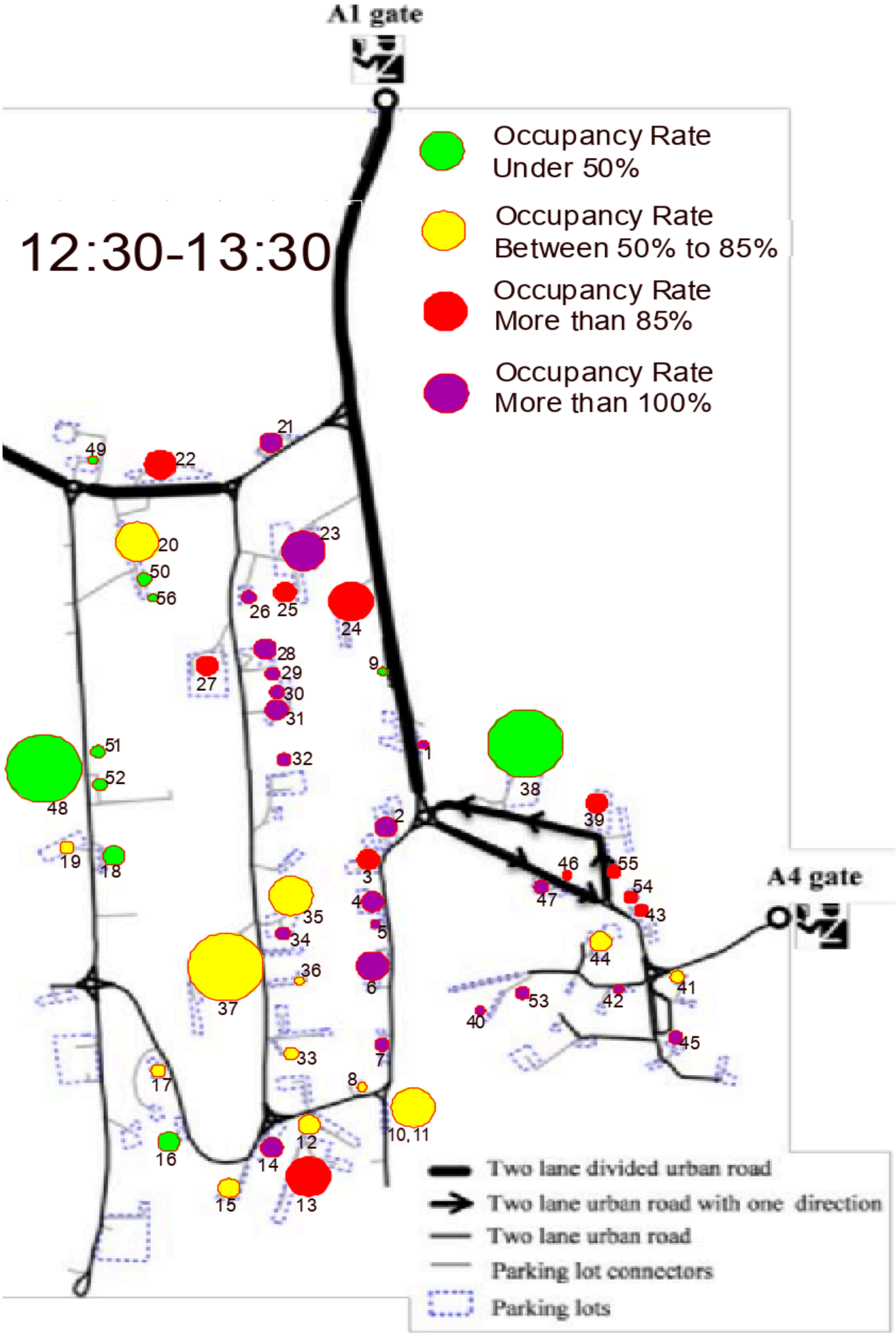


Figure 5.7 Occupancy Rate of Parking Lots at Noon

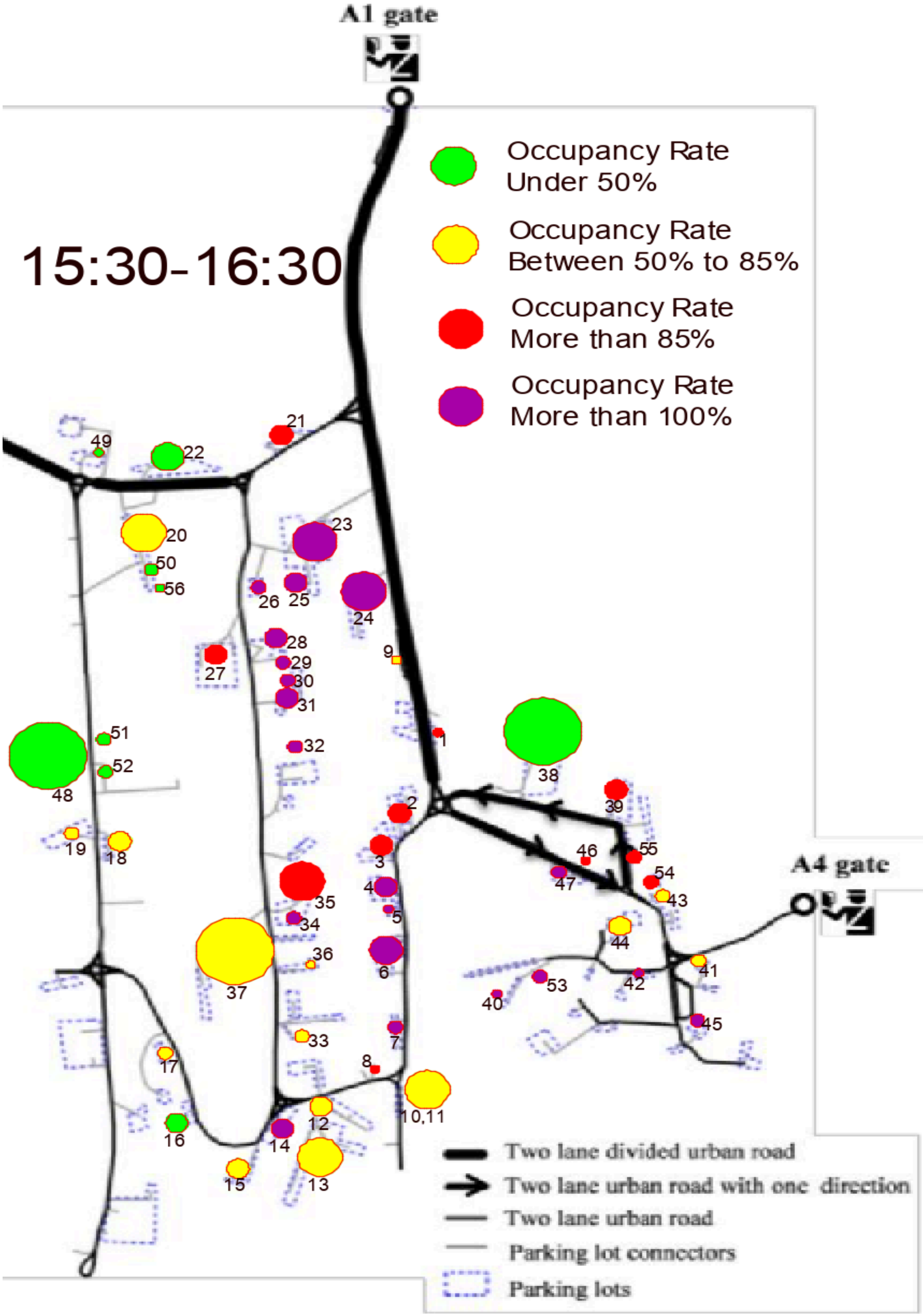


Figure 5.8 Occupancy Rate of Parking Lots in the Afternoon

Table 5.2 Occupancy, Sticker Violation and No-Parking Violation Rate of the Parking Lots

		Occupancy Rate (%)			Sticker Violation Rate (%)			No-Parking Violation Rate (%)		
PLot No	**D_Cap**	**AM**	**Noon**	**PM**	**AM**	**Noon**	**PM**	**AM**	**Noon**	**PM**
Region 1										
40	18	333.3	527.8	594.4	90.0	83.2	87.9	1.7	1.1	1.9
42	16	162.5	218.8	243.8	46.2	42.9	38.5	19.2	11.4	25.6
53	25	120.0	164.0	200.0	66.7	73.2	78.0	10.0	9.8	8.0
45	33	97.0	109.1	139.4	65.6	52.8	34.8	18.8	25.0	32.6
41	34	64.7	70.6	79.4	50.0	50.0	59.3	4.5	12.5	18.5
Region 2										
47	42	109.5	138.1	116.7	65.2	0.0	65.3	6.5	5.2	4.1
55	31	93.5	93.5	100.0	37.9	0.0	32.3	0.0	0.0	0.0
46	18	83.3	94.4	88.9	20.0	0.0	31.3	0.0	0.0	0.0
54	33	39.4	100.0	87.9	30.8	69.7	0.0	0.0	0.0	0.0
43	36	80.6	97.2	77.8	17.2	20.0	32.1	0.0	5.7	3.6
44	72	83.3	66.7	51.4	31.7	10.4	37.8	6.7	10.4	0.0
Region 3										
1	12	116.7	116.7	100.0	7.1	14.3	16.7	0.0	0.0	0.0
39	73	43.8	100.0	100.0	43.8	45.2	53.4	6.3	9.6	5.5
38	294	9.9	40.8	39.8	24.1	30.0	41.9	10.3	2.5	2.6
Region 4										
49	0	-	-	-	-	-	-	-	-	-
21	57	112.3	115.8	89.5	7.8	6.1	3.9	0.0	7.6	3.9
22	93	102.2	89.2	43.0	32.6	37.3	42.5	2.1	0.0	0.0
Region 5										
20	142	38.0	69.7	59.9	11.1	10.1	9.4	0.0	0.0	0.0
56	21	52.4	28.6	23.8	45.5	66.7	0.0	0.0	0.0	0.0
50	26	15.4	7.7	11.5	50.0	0.0	0.0	0.0	0.0	0.0
Region 6										
19	44	65.9	84.1	77.3	27.6	21.6	26.5	0.0	0.0	0.0
18	54	51.9	50.0	74.1	10.7	7.4	5.0	0.0	0.0	0.0
48	158	19.6	32.3	32.3	0.0	0.0	0.0	0.0	2.0	0.0
51	40	10.0	20.0	27.5	75.0	0.0	0.0	0.0	0.0	0.0
52	34	0.0	0.0	0.0	-	-	-	-	-	-
Region 7										
14	57	108.8	110.5	101.8	16.1	20.6	12.1	6.5	4.8	3.4
17	40	80.0	80.0	75.0	18.8	6.3	16.7	0.0	0.0	0.0
15	62	48.4	62.9	59.7	53.3	59.0	62.2	0.0	0.0	0.0
16	64	32.8	29.7	37.5	19.0	36.8	37.5	9.5	0.0	4.2

Table 5.3 Occupancy, Sticker Violation and No-Parking Violation Rate of the Parking Lots (cont'd)

		Occupancy Rate (%)			Sticker Violation Rate (%)			No-Parking Violation Rate (%)		
PLot No	**D_Cap**	**AM**	**Noon**	**PM**	**AM**	**Noon**	**PM**	**AM**	**Noon**	**PM**
Region 8										
12	57	42.1	68.4	84.2	25.0	25.6	29.2	4.2	2.6	4.2
13	129	47.3	86.0	82.2	24.6	20.7	23.6	3.3	1.8	0.9
10	76	64.5	67.1	75.0	6.1	3.9	5.3	0.0	0.0	0.0
11	68	13.2	45.6	55.9	0.0	0.0	0.0	0.0	0.0	0.0
Region 9										
5	0	-	-	-	0.0	20.0	15.4	100.0	100.0	100.0
6	83	96.4	124.1	116.9	7.5	15.5	16.5	3.8	9.7	8.2
4	69	69.6	110.1	115.9	6.3	14.5	1.3	0.0	1.3	2.5
7	46	45.7	113.0	108.7	0.0	5.8	6.0	0.0	9.6	12.0
8	8	87.5	75.0	100.0	0.0	0.0	37.5	0.0	0.0	0.0
3	70	96.4	100.0	96.4	7.4	14.3	18.5	0.0	0.0	0.0
Region 10										
23	105	69.5	123.8	125.7	20.5	23.8	18.9	1.4	0.0	0.0
24	120	54.2	98.3	109.2	7.7	6.8	6.9	0.0	0.0	1.5
2	54	98.1	113.0	94.4	20.8	21.3	19.6	1.9	13.1	2.0
9	20	75.0	85.0	75.0	6.7	17.6	26.7	0.0	0.0	0.0
Region 11										
26	25	96.0	228.0	200.0	20.8	14.0	32.0	0.0	0.0	0.0
29	37	105.4	218.9	170.3	10.3	21.0	19.0	2.6	2.5	3.2
28	67	59.7	101.5	106.0	15.0	16.2	19.7	0.0	0.0	1.4
25	57	77.2	98.2	103.5	20.5	17.9	22.0	2.3	3.6	10.2
27	60	91.7	98.3	93.3	20.0	16.9	26.8	3.6	0.0	1.8
Region 12										
34	37	83.8	148.6	159.5	22.6	30.9	32.2	3.2	12.7	11.9
30	28	100.0	132.1	139.3	17.9	21.6	15.4	3.6	2.7	5.1
32	30	93.3	120.0	106.7	28.6	13.9	12.5	7.1	8.3	9.4
31	71	94.4	105.6	104.2	13.4	17.3	9.5	1.5	2.7	2.7
35	131	54.2	84.0	88.5	12.7	14.5	16.4	0.0	2.7	1.7
Region 13										
36	22	95.5	77.3	81.8	9.5	0.0	5.6	0.0	0.0	0.0
37	163	49.7	68.7	63.8	22.2	17.0	17.3	2.5	7.1	3.8
33	46	41.3	56.5	54.3	36.8	26.9	12.0	0.0	0.0	0.0
TOTAL										
	3308	**60.9**	**85.9**	**83.9**	**23.8**	**22.4**	**25.0**	**3.0**	**4.0**	**4.2**

5.4 Parking Violation Evaluation

From 56 parking lots, it was found that 75% of the parking spaces are designated parking spaces. Remaining 17% is undesignated areas on the spatial outputs. In addition, although there can't be any parking space that is assigned for No-Parking areas, it was estimated that in total 357 vehicles are able to be parked at these areas (see Figure 5.9). Parking on these areas is accepted as No-Parking Violation. A vehicle's dimension was assumed as 2.5 to 5 meters.

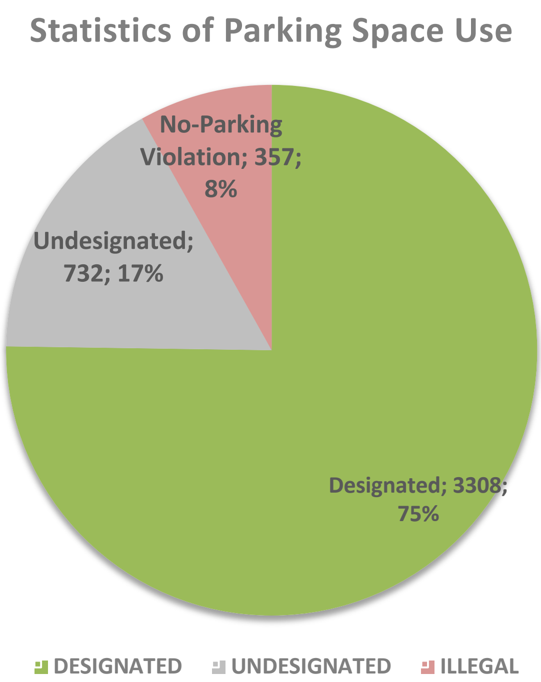


Figure 5.9 Areas that are being used for parking

5.4.1 Sticker Violation

Sticker violation is defined as, parking on a lot that is dedicated to another community. It is important to mention that if the sticker on the vehicle doesn't match with the sign located at the entrance of a certain parking lot, it causes sticker violation. A spatial demonstration of parking violation is provided (see Figure 5.10).

On the figure (highlighted with red rectangular box), an example of a vehicle with the brown stickers violating the regulations at noon and in the afternoon is given. As indicated, the same parking space was available in the morning (see Figure 5.10).

