FINAL PROJECT – TI 184833

ON-STREET PARKING ZONING FOR DIGITAL PARKING BY USING BINARY LINEAR PROGRAMMING (STUDY CASE: SIDOARJO REGENCY)

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FINAL PROJECT

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ABSTRACT

Having a convenient traffic system is not only securing the safety and giving services for the vehicle users but also can be profitable for the government. For the autonomous region, parking levy is one of the sources of *Pendapatan Asli Daerah* or Own-Sourced Revenue (OSR). The current parking system that applies in Sidoarjo is not giving a contribution to OSR as targeted due to illegal levies from illegal parking officers. From this finding, the digital parking system was chosen as a solution to create a better parking system in Sidoarjo. Therefore, this research will accommodate the shifting system from offline parking to digital parking in the first year of implementation. A solution to this problem is proposed by formulating binary linear programming, which can generate a result of the parking system by optimizing the profit for service provider and total cost for parking users. Three different scenarios are depending on decision-making tools. If the models are solved independently, for PSP model areas selected for mixed system are in front of Porong market, new Tulangan market, and Jaksa Agung Suprapto street with total profit Rp 901.405.000 while user model resulted in full digital system for all areas with total cost Rp 44.007. For the full cooperative game, selected areas for mixed system are the same as the PSP model; thus, the total cost is Rp 47.575,53. Vertical Nash equilibrium result demonstrated that mixed strategy for parking users 2% of the time choose area in Porong market, and 98% of the time area in Jaksa Agung Suprapto street with the value of the game is Rp 46.139,5. Another player resulted in 54% choose area in Porong market, and 45% choose area in Tulangan market with total profit Rp 839.855.355.

Keywords: Binary Linear Programming, Digital parking system, Game Theory, Vertical Nash.

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Surabaya, 21st July 2020

Writer

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CHAPTER 1
INTRODUCTION

This chapter consists of the background of the problem being observed, problem formulation, objectives of this research, benefits of the research, limitations, and assumptions, and research outline.

1.1 Background

Badan Pusat Statistik recorded the growing population of Indonesia in 2018, about 1,15% greater than in 2017. Therefore, previous studies had evaluated the effect of population growth in many aspects, for instance, economic condition, human habitation, the structure of the city as well as the number of vehicles. With the rising number of citizens, the number of vehicles also depicts the same pattern. Vehicles in Indonesia are also increasing. In 2018, the number of four wheels vehicle was 16.440.987 or 6,6% higher than in 2017 (BPS, 2018). While for two wheels vehicles, there are 120.101.047 units with a growth rate of 7,24% (BPS, 2018). Additionally, research conducted by Wantara (2015) concluded that the number of vehicles is positively correlated with the number of citizens.

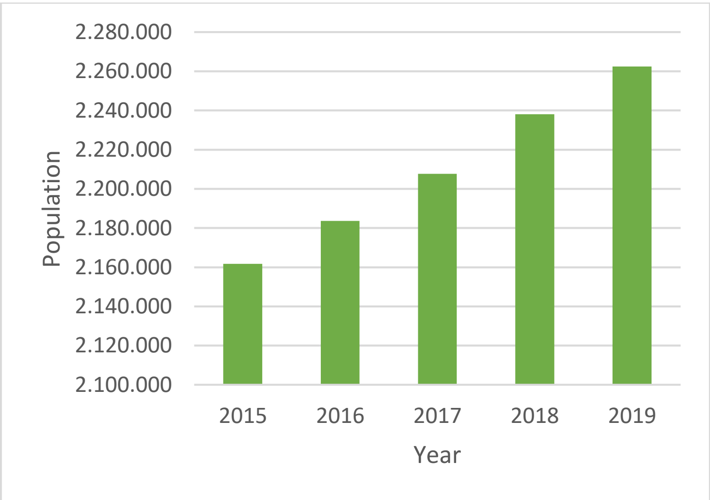

Figure 1.1 Population in Sidoarjo Regency
Source: Dispenduk and BPS (2019)

Sidoarjo, a growing regency in southern Surabaya, currently has the same pattern. Figure 1.2 represents the number of vehicles in Sidoarjo regency, which increase gradually between 2015 and 2017. Compared to the chart in figure 1.1, both are showing an upward trend. Moreover, the data suggests a significant difference between the two types of vehicles. Two-wheels vehicles number are exceedingly larger compared to four-wheels vehicles. Following the increasing rate of vehicles, infrastructures to facilitate the citizens, such as roads and parking spaces, must be constructed expertly because those play a vital role in preventing excess traffic that can cause delays. Besides, the government has given the mandate to organize the traffic in Indonesia, which stated in Undang-Undang No. 22 tahun 2009.

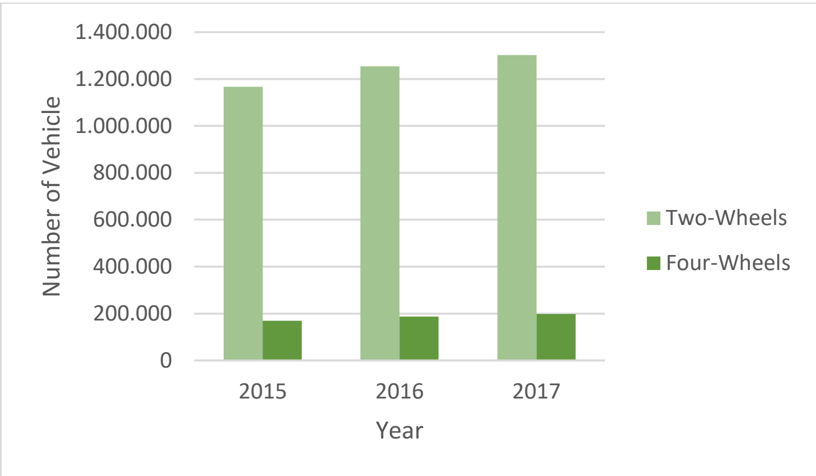

Figure 1.2 Vehicles Growth in Sidoarjo Regency
Source: Badan Pusat Statistik (2017)

Infrastructures and facilities can be improved if there is enough local government budget (*Anggaran Pendapatan dan Belanja Daerah*). Since Sidoarjo is an autonomous region, therefore it is the government's right to manage its fund independently. One of the sources of the local government budget is called Own-Sourced Revenue (*Pendapatan Asli Daerah*), abbreviated as OSR. The regulation of OSR stated in Undang-Undang No. 33 Tahun 2004 about the financial balance of local government and central government. In the 6th article specified that one of the OSR sources is the regional retribution, which includes the parking levy. There are two types of parking levy in Sidoarjo, incidental parking and subscription parking. Incidental parking levy is paid whenever people use the parking area.

In comparison, subscription parking is paid annually, along with vehicle tax payment. Subscription parking system initiated by the local government to control traffic and to raise the OSR in Sidoarjo regency (Rudiyanto & Hariyanto, 2016). The regulation is based on Peraturan Daerah No. 17 Tahun 2019. Subscription parking system implementation started in 2010, and the vehicle owner must pay Rp 25.000 for motorcycle and Rp 50.000 for car. Technically, there is a parking area dedicated to subscription parking across the regency, equipped with board, as seen in figure 1.4. However, the system failed to give satisfaction to Sidoarjo regency citizens as customers. Many Sidoarjo citizens are showing disagreement about the subscription parking levy system because, in reality, costumers still need to pay levies to unregistered parking officers in some areas that are supposed to be a subscripted parking area (Taufik, 2018). Based on a news article on Faktualnews.co, in 2019, a Sidoarjo citizen named Prayitno filed a lawsuit to Sidoarjo district court about subscription parking. He suffered a material loss due to improper execution of the subscription parking system. The protests have attracted the local government and city council, and therefore according to Sidoarjo's head of city council, they had been planning to stop the subscription parking since 2018. Additionally, a survey conducted in 2019 indicated that 79% of vehicle users in Sidoarjo agree for parking service to be improved, as shown in figure 1.3.

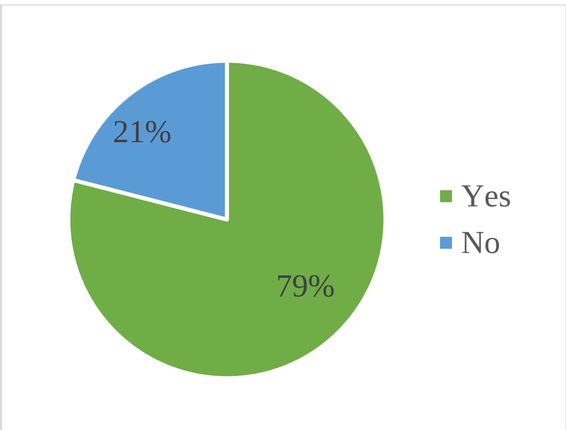

Figure 1.3 The Needed of Parking Service Improvement
Source: Survey by Dinas Perhubungan Sidoarjo (2019)

Both incidental parking and subscription parking levy did not contribute to the OSR as targeted. In 2018, the contribution of the parking retribution to the OSR only Rp 28.176.793.500 from potential amount Rp 102.147.595.652, or only 27,5% from the target (PT. Wukir Mahendra Sakti, 2019). This indicates there are still illegal levies from parking activities that causing the levies do not give to the government. The problems mentioned above need to be solved immediately to prevent further loss of opportunity cost.

Figure 1.4 Board Sign of Subscription Parking in Sidoarjo
source: faktualnews.co

There are two types of parking, on-street parking and off-street parking. On-street parking is the activity when vehicles owner put away their cars/motorcycles along the roadside (Biswas, et al., 2017). The on-street parking area shares the same area with other vehicles moving on the road and allows the users to park their vehicles nearer to their destinations (Biswas, et al., 2017). The government manages the on-street parking system. While for off-street parking, the parking spaces are privately owned (Gupta, 2018). Usually, off-street parking facilities are like garages, lots, or buildings.

Dinas Perhubungan Sidoarjo, as the party who is responsible for managing the parking system then initiated a solution, which is a new parking system in Sidoarjo. The plan is to change the current conventional parking system, which is using cash to pay the parking officer, to digital parking system which utilizes internet-based technology. The digital parking system has several advantages, such as increasing the parking service, reducing the risk of the illegal levy, decreasing traffic congestion, also a manifestation of local innovation. This huge leap is not a groundless decision for *Dinas Perhubungan Sidoarjo*. Indonesian Internet Service Providers Association (JPJII) survey resulted in 2018 stated that 171,17 million of Indonesia's citizens are internet users or 64,8% from the whole population. The number was 10,12% higher than in 2017.

Moreover, based on a survey conducted by *Dinas Perhubungan Sidoarjo*, from 344 people surveyed, 99% of them owned a smartphone. The same study also found that 59,3% of the respondents agree for digital parking system. These findings deduce that the regency is possible to have digital parking system. A previous study conducted in 2019 by *Dinas Perhubungan Sidoarjo* and *ITS Tekno Sains*, concludes that from the aspect of user readiness and economy, digital parking system is feasible to be applied in Sidoarjo regency. In this project, *Dinas Perhubungan Sidoarjo* is working together with a third party company or then called a parking service provider. Therefore, the study of the digital parking system is still conducted from many other aspects. Expectedly, this digital parking system not only maximizing Sidoarjo OSR potential but will also increasing the service level to the customers (vehicle users).

According to *Dinas Perhubungan Sidoarjo,* there are 300 on-street parking areas across Sidoarjo with total capacity 4728 for four wheels vehicle and 22383 for two wheels vehicle as shown in table 1.1. Based on the parking crowd level, there are 3 type area, crowded area, intermediate area, and traditional market area. Sidoarjo sport center, Masjid Agung Sidoarjo, and Jl. Gajahmada are the example of on-street parking areas that have high parking intensity. The intermediate area which not as crowded, the examples are Jl. Mojopahit, Jl. Teuku Umar, and Jl.Dr. Soetomo. While there are 17 different traditional markets (pasar) across Sidoarjo, such as Pasar Larangan, Pasar Baru Krian, and Pasar Taman.

Table 1.1 Parking Capacity in Sidoarjo

No.	Districts	Vehicle Capacity		Parking Area
		2 Wheels	4 Wheels	
1	SIDOARJO	6438	1857	128
2	CANDI	2895	348	11
3	KRIAN	3474	738	40
4	PRAMBON	420	168	8
5	TARIK	195	105	3
6	BALONGBENDO	120	60	2

No.	Districts	Vehicle Capacity		Parking Area
		2 Wheels	4 Wheels	
7	KREMBUNG	180	48	4
8	TANGGULANGIN	615	90	8
9	PORONG	1281	189	27
10	JABON	75	33	2
11	BUDURAN	630	123	11
12	TAMAN	2595	318	21
13	WARU	1260	174	12
14	SEDATI	225	48	4
15	GEDANGAN	1140	249	9
16	SUKODONO	330	69	3
17	WONOAYU	135	33	2
18	TULANGAN	375	78	5
TOTAL		22383	4728	300

With around 28,5% of the population is disagree with the idea of digital parking, showing that the digital system cannot immediately implement, instead it must be done in stages. Therefore, to accommodate the shifting system from offline parking to digital parking, not all on-street parking areas in Sidoarjo will have digital parking system immediately. Instead, a decision needs to be taken to determine which area will implement the digital parking system and which area will implement mixed system. To do this, a quantitative scheme will consider from the parking service provider and from the user perspective, which can maximize the profit for parking service provider and minimize the cost for user. By doing this, the parking service provider as the project owner can also evaluate the result after implementing for one year.