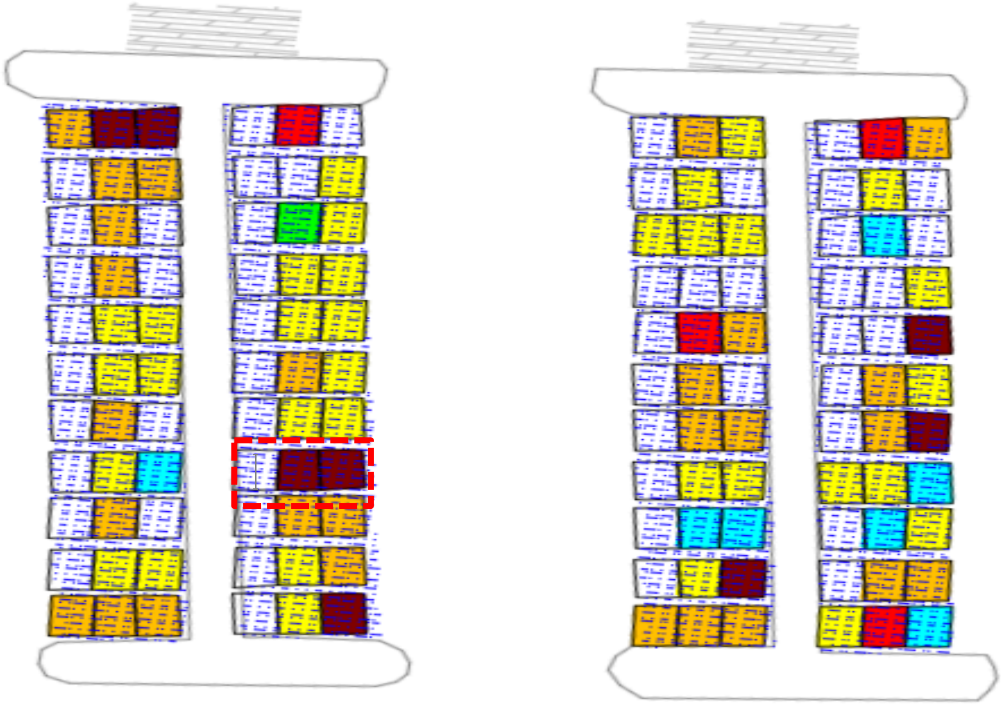


Figure 5.10 Spatial Demonstration of Parking Violation

Moreover, sticker violation rates among communities were estimated. Each community was evaluated on their own. For instance, if there are 100 vehicles in parked with yellow sticker at certain time and 20 of them are violating sticker rule, without looking other vehicles with other sticker types, sticker violation of yellow sticker owners at that specific time was estimated as 20% (see Figure 5.11).
Firstly, it is important to denote that most of the parking spaces at the center of METU campus are reserved for academics, personnel, and students who are yellow sticker owners. Sticker violation is observed less among personnel, academics, and yellow sticker owners comparing to others (see Figure 5.11). It is recognized that it is a common behavior to park without being permitted, among brown and "others" types of sticker owners. Moreover, it was observed that 74% of the vehicles without visitor's card or sticker were parked on a parking lot which is forbidden to them.

Sticker violation was seen approximately at the quarter of the parked vehicles. Among 2840 vehicles parked at noon, 710 of them were violated sticker rule.

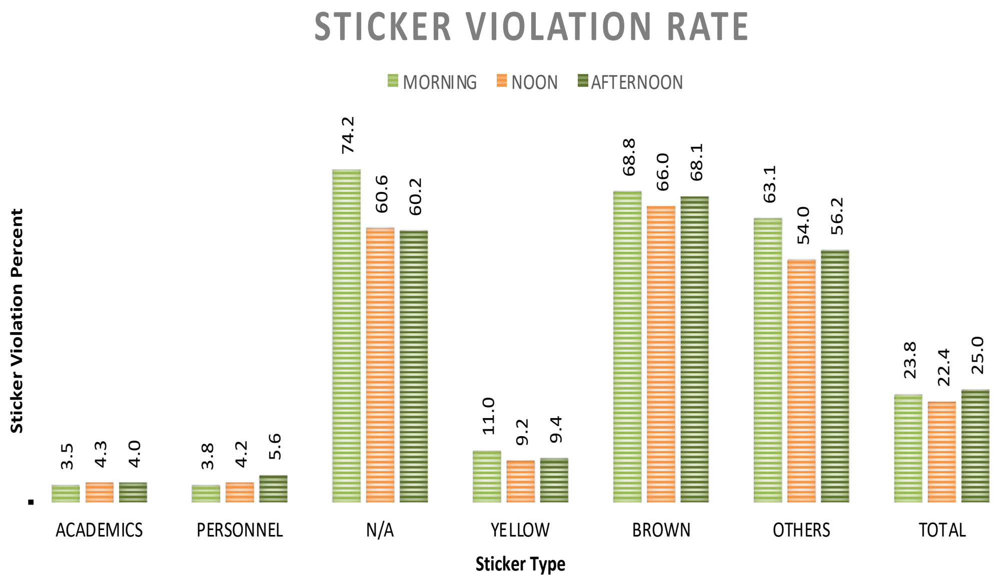


Figure 5.11 Parking Sticker Violation Rate According to Communities

In addition, it is essential to mention Culture and Convention Center (KKM) parking lot. It was restricted to brown sticker owners up till last year. Altıntaşı (2013) estimated the occupancy rate of Culture and Convention Center parking lot as in orderly 75%, 97.5%, and 65%. It can be observed that 85% of the occupancy limit is exceeded just in the afternoon. Nevertheless, it was observed that the occupancy level at Culture and Convention Center from morning to afternoon in the order of 9.86%, 40.82%, and 39.80%, respectively (see Table 5.2). Because occupancy level at Culture and Convention Center parking lot is too low for effective use of parking lot, it might be reconsidered to remove restrictions. Because the occupancy rate of the remote parking lot which is located near the mosque is in the order of 40.28%, 56.94%, and 65.97%. Moreover, Technopolis Satellite Parking Lot has an occupancy rate of 19.62%, 32.28%, 32.28%, respectively (see Table 5.2). By considering the violation rate by brown sticker users, it is approximately 68% at noon (338 vehicles out of 496). It can be concluded that remote parking lots are not being used efficiently and restrictions on Culture and Convention Center parking lot might be loosened at least in the morning and afternoon for making use of it effectively.

5.4.2 No-Parking Violations

No-Parking Violation is that parking the vehicle at forbidden areas, which are identified by delineators or no parking signs at the campus. No-Parking Violation is not a common behavior like sticker violation among METU commuters. In total, No-Parking violation is observed less in the mornings because of the low demand for parking. When the occupancy rate of parking lots increases, No-Parking violation is expected to increase, too. Yet, it depends on not only the occupancy rate of the parking lots but also the desire for walking low distance. For Spiliopoulou (2012), another reason why people park illegally is that people tend to park their vehicles close to the destination. For instance, at Culture and Convention Center parking lot, No-Parking violation rate in the morning was 10% (3 vehicles) At noon, it was 2.5% (3 vehicles), and 2.5% (3 vehicles) in the afternoon. So, it can be inferred that No-Parking violation can not be explained by the occupancy rate, as the major reason was the lack of enforcement since people park their vehicles on the entrance of buildings because of proximity although it is forbidden (Figure 5.12). The reason might be because it is no further penalty requires when the driver does No-Parking violation and sticker violation at the same time.

In total, No-Parking violation was observed slightly more among brown sticker owners compared to the others (see Figure 5.13). Moreover, an inventory which was done at University of West Florida shows that illegal parking occurs more around late office hours comparing to early times (Bjorklund et al., 2005). Likewise it is found that both parking violations had been observed more at late office hours (see Table 5.3).

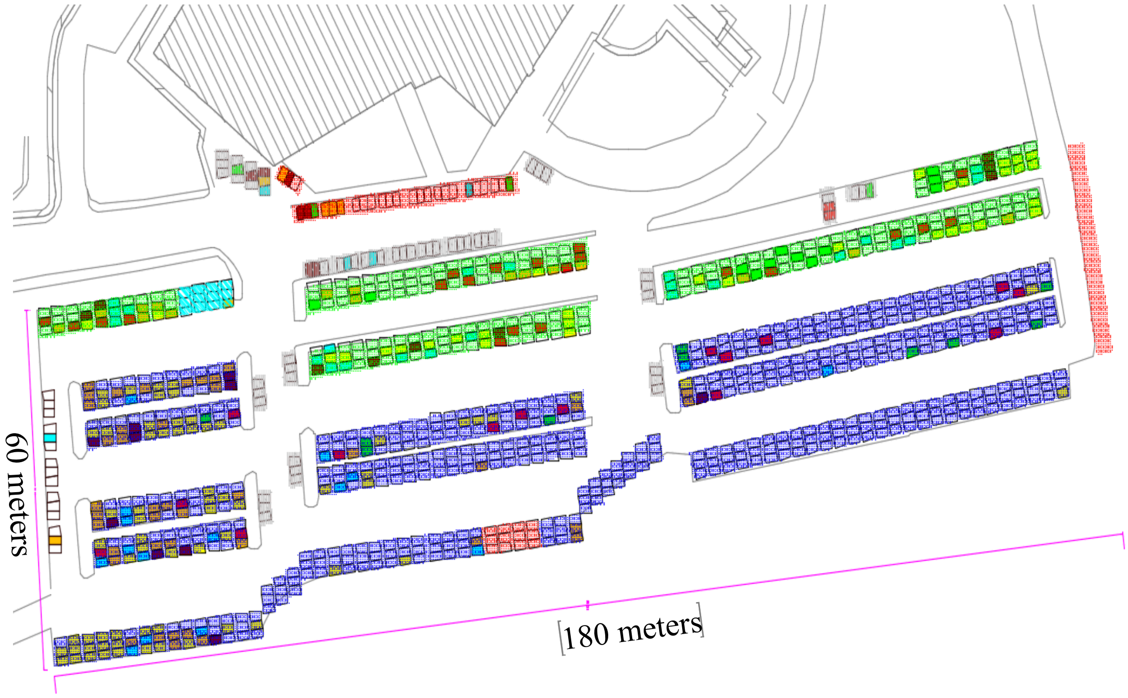


Figure 5.12 Culture and Convention Center Parking Lot Realtime Parking and Authorization for Use Info

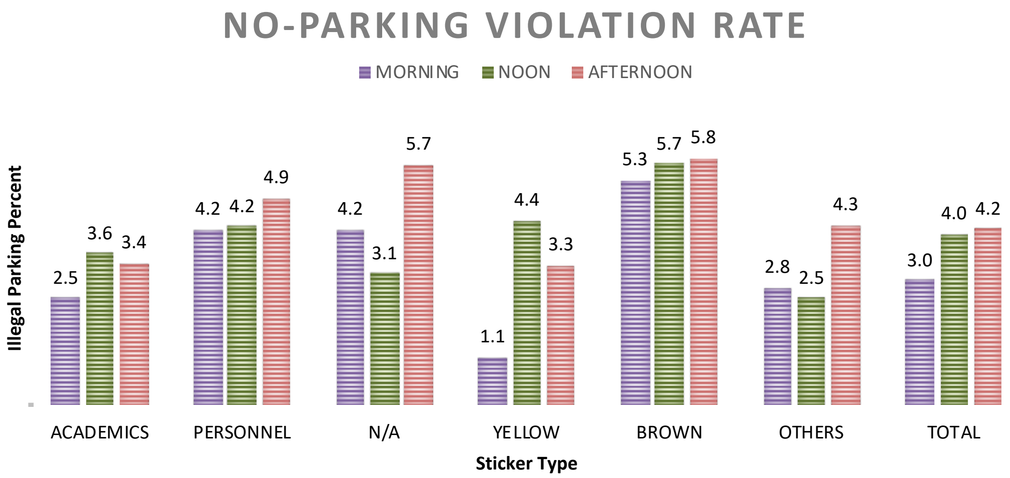


Figure 5.13 No-Parking violation Rate According to Communities

5.5 On-Campus Parking Behavior Evaluation

On-campus parking behavior evaluation consists of a smart campus transportation survey that indicates parking-related behaviors and opinions of METU commuters.

Smart Campus Transportation Survey

It has been found that the majority of the METU campus commuters consider that number of vehicles at METU campus is high. Results indicated that more than 85% of the respondents at the online survey, 90% of the respondents at the face-to-face survey reported the number of vehicles at METU campus as high or very high (see Table 5.4). Nevertheless, more than 90% of the respondents stated that parking supply for these vehicles at METU campus is insufficient (see Table 5.4). It is found that private car use at METU campus was 34.7% according to the online survey. On the other hand, it was 22.8% according to face-to-face survey. (see Table 5.4). Moreover, the most used parking lots were defined as academic and central parking lots according to the online survey (see Table 5.5).

Table 5.4 Perceived number of the vehicles, parking supply and private car use at METU campus

Q1. What do you think about the number of cars in the campus?					
		ONLINE		FACE TO FACE	
N: 865		Frequency	Percent	Frequency	Percent
Valid	Low	6	.7	2	.6
	Moderately low	114	13.2	22	6.9
	High	516	59.7	198	61.9
	Very_high	229	26.5	98	30.6
	Total	**865**	**100.0**	**320**	**100.0**
Q2. What do you think about the parking lot capacity in the campus?					
	Low	458	52.9	159	50.3
	Moderately low	330	38.2	131	41.5
	High	69	8.0	22	6.9
	Very_high	8	.9	4	1.3
	Total	865	100.0	316	100.0
Q3. Do you use private car for in campus transportation?					
	No	565	65.3	247	77.2
	Yes	300	34.7	73	22.8
	Total	865	100.0	320	100.0

Table 5.5 Parking Lot Selection of the Commuters

Q4.I Which parking lot(s) do you generally use? **Descriptive Statistics**					
ONLINE					
	N	N_Yes	Maximum	Mean	Std. Dev.
[Parking lot near my department/unit]	291	0	1	0.74	.438
[Remote parking lot_Main Sports Center]	291	0	1	.18	.381
[Dormitories (East/West)]	291	0	1	.26	.438
[Remote parking lot at mosque]	291	0	1	.12	.322
[Technopolis Satellite Parking Lot	291	0	1	.11	.309
[Remote parking lot at A2 entrance]	291	0	1	.06	.241
[Central parking lots (Library, KKM, Tennis Courts, Shopping Center, Sports Hall, Cafeteria)	291	0	1	.54	.499

In parking occupancy evaluation, although it was concluded that more than quarter of METU commuters park illegally (both sticker violation and No-Parking violation), survey results indicated that only 4.9% of the respondents at the online survey and 13.9% of the respondents at face-to-face survey confessed that they park illegally when their preferred parking lot is full. On the other hand, the majority of respondents (more than 70%) stated that they prefer to check the closest parking lot. (see Table 5.6).

Furthermore, the behavior of No-Parking violation was investigated, in order to discover how often people do parking violation and what enforcements they have experienced. At both of the surveys, 50% of the respondents said that they have never parked illegally by means of both No-Parking violation and sticker violation. On the other hand, at the online survey only 4.9 percent of the respondents and at face-to-face survey 9.2 percent of the respondents stated habitual parking violation (see Table 5.6). Besides, it was reported that approximately 80% of the respondents at the online survey and 65% of the respondents at the face-to-face survey have experienced enforcements like warning, losing sticker temporarily, or permanently (see Table 5.6). These answers also contradict while half of the respondents stated that they have never parked illegally. On the other hand, the answers indicated that 79.2% of them had a warning in the past. Perhaps, they are not aware of what causes parking violations. Therefore, it is important to inform people about parking violation, their rights and the use of parking lots.

Table 5.6 Responses to Questions 5, 6 and 7 regarding Parking Violation in the USTDA survey

Q5. What do you do, if the parking lot you want to park in is full?					
		ONLINE		FACE TO FACE	
		Frequency	%	Frequency	%
Valid	closest_parking_lot	219	76.8	46	70.8
	wait_open_up	31	10.9	4	6.1
	overflow_parking_lot	14	4.9	6	9.2
	parking violation	13	4.6	9	13.9
	other	8	2.8	0	0
	Total	285	100.0	65	100.0
Q6. How often do you park illegally on campus?					
	Never	160	56.6	33	50.8
	Sometimes	109	38.5	26	40.0
	Often	12	4.2	5	7.7
	Always	2	0.7	1	1.5
Q7. What kind of enforcement have you experienced for Parking Violation within campus?					
	no_warning	26	20.8	18	34.6
	got_warning	86	68.8	29	55.8
	sticked_revoked_temporarily	12	9.6	5	9.6
	sticker_revoked_permanently	1	0.8	0	0
	Total	125	100.0	52	100.0

It was asked to respondents about the potential improvements that can be done in purpose of increasing the attractiveness of remote parking lots. According to answers, people want remote parking lots to be closer to the center and the demand for them may be increased by increasing the frequency of the shuttle services. It means that METU campus commuters expect remote parking lots to be more accessible in the first place. Furthermore, increasing the number of parking lots and the capacity of the parking lots were also proposed by many respondents. It draws the attention that in order to make remote parking lots desirable, people suggested parking management strategies and enhancements that tend to increase the use of other modes rather than automobiles. Especially, cycling seems attractive to those who had responded to the questions (Table 5.7).

Table 5.7 Suggestions to Increase Attractiveness of the Remote Parking Lots

Q8. What can be improved at the remote parking lots to make them more desirable places?				
	ONLINE		FACE TO FACE	
	Frequency	%	Frequency	%
Parking Management Strategies				
Increasing Number of Plots	32	7	29	18
Building Recreational Areas Around Plot	9	2	1	1
Advertisement of Plot	8	2	3	2
Increasing Plot Capacity	20	5	12	7
Distribution of Plots	7	2	4	2
Proximity to Center	83	19	52	32
Decreasing Brown Sticker Price	15	3	2	1
Accessibility	25	6	0	0
More rights to Brown Sticker	3	1	4	2
Restriction to Other Stickers	6	1	3	2
Restricting Traffic on Campus	3	1	0	0
Following Rules Strictly	9	2	0	0
Initiatives–- Parking Lot				
Structure	9	2	11	7
Guidance Information System	13	3	2	1
Garage or Multistory PLot	10	2	5	3
Safety	9	2	2	1
Camera	1	0	0	0
Initiatives–- Improved Shuttle Services (29) (18)				
Increasing Shuttle Frequency	86	20	21	13
Shuttle Information System	6	1	0	0
Increasing Reliability	14	3	4	2
Increasing Route Variety	3	1	1	1
Adding Direct Routes	6	1	2	1
Initiatives–- Bicycle				
	27	6	3	2
Initiatives–- Tramway–- Cable Car				
	11	3	1	1
Initiatives–- Walking				
	15	3	1	1

The main purpose of the concept of remote parking is to discourage automobile use at the central district of the campus in order to decrease traffic congestion. Yet, many respondents stated that some parking spaces that locates at near faculties should be dedicated to everyone. At the parking survey, it was found that the top preferred parking lots by brown sticker owners instead of remote ones are that Sport Center and Courts, Swimming Pool, 2,3,4 Dorm Territory, and Tennis Courts parking lots. In other words, the sticker violation was observed mostly on parking lots near the recreational areas.

Furthermore, at face-to-face survey, the respondents were asked what can be other locations for remote parking lots and the face-to-face survey results indicate that respondents want mostly Culture and Convention Center (also shopping area and center is close to those recreational areas) to be remote parking lot which is close to the majority of the recreational areas.

In addition, according to face-to-face survey, it was revealed that there is a demand for parking space close to the faculties, library, cafeteria, and center. Many of the respondents want Cult. Conv. Center (63 respondents) to be remote parking lot. Then, mentioned areas for remote parking are as following; Faculties (29), Center (14), West Dorms (12), Gates (10), East Dorms (9), Cafeteria (9), Library (8) and Shopping Area (7). In other words, it can be inferred that respondents proposed these parking lots as allowed for everyone. They are not supposed to be remote parking lots. It is the fact that both online and face-to-face surveys indicate that there is a demand for more parking lots in which everyone is permitted to park their vehicles.

5.6 Parking Management Needs Assessment

It was observed that the high occupancy rates, overflows, and parking violations decrease the efficiency of parking lots. Therefore, a METU campus parking management strategy was needed to be created. Besides, in this study, it was revealed that each users' perception is different. In addition, sticker violation on the certain parking lot is high, even though its occupancy rate is low. It means that enforcements should be considered for this parking lot. Moreover, at some parking lots overflow had been observed. Thus, the parking lots should be separately analyzed according to their situation. So, parking lots were distributed according to their situations (see Figure 5.14). Parking Lots were separated into 5 categories as: Remote (long-term) Parking Lots, Parking Lots with Lack of Enforcement, Time-dependently High Occupancy Rate, Low-Demanded Parking Lots and High-Demanded Parking Lots that contain parking lots with High Occupancy Rate, and Very High Occupancy Rate.

Parking Lots with Lack of Enforcements

According to the result of the parking survey, it was concluded that at some parking lots behavior of sticker violation is quite common although occupancy rate of these parking lots is low at certain times. The situation might arise due to the lack of enforcement. When examining these parking lots, it was revealed that these parking lots locate at outer proximity of the campus center comparing to others (see Figure 5.14). Lack of Enforcement Category involves parking lots with an occupancy rate that is under 85% and violation rate over the average (23.7%). For instance, at Tennis Courts parking lot average occupancy rate is 81.3 % which is lower than 85%. Moreover, its average sticker violation rate is 47.5 % which is more than the average in total. Therefore, Tennis Courts parking lot is assigned as a parking lot with lack of enforcement. At these parking lots, enforcements are required to be applied stricter. In addition, these parking lots should be considered for sticker redistribution by use.

Parking Lots with Time-Dependently High Occupancy Rate

Peak management is useful while considering campus parking management. It decreases the necessity for more parking space. In order to apply the appropriate strategy, it requires an understanding of peak hours of a certain parking lot. Category of parking lots with a time-dependent high occupancy rate involves parking lots with an average occupancy rate under 85% but more than 85% occupancy rate at a certain time of day (Table 5.8).

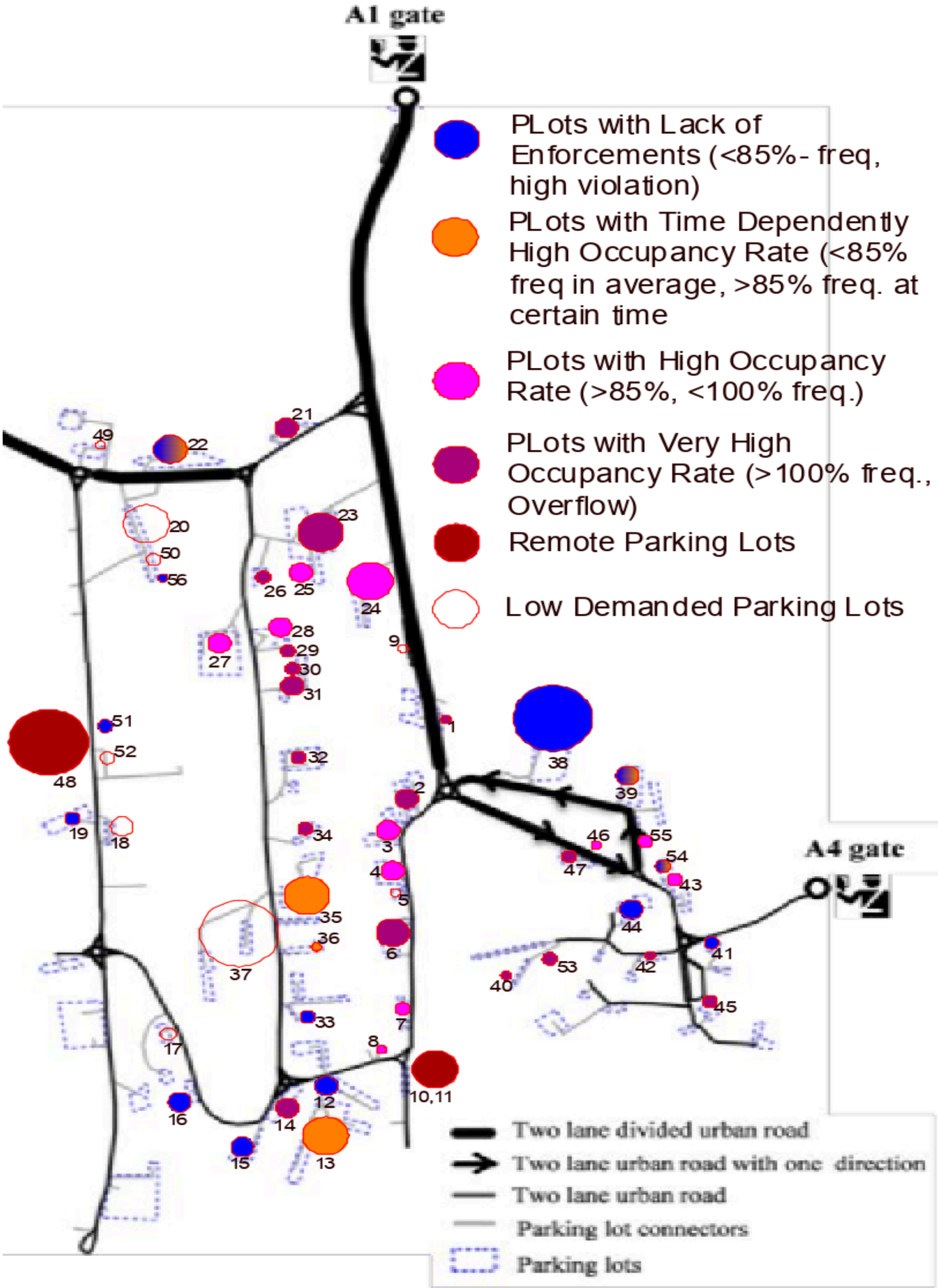


Figure 5.14 Classification of the Parking Lots According to Their Situations

It consists of 6 different parking lots. Moreover, 3 of these parking lots (22,39,54) also assigned for lack of enforcement category because of satisfying requirements for both categories. Furthermore, the occupancy rate of those six parking lots were observed as more than 85% in the morning, at noon or in the afternoon. Therefore, instead of taking precaution for all day long, only the time of day when the occupancy rate of the parking lot is higher than 85% was considered to resolve the high occupancy rate problem.

Table 5.8 Parking Lots with Time-Dependently High Occupancy Rate

PLot No	Description	PSpace	Occupancy Rate			
			A.M	Noon	P.M	Average
13	Dept. of Metal. and Materials Eng.	129	47.3	**86.0**	82.2	**71.8**
22	School of Foreign Lang. Lab.	93	102.2	**89.2**	43.0	**78.1**
35	Dep. of Elect. and Electronics	131	54.2	84.0	**88.5**	**75.6**
36	Central Laboratory	22	**95.5**	77.3	81.8	**84.8**
39	Tennis Courts	73	43.8	**100.0**	**100.0**	**81.3**
54	Housing Territory 2	33	39.4	**100.0**	**87.9**	**75.8**

High-Demanded Parking Lots

Category of High-Demanded Parking Lots involves parking lots with more than 85% occupancy rate on average. Because of the high demand for these parking lots, it is essential to take precautions. High-Demanded Parking Lots Category is divided into two, one of them involves parking lots with occupancy rate (in average) between 85% to 100% and the second one involves parking lots that are overflow. In other words, the other one consists of parking lots with over than 100% occupancy rate on average. In total 28 parking lots at the study area are with more than 85% occupancy rate. Northern part of METU campus seems critical because almost every parking lot at there is with high occupancy rate (see Figure 5.14)

Remote Parking Lots

Remote Parking Lots were defined as long-term parking lots. Normally, transportation from these parking lots needs to be by shuttle services. However, parking lots 10 and11 (Mosque PLot) are located at a walking distance from some of the departments. On the other hand, Technopolis Satellite Parking Lot (48) is far from most of the departments. (See Figure 5.14)

Low-Demanded Parking Lots

There are 9 remaining parking lots that is not involved at any of the categories. From these parking lots, School of Foreign Language Basic (49) was under construction. Therefore, it wasn't involved within the parking survey. Moreover, parking at Civil Engineering Storage (5) is forbidden, although it is being used currently. Remaining parking lots with low-demand are 9,17,18,20,37,50,52 (see Figure 5.14).

5.7 Summary of the Major Findings

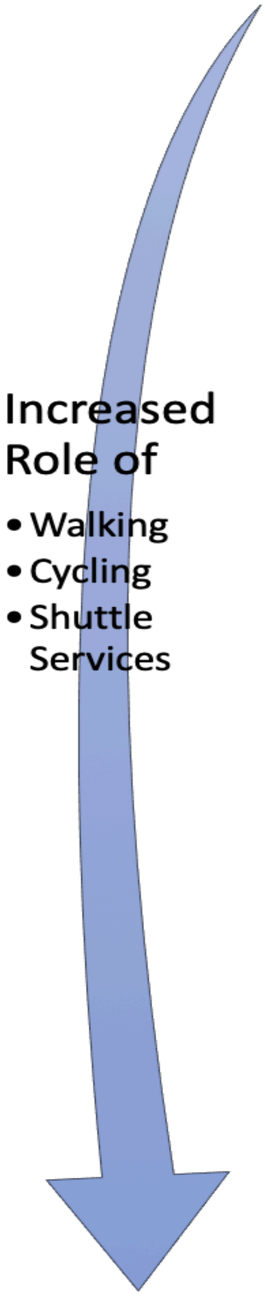
Evaluation of the parking supply and demand is important in order to establish a parking management plan for METU campus. It is therefore necessary to identify infrastructure overflows, parking violations, and the extent of parking problems and parking behavior of commuters. So, the parking needs of METU campus were identified by utilizing a series of analyses. The smart parking strategy plan, which was discussed in the following chapter, was prepared according to the analysis presented in this chapter, literature (Chapter 2), and previous METU campus transportation studies (Chapter 3).

CHAPTER 6

METU CAMPUS SMART PARKING MANAGEMENT STRATEGY PLAN

According to the findings of the previous chapters, a parking management strategy plan was established in order to overcome parking-related problems at METU campus. The plan consists of two different phases: i) a campus-wide strategy plan, and ii) a strategy plan for only problematic areas. Initially, a campus-wide parking management plan was prepared based on the evaluations in Chapter 5, and then another strategy was proposed for only problematic areas at the campus. The campus-wide parking management plan consisted of seven stages. And they were identified in order to cope with the traffic congestion on campus. These stages were indicated (see Figure 6.1).

By following these stages, different strategies were developed for the different locations of the campus. Accordingly, parking pricing and restrictions were identified as the main strategies. However, the identification of the potential areas for the implementation of parking pricing and restriction strategies was essential (see Figure 6.2). Thus, for the analysis, the campus area was divided into 5 main zones and a strategic plan was improved by considering these zones (see Figure 6.3). The borders of the zones were determined by considering walking distance mainly (approximately 400 meters). Strategies that were proposed for zones were improved by considering the occupancy rate of parking lots, sticker violation frequencies, and serving area of the parking lots.



STAGE 1 Decision Making Parking Management Strategies • Parking Maximums Parking Management Systems
STAGE 2 Signs • Clear Markings on Parking Spaces and No-Parking Areas • Implementing PGI Parking Regulations • Prohibit Roadside Parking, Parking at high pedestrian mobility, Plot Alley and Entrance
STAGE 3 Parking Pricing • Smart Payment System Enforcements Parking Regulations • Parking Sticker Redistribution by Sticker Use
STAGE 4 Enforcements • Direct Punishments • Camera-Electronic Enforcements Campaigns to inform people regarding what causes parking violation
STAGE 5 Parking pricing • Increased Fees • More parking spaces for a fee
STAGE 6 Remote Parking Lots • Increased Shuttle Services • Transit-Based Information System • Construct new Remote Parking Lots
STAGE 7 • Parking Restrictions • Non-motorized and public transportation oriented transportation system • Parking Reservation System

Figure 6.1 METU Campus-wide Parking Management Strategy Plan

6.1 METU Campus-wide Smart Parking Management Strategy Recommendations

Bond and Steiner (2006) liken universities with campuses to central business districts as they have less parking supply than the demand for parking. Therefore, the campus-wide smart parking management strategic plan was developed based on the central business district plan of Bond and Steiner (2006), insight of the surveys, and inventory. The campus-wide strategic plan involves an order of the required strategies and systems. Current situations and reactions regarding parking at METU campus were discussed below based on the 7-stage approach shown in Figure 6.1.

Stage 1: At first, it requires to understand the extent of the parking problem at the campus. If the attractiveness of the area is affected by parking behavior, it requires to develop reactions in order to overcome parking problems. The first stage is the determinations of the parking measures that need to be taken. The findings of parking inventory, parking survey and smart campus transportation survey indicated that currently, METU campus suffers mainly from parking problems because of the lack of management strategies. In order to deal with the parking problems at METU campus, parking management strategies, systems, and smart sustainable campus policies require to be determined for the campus.

Stage 2: During parking space inventory, it was observed that road markings for parking spaces were missing (See the evaluation of parking supply in Chapter 5) and it causes vagueness. At the parking space inventory study, it was recognized that from the designated parking spaces, only 68% of the parking spaces (2235) are marked. Besides, from these 2235 parking spaces, approximately only half of them are marked clearly. The rest of them are hardly visible. First of all, all the pavement markings require to be clean and visible.

Furthermore, Parking Guidance Information System (PGI) (Section 2.3.1) systems could be implemented in order to direct the drivers to available parking spaces or parking lots. Since there is no PGI system applied within the campus, traffic congestion occurs due to cruising in high demanded areas. For instance, findings of parking surveys indicated that at the Northern part of the campus occupancy rates of parking lots (PLot No: 21,23,24,25,26,27,28,29,30,31) are high. Correspondingly, Altıntaşı (2013) found that corridors around these parking lots suffer from high traffic volume. In addition, according to Gulluoglu (2005) populations of near buildings are high, and trip demand is high like Faculty of Economics and Administrative Science and Architecture.

Moreover, although roadside parking is undesirable at some areas with high pedestrian volume, this behavior seems common among the community. Rearrangement needs to be done and it should be prohibited in order to provide a safe environment for both pedestrians, cyclists, and drivers. As Karatas (2015) found that there is high pedestrian mobility from Dormitories Zone (see Figure 1.2 and 3.3) to Faculties, vehicular traffic creates a risky environment. Therefore, parking in these areas needs to be prohibited in order to promote walking.