Overall, there will be two types of parking systems, mixed system (proportional offline and digital) and full digital system. To determine which parking areas implement which parking system, several parameters need to be considered. Parameters like parking levy, operational cost, investment cost and parking potential (demand). Parking provider, as the project owner, want to maximize profit with its limited cost, consider also the willingness of the parking user, as well as to achieve minimum number of each proposed parking system. Not only from the service provider side but also users' party must be taken into account for the decision. They have a willingness index that shows whether users wanted to use digital parking. They also want to minimize cost, which then defined as the expense of waiting to be served or better service for them. With these objectives and limitations, a model needs to be constructed to obtain the optimal solution.

A method that will generate an optimal solution with the allocation of limited cost and some other considerations is linear programming. Besides, the problem is showing proportionality between the objective function and the parameters. The model will be developed for both parties, service provider, and user. Moreover, the decision variables of whether an area implements digital parking system and whether an area implements mixed parking system will be in binary. After obtaining the binary linear programming results, a full cooperative game and vertical Nash equilibrium will be used to give more scenarios for the decision maker.

1.2 Problem Formulation

Based on the problems explained in the background, the research question is how to design of zoning on-street parking area in Sidoarjo regency in order to support the government in gradually changing the parking system from offline to digital, while considering several parameters and estimating the profit in the first year of implementation. A conceptual model reflecting the problem situation and its corresponding mathematical model set will be developed by using binary linear programming. Moreover, some scenarios will be analyzed, and some optimum solutions will be derived. In addition, some insightful discussion would be brought forward. By doing these both theoretical and practical contribution might be provided.

1.3 Research Objectives

The objectives of this research are:

1. To construct linear programming optimization modelling as the decision-making tools for zoning of on street parking.
2. To perform sensitivity analysis to know how changing parameters affect the optimization result.
3. To analyze different approach of decision-making tools of zoning on street parking to obtain fairer result.

1.4 Research Benefits

The benefits that can be obtained from this research are:

1. As the decision-making tools for parking service provider to design the zoning of on-street parking area in Sidoarjo Regency.
2. Knowing how the changing in parameters will affect the optimization result.
3. Giving alternative decision of zoning on street parking area.

1.5 Scope of Research

During this research, there are several limitations and assumptions that are used to set boundaries of the observed system.

1.5.1 Limitations

Limitations used in this research are:

1. On-street parking that are used in this research for zoning is only for traditional public facilities market area, and main roads with three different locations each.
2. This research limited only in determining the parking system for each parking area using different approaches.
3. There are only 2 types of zones: full digital system, and mixed system.
4. Considerations that included in the model are only quantitative perspective.
5. The model limited only for the car and motorcycle.

1.5.2 Assumptions

Assumptions used in this research are:

1. All parking officers are ready for the implementation of all type of parking system.
2. There will be no change in system for one year.
3. All parking slot in each parking area are fully used for parking.
4. All parameters for optimization modelling are deterministic.

5. Survey data is assumed to be sufficient.
6. Technical assumptions will be explained in the following chapter.

1.6 Research Outline

The outline of this research is classified into 6 chapters that will be explained briefly below.

CHAPTER 1 INTRODUCTION

This chapter consists of background, problem formulation, research objectives, research benefits, scope of research, research outline.

CHAPTER 2 LITERATURE REVIEW

This chapter explains the basic theories obtained from sources such as books, journals or any other reliable sources that are used by the writer to support the method in the research.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter explains the writer's systematic steps in constructing the research presented in form of flowchart. The overall steps are parameter identification stage, model construction stage, running optimization stage, Monte Carlo simulation test, and analysis and conclusion stage.

CHAPTER 4 PARKING ZONING OPTIMIZATION MODELLING

This chapter shows the steps in modelling the zoning optimization in central Sidoarjo area. The process starts by deciding the variable needed for the model, then continue with making mathematical model as well as LINGO model including the objective function and constraints.

CHAPTER 5 PARKING ZONING OPTIMIZATION RESULT ANALYSIS

This chapter provides analysis of optimization result. Sensitivity analysis will also be conducted to see the impact of changing parameters to the result.

CHAPETR 6 DECISION MAKING OF PARKING ZONING

This chapter explains the further actions using fully cooperative game and vertical Nash equilibrium to provide more scenarios of parking zoning decision making.

CHAPTER 7 CONCLUSION AND RECOMMENDATION

This chapter is the closing part of the research which consists of concluding remarks and recommendations based on the research conducted.

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CHAPTER 2
LITERATURE REVIEW

This chapter delivers the explanation of relevant literatures and research that related to parking management system, regional own-source revenue, binary linear programming, and game theory.

2.1 Parking Management System

People move with their vehicles from one place to another simultaneously is a common thing happen especially in big cities. The rapid movement can be a sign of ongoing economic condition such as people going to work, supply chain activity. On the other hand, insufficient facilities can cause loss such as traffic congestion, not enough parking facility and many more (Zaretsky, 1997). The definition of parking according to Undang-Undang No. 22 tahun 2009 is the situation where the vehicle stops or not moving because the driver is leaving the vehicle for a moment. On every journey with vehicles will always begin with parking and end with parking too, because of this, parking spaces prior to the journey like garage or field and parking spaces in the destination like on the sideways or parking building are available (Direktorat Jenderal Perhubungan Darat, 1998).

According to Victoria Transport Policy Institute, parking management is a system that involves a variety of strategies that encourage more efficient use of existing parking facilities, improve the quality of service provided to parking facility users and improve parking facility design. With more people as well as vehicles, government as the regulators need to evaluate the parking system regularly because, the rapid changes that could happen in the society such as in demography, economy, or social have impact to the parking sector (Direktorat Jenderal Perhubungan Darat, 1998). Instruments that must be considered are rules, parking location and the parking levy (Direktorat Jenderal Perhubungan Darat, 1998).

2.1.1 On-Street Parking

On-street parking is the activity when vehicles owner put away their cars/motorcycles along the roadside (Biswas, et al., 2017). Parking places on the sideways or on-street parking is an attractive facility for vehicle drivers (Purnawan & Yousif, 1999). One of the criteria for people to come to a destination is the availability of on-street parking (Biswas, et al., 2017). Economic development of a commercial area is also correlated with the condition of on-street parking (Biswas, et al., 2017). However, on-street parking is often effecting the capacity of the road and causing the high number of road traffic accidents and other direct or indirect effects on other issues like business, environment, public transport, and property values (Purnawan & Yousif, 1999). Increasing delay in the road caused by the physical use of road space, parking maneuvers as well as the activity of opening or closing the car's doors (Hobbs, 1979).

In Sidoarjo regency, regulation about parking system is written in Peraturan Daerah Sidoarjo No. 17 Tahun 2019. Location determination of on-street parking in Sidoarjo must fulfill these requirements:

1. Accessible to the road users.
2. Does not interfere with the safety of the users and traffic.
3. Safe for the environmental of living creatures around the location.
4. Does not use facilities for pedestrian.
5. Does not use facilities for disable people.

The amount of parking retribution in Sidoarjo regency is based on the service provision cost, citizen's welfare, fairness aspect, and effectivity of the service control. In Sidoarjo applies two types of parking retribution, flat tariff, and progressive tariff. The emplacements of parking tariff are regulated by the head of Sidoarjo regency.

In the article number 34, structure and the amount of incidental on-street parking levy for flat tariff is:

a. Bicycle, Rp. 1.000,00 (one thousand rupiah).
b. Motorcycle, Rp. 2.000,00 (two thousand rupiah).
c. Sedan, minibus, or similar vehicle type, Rp 4.000,00 (four thousand rupiah).

d. Bus, truck, or similar vehicle type, Rp. 5.000,00 (five thousand rupiah).
e. Trailer truck, Rp. 5.000,00 (six thousand rupiah)

While structure and the amount of incidental on-street parking levy for progressive tariff is:

a. Bicycle, tariff for the first 4 hours is Rp. 1.000,00. More than 4 hours the tariff is Rp. 3.000,00.
b. Motorcycle, tariff for the first 4 hours is Rp. 2.000,00 (two thousand rupiah). More than 4 hours the tariff is Rp. 6.000,00.
c. Sedan, minibus, or similar vehicle type, tariff for the first 4 hours is Rp 4.000,00 (four thousand rupiah). More than 4 hours the tariff is Rp. 12.000,00.
d. Bus, truck, or similar vehicle type, tariff for the first 4 hours is Rp. 5.000,00 (five thousand rupiah). More than 4 hours the tariff is Rp. 15.000,00.
e. Trailer truck, tariff for the first 4 hours is Rp. 5.000,00 (six thousand rupiah). More than 4 hours the tariff is Rp. 15.000,00.

2.1.2 Digital Parking System (E-Parking)

Digital parking system is internet-based system used to reserve place to park and process data (Corneille, 2018). The emergence of the digital parking is because of the expensive process in time effort spent in finding parking spot (Kotb, et al., 2016). Kotb, et al believe that better parking management system must be developed. There are already many studies about digital parking system. Those mostly provide solution for the parking reservation system, availability information system, occupancy detection and management of parking lot (Sadhukhan, 2017). Technologies used in digital parking system in several studies are radio frequency identification (RFID), wireless sensor network (WSN), Bluetooth, Wi-Fi, ZigBee and many more (Sadhukhan, 2017).

Sadhukhan (2017) proposed an digital parking system that take on an integrated component named Parking Meter (PM) which address the following issues.

- Real-time detection of improper parking

- Estimation of parking duration
- Automatic parking payment

The components required for Parking Meter based E-Parking (PM-EP) are parking meter which placed at the middle of the back end of the parking area, local parking management server (Wi-Fi integrated with laptop/workstation), Access Points (Aps), and central server to provide information about parking availability across the city as well as receiving driver's reservation request. The scheme of working for PM-EP system is illustrated in figure 2.1.

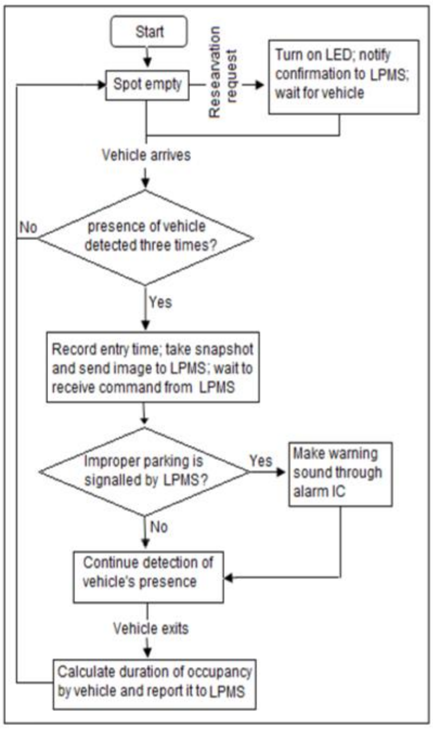

Figure 2.1 Flow Chart of PM-EP System
Source: Sadhukhan (2017)

In Surabaya, the capital city of East Java province, in 2018 implemented the E-Parking system in several parking areas. The local government hopes that E-Parking can reduce the leakage in local OSR, disciplined the parking officers, increase the service level to the users and support Surabaya to become smart city (Artamalia & Prabawati, 2018). In practices, E-Parking uses a device called parking meter to record parking duration and receive the payment. Payment method for the users is using electronic money.

Dinas Perhubungan Sidoarjo has its own scheme in implementing digital parking. To be able to use the digital parking facility, smartphone and internet connection will be needed for both users and parking officers. Every user can register to the application system as well as his/her vehicle(s). In the application installed in users' smartphones, they can book parking space and pay the parking levy using e-money. Parking officers will also be equipped by smartphones. Every parking officers will have his own QR code. QR code will be scanned by the users to confirm the parking space and to transfer the e-money from users to parking officers.

2.2 Regional Own-Source Revenue

Referring to Undang-Undang No. 33 Tahun 2004 regional own-source revenue is income earned in the region and collected based on the regional regulation. Composition of regional OSR nationally in 2017 divided into 4 parts, local tax, local retribution, municipally owned business revenue (BUMD), and other legal income sources (Direktorat Jenderal Perimbangan Keuangan, 2017). Figure 2.2 shows the portion of each source.

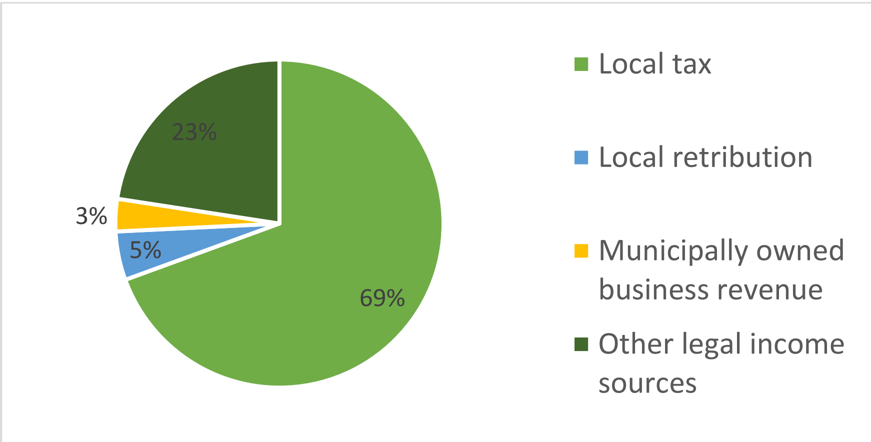

Figure 2.2 Composition of regional OSR nationally
Source: Direktorat Jenderal Perimbangan Keuangan (2017)

2.2.1 Local Retribution

Local retribution is the levy paid by citizens to the government for services they received directly or for any approval they received. It is different with tax which is paid not based on what the citizens obtained directly, retribution is charged to the citizens directly after or before government give service directly to them (Direktorat Jenderal Perimbangan Keuangan, 2018).