Stage 3: Parking time limitation as a strategy can be also implemented at METU campus. In high demanded areas, it would be very useful to discourage long term parking. Nevertheless, for a campus environment, implementing time restriction may be difficult to manage but parking pricing strategy can be applied at different prices by considering peak hours as found at parking surveys from noon to afternoon (12:00 to 17:00). Parking pricing strategy can be applied with a smart payment system in order to provide ease and convenient service to the customer. In addition, priced parking would provide a privilege to those who need parking space for a short period. So, the demand for remote parking lots can be increased. So, a driver would be able to use paid parking space in case of having a rush or if traveling more than one person. The reason is to decrease traffic congestion by encouraging people to use parking lots that locate outside of the central district.

Nevertheless, in order to achieve such a strategy, it requires to implement enforcement in the first place. Actually, without applying enforcements efficiently, parking pricing strategy collapses. According to the parking survey, it was found that almost 25% of the parking actions resulted in parking violation and there were parking lots with low occupancy rate and high parking violation rates, it can be concluded that enforcement application is weak at METU campus.

Stage 4: Moreover, there is a distinction between sticker owners at METU campus, too. Some building parking lots are only reserved for faculty members, personnel or yellow sticker owners. Moreover, visitors are only allowed to use general parking lots. Violating parking rules three times, results in loss of sticker temporarily or permanently but visitors don't have any, so there is no enforcement to visitors. Since there is no enforcement to the visitor drivers, it is found that drivers with visitor card park their vehicles to nonauthorized parking lots. So, visitors need to be under control by means of parking. Moreover, with an application, it is possible to record the plate number of visitors. Thus, violators can be banned from entering to METU campus and people would be discouraged to penetrate rules. Moreover, visitors can be directed to paid parking spaces or remote parking lots, which everybody can park their vehicles, if they don't want to pay for parking. So, general parking lots can be removed and dedicated for other communities. Besides, enforcement that is applied at the moment is not sufficient, sticker violation observed too much among brown sticker owners (Approximately 68%).

It proves that both the efficiency of remote parking lots and the enforcements need to be reconsidered and rearranged. Enforcements can be conducted electronically by cameras. Also, the scope of the parking violations (what does cause parking violation) requires to be explained with campaigns and it requires more direct punishments and stricter enforcements.

Stage 5: Before implementing and observing the results of the strategies in the first four stages, there is no need to consider the fifth stage. After applying the first four stages, if it will be considered necessary (existence of parking problem, full parking lots, spillover), the fifth stage should be applied. According to the parking survey, currently, 17 (32%) parking lots suffer from spillover problems. After implementing the strategies at the first four stages, the number of parking lots which face spillover should be evaluated again.

Because the majority of parking lots which suffer from spillover locate at the central district, demand requires to be declined at these parking lots. At this level what is being discussed is the amount of parking fee in order to discourage demand for parking space. At this level, the parking fee should be arranged in order to hold the occupancy rate at maximum 85%. Right now there are 28 parking lots (52%) which are with more than 85% occupancy rate. Moreover, the number of the parking spaces reserved for paid parking can be increased in order to hold the demand for parking far from the campus central district because most of the high occupied parking lots are located at the center of the campus (see Figure 5.14).

Stage 6: If the parking problems still continue, it is important to increase the attractiveness of remote parking lots that locate at the outer circle of the campus. Although shuttle services need to be enhanced at every stage, at the sixth stage the improvements should be devoted to shuttle services. As it was mentioned, according to the smart campus transportation survey about the efficiency of shuttle services, people mostly complain about the frequency of shuttle services. In order to increase the efficiency of the remote parking lots, frequency and punctuality of shuttle services should be increased. Moreover, Gulluoglu (2005) proposed shuttle service routes and stops by considering the population density of the buildings. To increase the attractiveness of the remote parking lots, shuttle services should be managed as oriented to remote parking lots and high occupied buildings.

In addition, a transit-based information system can be implemented in order to provide better service to users. Besides, more remote parking lots can be constructed if needed.

Stage 7: The final precaution for smart parking management at METU campus is related to mobility. For a campus-like METU, a mobility management strategy is needed to be implemented without looking at other strategies. In other words, the mobility management strategy is needed to be enhanced independently from strategies that are mentioned above.

The idea of mobility management is to improve accessibility on campus. Thus, it is essential to have a good quality of walking path, cycling path, and shuttle services. Yet, from the surveys, it was found that people complain about safety-related problems mostly regarding to walkability. As it was stated in the previous studies and surveys, these problems are majorly due to wild animals and lack of lights. Hence, it is important to provide a safe, walkable environment at the campus. The same obstacles are valid for bicycle users, too. Besides, there are only two cycling paths which are located between A1 gate to rectorate building and A4 gate to Sunshine cafeteria. Online survey results indicated that people are willing to use bicycles if circumstances are convenient. In addition, walkways are narrow for both walking and cycling. Therefore, a cycling path, that combines the whole campus, is needed to be constructed. In addition, wide walking path (alley) that is located between faculties is not suitable for cycling. Besides, in order to promote cycling, it is important to provide bicycle stands, lockers, campus map, and safe environment. In addition, bike-sharing system accompanied with a mobile application may have great effect use of bicycles at METU campus.

The efficiency of shuttle services is another issue at METU campus. First of all, people complain mostly about shuttle service frequency which has proofed that shuttle services are not able to respond to the demand. Moreover, it was recognized that there is a hitchhiking culture at METU campus. Ozbilen (2016) estimated that from 852 trips, 86 of them was hitchhiking, which is 10% of all trips. Generally, people hitchhike in between rectorate building and A1 gate. It reveals that the frequency of shuttle services is not sufficient right now because there is also a shuttle bus service that follows the same route every 15 minutes. The time intervals can be organized according to the peak hours (According to Altıntaşı (2013) in terms of trip demand, peak hours are as 08:15 - 09:15 and 17:15 - 18:15). Besides, people expect shuttle services to work punctually.

Moreover, walking long distances to shuttle services stops after parking the vehicle on remote parking lots encourage people not to use those remote parking lots. Therefore, according to Gulluoglu (2005), shuttle stops should be frequent near high populated buildings which are located generally in the northern part of the campus. Furthermore, survey results indicated that people demand for more direct and variable routes for the shuttles. Comfort is another expectation. In order to decrease automobile use at METU campus, it is crucial to design user-friendly shuttle services.

As a summary, initially, the frequency and routes of shuttle services are needed to be optimized according to the trip demand. Then, they are required to be timewise. In other words, factors that cause loss of time to users are needed to be eliminated. For increasing the reliability, shuttle services require to be managed on time and controlled. Also, it is essential to give information to users. Respondents at the Smart Campus Transportation survey stated that the current mobile application is not working effectively, and providing wrong information about where the bus at a specific time. It is essential to enhance the mobile application and provide precise information about the destination arrival time and the current location of the buses. That information requires to be visible on bus stops, too.

Also, surveys indicated that people demand cableway or tramway from A1 gate to rectorate building as an additional mode to shuttle services. In 2005, Gulluoglu proposed Trolleybus and Monorail as public transportation within the campus.

Moreover, for the purpose of contributing environmental, shuttle services are needed to be switched with electric buses in time, and bus stops can be worked with solar energy. So, Stage 7 involves a non-motorized and public transportation-oriented transportation system. In other words, the modes that are mentioned above oriented transportation system is proposed for Stage 7. In this case, parking restrictions should be applied strictly. Parking at many areas of the campus should be forbidden. In addition, a parking reservation system can be implemented at parking lots. Thus, the only identified vehicle owner can use the parking lot. Above all, shuttle services, public transportation services require to be very well-provided. Furthermore, the environment for walking and cycling must be convenient.

6.2 Proposed Parking Management Zoning for METU Campus

Applying different strategies to the parking lots might cause conflict in management. Thus, handling these parking lots might be difficult. Therefore, it is essential to implement a strategy for larger areas. Hence, the campus area was divided into zones. By analyzing the use of parking lots and their occupancy rate, 5 different major zones were defined for improving a parking strategy. These 5 Zones were defined as Center Zone (Campus Core District) consist of department parking lots mostly, North Zone, South Zone, East Zone, and West Zone. Moreover, these zones were divided into smaller pieces by considering the walking distance of 400 meters (see Figure 6.3). The Figure 6.3, also includes Technopolis and Houses, those areas were not included in the study area and they were illustrated by gray shape.

In addition, at areas with high pedestrian mobility, parking requires to be prohibited at campus environment in order to provide walkable environment to people. Furthermore, on-street parking causes a risky environment at the campus. Thus, on-street parking should be prohibited. In addition, at alleys and entrances of parking lots should be banned for parking too. Furthermore, no-parking zones should be under strict enforcement. Therefore, No-parking zone involves areas with high pedestrian mobility, on-street parking, parking lot alleys, and entrances. Moreover, undesignated areas that are being used for parking, which were identified as No-Parking zones and those are visualized by gray color code (See Appendix C). Besides, remote parking lots were illustrated separately and identified as Long-Term Parking Zone although they are included in certain zones (see Figure 6.2).

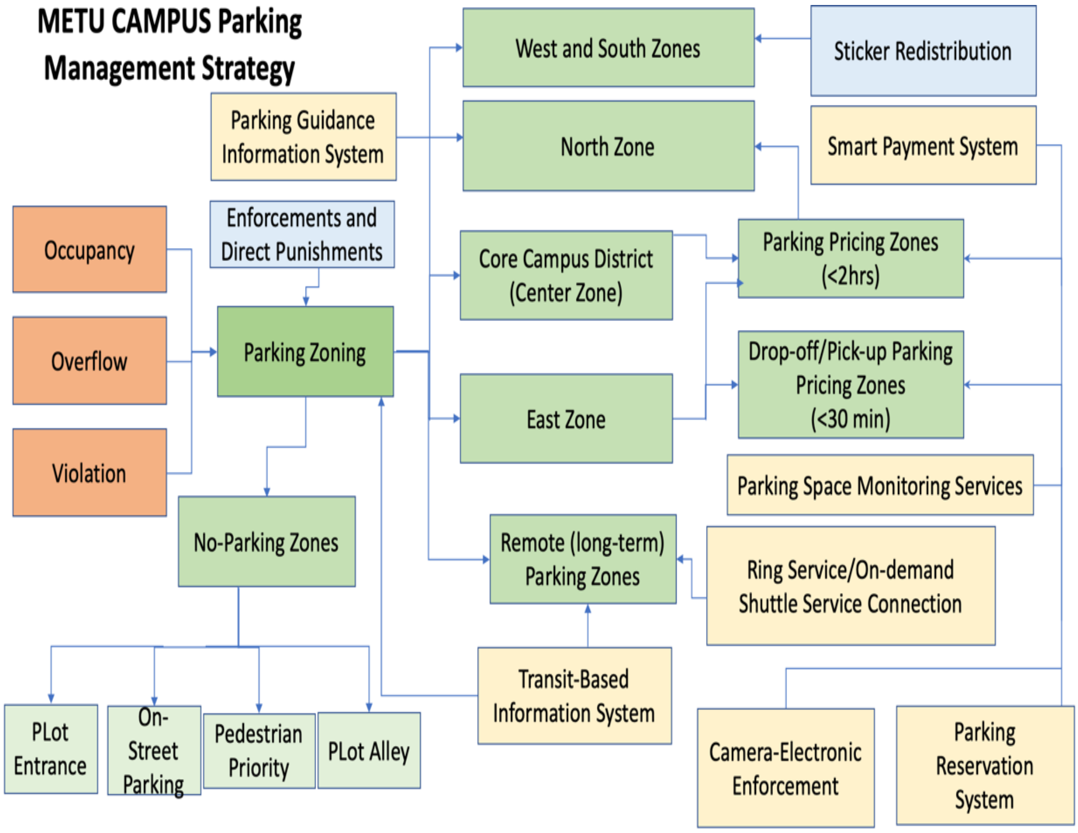


Figure 6.2 Parking Management Plan by Zones

Figure 6.3 Zones for Parking Management Strategies

Center Zone: Center Zone consists of parking lots that are very highly-demanded (see Figure 6.3). Because of high demand and high occupancy rates of the parking lots, and common behavior of parking at undesignated areas in Center Zone, parking problem occurs at Center Zone mostly. Besides, the majority of the departments are located in high demanded areas. Therefore, it is essential to take precautions for these parking lots primarily. For instance, it can be suggested that certain parts of some parking lots can be priced at these high demanded areas. With applied parking pricing strategy, the drivers can be able to find available parking space (short term paid) or drive to free parking lots if the driver does not want to pay for parking. Parking lots at these zones can be supported by smart payment systems, and parking reservation systems can be implemented too. Most importantly, enforcements are needed to be followed strictly, therefore electronic enforcement with cameras can be considered for these areas. In this study, Center Zone, which is indicated by red lines at Figure 6.3, is divided into 7 smaller areas. At Center Zone, parts of 13 parking lots are selected for implementing parking pricing strategy. Parking fee is proposed to be collected with two hours intervals. In total 236 (17%) parking spaces out of 1361 parking spaces are proposed for paid parking at Center Zone (see Table 6.1).

East Zone: Another high-demanded area is around Shopping Area which is located at East Zone. It is indicated with a yellow line (see Figure 6.3). Parking pricing strategy requires to be implemented to parking lots around the shopping area, too. Thus, some parking lots at East Zone can be switched into priced parking lots. In addition, in order to increase circulation, parking fees should be collected with short intervals at these parking lots. For this purpose, five parking lots were selected for parking pricing strategy. Similar to the parking lots at Center Zone, part of Culture and Convention and Tennis Courts Parking Lots are proposed to be paid parking with 2 hours intervals. In total, 61 parking spaces are proposed for priced parking at Zone E1 (see Table 6.1). Moreover, three parking lots that are Bank Territory, Gymnasium and Shopping Center are proposed as paid parking entirely with 30 minutes intervals. In total, 91 parking spaces are offered for priced parking with 30 minutes interval (see Table 6.1 and Figure 6.3).

Table 6.1 Proposed Parking Pricing Plan for METU

Plot No	Plot Name	PS	PPS	%	Parking Pricing	Parking Zone
PMZC1 (TPS= 187), (PPS=37), (%=20)						
23	Fac. of Economics and Adm. Sci.	105	27	26	2-hr parking	C1
26	Fac. of Arch. 1	25	10	40	2-hr parking	C1
PMZC2 (TPS= 192), (PPS=34), (%=18)						
27	Dept. of Biology	60	14	23	2-hr parking	C2
28	Human Sciences	67	11	16	2-hr parking	C2
29	Dep. of Math.	37	9	24	2-hr parking	C2
PMZC3 (TPS= 152), (PPS=59), (%=39)						
1	Social Building	12	12	100	2-hr parking	C3
9	Presidency Roadside	20	20	100	2-hr parking	C3
24	Library	120	27	23	2-hr parking	C3
PMZC4 (TPS= 207), (PPS=27), (%=13)						
34	Industrial Engineering	37	27	73	2-hr parking	C4
PMZC5 (TPS= 193), (PPS=39), (%=20)						
2	Cafeteria	54	34	63	2-hr parking	C5
4	Computer Center	69	5	7	2-hr parking	C5
PMZC6 (TPS= 184), (PPS=20), (%=11)						
35	Dep. of Elect. and Electronics	62	20	32	2-hr parking	C6
PMZC7 (TPS= 246), (PPS=20), (%=8)						
6	Civil Engineering	83	15	18	2-hr parking	C7
33	Chemical Engineering	46	5	11	2-hr parking	C7
PMZN (TPS= 219), (PPS=16), (%=7)						
22	School of Foreign Lang. Lab.	93	16	17	2-hr parking	N1, N2
PMZE1 (TPS= 367), (PPS=61), (%=17)						
38	Cult. And Conv. Center	294	42	14	2-hr parking	E1
39	Tennis Courts	73	19	26	2-hr parking	E1
PMZE2 (TPS= 91), (PPS=91), (%=100)						
46	Bank Territory	18	18	100	30-minute parking	E2
47	Gymnasium	42	42	100	30-minute parking	E2
55	Shopping Center	31	31	100	30-minute parking	E2
No-Parking Zones						
40	Sport Center and Courts	18	---		Both designated and undesignated spaces used for parking should be forbidden.	E3
42	2,3,4 Dorm. Territory	16	---			E3
53	Swimming Pool	25	---			E3

PS: Parking Spaces; PPS: Paid Parking Spaces; TPS: Total Parking Spaces at Zone

Besides, because of high pedestrian mobility, Sport Center and Courts, 2,3,4 Dormitory Territory and Swimming Pool parking lots are assigned as No-Parking Zone (see Figure 6.3). In total 59 parking spaces are proposed as forbidden to parking rather roadside parking. (see Table 6.1).

North Zone: North Zone that is illustrated with a blue line (see Figure 6.3), involves three parking lots. Only, a part of the parking lot of School of Foreign Language Lab is proposed for paid parking in order to provide available parking lot for the drivers (see Table 6.1).