Undang-Undang No. 28 Tahun 2009 listed 30 types of local retribution that can be charged by province/regency/city. This number increased to 32 types in PP No. 97 Tahun 2012. Local retribution types then classified in 3 different groups, general services (*jasa umum*), business services (*jasa usaha*), and specific permission.

Jasa Umum	Jasa Usaha	Perizinan Tertentu
1. Retribusi Pelayanan Kesehatan	1. Retribusi Pemakaian Kekayaan Daerah	1. Izin Tempat Penjualan Minuman Beralkohol
2. Retribusi Persampahan/ Kebersihan	2. Retribusi Pasar Grosir/Pertokoan	2. Retribusi Izin Mendirikan Bangunan
3. Retribusi KTP dan Akte Capil	3. Retribusi Tempat Pelelangan	3. Retribusi Izin Gangguan
4. Retribusi Pemakaman/ Pengabuan Mayat	4. Retribusi Terminal	4. Retribusi Izin Trayek
5. Retribusi Parkir di Tepi Jalan Umum	5. Retribusi Tempat Khusus Parkir	5. Retribusi Izin Usaha Perikanan
6. Retribusi Pelayanan Pasar	6. Retribusi Tempat Penginapan/ Pesanggrahan/ Villa	6. Retribusi Perpanjangan IMTA
7. Retribusi Pengujian Kendaraan Bermotor	7. Retribusi Rumah Potong Hewan	
8. Retribusi Pemeriksaan Alat Pemadam Kebakaran	8. Retribusi Pelayanan Kepelabuhanan	
9. Retribusi Penggantian Biaya Cetak Peta	9. Retribusi Tempat Rekreasi dan Olahraga	
10. Retribusi Pelayanan Tera/ Tera Ulang	10. Retribusi Penyeberangan di Air	
11. Retribusi Penyedotan Kakus	11. Retribusi Penjualan Produksi Usaha Daerah	
12. Retribusi Pengolahan Limbah Cair		
13. Retribusi Pelayanan Pendidikan		

Figure 2.3 Classification of Local Retribution
Source: Direktorat Jenderal Perimbangan Keuangan (2009)

General services retribution is levy paid for services provided by local governments for the purposes of public interest and benefit, thus can be enjoyed by individuals or entities (Direktorat Jenderal Perimbangan Keuangan, 2018). Business service retribution is levy paid for services that commercially provided by government, which are:

- Services utilizing regional assets that have not used optimally; and/or

- Services by local government that have not provided adequately by private parties.

Specific permission retribution is the levy for permission given by the government to individuals or organizations that are intended for regulation and supervision of spatial use activities, use of natural resources, goods, facilities in order to protect the public interest and preserving sustainability.

2.3 Linear Programming

Linear programming was introduced as one of the optimization tools (Winston, 2004). Frederick S. Hillier & Gerals J. Lieberman (2010) stated that linear programming uses mathematical model to describe the concerned optimization problem. The mathematical model depicts the real problem through linear functions. In linear programming, there are some characteristics that are important as those help in systematically formulate the problem. First, decision variables must be defined. Decision variable describes the decisions to made. After that, defining the objective function of the decision maker for the problem, it can be maximizing or minimizing (Winston, 2004). Third, every linear programming problem must have constraints. It is something that limiting the decision (Jensen, 2004). Linear programming problems applies in competing activities for scarce resources or allocating resources by choosing the levels of activities (Hillier & Lieberman, 2010). Optimization problems example areas can be in education, petroleum, manufacturing industry, etc. Problems that are suitable to be solved using linear programming must follow these requirements:

- The goal of the problem is to either maximize or minimize a linear function of the decision variables. The linear function that is to be maximized or minimized is called objective function.
- Decision variables that are to be find using linear programming must satisfy a set of constraints. Therefore, each constraint must be a linear equation or linear inequality.
- A sign restriction is associated with each variable. For any variable xi, the sign restriction specifies that x_i must be either nonnegative ($x_i \geq 0$) or unrestricted in sign.

There are several methods available to solve linear programming. First, simplex method. It requires iterative procedure until the result is the most feasible solution. If the problem has only 2 decision variables, solving using graphical method is possible. When the problem gets more complex, with more than hundreds decision variable, it is better to solve using solver software such as LINGO, Excel, MATLAB, and many more.

There are variations of linear programming depends on the decision variable result. Linear programming assumes that the decision variable's value is divisible, which means that non-integer values allowed. If the decision maker wants to have result in integer value, then the method is integer linear programming (Hillier & Lieberman, 2010). The difference between integer linear programming mathematical model and linear programming mathematical model is only the additional restriction (constraints) in the variables must have integer value (Hillier & Lieberman, 2010). Moreover, there is one more modification of this model named binary integer programming. Which is used if the decision maker wants to have only some of the variables to have integer values and the rest are divisible.
Standard form of linear programming model is:

Objective function (maximize or minimize)

$$\text{Min/max } Z_{x_i} = c_1x_1 + c_2x_2 + \dots + c_nx_n \quad \textbf{(2.1)}$$

Subject to restrictions

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1 \quad \textbf{(2.2)}$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2 \quad \textbf{(2.3)}$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leq b_m \quad \textbf{(2.4)}$$

With non-negativity constraints

$$x_1 \leq 0, x_2 \leq 0, \dots, x_n \leq 0 \quad \textbf{(2.5)}$$

The usage of linear programming not only for problems that have linear objective function subject to linear constraints. However, in a modeling point of view, other assumptions such as proportionality, additivity, divisibility, and certainty (Hillier & Lieberman, 2010). Proportionality assumptions is about each contribution of activities x_j will be proportional to the value of objective function Z. Moreover, additivity is the function in linear programming on the left-hand (Z) is the total of the contributions of each decision variable of the activities. This assumption is violated if the model of summation is not following the real condition of the problem. For example, if there are two products in a company that somewhat competitive so selling both products will eventually decreasing the profit. For divisibility assumption, it is about the value of the decision variables. Linear programming allows all values including non-integer values, and binary (Hillier & Lieberman, 2010). Lastly, the value assigned to the parameter is assumed to be known constant. However, it is difficult in real applications that precise parameter is known or uncertain. Thus, that is the reason why sensitivity analysis is important to be done after found the solution.

2.4 Game Theory

One of the decision-making tools to solve variety range of problems is game theory. Founded in 1920 by Emile Borel and John von Neumann, game theory focuses on understanding the interaction between decision makers. Neumann first book about game theory, with titled *Theory of games and economic behavior* was a result of collaboration with the Princeton economist, Oskar Morgenstern (Osborne, 2000).

Game theory allows the decision makers to be more considerable towards each other (Brown & Shoham, 2008). Therefore, because one's decision will always depends on the behavior of others, game theory studies strategic interaction within group of individuals. A game, in the context of game theory, consists of players, strategies, and payoff. Players are the entity who participate and interact in the game. A player can be more than one person, it can be a company, political candidates, government, etc. In game theory players must be rational, meaning that he has well-defined objectives over the set of possible results and therefore has plan to implement best available strategy to achieve them (Koçkesen, 2007). While strategies are the rules of the game. Payoff means the advantage or disadvantage of the players because of the strategy selection, which is measured in similar unit, for example: profit, cost, sales, risk, etc. Moreover, between player can play the game in cooperative or non-cooperative. Cooperative game theory analyzes the competition and cooperation as coalitions in unstructured interactions (Augier &

Teece, 2016). On the other hand, non-cooperative game is modelling the actions of players, maximizing their utility in a structured procedure with detailed description of the moves and information available for each player (Augier & Teece, 2016). This method can be applied in a very broad range of reals, from economics, biology to political science can use game theory approach (Osborne, 2000).

In presenting the problem, there are two type of forms normal form and extensive form. Normal form or strategic form is a model of interacting decision-makers (Osborne, 2000). The form depicts combination action between players' strategies. To represent strategic games is using n-dimensional matrix. Overall, in row side assign for player 1 strategies, and column side corresponds for player 2 strategies, and each cell corresponds to the possible outcome or called payoff (Brown & Shoham, 2008). Even so, this model cannot picture the time when making the decision. Therefore, the assumption is that the actions are chosen once and for all. Based on the value inside the payoff cell, there are two types, zero sum game and non-zero game. If the winning of one player means the same value of losses for the other player, it is zero sum game. While, if adding the payoff value equals to value other than zero, or in another meaning the winning of one player does not equal to losing to other player, the game called non-zero sum game.

	C	D
C	a, a	b, c
D	c, b	d, d

Figure 2.4 Normal Form
Source: Brown & Shoham (2008)

On the other hand, extensive game is described by a game tree with every node represents every possible stage of the game as it is played. In addition, the model maker needs to specify the sequence of actions that might be occurred. Node is connected with edges that represent the strategies or actions that can be taken by a player. On every node that only has one edge connected to it, is a terminal node and it represents the payoff for the players if such combination of actions is taken (Hotz, 2005).

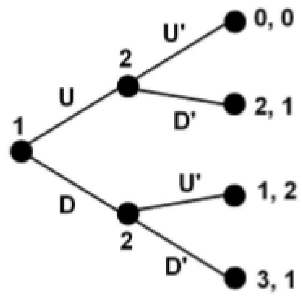

Figure 2.5 Extensive Form
Source: Heiko Hotz (2005)

Nash equilibrium according to Osborne (2000) is selecting the strategy to achieve a^* with the understanding that no player i can do better by choosing a strategy different from a_i^*, given that every other player j adheres to a_j^*. For achieving Nash equilibrium, a player can choose one of its strategy (pure strategy) or mix of the strategies based on certain probability. According to John Nash (1950), the first person who describe Nash equilibrium, every game with a finite number of agents and finite number of actions has at least one mixed strategy Nash equilibrium.

2.5 Data Collection

In order to come up with proper analysis, data is needed. Data collection is the process of gathering data of parameters needed for the research in a systematic way that enable to obtain information (Kabir, 2016). Accuracy and honesty in collecting the data are very important to maintain the integrity of the research. This process starts with identify what kind of data required. After that, determining the technique to collect the data. Experiments, telephone surveys, questionnaires and surveys, direct observations are the example of the most useful and frequently used data collection method (Groebner, et al., 2010).

2.5.1 Sampling Technique

Population is a complete set of individuals/objects that have similar characteristics. While sample is part of the population. This research is designed to learn about the entire population from the sample taken. In this research, the population is vehicle owners who like to park in Larangan market, Kedungrejo market, Tulangan market, Jaksa Agung Suprapto street, Gajahmada street, Basuki Rahmat street, Sidoarjo public health centre, *Dispenduk* office, and in front of train station.

Two categories of sampling techniques are statistical (probability) and non-statistical (non-probability) sampling. Probability sampling concept involves randomization, where the units are selected according to their inclusion probabilities (Vehovar, et al., 2016). On the other hand, non-probability sampling used arbitrary or purposive sample selection instead of randomized selection. The sampling technique for this research will use non-probability sampling because the data will be collected using questionnaire that will be exposed in the social media. The decision to participate in filling the questionnaire is up to the respondents or called volunteer sampling (Vehovar, et al., 2016). Non-probability sampling method in the last two decades has been extremely popular especially for commercial and market research practice due to the internet expansion. Moreover, survey using internet is much less costly even if compared to mail survey. Yet this internet survey is less reliable because of non-response (Brick & Williams, 2013).

2.5.2 Data Sufficiency

Number of sample for gathering data is important for the study which the goal is to make inferences about a population from a sample (Taherdoost, 2017). Three important criteria that must be specified to have the right sample size are sampling error, confidence level, and degree of variability (Miaoulis & R. D. Michener, 1976).

- Sampling Error

  Sampling error or level of precision is the range in which the true value of population is estimated to be. The common percentage of sampling error is 5%. The larger the number of errors, the greater the sample size required. However, large sample cannot guarantee precision (Bryman & Bell, 2003).

- Confidence Level

  This is the probability that the result of the survey falls within a specified range of values. Meaning that how sure the specified attribute of the population is estimated by sample survey.

- Degree of Variability

  Degree of variability is the estimation of the population's variance. If the population is more heterogeneous, then greater sample size is needed to achieve certain level of accuracy.

For population that are large and unknown, Cochran (1963) developed the equation 2.1 to calculate the number of samples.

$$n_o = \frac{Z^2 p(1-p)}{e^2} \quad \textbf{(2.6)}$$

Where,

n_o = Sampling size

Z^2 = The value corresponding to level of confidence required

p = Probability of sampling success

e = Degree of precision/error

There is, however, a simplified formula of Cochran (1963) that can be used when the population is known. The equation 2.7 provided by (Yamane, 1967).

$$n = \frac{N}{1 + N(e)^2} \quad \textbf{(2.7)}$$

Where,

n = Sample size

N = Population size

e = Level of precision

2.6 Research Position

Despite the basic theories explained in the previous sub chapter, this research also inspired by research papers. Actually, the study about parking system is not a common research in term of city planning. Although researches about parking system are available, there is no single paper which analyzed about parking zoning for digital system. Previous researchers are focused on optimize parking capacity, agen-based simulation for the parking capacity, analysis about the economic and safety for on-street parking, digital or digital parking design for smart cities, and so on. This research explores how to determine zones of parking in way of achieving optimum solution based on two perspective, parking service provider and parking users. Previous studies contend mostly in offline parking system and therefore this research will present new aspect of parking.