West Zone: At Figure 6.3 the area that locates in shape with green color refers to West Zone. Occupancy rates of the parking lots at West Zone are low compared to the other zones. Therefore, a parking pricing strategy is not proposed for this zone. Yet, it is important to mention the remote parking lot that locates at West Zone. Technopolis Satellite Parking Lot (48) can be considered as Remote parking lot. It is shown in the brown line at West Zone (see Figure 6.3). Effectiveness of Technopolis Satellite Parking Lot can be increased by adding shuttle services with high frequency and Transit-Based Information System accordingly. In other words, the attractiveness of the parking lot can be increased.

South Zone: South Zone that is shown by a purple line (see Figure 6.3). It is one of the low demanded zones. Therefore, there is no proposed paid parking lot. Yet, parking management requires for South Zone, too. First of all, although parking lot 10,11 is identified as Remote Parking Lot (see Figure 6.3, brown line at South Zone), it should be considered as a parking lot where every sticker owner is allowed to use. Like Parking Lot 10,11, some parking lots can be switched into parking lot that is allowed for everyone. Parking Lots with low occupancy rates requires to be switched into parking lots that are allowed for everyone.

Moreover, after prohibiting roadside parking at S3 (South 3) Zone, a parking lot with high capacity should be constructed in order to respond the parking demand.

Furthermore, Sticker Redistribution can be considered for remaining parking lots (9,17,18,20,37,50,52) with the low occupancy rates and parking violations. In other words, they can be converted to be allowed for all sticker type owners as they have low occupancy rates. Those parking lots can be allowed for everyone like parking lot 10 and11. Thus, it is possible to decrease sticker violation, no-parking violation, and demand for parking lots with high occupancy rates.

CHAPTER 7

CONCLUSION AND FUTURE RECOMMENDATIONS

7.1 Conclusion

With the development of technology, the built environment concept has become more complex. According to these developments, transportation problems also require more systematic and rational solutions. Middle East Technical University (METU) suffers from transportation-related problems due to the limited number of parking spaces at the campus. On the other hand, increasing the number of parking lots would cause problems such as traffic congestion, air pollution, and unsafe environment for pedestrians and cyclists. Therefore, the need for a well-developed parking management is emerged for the campus.

As a summary of this thesis study, a comprehensive smart campus transport survey was developed and carried out both face-to-face and online. Surveys were conducted to analyze the transportation experience on METU campus and the status of parking lots. Findings are as following:

- It was concluded that automobile use is common in METU campus and the number of parking spaces is insufficient. However, many of the respondents do not prefer to use automobile within METU campus.
- According to statements of the respondents, the most used parking lots are departments, Library, KKM, Tennis Courts, Shopping Center, Gymnasium and Cafeteria parking lots.
- The majority of the respondents specified that in case of desired parking lot is full, they prefer to use the closest parking lots which causes cruising and traffic congestion.

- Although more than 50% of the respondents denoted that they have never parked illegally, only a minority of the respondents denoted that they didn't take a penalty. So, it was understood that people don't aware of what causes parking violations.
- In order to promote the use of remote parking lots, people expect increased frequency of shuttle services and remote parking to be located close to the center of the campus.

In addition, an inventory of parking space was performed to measure the parking supply of the METU campus. Then, a separate parking survey was conducted to examine the occupancy rates of parking lots, parking violations, and parking behavior.

- It was revealed that at many of the designated parking spaces, pavement markings are missing or not visible.
- The number of stickers given at METU campus has been increased by 60 percent in the last decade.
- It is found that there are 3308 designated and 732 undesignated parking spaces at METU campus. All of the undesignated parking spaces are proposed as forbidden, considering traffic and pedestrian safety.
- It is found that the occupancy level of the parking lots has been increased since 2013.
- It was detected that out of 56 parking lots, 20 of the parking lots exceed the 85% capacity limit all the time. It means that occupancy levels of the parking lots are drastically high.
- It is recognized that it is a common behavior to park without being permitted, among brown and "others" types of sticker owners. Also, many vehicles without visitor's card or sticker were found as parked at forbidden parking lots.
- Proximity related No-parking violations were observed.
- Efficiencies of the remote parking lots are low at the moment.
- Enforcements are not applied strictly.

- Personnel tend to park for a long time. On the other hand, student population increases more in the afternoon.

Consequently, the high levels of occupancy, overflows and parking violations have been observed that lower the efficiency of parking lots. In addition, the sticker violation on some parking lots is high, even though their occupancy level is low. This ensures that enforcements at these parking lots require to be considered. In addition, the overflow of some parking lots was observed. The parking lots can also be evaluated separately according to their situation. As a result, parking lots were allocated according to their circumstances. Parking lots are divided into five categories as follows: Remote (long-term) Parking Lots, Parking Lots with Lack of Enforcement, Time-dependently High Occupancy Rate, Low-Demanded Parking Lots and High-Demanded Parking Lots that contain parking lots with High Occupancy Rate, and Very High Occupancy Rate. As a result, it was concluded that it is necessary to develop a METU parking management strategy.

After understanding the transportation habits of METU commuters and the current status of the vehicles and parking lots, potential strategies were determined by following earlier studies on central business districts in the literature in order to achieve smart mobility requirements in the campus environment. The results indicate that at METU campus there is a need for smart parking management.

In order to achieve smart mobility at the campus by means of parking, a strategic plan was created. The strategic plan was created in the scope of smart parking management which concerns the environment, social and economic outcomes by providing an accessible environment and using technology. The strategic plan consists of 7 stages which were proposed to be followed. Rather than increasing parking supply, more convenient and promising strategies were offered.

Moreover, the campus was divided into zones in order to interfere with the most problematic areas. For most problematic areas that suffer from parking, the strategy of parking pricing was offered in order to conserve the occupancy rate of parking lots at 85%. Furthermore, areas with high pedestrian mobility, parking lot alleys and roadside parking were offered as No-parking areas in order to provide a safe environment for pedestrians and cyclists.

7.2 Limitations and Further Recommendations

The parking survey was conducted on a single day due to budget limitations. During the data collection, some parking lots were under construction. Therefore, these parking lots need to be also considered in the future studies. In addition, the study area may be extended to Technopolis and Dormitory areas. Furthermore, surveys that are conducted at different times of the year would provide more precise results, therefore several repetition of the parking survey should be considered.

After implementing the proposed strategy, parking fees should be set according to preserve occupancy rates of the parking lots at 85%. Parking spaces that are dedicated for parking pricing strategy can be increased, if it is needed. Moreover, parking survey should be repeated, after implementing the suggested strategies since the level of the traffic congestion and critic locations would change. Furthermore, a study that consists of the evaluation of shuttle services and public transportation services should be conducted because it is essential to understand public transportation services in order to promote their use. Also, investments on ride-sharing programs like carpooling and car-sharing (car, bike, scooter etc.) could be tried in the future.

In addition, this study can be adaptable for not only universities with campuses but also it enlights CBD’s parking problems, too. In the future, smart parking systems should be studied in detail due to the progress in technology.

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APPENDICES

A. SMART CAMPUS TRANSPORTATION SURVEY

Table A. 1 Smart Campus Transportation Survey

1. What do you think about the number of cars in the campus? ( ) Low ( ) Somewhat low ( ) High ( ) Very high
2. What do you think about the parking lot capacity in the campus? ( ) Low ( ) Somewhat low ( ) High ( ) Very high
3. When you drive a private car, which parking lot(s) do you generally use? (Select all applies) ( ) I do not drive in campus ( ) Parking lot near my department/unit ( ) Dormitories (East/West) ( ) Remote parking lot at mosque ( ) Remote parking lot at tec ( ) Remote parking lot at A2 entrance ( ) Central parking lots *(Library, KKM, Tennis Courts, Shopping Center, Sports Hall, Cafeteria)* ( ) Remote parking lot at Main Sports Center ( ) Other (Please, specify)………………………………..
4. What do you do, if the parking lot you want to park in is full? (check one) ( ) Go to the next closest parking lot. ( ) Wait for a space to open up. ( ) Go to an overflow parking lot. ( ) Park illegally ( ) Other (Please specify)………………………
5. How often do you park illegally on campus? ( ) I do not drive in campus ( ) Never ( ) Seldom ( ) Often ( ) Always
6. What kind of enforcement have you experienced for Parking Violation within campus? ( ) I did not get any warning ( ) My sticker was revoked temporarily ( ) I got a warning ( ) My sticker was revoked permanently. ( ) Other (please specify)…………………………………………………………………
7. What can be improved at the remote parking lots to make them a more desirable places? ……………………………………………………………………….
8. Which locations should be selected for remote parking lots? **…………………………………………………………………………………………..**

B. PARKING PRICING AND WILLINGNESS TO PAY INTERVIEW

1. Sıradan bir gününüzde genel olarak kampüs ulaşımınızı nasıl sağladığınızı anlatır mısınız?
   a. Kampüse gelirken özel araç kullanıyor musunuz? Bu tercihinizi etkileyen faktörler hakkında konuşabilir miyiz?
   b. Hangi taşıt puluna sahipsiniz? Almış olduğunuz taşıt pulu sizce hangi hakları sağlıyor?
   c. Genelde nereye park ediyorsunuz?
2. Kampüs içi ulaşımda, ne sıklıkta ve nerelere giderken özel araç kullanıyorsunuz? Gittiğiniz yerlerde park yeri bulabiliyor musunuz?
3. Kampüs içerisinde yaşanan park sıkıntıları hakkında ne düşünüyorsunuz?
   a. Öğrencilere otopark hakkı tanınması,
   b. Misafirlere otopark yeri ayrılması,
   c. Uydu otoparkları,
4. Sizce bu sıkıntıların giderilmesi/azaltılması için ne tür uygulamalar/politikalar geliştirilebilir?
5. Uydu otoparklarının daha etkin kullanımı için ne tür uygulamalar yapılabilir?
6. Kampus içerisinde sıklıkla/çoğunlukla talep edilen yerlerde (kütüphane, çarşı bölgesi, kafeterya gibi) şehir (kent merkezi)'deki uygulamalar gibi, daha adil kullanım sağlamak için kısa süreli ve ücretli otopark yönetimi konusunda neler düşünüyorsunuz? Böyle bir uygulama geliştirilirse sizce nasıl bir ücret tarifesi geliştirilmelidir ?

☐ <Yarım saatten az.................. ☐ 1-2 saate kadar..................

☐ 4 saate kadar .... ☐ Tüm gün..........................