Table 2.1 Previous Research and Research Position

No	Authors	Year	Title	Type of Parking System		Aspect Analyzed				Method			
				Digital	Offline	Parking Capacity	Parking Space Management	Smart Parking Design	Effect of On-Street Parking	Linear Programming	Simulation	Qualitative Analysis	Tabu Search
1	**Abdelfatah,Akmal S. & Taha, Mahmoud A.**	**2014**	**Parking Capacity Optimization Using Linear Programming**		√	√				√			
2	**Banerjee, Soumya & Al-Qaheri, Hameed.**	**2011**	**An Intellignet Hybrid Scheme for Optimizing Parking Space: A Tabu Metaphor and Rough Set Based Approach**		√	√							√
3	**Zhao, Cong et al**	**2018**	**Advanced Parking Space Management Strategy Design: An Agent-Based Simulation Optimization Approach**		√		√				√		
4	**Mendoza-Silva, Germán Martín et al**	**2019**	**An Occupancy Simulator for a Smart Parking System: Developmental Design and Experimental Considerations**	√				√			√		
5	**Biswas, Subhadip. Chandra, Satish & Ghosh, Indrajit**	**2017**	**Effects of On-Street Parking in Urban Context: A Critical Review**		√				√			√	
6	**Sadhukhan, Pampa**	**2017**	**An IoT-based E-Parking System for Smart Cities**	√				√				√	
7	**Widodo & Rahmasari**	**2020**	**On-Street Parking Zoning for Digital Parking by Using Binary Linear Programming (Case Study: Sidoarjo Regency)**	√		√		√	√	√			

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CHAPTER 3
RESEARCH METHODOLOGY

This chapter attempts to describe the steps in conducting the research. There are 5 major steps: parameter identification stage, model construction stage, running model stage, analysis and interpretation stage, and conclusion and recommendation.

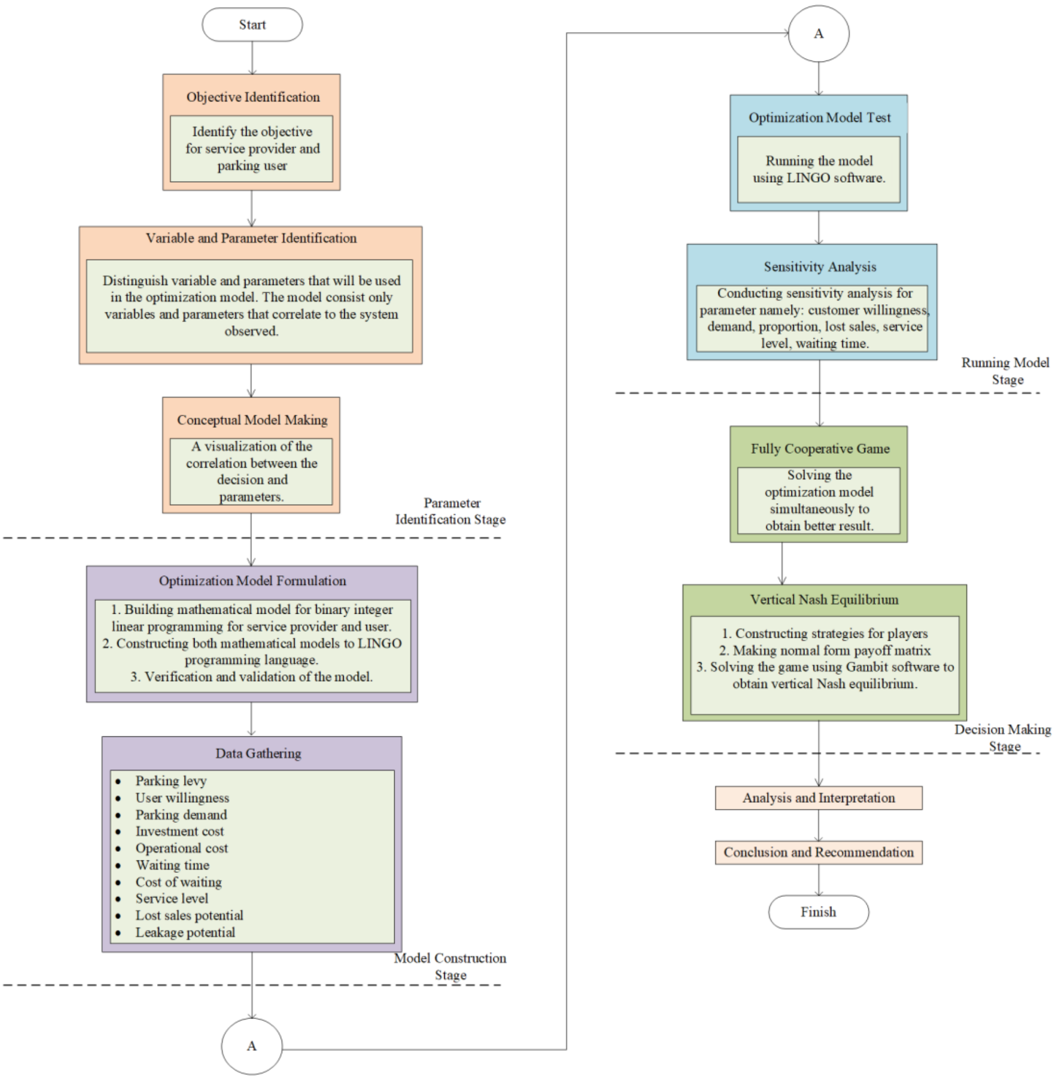


Figure 3.1 Methodology of Research

3.1 Parameter Identification Stage

This first stage aims to identify the variables that are relevant to be included in optimization model and the objectives of parking services provider and the parking user.

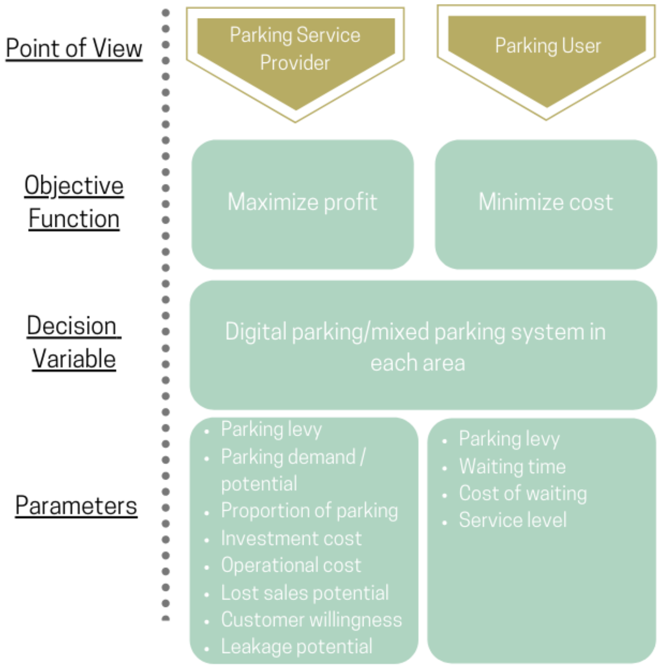


Figure 3.2 Parameter Identification Stage

3.1.1 Objective Identification

Identify the objective is the sub-stage of parameter identification stage. Output of this sub-stage is knowing what goal should be achieved from implementing the parking zoning in Sidoarjo. Objective will be used in the optimization model construction. The objective function for each party is shown in figure 3.2.

3.1.2 Variable and Parameters Identification

Variables, including decision variable, are the constituent components for the optimization model. Moreover, identifying parameters further determines the data needed. To identify parameters can be done by discussion with relevant parties and study literature. This step includes as well identify the limitations that both parties wanted to consider.

3.1.3 Conceptual Model

Conceptual model is made to give overall understanding about the problems including the connection of variables, decision, and output. The conceptual model illustrates in figure 3.3.

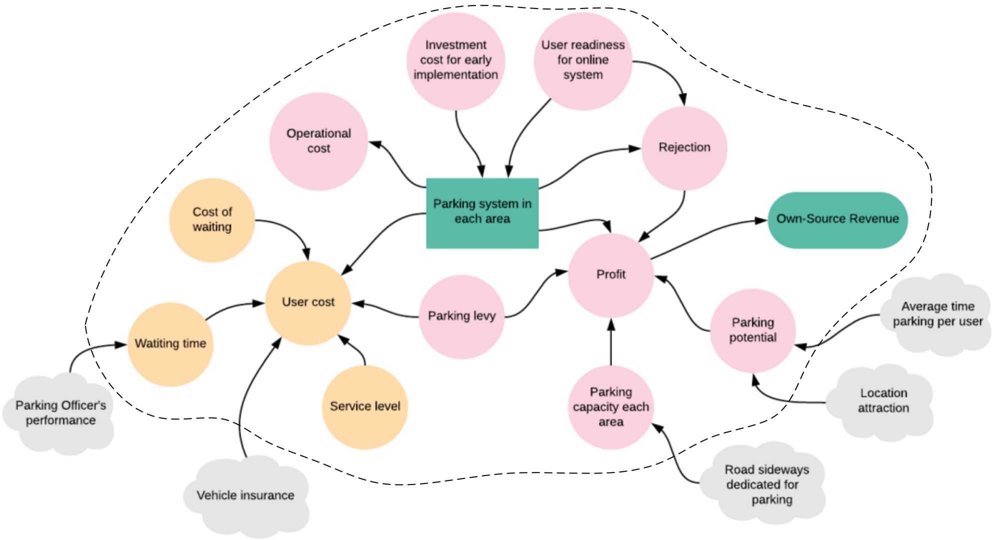


Figure 3.3 Conceptual Model of the Research

3.2 Model Construction Stage

The second stage is constructing the optimization model. This stage consists of two steps, data gathering and model formulation. Information obtained in the previous stage will be used as input in this stage. The purpose is to build optimization model from information that already obtained.

3.2.1 Optimization Model Formulation

In this sub-stage, the first step is making the mathematical model for binary linear programming. From the previous stage, objective and parameter identification, will be formulate into mathematical form of objective function. There will be two mathematical model, one is to accommodate parking service provider and the other is to accommodate parking user. After constructing objective function, formulate the constraints that already identified in previous stage in mathematical form.

In this research the objective function for parking service provide is to maximize profit. On the other hand, parking users' objective function is to minimize cost. Basic equation for parking service provider objective function is shown below,

Maximize profit = revenue – cost – lost sales – leakage **(3.1)**

Mathematical form of the equation 3.1 is explained in table 3.1 below

Table 3.1 Optimization Model for Parking Service Provider

$Profit$ (Z)	= revenue – cost – lost sales – leakage
$Revenue$	= Sales in full digital area + sales in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} D_{ijk} \times PO_i \times x_{jk}) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} (QO \times D_{ijk} \times PO_i) + ((1 - QO) \times D_{ijk} \times PF_i \times x_{jk}))$ **(3.2)**
$Cost$	= Investment cost in full digital area + (operational cost in full digital area + operational cost in mixed area)
	$= IC + \sum_{j=1}^{n}\sum_{k=1}^{q} OC_{jk} \times x_{jk}$ **(3.3)**
$Lost\ sales$	= lost sales in full digital area + lost sales in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LS_{ijk} \times x_{jk} \times PO_i \times D_{ijk}) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LS_{ijk} \times x_{jk} \times PF_i \times D_{ijk})$ **(3.4)**
$Leakage$	= Leakage in mixed area
	$= \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LP_{jk} \times (1 - QO) \times D_{ijk} \times PF_i \times x_{jk}$ **(3.5)**

Subject to,

1. Operational cost

$$\sum_{j=1}^{n}\sum_{k=1}^{q} OC_{jk} \times x_{jk} \leq b \quad \textbf{(3.6)}$$

2. Minimum full digital system

$$\sum_{j=1}^{n}\sum_{k=1}^{q} x_{jk} \geq g\,, \qquad k = 1 \tag{3.7}$$

3. Maximum mixed parking system

$$\sum_{j=1}^{n}\sum_{k=2}^{q} x_{jk} \leq h, \qquad k = 2 \tag{3.8}$$

4. Each area only has one system

$$x_{j1} + x_{j2} = 1, \qquad \forall j \tag{3.9}$$

5. Binary constraint for decision variable

$$x_{jk} \in \{1,0\}, \qquad \forall \mathrm{j,k} \tag{3.10}$$

Where,

Z = profit that will be maximized.

i = Type of vehicle (1,…,m).

j = Location of parking facility (1,…,n).

k = Parking system (1,…,q).

c = investment cost of parking system.

b = operational cost of parking system.

x_{jk} = Decision variable.

PO_i = Parking price for vehicle i in digital parking system.

PF_i = Parking price for vehicle i in offline parking system.

QO = Proportion of digital parking.

IC_{jk} = Investment cost in location j for system k.

OC_{jk} = Operational cost in location j for system k.

LP_{jk} = Leakage potential in location j for system k.

D_{ijk} = Demand/parking potential for vehicle i in location j for system k.

D_{ijk} = Demand/parking potential for vehicle i in location j for system k.

LS_{ijk} = Lost sales for vehicle i in location j for system k.

While from the user's perspective, the basic objective function model is shown in equation 3.11.

Minimize cost = parking levy + cost of waiting + parking service worth **(3.11)**

Mathematical model for equation 3.11 is explained in table 3.2.

Table 3.2 Optimization Model for Parking User

$Cost$ (Z)	= parking levy + cost of waiting – service worth
$parking\ levy$	= levy in full digital area + levy in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} (PO_i \times x_{jk})) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}(0.5 \times (PO_i + PF_i) \times x_{jk}))$ **(3.12)**
$Cost\ of\ waiting$	= Cost of waiting in full digital area + cost of waiting in mixed area
	$= \sum_{j=1}^{n}\sum_{k=1}^{q}(WC \times WO_{ij} \times x_{jk}) + \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}((0.5 \times (WF_{ij} + WO_{ij})) \times WC \times x_{jk})$ **(3.13)**
$Service\ worth$	= service worth in full digital area + service worth in mixed area
	$= \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}(SO_{ij} \times PO_i \times x_{jk}) + \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}(0.5 \times ((SO_{ij} \times PO_i) + (SF_{ij} \times PF_i)) \times x_{jk})$ **(3.14)**

Subject to,

1. Minimum full digital system

$$\sum_{j=1}^{n}\sum_{k=1}^{q} x_{jk} \geq g, \qquad k = 1 \tag{3.15}$$

2. Maximum mixed parking system

$$\sum_{j=1}^{n}\sum_{k=2}^{q} x_{jk} \leq h, \qquad k = 2 \tag{3.16}$$

3. Each area only has one system

$$x_{j1} + x_{j2} = 1, \qquad \forall j \tag{3.17}$$

4. Binary constraint for decision variable

$$x_{jk} \in \{1,0\}, \qquad \forall \text{j}, \text{k} \tag{3.18}$$

5. Minimum 50% customer willingness

$$\left(0.5 \times \left(WL_{1j} + WL_{2j}\right)\right) \geq 0.5 \times x_{j1}, \qquad \forall j, k \tag{3.19}$$

Where,

Z = Cost that will be minimized.

i = Type of vehicle (1,…,m).

j = Location of parking facility (1,…,n).

k = Parking system (1,…,q).

x_{jk} = Decision variable.

PO_i = Parking price for vehicle i in digital parking system.

PF_i = Parking price for vehicle i in offline parking system.

WO_j = Waiting time for digital parking system in location j.

WF_j = Waiting time for offline parking system in location j.

SO_j = Service level for digital parking system in location j.

SF_j = Service level for offline parking system in location j.

WL_{ij} = Customer willingness using vehicle i for digital system in location j.

After mathematical model is finished, it will be translated into LINGO model. There will be two binary linear programming mode, for parking service provider and parking user each. Objective function, constraints and data will be needed. Then, the model in LINGO must be verified with the mathematical model. The LINGO model must be in the same functions with the mathematical model.

3.2.2 Data Gathering

Table 3.3 Parking Area in Sidoarjo Regency

No	Parking Area
Public Facility	
1	Puskesmas Sidoarjo
2	Dispenduk Capil Office Sidoarjo
3	In front of Sidoarjo train station
Traditional Market	
1	In front of Larangan market
2	In front of Porong maket
3	New Tulangan market
Main Street	
1	Gajahmada street (Sop Ayam Klaten until UFO)
2	Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)
3	Basuki Rahmat Krian street (Indomart until Persebaya Store)

In this sub-stage, data that needed will be collected. The method to collect the data will be through online survey and secondary data from the research object. Due to time constraint, this research is limited only for 9 on-street parking area in Sidoarjo regency. Those are divided into 3 groups, public facility, traditional market, and main streets. By choosing those, the writer aims to create representative research. Table 3.3 lists all areas that are considered in this research.

Table 3.4 Data Gathering Plan

<table>
<tr><th>Party</th><th>Data Needed</th><th>Unit</th><th>Data Gathering Plan</th></tr>
<tr><td rowspan="8">Parking service provider</td><td>Parking levy</td><td>Rupiah (Rp)</td><td rowspan="7">Given from parking service provider</td></tr>
<tr><td>Parking demand / potential</td><td>Unit/day</td></tr>
<tr><td>Capacity of parking</td><td>Unit/area</td></tr>
<tr><td>Investment cost</td><td>Rupiah (Rp)</td></tr>
<tr><td>Operational cost</td><td>Rupiah (Rp)</td></tr>
<tr><td>Proportion parking</td><td>Percentage (%)</td></tr>
<tr><td>Leakage potential</td><td>Percentage (%)</td></tr>
<tr><td>Customer willingness</td><td>Percentage (%)</td><td>Survey</td></tr>
<tr><td rowspan="3">User</td><td>Waiting time</td><td>Minute</td><td rowspan="3">Survey</td></tr>
<tr><td>Cost of waiting</td><td>Rupiah (Rp)</td></tr>
<tr><td>Service level</td><td>Percentage (%)</td></tr>
</table>

The table 3.4 gives the list of data needed in order to conduct the research and the plan on getting the data. There are data that need survey to the parking user in Sidoarjo. Survey will be conducted using google form and using Bahasa. The survey questions plan is presented in table 3.5.

Table 3.5 Questions for Survey Plan

No	Data	Questions
1	Customer willingness	In scale of percentage, how willing are you to use digital parking system?
2	Waiting time	How long do you usually wait to be served by parking officer?
3	Cost of waiting	If waiting time quantified as the money you lose, how much it will be for each minute waiting?
4	Service level	How much do you think the parking levy worth for the service given?

3.3 Optimization Stage

This stage is carried out to bring optimal result of parking zoning in nine on-street parking areas in Sidoarjo regency. There are two steps in this stage, model running and sensitivity analysis.

3.3.1 Optimization Model Test

Model in LINGO will be run and the result of parking zoning in Sidoarjo will be obtained. Model test will be done in two steps, first running both models separately, and second run the models simultaneously. If the results are different, further analysis will be proposed.

3.3.2 Optimization Result Analysis

After getting solution from binary linear programming model, further analysis is conducted. Analysis on how the result differ from binary linear programming running model between parking service provider model and parking user model.

3.3.3 Sensitivity Analysis

This substage purpose is to analyze the effect on some parameters to the solution of the parking zones. The objective of this substage is to have a broader view of the effect of this solution that is obtained. By having this view, decision maker can at least consider several parameters that can change the solution of binary linear programming model. Parameters that are going to be sensitivity analyzed are described in table 3.6.

Table 3.6 Parameters for Sensitivity Analysis

No	Parameter for Sensitivity Analysis
1	Customer willingness
2	Parking demand
3	Mixed proportion
4	Lost sales mixed system
5	Waiting time
6	Service level

3.4 Decision Making Stage

The result from previous stage will need another decision making tools to achieve agreement between two parties. There are two decision making approach that will be utilized. First, solving the models simultaneously as maximize profit and minimize cost. Second, using game theory method to have satisfactory result of vertical Nash equilibrium of both players.

3.5 Analysis and Interpretation

In this stage, after obtaining the result from decision making stage, the result will be analyzed.

3.6 Conclusion and Recommendation

The last stage of this research is concluding and giving to the object observed based on the research result. Conclusion should answer the research objective.

CHAPTER 4
PARKING ZONING OPTIMIZATION MODELLING

In this chapter carries out overall steps in constructing the optimization model. Starting from objectives and parameters identification, conceptual model, model formulation, and data gathering.

4.1 Objectives and Parameters Identification

The first step in building the linear programming model for parking zoning is by knowing the goal for the parties as well as identifying parameters related to the whole system. With the objective known, the formulation of the binary programming will be more directed. While for the user the objective is to minimize cost. Parameters identification is conducted to know what parameters that can depict the objective function and the constraints. Process of identifying parameters is from the interaction with related stakeholders and literature review.

4.1.1 Objective and Parameters for Parking Service Provider

Parking service provider is the player who is given the responsibility by Dinas Perhubungan Sidoarjo to manage the digital parking. Therefore, the objective for the parking service provider is to maximizing profit. Profit is defined as gross profit that obtained from revenue minus cost. Parking revenue value is from the sales of parking in full digital system and mixed system. Moreover, there are two cost components from conducting the parking, investment cost and operational cost. Investment cost occurred only once, only for digital parking as the initialization cost. While operational cost occurred monthly.

In addition, parking service provider wants to consider the lost sales that might happened for both full digital parking zone and mixed zone. The definition of lost sales is when the parking user cannot get the parking area in selected parking zone. For full digital parking zone, parking users who refuse to use digital parking system will be counted as lost sales. While in the mixed parking system, lost sales can happen if the parking capacity of the offline system is smaller than the parking demand.

To generate lost sales value, customer willingness parameter needs to be generated. Previous study from Pomery et al (2015) defined customer willingness as individual's openness to chance, that her or his willingness to conduct certain behavior in situations that are conducive to that behavior. Moreover, this parameter also used as the idea to evaluate customer satisfaction of new technology of self-service kiosk (SSK) in a hotel setting (Hong & Slevitch, 2018) and as one of the prediction parameters in continuation of e-learning (Wu, et al., 2006). The Author then adopted the customer willingness parameter as the component of parking profit while embracing the new technology. While for the leakage component is amount of money that is potentially not given to the government, as the contribution for OSR. Leakage only happens in mixed system.

Table 4.1 Objective and Parameters for Parking Service Provider

Parking Service Provider	
Objective	Maximize Profit
Parameters	Parking levy
	Parking potential/demand
	Investment cost
	Operational cost
	Customer willingness
	Parking proportion
	Lost sales potential
	Leakage potential

4.1.2 Objective and Parameters for Parking User

Parking user is the party who uses the parking facilities in Sidoarjo. The objective function from the parking user perspective is minimize cost. This to have the same value in terms of money, with the other model that represents the parking service provider. Moreover, based on the previous study conducted by ITS Tekno Sains, in the table 4.2 shows the request of the parking users as well as the score for each request. To define the cost composition for the parking users, it is not merely about the parking levy paid by them but also consist of other components.

Table 4.2 Parking User's Demands for Parking Service in Sidoarjo

Code	Variable	Score
C1	Cashless payment to fasten the transaction process	3.49
C2	Progressive tariff is suitable to be used	2.15

Code	Variable	Score
C3	Parking transparency	4.03
C4	Parking security to ensure the safety of the vehicles	4.51
C5	Vehicle insurance	4.21
C6	Parking booking system to order parking slot	3.60
C7	Parking officers giving the best service and having the integrity	4.35
C8	Getting the information about vacant parking slot in the intended location	4.02
C9	Ease of getting parking space	4.07
C10	Ease of parking the vehicle	4.17

The score represents the scale of the level of agreement of the variable stated. The score ranges from 1 to 5, which 1 means the user strongly do not agree with the variable while 5 means the user strongly agree with the variable. The cost in linear programming model will consider the variables with code C7, C8, C9, and C10 because all of them have score above 4 in 1-5 score scale. C8, C9, and C10 will be defined as the waiting time for parking users getting the parking slot and for waiting to be served by the parking officers. Moreover, for C7 will be represented by the service level of the parking service. Service level defined as how many percent the parking levy is worth for the service given. Those are parameters that will be used in the linear programming model. Meanwhile parking safety and insurance will not be included in the model due to limited information.

Previous studies stated that waiting time is an important metric for firms to measure customer overall satisfaction (Luo, et al., 2003). Waiting time usually be seen as negative experience by customers from both an economic and psychological perspective (Kumar, et al., 1997). Due to its importance Mittal (2016) think that waiting time is one of the components of total cost that the customer bears. In order to give value to the loss because of waiting, a reliable estimation approach is necessary. Nonetheless, the study of estimating the waiting time value is very rare (Robinson & Chen, 2011). Therefore, due to difficult condition and all limitations, the value of waiting time will be obtained from survey.

The concept of service level or customer service according to a marketing book written by Gritomer, J (1998) is the consumer's assessment of a product or service whether it meets his or her expectations. There are several ways to measure service level. The goal is to measure cost, therefore the measurement of quality is relative to price paid or perceived value (Ilieska, 2013). Moreover, Anderson EW, Fornell C, Rust RT (1997) and Rust RT, Zahorik AJ (1993) have demonstrated the importance of service level to achieve maximum revenue in companies.

Table 4.3 Objective and Parameters for Parking User

Parking User	
Objective	Minimize cost
Parameters	Parking levy
	Waiting time
	Cost of waiting
	Service level

4.2 Conceptual Model

After identifying the parameter and objective for each player, a conceptual model is made to show the correlation between one to another. There are options of conceptual model format, that being used in here is influence diagram. Influence diagram useful when using process approach because it shows diagrammatically the system transformation process (Daellenbach & McNickle, 2005).