C. STATUE OF PARKING SPACES

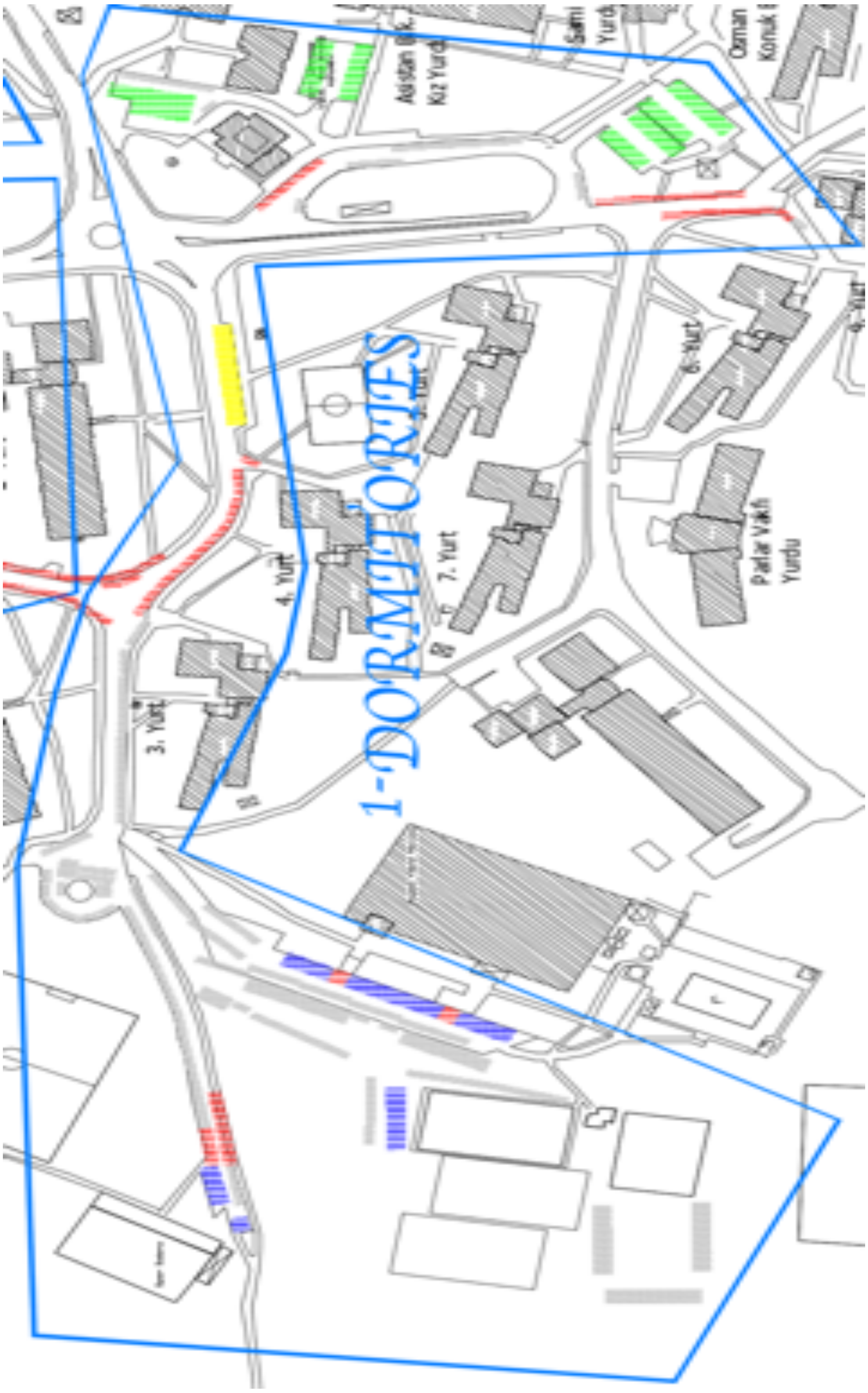

Figure C.1 Statue of Parking Spaces at Dormitories Region

Figure C.2 Statue of Parking Spaces at Shopping Area Region

Figure C.3 Statue of Parking Spaces at KKM Region

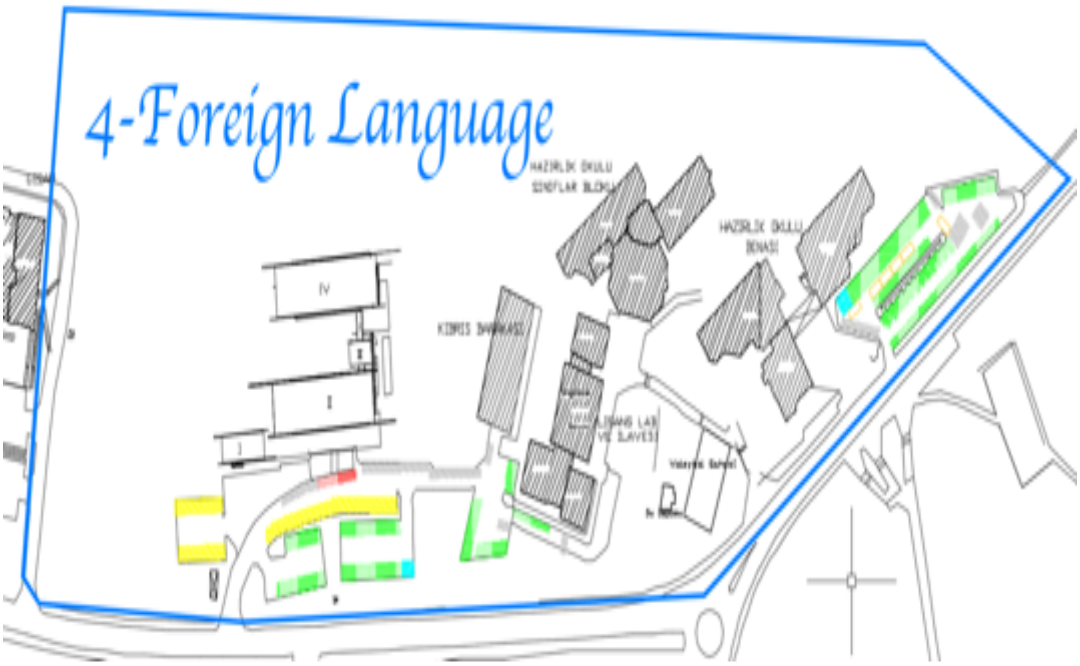

Figure C.4 Statue of Parking Spaces at Foreign Language Region

Figure C.5 Statue of Parking Spaces at Business Administration Region

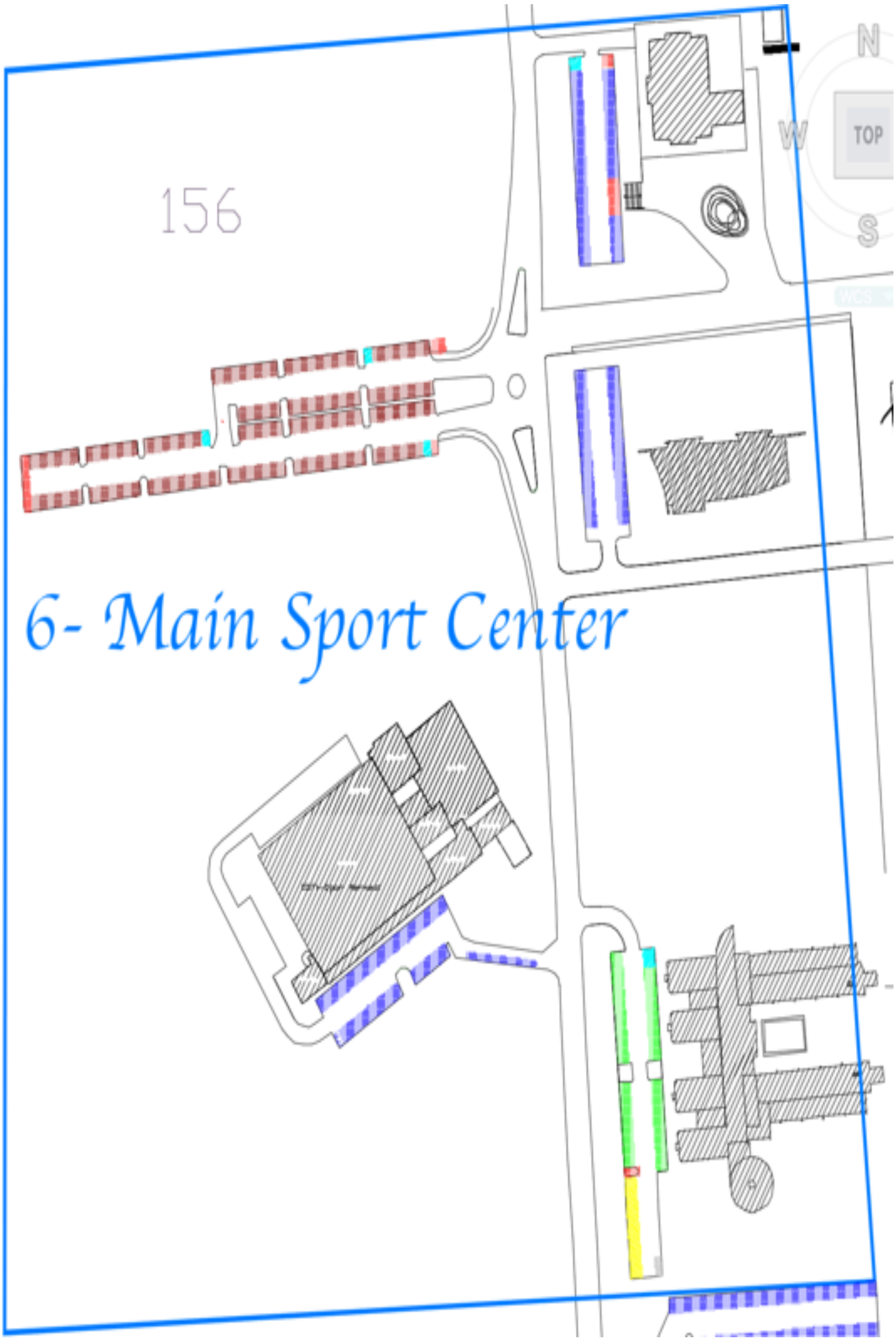

Figure C.6 Statue of Parking Spaces at Main Sport Center Region

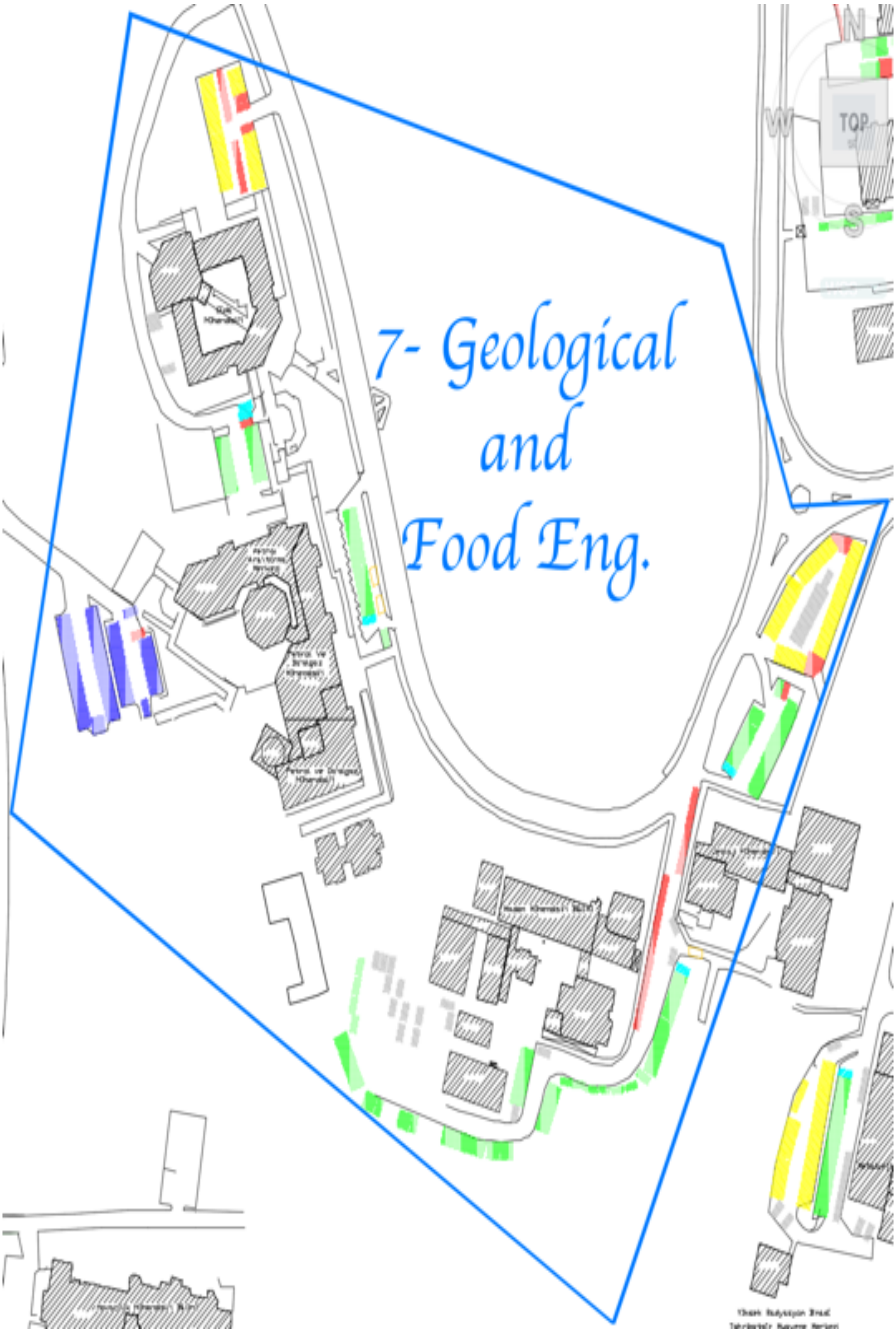

Figure C.7 Statue of Parking Spaces at Geological and Food Engineering Region

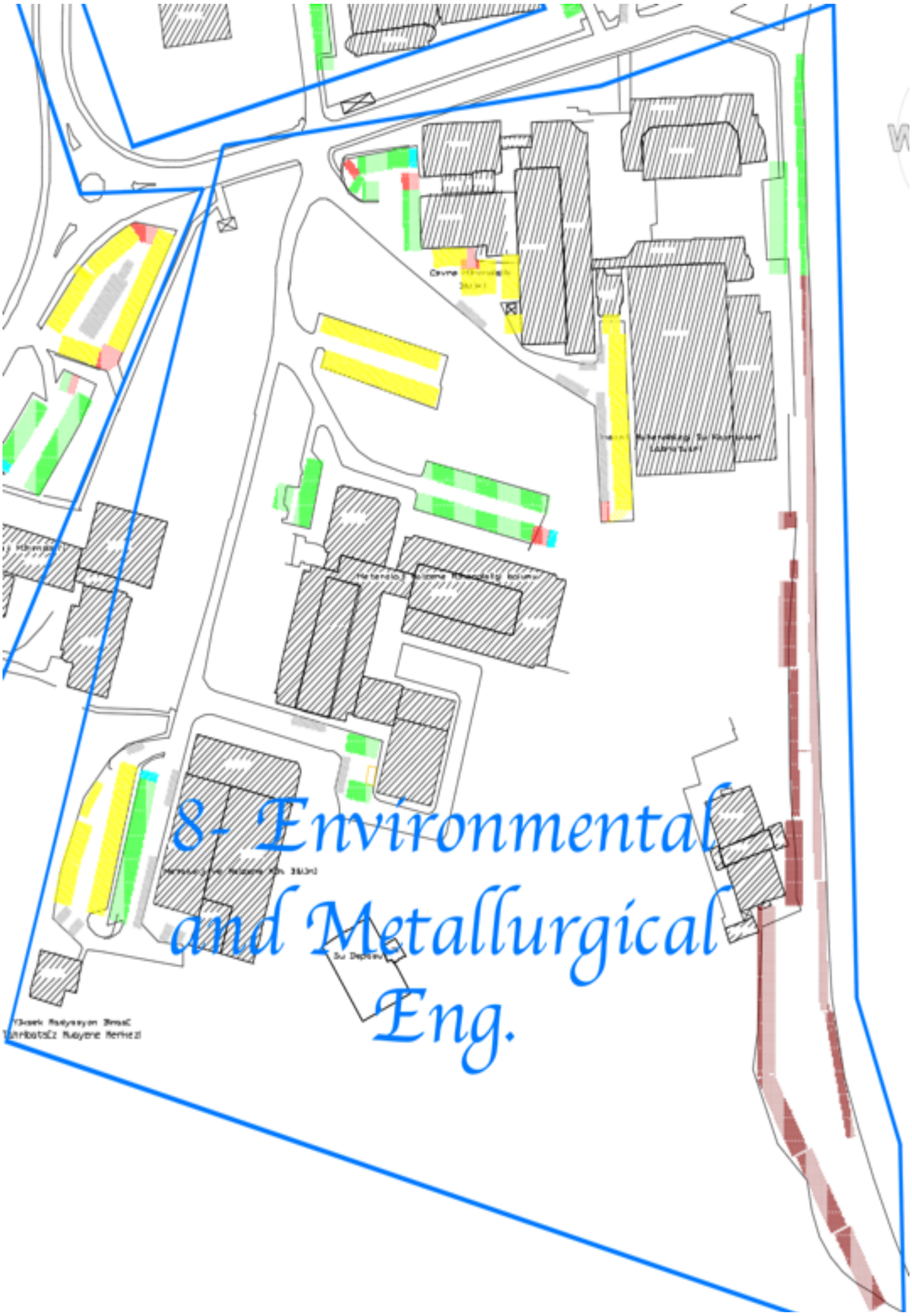

Figure C.8 Statue of Parking Spaces at Environmental and Metallurgical Engineering Region