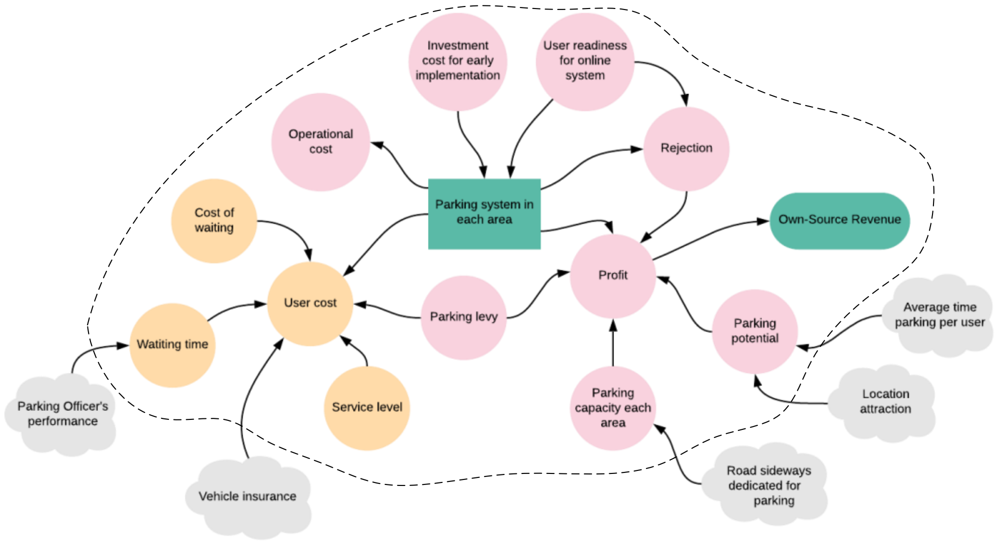


Figure 4.1 Influence Diagram of the Research

Figure 4.1 depicts the influence diagram of the system observed for the research. There are several forms of nodes in the influence diagram. The cloud-shape node represents the uncontrollable input. While round-shape node is the system variables. For node in square-shape, it represents the goal or decision rule in the system. Moreover, for the rounded square-shape node is for the output of the system. The dashed line function is to set the boundary for the

Round-shape node in pink color, it is the system variable for parking service provider. While round-shape node in light orange color represents the parking user's system variable. Overall, there are five cloud-shape nodes. Average time parking for each user or the duration of the parking as well as the attraction in each location are neglected in the system. This too applied for allocation road sideways for on-street parking to know the parking capacity. User cost variable components supposedly considering the vehicle insurance, therefore in this system it is not included. Furthermore, waiting time for vehicle user in the system neglects the factor of parking officer's performance.

4.3 Model Formulation

Optimization model building start with constructing the mathematical model and continue with translating the model into Lingo software. The model consists of the parameters that already decided beforehand and therefore follows the objective as well as constraints that already determined. Moreover, in this research the model is limited to car and motorcycle.

There are two linear programming models that are constructed, one from the parking service provider's perspective and the other is from parking user. As the parking service provider determined to maximize their profit, therefore their definition of profit is revenue subtracted by the cost to manage the parking, lost sales potential, and the leakage potential. While for parking user, the goal is to minimize the total parking cost paid by the user with factors considering in the model are waiting time and service level. Moreover, both models' decision variable will be in zero one integer programming, whereas its value must be either 0 or 1.

4.3.1 Parking Service Provider Model

In this sub chapter explains the structured way to formulate model for parking service provider.

a. Model Notation

Hereby the indices, parameters, decision variables that being used in parking service provider model.

Indices

i = Type of vehicle; i = 1,…,m

j = Location of parking facility; j = 1,…,n

k = Parking system; k = 1,…,q

Parameters

PO_i = Parking price for vehicle i in digital parking system.

PF_i = Parking price for vehicle i in offline parking system.

QO = Proportion of digital parking.

IC = Investment cost.

OC_{jk} = Operational cost in location j for parking system k.

LP_{jk} = Leakage potential in location j for parking system k.

D_{ijk} = Demand/parking potential for vehicle i in location j for parking system k.

D_{ijk} = Demand/parking potential for vehicle i in location j for parking system k.

LS_{ijk} = Lost sales for vehicle i in location j for parking system k.

Decision Variables

x_{jk} = Decision in parking location j implements parking system k.

b. Objective Function

The object of this research defines the revenue is amount of money generated from the parking levy of both system, full digital parking and mixed system. Moreover, for sales in full digital system it is the result of multiplication of parking levy and parking demand. For the mixed system sales is little different with the usage of parking proportion with symbol QO. While for the cost component is from the cost generated by the system which are investment cost and operational cost, each from the system applied. In fully digital system, lost sales are the opportunity losses of parking customers who prefer to have offline parking system. The equation of lost sales is the portion of customers who are not ready to implement digital parking times parking levy. Table 4.4 explains the information about mathematical model for the parking service provider. The blue shaded cell is for the basic equation while the yellow shaded cell is the mathematical translation.

Table 4.4 Optimization Model for Parking Service Provider

$Profit$ (Z)	= revenue – cost – lost sales – leakage
$Revenue$	= Sales in full digital area + sales in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} D_{ijk} \times PO_i \times x_{jk}) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} (QO \times D_{ijk} \times PO_i) + ((1-QO) \times D_{ijk} \times PF_i \times x_{jk}))$ **(4.1)**
$Cost$	= Investment cost in full digital area + (operational cost in full digital area + operational cost in mixed area)
	$= IC + \sum_{j=1}^{n}\sum_{k=1}^{q} OC_{jk} \times x_{jk}$ **(4.2)**
$Lost\ sales$	= lost sales in full digital area + lost sales in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LS_{ijk} \times x_{jk} \times PO_i \times D_{ijk}) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LS_{ijk} \times x_{jk} \times PF_i \times D_{ijk})$ **(4.3)**
$Leakage$	= Leakage in mixed area
	$= \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} LP_{jk} \times (1-QO) \times D_{ijk} \times PF_i \times x_{jk}$ **(4.4)**

c. Constraint Functions

After the objective function mathematical model formulated, the next step is to construct the constraints of the linear programming model. Overall, there are five constraints which are:

1. Operational cost

$$\sum_{j=1}^{n}\sum_{k=1}^{q} OC_{jk} \times x_{jk} \leq b \qquad \textbf{(4.5)}$$

2. Minimum full digital system

$$\sum_{j=1}^{n}\sum_{k=1}^{q} x_{jk} \geq g\,, \qquad k = 1 \qquad \textbf{(4.6)}$$

3. Maximum mixed parking system

$$\sum_{j=1}^{n}\sum_{k=2}^{q} x_{jk} \leq h, \qquad k = 2 \qquad \textbf{(4.7)}$$

4. Each area only has one system

$$x_{j1} + x_{j2} = 1, \qquad \forall j \qquad \textbf{(4.8)}$$

5. Binary constraint for decision variable

$$x_{jk} \in \{1{,}0\}, \qquad \forall \mathrm{j,k} \qquad \textbf{(4.9)}$$

4.3.2 Parking User Model

In this sub chapter consists of the formulation of objective function and constraints for parking user.

a. Model Notation

Indices

i = Type of vehicle; i = 1,…,m

j = Location of parking facility; j = 1,…,n

k = Parking system; k = 1,…,q

Parameters

PO_i = Parking price for vehicle i in digital parking system.

PF_i = Parking price for vehicle i in offline parking system.

WO_{ij} = Waiting time for digital parking system in location j.

WF_{ij} = Waiting time for offline parking system in location j.

SO_{ij} = Service level for digital parking system in location j.

SF_{ij} = Service level for offline parking system in location j.

WL_{ij} = Customer willingness using vehicle i for digital system in location j.

Decision Variable

x_{jk} = Decision in parking location j implements parking system k.

b. Objective Function

The objective function of parking user is to minimize the total cost paid for the parking service in 9 parking areas. Components of cost that are considered in the model beside parking levy are cost of waiting and the worthiness of parking service. Overall, the mathematical model of parking user is summarized in the table. Parking levy formulation is in equation 4.10, where in full digital area the formulation is the digital parking levy (PO_i), while for mixed area there are 2 types of parking levy therefore the formulation will take the average value.

Cost of waiting definition is the multiplication of waiting time and the cost of waiting based on customer's perspective. The mathematical model written in equation 4.11. Moreover, the service worth considers the service level of each parking system. In this model, the service level definition is how much the service worth from the parking levy. Service worth mathematical model in equation 4.12.

Table 4.5 Optimization Model for Parking User

$Cost$ (Z)	= parking levy + cost of waiting – service worth
$parking\ levy$	= levy in full digital area + levy in mixed area
	$= (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q} (PO_i \times x_{jk})) + (\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}(0.5 \times (PO_i + PF_i) \times x_{jk}))$ **(4.10)**
$Cost\ of\ waiting$	= Cost of waiting in full digital area + cost of waiting in mixed area
	$= \sum_{j=1}^{n}\sum_{k=1}^{q}(WC \times WO_{ij} \times x_{jk}) + \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}((0.5 \times (WF_{ij} + WO_{ij})) \times WC \times x_{jk})$ **(4.11)**

$Service\ worth$	= service worth in full digital area + service worth in mixed area
	(4.12) $= \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}(SO_{ij} \times PO_i \times x_{jk}) + \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{q}\left(0.5 \times \left((SO_{ij} \times PO_i) + (SF_{ij} \times PF_i)\right) \times x_{jk}\right)$

c. Constraint Functions

Meanwhile for the limitations of the parking user model there are five limitations as listed below:

1. Minimum full digital system

$$\sum_{j=1}^{n}\sum_{k=1}^{q} x_{jk} \geq g\,, \qquad k = 1 \tag{4.13}$$

2. Maximum mixed parking system

$$\sum_{j=1}^{n}\sum_{k=2}^{q} x_{jk} \leq h, \qquad k = 2 \tag{4.14}$$

3. Each area only has one system

$$x_{j1} + x_{j2} = 1, \qquad \forall j \tag{4.15}$$

4. Binary constraint for decision variable

$$x_{jk} \in \{1,0\}, \qquad \forall \mathrm{j,k} \tag{4.16}$$

5. Minimum 50% customer willingness

$$\left(0.5 \times (WL_{1j} + WL_{2j})\right) \geq 0.5 \times x_{j1}, \qquad \forall j,k \tag{4.17}$$

4.3.3 Verification and Validation Parking Service Provider Optimization Model

In this sub chapter will explain the verification and validation step of the mathematical model that already constructed beforehand.

4.3.3.1 Verification Optimization Model

The first verification model method is by checking the error in LINGO solver. After writing the optimization model, pressing CTRL + G on the keyboard then LINGO will begin compiling the model. The software will check whether the model does not have any syntax error. There are more than 100 type of errors that LINGO can detect. If there is no error occurs in the model, a generated model report window will appear. If not, an error report window will pop out like in the figure 4.2.

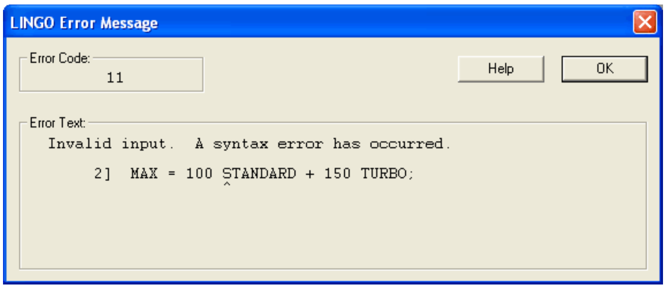


Figure 4.2 LINGO Error Message

For parking service provider model, error message window does not appear in the LINGO software. Instead, a generated model report appears as shown in figure 4.3.

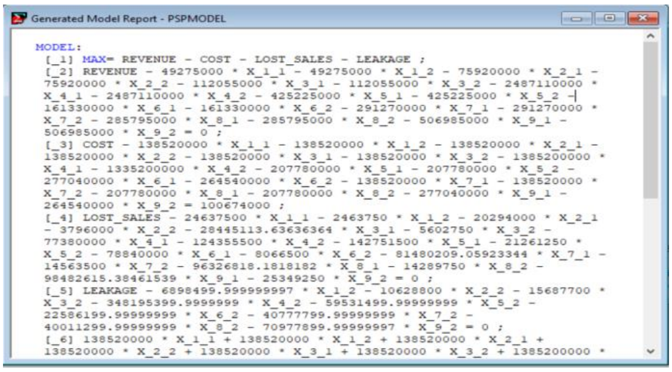


Figure 4.3 LINGO Model Report PSP Model

On the other hand, the same method applies for parking user model. There is no error message appeared. Instead, the generated model report comes up as shown in the figure 4.4.

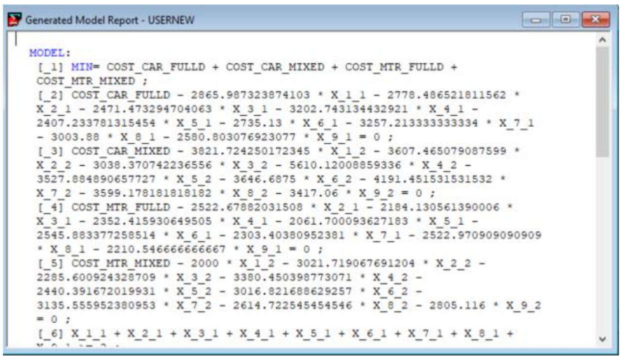


Figure 4.4 LINGO Model Report User Model

Another way to approach this process is by checking the solver information status of the algorithm written on the LINGO software. The information status or solver status window will appear if there are no formulation errors during the compilation phase. Figure 4.5 is the example of the LINGO solver status. To confirm the verification of the model, see model class and state in solver status box on the top left.

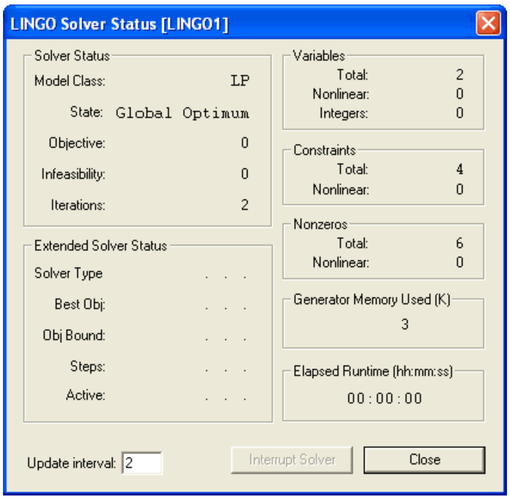


Figure 4.5 LINGO Solver Status

Model class defines the classification of the written model. There are many model class types, for example linear programming (LP), quadratic programming (QP), and conic program (CONE). Meanwhile for state, it gives the status of the current solution. Once the solver starts working, the state will change to “Infeasible”, meaning that the solver already generates tentative solutions, but not all constraints are satisfied. When all constraints are satisfied, the status will change into “Feasible” state until the best solution appear. States that might appear when solver stop running are “Global Optimum” or “Local Optimum”. Other states can be “Unbounded”, “Interrupted”, and “Undetermined”.

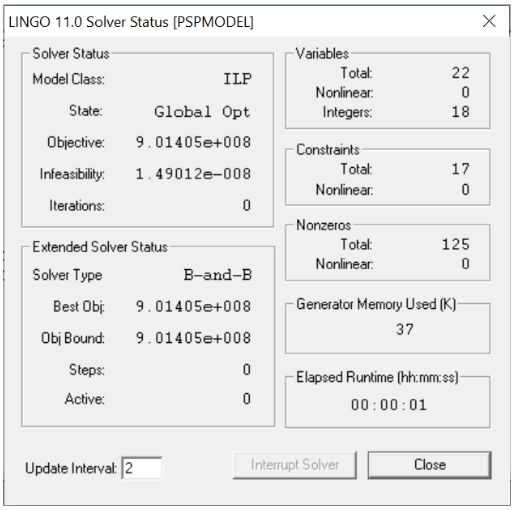


Figure 4.6 LINGO Solver Status PSP Model

Figure 4.6 depicts the solver result of parking service provider model. The model class appears to be ILP (Integer Linear Programming), which corresponds to the model. Moreover, the state of the solver is global optimum which means the solution is on the peak. Based on the two explanations of model verification, it can be concluded that parking service provider model is verified.

Meanwhile in figure 4.7 shows the solver status report for parking user model. Integer Linear Programming (ILP) is identified as the model class. Thus, the state of the solver is global optimum. It can be concluded for parking user model is verified.

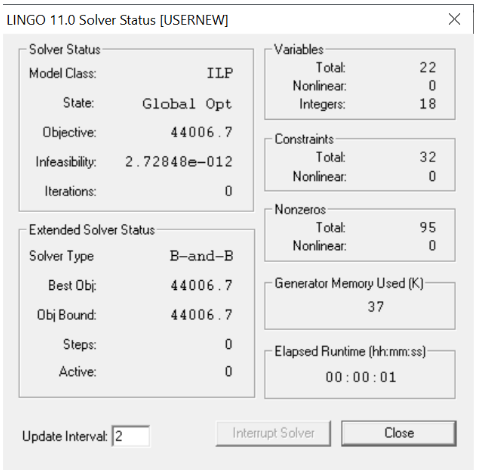


Figure 4.7 LINGO Solver Status PSP Model

4.3.3.2 Validation Optimization Model

Hillston (2003), a Professor in University of Edinburgh stated that overall, there are three approaches to validate model which are expert intuition, real system measurements, and theoretical results/analysis. The author is incapable to discuss the model with the expert, which is parking service provider, due to their internal conflict. While for real system measurement it is also impossible to do because there is no comparing data for the new system. Moreover, due to the context of new parking system, no historical data is available that can be used as tools for validation.

Lastly, checking the theoretical results will be used to validate both models. Theoretical result means that if the operational law is concurring with the model output then the model behave correctly. Behavior that going to be verified is the expected leakage in PSP model. With new digital system, leakage amount should be lower than initial system. While for parking user model, validating the model by comparing the total cost for full digital scenario with mixed scenario. If the model behave correctly, total cost for mixed will be higher than full digital.

Based on the data given by parking service provider, in the latest 2 years, the target of Own Source Revenue (OSR) from parking activity only achieved 30%. Even though there are other reasons of this phenomena, therefore it is assumed 70% of those are leaked because of the illegal levy. Moreover, dummy data for demand, willingness, investment cost, and operational cost are generated to calculate the leakage amount.

Table 4.6 Demand Dummy Data

Vehicle	Location Index	Digital	Mixed
Car	1	2.000	2.000
	2	3.000	3.000
	3	4.000	4.000
	4	5.000	5.000
	5	6.000	6.000
	6	7.000	7.000
	7	8.000	8.000
	8	9.000	9.000
	9	10.000	10.000
Motorcycle	1	-	-
	2	4.000	4.000
	3	5.000	5.000
	4	6.000	6.000
	5	7.000	7.000
	6	8.000	8.000
	7	9.000	9.000
	8	10.000	10.000
	9	11.000	11.000

Table 4.6 is the dummy data for annual parking demand for each vehicle in every location. The number of demands is determined arbitrarily, not following any specific pattern. Moreover, among those parking users, not all willing to use digital parking. In the table 4.7 gives dummy portion in each location about the willingness of user to use digital parking.

Table 4.7 Customer Willingness Dummy Data

Vehicle	Location	Willingness
Car	1	0,50

Vehicle	Location	Willingness
	2	0,70
	3	0,75
	4	0,80
	5	0,60
	6	0,50
	7	0,71
	8	0,90
	9	1,00
Motorcycle	1	-
	2	0,80
	3	0,60
	4	0,50
	5	0,60
	6	0,30
	7	0,50
	8	0,64
	9	0,60

With the dummy data available, total profit of the arbitrarily parking system is calculated in the table 4.8. The total profit is Rp 22.142.857 after subtracting the total revenue with cost, lost sales and leakage. The leakage potential for the new system is Rp 11.600.000. Compared with table 4.9 that describes the leakage for initial condition, the total leakage is Rp 197.400.000, therefore this value is higher than the new system.

Table 4.8 Leakage from New System

System	Location	Revenue	Investment Cost	Operational Cost	Lost sales	Leakage	Profit
full	1	Rp 6.000.000		Rp 20.000.000	Rp 3.000.000		-Rp 17.000.000
full	2	Rp 17.000.000		Rp 25.000.000	Rp 4.300.000		-Rp 12.300.000
full	3	Rp 22.000.000		Rp 15.000.000	Rp 7.000.000		Rp -
full	4	Rp 27.000.000		Rp 30.000.000	Rp 9.000.000		-Rp 12.000.000
mixed	5	Rp 32.000.000	Rp 20.000.000	Rp 16.000.000	Rp 1.600.000	Rp 3.200.000	Rp 11.200.000
mixed	6	Rp 37.000.000		Rp 20.000.000	Rp 1.850.000	Rp 3.700.000	Rp 11.450.000
full	7	Rp 42.000.000		Rp 15.000.000	Rp 15.857.143		Rp 11.142.857
mixed	8	Rp 47.000.000		Rp 24.000.000	Rp 2.350.000	Rp 4.700.000	Rp 15.950.000
full	9	Rp 52.000.000		Rp 9.500.000	Rp 8.800.000		Rp 33.700.000
						Total Leakage	Rp 11.600.000

Table 4.9 Leakage from Initial System

Location	Revenue	Leakage
1	Rp 6.000.000	Rp 4.200.000
2	Rp 17.000.000	Rp 11.900.000
3	Rp 22.000.000	Rp 15.400.000
4	Rp 27.000.000	Rp 18.900.000
5	Rp 32.000.000	Rp 22.400.000
6	Rp 37.000.000	Rp 25.900.000
7	Rp 42.000.000	Rp 29.400.000
8	Rp 47.000.000	Rp 32.900.000
9	Rp 52.000.000	Rp 36.400.000
Total Leakage		Rp 197.400.000

Based on the explanation above, it can be concluded that parking service provider model is valid based on leakage potential calculation. As for parking user model, different approach is use to validate the model. Using dummy data, the total cost are calculated when all location choose full digital and when all location choose mixed system. The dummy data are set in accordance to the real condition. For example, waiting time of offline system is longer than it is for digital system. Table 4.10 shows the calculation of cost that the user has to paid if each area implement digital parking system. While table 4.11 provides calculation of cost that the user has to paid if each area implement mixed parking system. The result shows the total cost for digital system is lower than total cost for mixed system. This implication is appropriate with the waiting time and service level. In conclusion, the model already described the real condition of the system.

Table 4.10 Total Cost for Digital System

Location Index	Car Digital Cost	Motor Digital Cost	Cost
1	Rp 2.154	Rp -	Rp 2.154
2	Rp 2.454	Rp 2.054	Rp 4.508
3	Rp 2.634	Rp 1.714	Rp 4.348
4	Rp 2.364	Rp 1.554	Rp 3.918
5	Rp 2.214	Rp 1.654	Rp 3.868
6	Rp 2.154	Rp 2.354	Rp 4.508
7	Rp 2.754	Rp 2.154	Rp 4.908
8	Rp 2.514	Rp 1.854	Rp 4.368
9	Rp 2.724	Rp 1.994	Rp 4.718
Total Cost			Rp 37.296

Table 4.11 Total Cost for Mixed System

Location Index	Car Mixed Cost	Motor Mixed Cost	Cost
1	Rp 3.558	Rp -	Rp 3.558
2	Rp 3.544	Rp 2.647	Rp 6.191
3	Rp 3.202	Rp 2.647	Rp 5.849
4	Rp 5.146	Rp 2.647	Rp 7.793
5	Rp 3.412	Rp 2.647	Rp 6.059

Location Index	Car Mixed Cost	Motor Mixed Cost	Cost
6	Rp 3.081	Rp 2.647	Rp 5.727
7	Rp 4.485	Rp 2.647	Rp 7.131
8	Rp 3.351	Rp 2.647	Rp 5.997
9	Rp 3.222	Rp 2.647	Rp 5.869
Total Cost			Rp 54.174

4.4 Data Gathering and Processing

In order to obtain data for the linear programming model, the sources are from the object of this research (parking service provider) and from parking user survey. As seen in the table 4.12, the data needed, unit data, and the gathering plan is detailed.

Table 4.12 Data Gathering Plan

Model	Data Needed	Unit	Data Gathering Plan
Parking service provider	Parking levy	Rupiah (Rp)	Given from parking service provider
	Parking demand / potential	Unit/day	
	Capacity of parking	Unit/area	
	Investment cost	Rupiah (Rp)	
	Operational cost	Rupiah (Rp)	
	Parking proportion	Percentage (%)	
	Customer willingness	Percentage (%)	Survey
User	Waiting time	Minute	Survey
	Cost of waiting	Rupiah (Rp)	
	Service level	Percentage (%)	

Prior to the survey, a data minimum data sample was calculated using equation 2.7. However, the survey data is not sufficient as it is difficult to reach parking users through online survey. Therefore, the data is assumed sufficient. The survey was conducted for one month with total 257 respondents. The demographic of the from the parking area is 19 respondents from Puskesmas Sidoarjo, 21 respondents from office Dispenduk capil, 21 respondents from in front of Sidoarjo train station, 28 respondents from in front of Larangan market, 18 respondents from in front of Porong market, 16 respondents from Tulangan market, 80 respondents from Jl. Gajahmada, 23 respondents from Jl. Jaksa Agung Suprapto, 28 respondents from Jl. Basuki Rahmat Krian. Recapitulation data for survey result after conducting uniformity test is shown in the table below,

Table 4.13 Total Data from Survey

Model	Data Needed	Unit	Total Data
PSP	Customer willingness	Percentage (%)	257
User	Waiting time offline	Minute	250
	Cost of waiting	Rupiah (Rp)	225
	Service level digital	Percentage (%)	253
	Service level offline	Percentage (%)	253

4.4.1 Parking Levy

Parking levy parameter is included in the model with the variable of PO_i for digital system and PF_i for offline system. Parking levy is regulated in Peraturan Daerah Kabupaten Sidoarjo Nomor 17 tahun 2019 about parking mechanism. Parking levy for car is Rp 3000 and motorcycle is Rp 2000 for both digital and offline system.

Table 4.14 Parking Levy data

	Digital	Offline
Car	Rp 3.000	Rp 3.000
Motorcycle	Rp 2.000	Rp 2.000

4.4.2 Parking Demand

Parking demand data that is given by parking service provider is the average number of vehicle (car and motorcycle) that park in the parking area each day. Subsequently, those numbers will be multiplied by 365 to generate demand in one year. In the table 4.15 also presents the parking space unit in each parking area.

Table 4.15 Parking Demand Data for Each Location

No.	Detail Location	Parking Space Unit		Demand	
		R4	R2	R4	R2
Public Facility					
1	Puskesmas Sidoarjo	15	0	45	0
2	Dispenduk Capil Office Sidoarjo	28	8	58	17

No.	Detail Location	Parking Space Unit		Demand	
		R4	R2	R4	R2
3	In front of Sidoarjo train station	43	13	85	26
Traditional Market					
1	In front of Larangan Market	800	120	2130	212
2	In front of Porong Market	50	30	345	65
3	New Tulangan market	50	18	124	35
Main streets					
1	Jl. Gajahmada (Sop Ayam Klaten until UFO)	76	19	228	57
2	Jl. Jaksa Agung Suprapto (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	117	26	229	48
3	Jl. Basuki Rahmat Krian (Indomart until Persebaya Store)	129	38	387	114

On average, one parking slot is being used 3 times per day. The highest parking turn over happens in front of Porong market with 7 times. Traditional market tends to have higher parking demand than public facility and main streets. Usually, people visit traditional market regularly in every morning and spend time from 30 minutes to 2 hours. Therefore, it is very crowded in the morning. Main streets average parking demand is below traditional market. Main streets' parking visitors number depends on the attractions around it (stores, restaurants,etc). Jl. Basuki Rahmat Krian attracts more customers due to its completeness of stores around. Meanwhile people are not visiting public facility everyday therefore, those areas have the lowest parking demand.