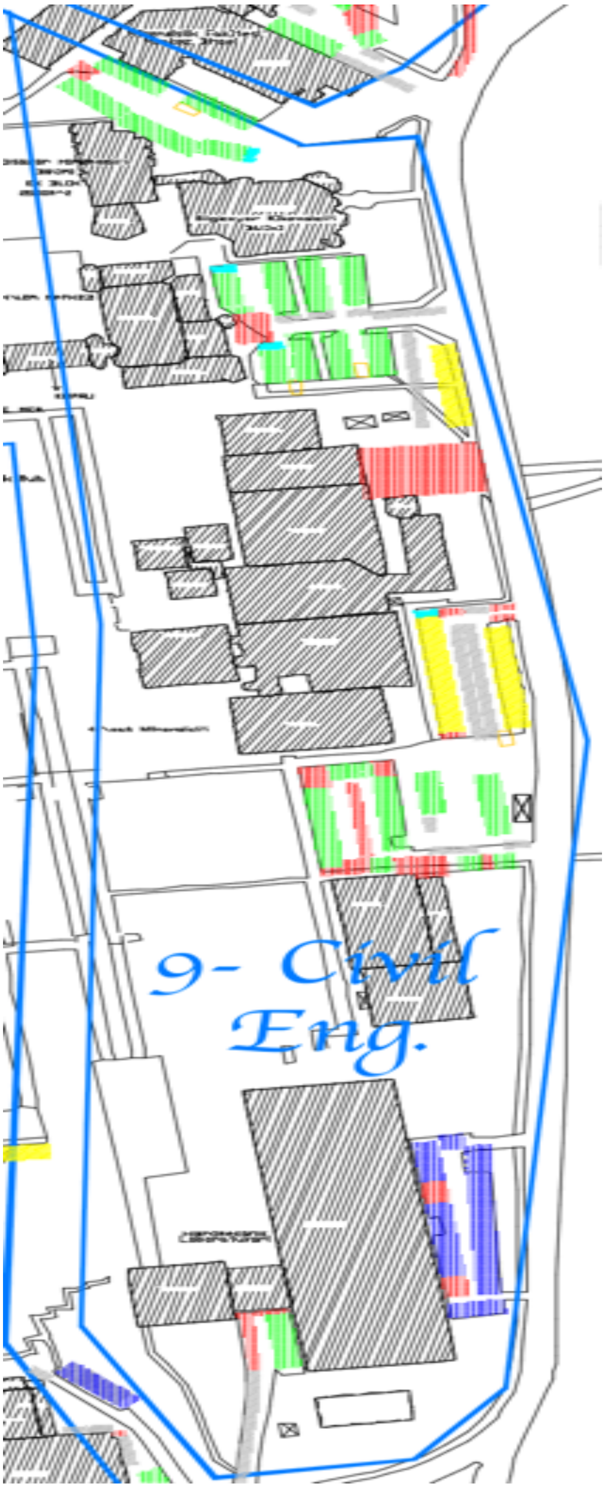

Figure C.9 Statue of Parking Spaces at Civil Engineering Region

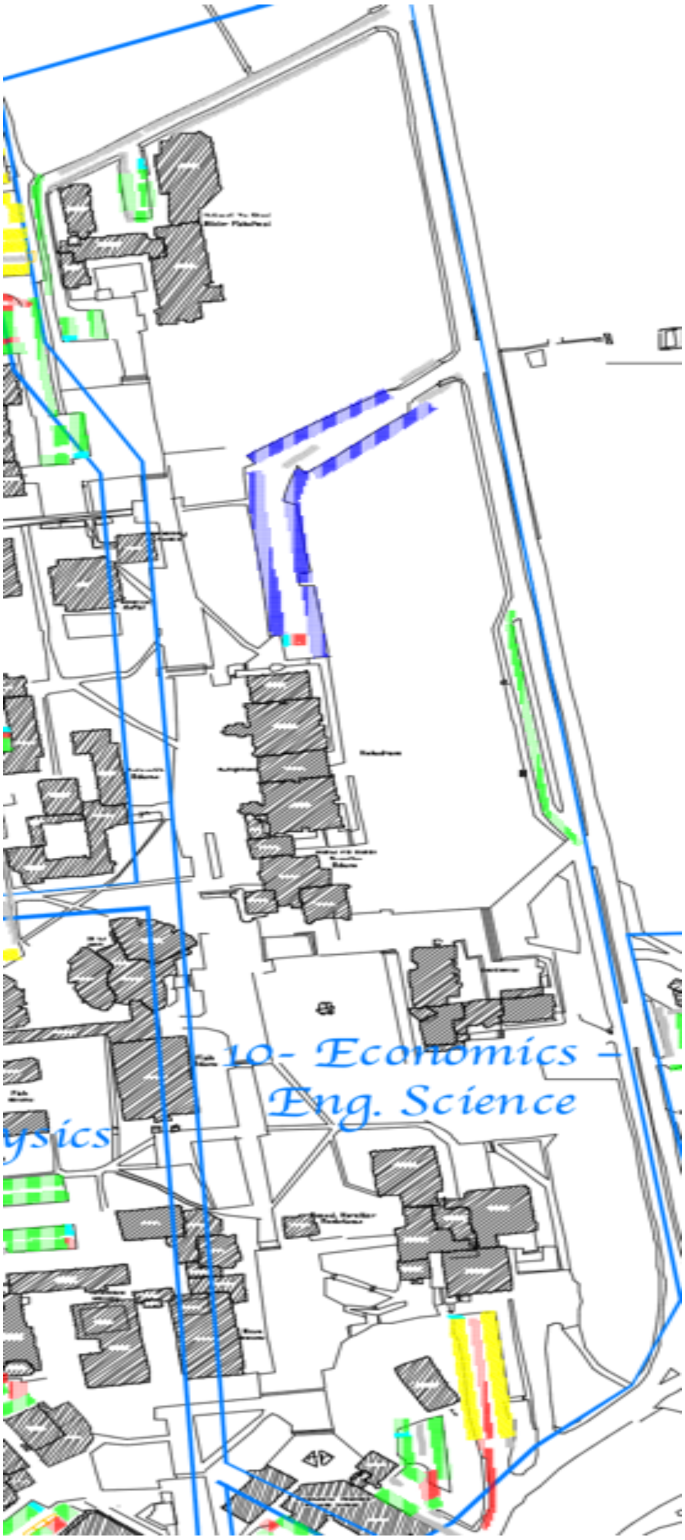

Figure C.10 Statue of Parking Spaces at Economics and Engineering Science Region

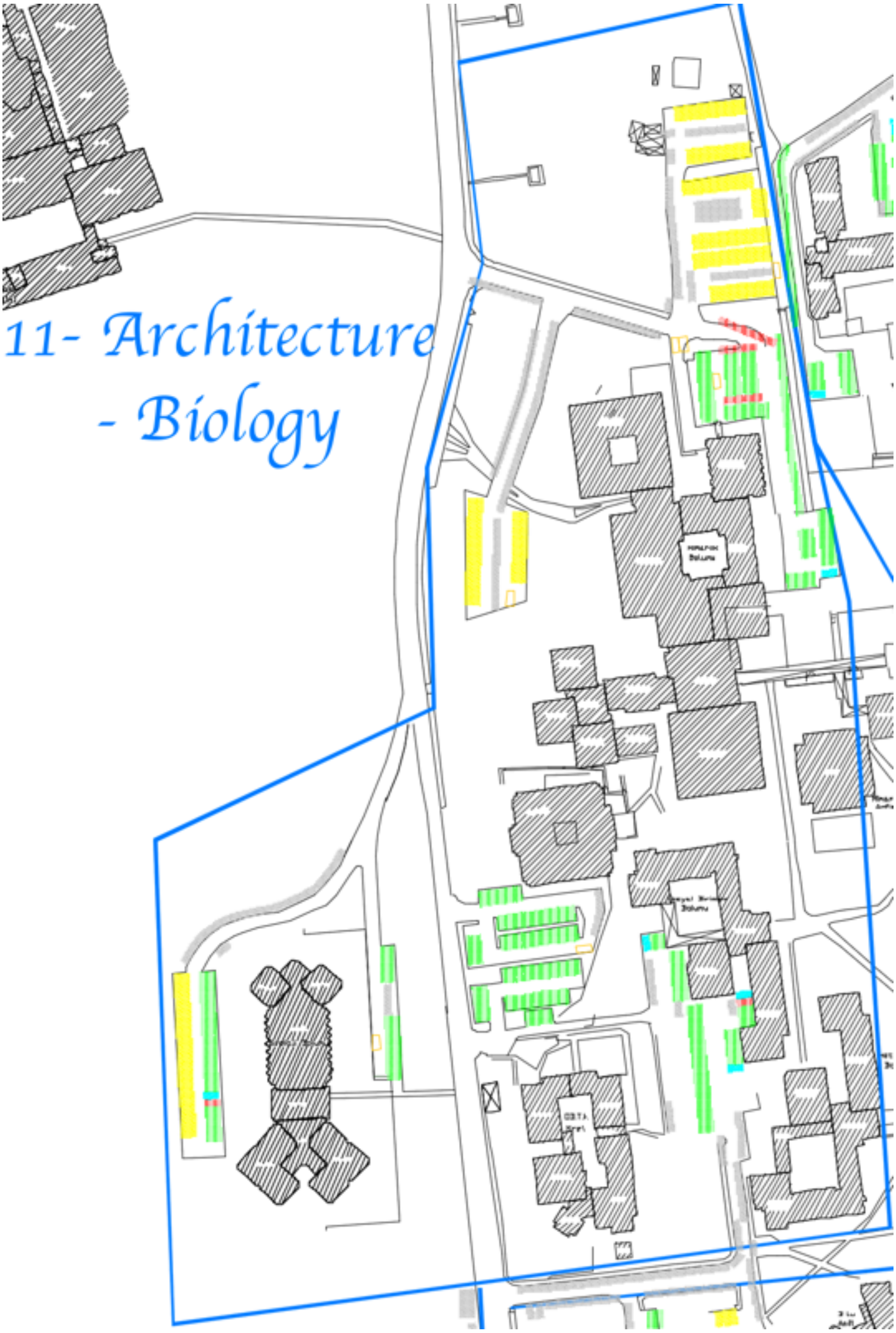

Figure C.11 Statue of Parking Spaces at Architecture and Biology Region

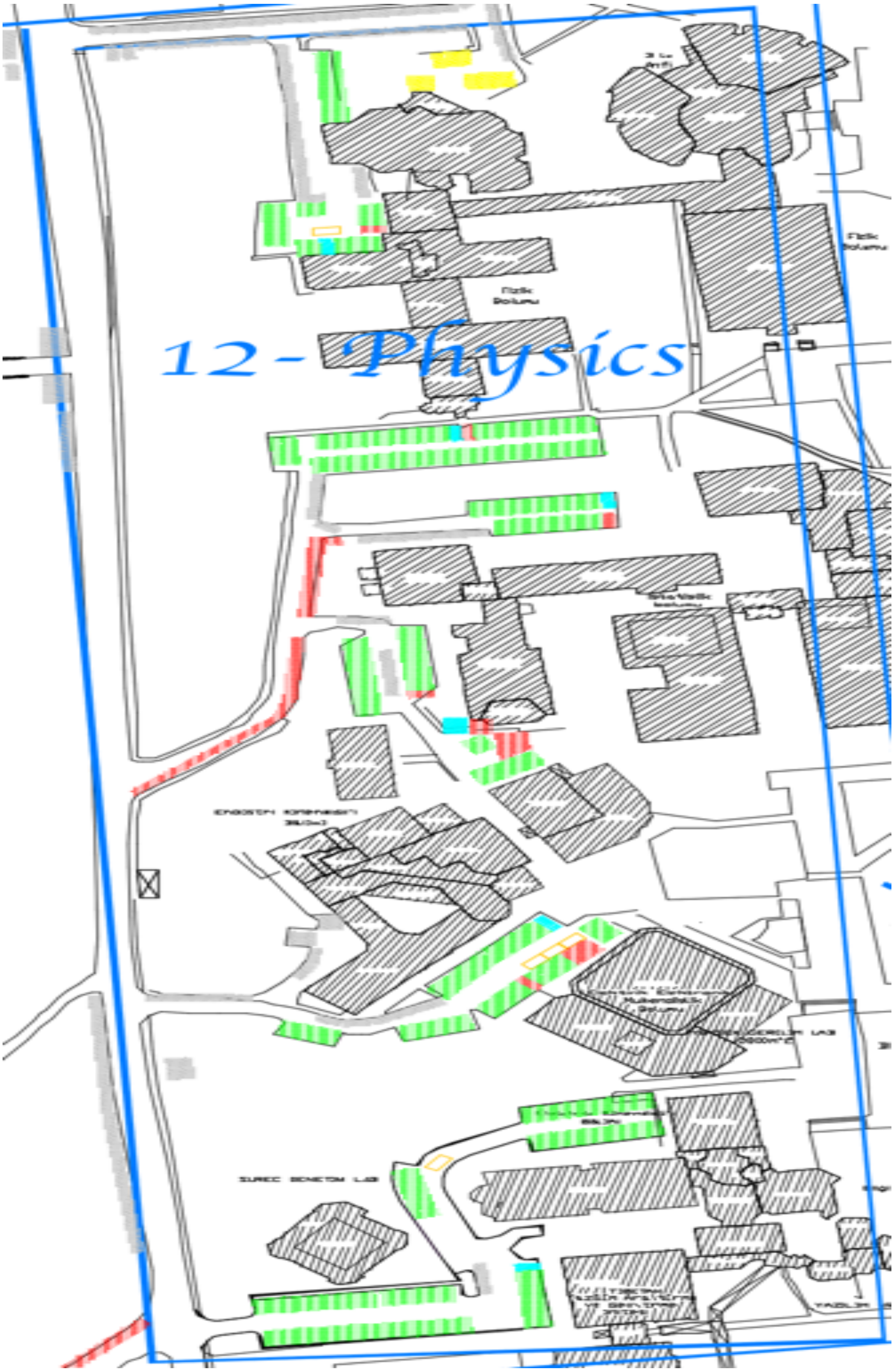

Figure C.12 Statue of Parking Spaces at Physics Region

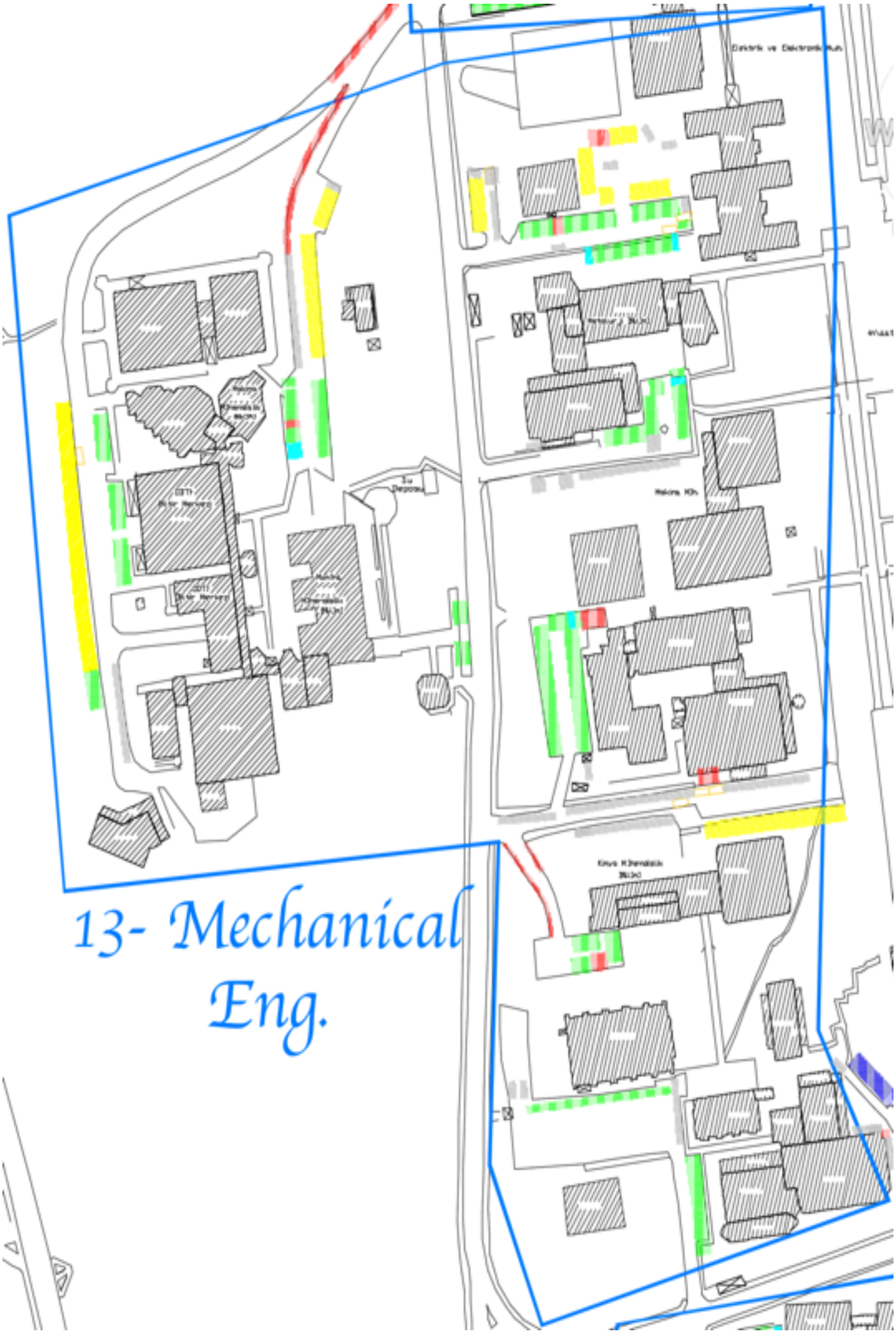

Figure C.13 Statue of Parking Spaces at Mechanical Engineering Region

D. OCCUPANCY OF PARKING SPACES

Figure D.1 Occupancy of Parking Spaces at Dormitory Region

Figure D.2 Occupancy of Parking Spaces at Shopping Area Region

Figure D.3 Occupancy of Parking Spaces at KKM Region

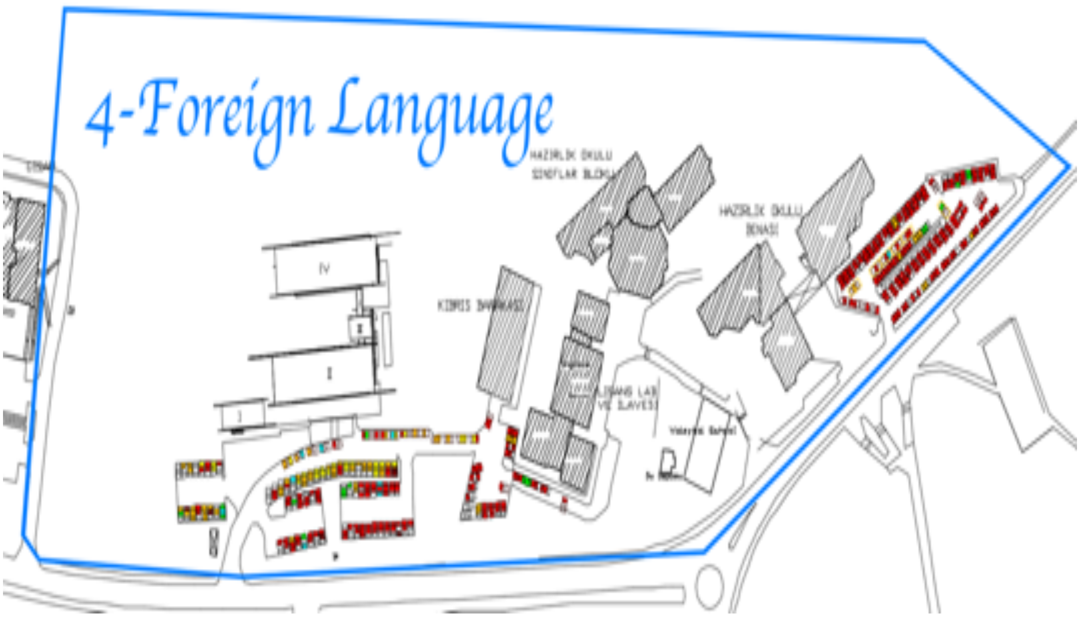

Figure D.4 Occupancy of Parking Spaces at Foreign Language Region

Figure D.5 Occupancy of Parking Spaces at Business Administration Region

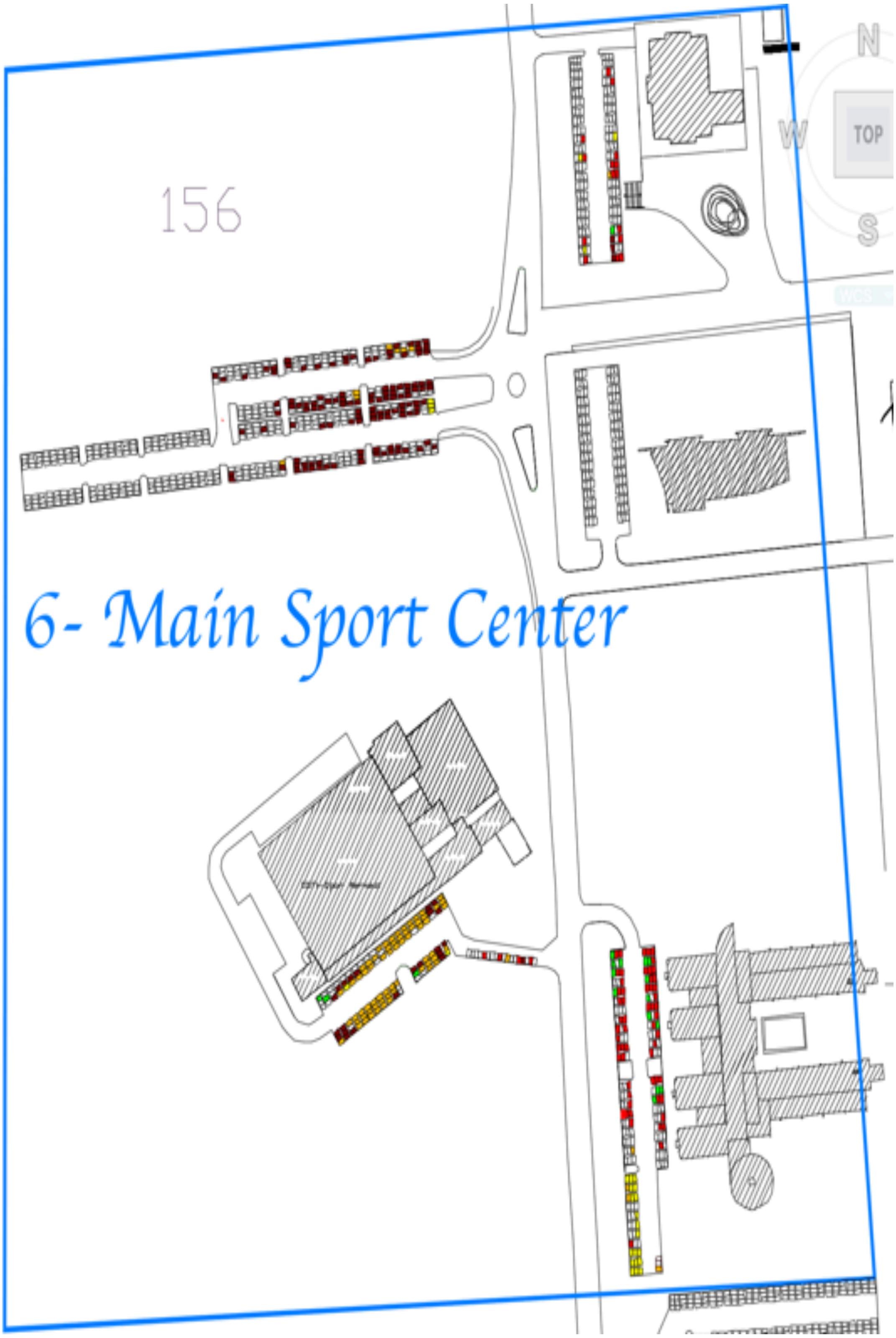

Figure D.6 Occupancy of Parking Spaces at Main Sport Center Region

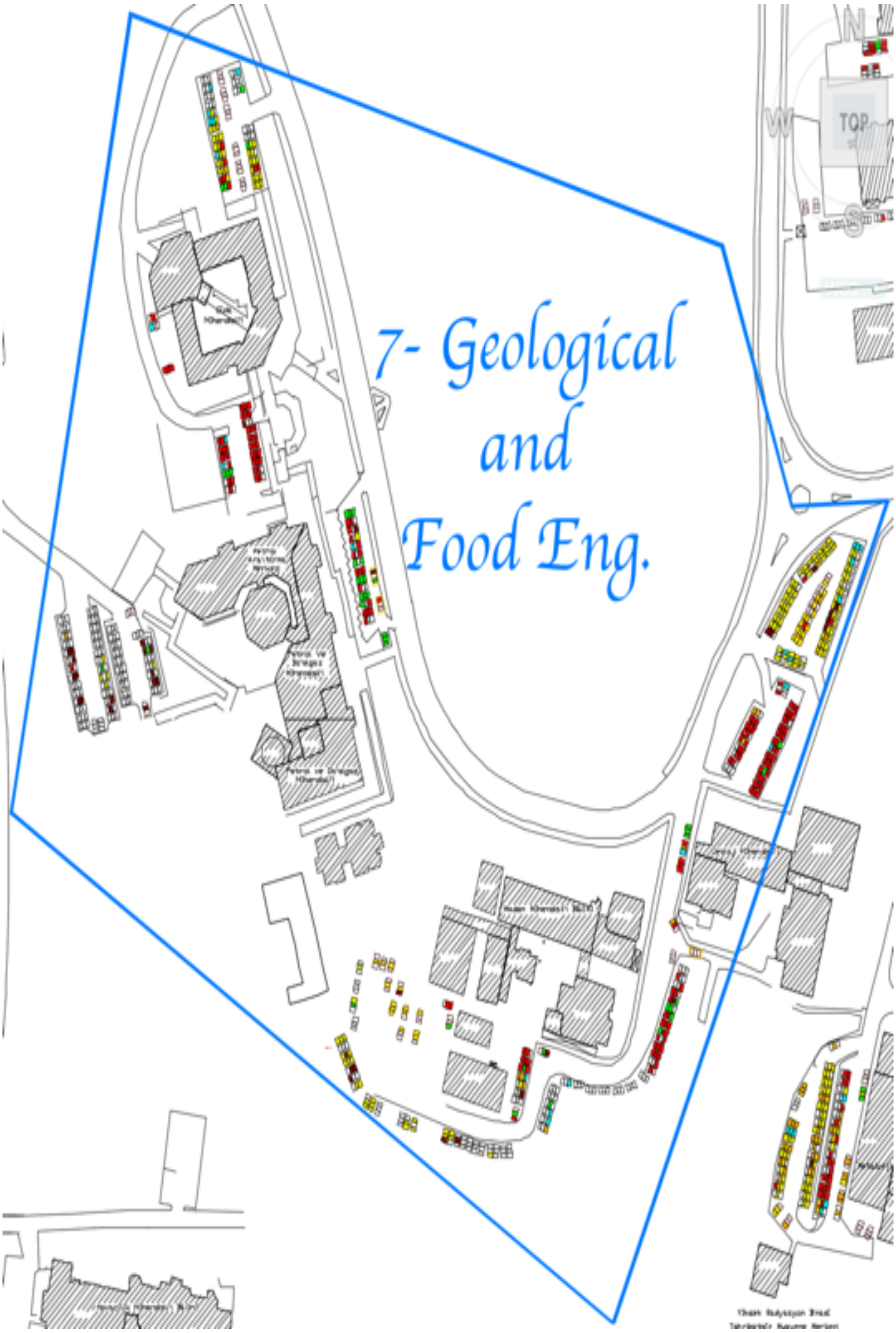

Figure D.7 Occupancy of Parking Spaces at Geological and Food Eng. Region

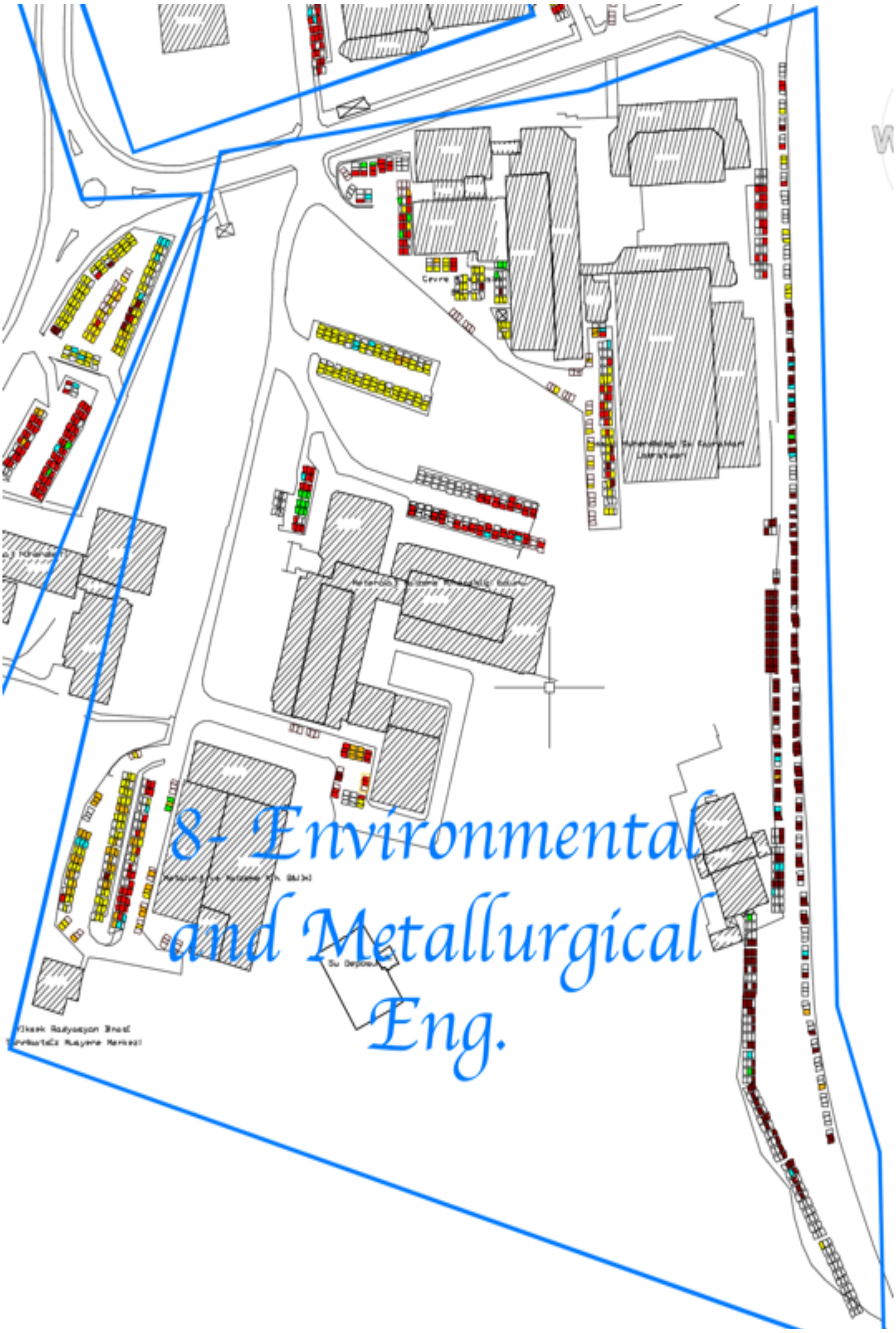

Figure D.8 Occupancy of Parking Spaces at Env. and Metallurgical Eng. Region

Figure D.9 Occupancy of Parking Spaces at Civil Engineering Region

Figure D.10 Occupancy of Parking Spaces at Economics and Eng. Science Region

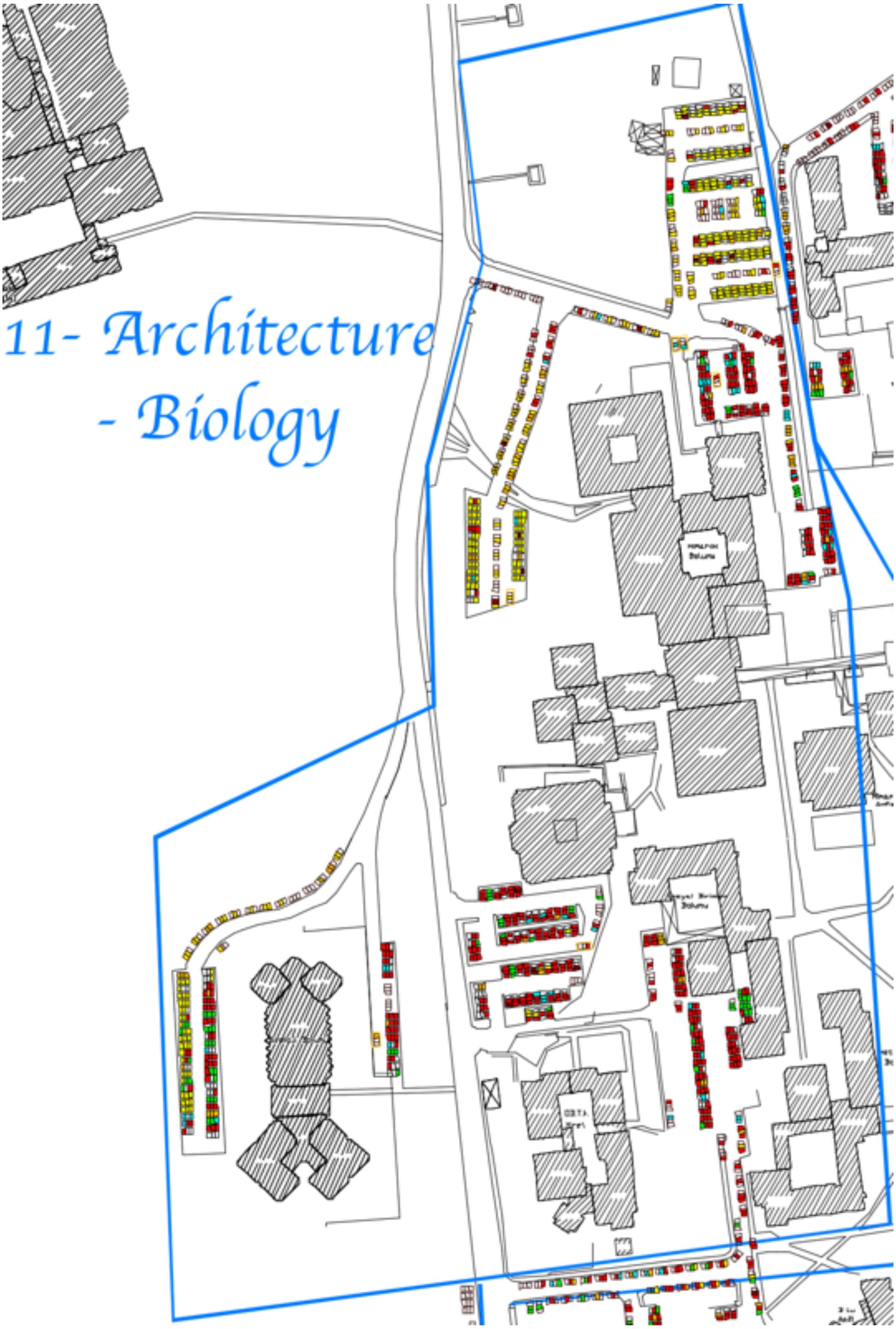

Figure D.11 Occupancy of Parking Spaces at Architecture and Biology Region

Figure D.12 Occupancy of Parking Spaces at Physics Region

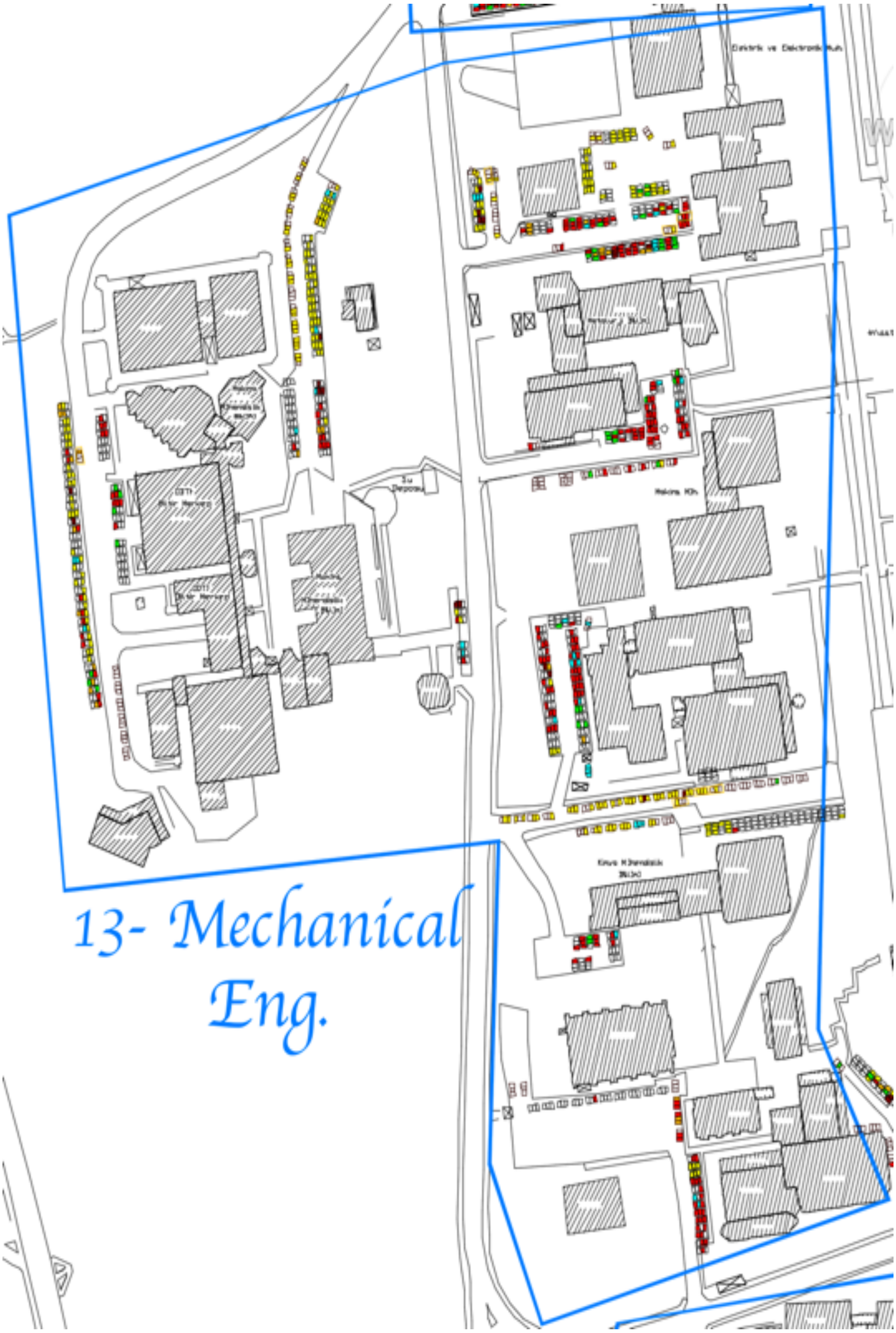

Figure D.13 Occupancy of Parking Spaces at Mechanical Engineering Region