4.4.3 Investment Cost

Investment cost is the amount of money that will be spend for initiating the digital parking in Sidoarjo city. Cost that included in the calculation is only for fixed cost. Table 4.9 gives detail information of the investment cost. The total cost is Rp 3.555.800.000, therefore this amount being spent to build a system for the entire Sidoarjo regency with 300 parking areas. Therefore, for the model build by the author, with 9 parking areas the amount of investment cost will be adjusted to Rp 100.647.000.

Table 4.16 Investment Cost for Digital Parking System

Cost Components	Quantity	Unit Price	Total
A. Fixed Investment			
1. Hardware			
a. Data Center (Server and other needs)			Rp650.000.000
Total Hardware			Rp650.000.000
2. Land and Building			
Building and other needs (45 % from hardware)			Rp292.500.000
3.Software			
Mobile Apps			Rp100.000.000
- Application for the parking officers			
- Application for parking users			
- Account playstore developer			
Total Software			Rp100.000.000
3. Workers			
General Manager	1 person	Rp12.000.000	Rp144.000.000
IT and Data Center	6 person	Rp8.000.000	Rp576.000.000

Cost Components	Quantity	Unit Price	Total
Total Workers			Rp720.000.000
EPC (2+3)			Rp1.762.500.000
Contigency 5% EPC			Rp88.125.000
Administration and Insurance Cost 2%EPC			Rp35.250.000
Environment and Social 5% EPC			Rp88.125.000
Fixed Investment			Rp1.974.000.000
B. Cost of Operational Preparation			
1. Preparation Cost			
10 % from project value (Fixed Investment)			Rp197.400.000
2. Maintenance Cost			Rp1.184.400.000
Fixed Capital			Rp3.355.800.000

4.4.4 Operational Cost

Another cost component that accounts to the model is operational cost. Operational cost attached to the parking areas because in each area the number of parking officers are different, depending on the size of it. Overall, there are two components of operational cost, parking officer cost and miscellaneous cost. Table 4.17 gives detail information about operational cost for full digital in Larangan market. Compared to the table 4.18 afterwards, in mixed system not all parking officers will be owned scanner QR cost and training.

Table 4.17 Operational Cost for Full Digital Parking System in Front of Larangan Market

Components	Cost	Quantity	Unit	Total
1. Parking Officers Cost				
Parking Officers	Rp 4.300.000,00	20	person	Rp 1.032.000.000,00

Components		Cost	Quantity	Unit		Total
Scanner QR code	Rp	1.000.000,00	20	person	Rp	240.000.000,00
Training Cost	Rp	500.000,00	20	person	Rp	120.000.000,00
Total Parking Officer Cost					Rp	1.392.000.000,00
2. Miscellaneous Cost						
Supervision Cost 10% Workers	Rp	103.200.000,00			Rp	103.200.000,00
Total Miscellaneous Cost					Rp	103.200.000,00
Total Operational Cost					Rp1.495.200.000,00	

Table 4.18 Operational Cost for Mixed Parking System in Front of Larangan Market

Components		Cost	Quantity	Unit		Total
1. Parking Officers Cost						
Parking Officers	Rp	4.300.000,00	20	person	Rp	1.032.000.000,00
Scanner QR code	Rp	1.000.000,00	16	person	Rp	192.000.000,00
Training Cost	Rp	500.000,00	16	person	Rp	8.000.000,00
Total Parking Officer Cost					Rp	1.232.000.000,00
2. Miscellaneous Cost						
Supervision Cost 10% Workers	Rp	103.200.000,00			Rp	103.200.000,00
Total Miscellaneous Cost					Rp	103.200.000,00
Total Operational Cost					Rp1.335.200.000	

The summary of operational cost for each parking system is presented in table 4.19.

Table 4.19 Summary of Operational Cost

Parking Location	Location Index	Operational Cost	
		Full Digital	Mixed
Puskesmas Sidoarjo	1	Rp 138.520.000	Rp 138.520.000
Dispenduk Capil Office Sidoarjo	2	Rp 138.520.000	Rp 138.520.000
In front of Sidoarjo train station	3	Rp 138.520.000	Rp 138.520.000
In front of Larangan market	4	Rp 1.385.200.000	Rp 1.335.200.000
In front of Porong market	5	Rp 207.780.000	Rp 207.780.000
New Tulangan market	6	Rp 277.040.000	Rp 264.540.000
Jl. Gajahmada (Sop Ayam Klaten until UFO)	7	Rp 138.520.000	Rp 138.520.000
Jl. Jaksa Agung Suprapto (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	Rp 207.780.000	Rp 207.780.000
Jl. Basuki Rahmat Krian (Indomart until Persebaya Store)	9	Rp 277.040.000	Rp 264.540.000

4.4.5 Parking Proportion

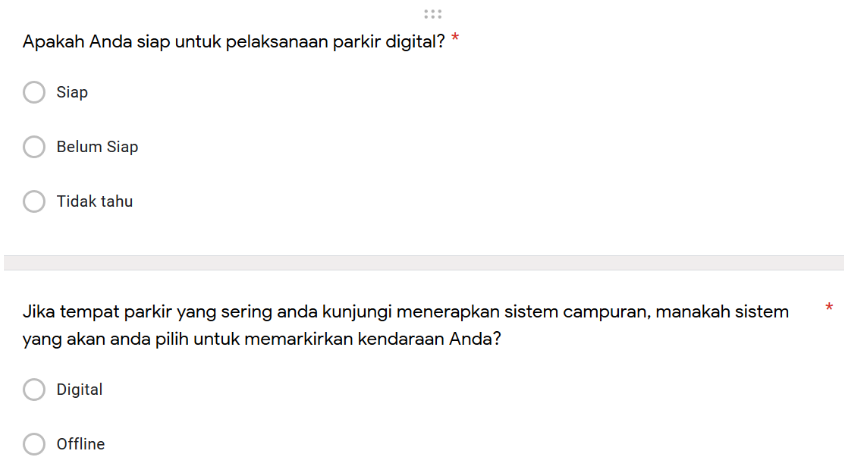
Parking proportion or QO as the variable in the model represent the portion of parking system in mixed area. Moreover, prior study about determining the parking proportion is not available yet. Hence, the assumption of parking proportion can be seen in table 4.20. In every parking area, if the chosen system is mixed, there will be 80% of the area implement digital system and the rest applies conventional system.

Table 4.20 Parking System Proportion

Parking System	Proportion
Digital System	80%
Offline System	20%

4.4.6 Customer Willingness

Customer willingness represents the demand of digital parking. The value of this parameter is gotten from survey. Figure 4.8 illustrates part of the survey questions that being used as the value for customer willingness. If the respondent answer the first question *"Apakah Anda siap untuk pelaksanaan parkir digital?"* (Are you ready/willing to use digital parking?) with "*siap*" (ready), and the following question answered with "digital" option, it means that the respondent willing to use digital parking instead of conventional system.



Apakah Anda siap untuk pelaksanaan parkir digital? *

- Siap
- Belum Siap
- Tidak tahu

Jika tempat parkir yang sering anda kunjungi menerapkan sistem campuran, manakah sistem yang akan anda pilih untuk memarkirkan kendaraan Anda? *

- Digital
- Offline

Figure 4.8 Survey Question for Customer Willingness

The survey result of customer willingness parameter shows in table 4.21. Customer willingness is associated with lost sales in certain area, therefore the index is based on location and vehicle type. The highest willingness is car users in Larangan market with the value equal to 1. On the other hand, the lowest willingness parameter is motorcycle in Porong market.

Table 4.21 Summary of Customer Willingness

No.	Detail Location	Customer Willingness	
		Car	Motorcycle
1	Puskesmas Sidoarjo	0,50	-
2	Dispenduk Capil Office Sidoarjo	0,70	0,90
3	In front of Sidoarjo train station	0,75	0,73
4	In front of Larangan market	1,00	0,50
5	In front of Porong market	0,70	0,38
6	New Tulangan market	0,50	0,57
7	Gajahmada street (Sop Ayam Klaten until UFO)	0,71	0,76

No.	Detail Location	Customer Willingness	
		Car	Motorcycle
8	Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	0,67	0,64
9	Basuki Rahmat Krian street (Indomart until Persebaya Store)	0,85	0,60

4.4.7 Lost Sales Potential

Lost sales potential is divided into two types, lost sales in full digital system and lost sales in mixed system. For lost sales in full digital, the value gotten from the equation 4.18 below.

$$lost\ sales\ full\ digital = 1 - customer\ willingness \quad \textbf{(4.18)}$$

Meanwhile for lost sales in mixed system, due to limitation of data, the value is assumed to be 5% of the parking demand in each parking location.

4.4.8 Leakage Potential

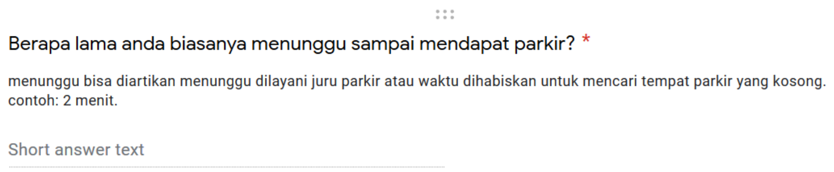
Leakage is the parameter that tells about the amount of unachievable OSR target. Based on the data in the table 4.22, for the latest 2 years data, the average achievement is only 30%. For this research, 70% of the target is assumed to be leakage potential caused by illegal levies.

Table 4.22 OSR Achievement

Year	Achievement
2010	108%
2011	134%
2012	116,25%
2013	122,63%
2014	29,40%
2015	101,44%
2016	39%
2018	27,50%

4.4.9 Waiting Time

Waiting time is the duration for the people wait to be served by parking officers or can also mean the time spend to find parking spot. In the survey form, the question is shown in the figure 4.9.


Berapa lama anda biasanya menunggu sampai mendapat parkir? *

menunggu bisa diartikan menunggu dilayani juru parkir atau waktu dihabiskan untuk mencari tempat parkir yang kosong.
contoh: 2 menit.

Short answer text

Figure 4.9 Survey Question for Waiting Time

In the parking user model, there are two variables that represents waiting time, WO is for digital parking system waiting time while WF is waiting time in conventional parking system. Parking user survey only for WF input, as the digital system has not yet implemented. Therefore, waiting time for digital system is set to be 1 minute. The new system offers a faster way to find parking slot and to do payment.

Table 4.23 Waiting Time

Vehicle	Location Index	Waiting Time	
		Digital	Offline
Car	1	1	2,53
	2	1	2,36
	3	1	1,25
	4	1	5,78
	5	1	2,20
	6	1	2,13
	7	1	3,49
	8	1	2,09
	9	1	1,85
Motorcycle	1	[redacted]	
	2	1	2,10
	3	1	1,17
	4	1	3,16
	5	1	1,57
	6	1	2,00
	7	1	2,63
	8	1	1,20
	9	1	2,07

The average waiting time for conventional system can be seen in table 4.22. Car and motorcycle perceived different parking waiting time. Overall, respondents who use motorcycle experienced faster waiting time than car user. Moreover, the longest waiting time is the parking area in front of Larangan market due to vast parking area which on average one parking officers handle 107 cars daily. While the shortest waiting time is in front of Sidoarjo train station.

4.4.10 Cost of Waiting

Cost of waiting parameter is used to convert the value of waiting time to become cost. This data also gotten from parking user survey with the question given in the figure 4.10. Moreover, the survey result for each location is detailed in the table 4.23. This parameter does not apply on certain indices, instead cost of waiting is a single value. The average value of the cost of waiting is Rp 953,88.

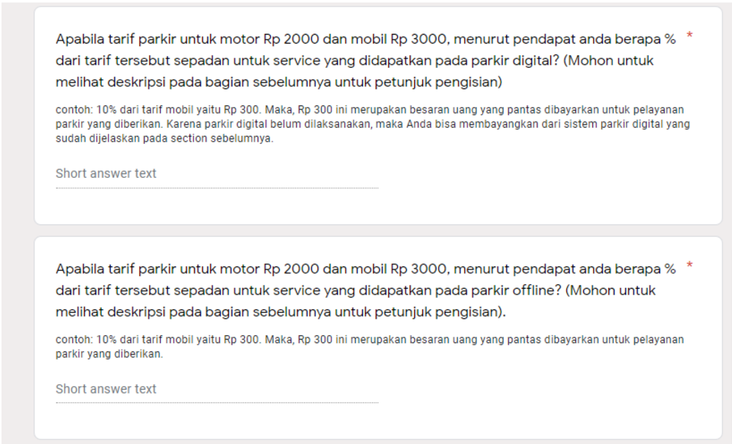
Figure 4.10 Survey Question for Cost of Waiting

Table 4.24 Cost of Waiting Survey Result

No.	Detail Location	Cost of Waiting
1	Puskesmas Sidoarjo	Rp 1.250
2	Dispenduk Capil Office Sidoarjo	Rp 781,75
3	In front of Sidoarjo train station	Rp 1.025
4	In front of Larangan market	Rp 1.347,8
5	In front of Porong market	Rp 861,11
6	New Tulangan market	Rp 1.357
7	Gajahmada street (Sop Ayam Klaten until UFO)	Rp 1.034
8	Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	Rp 931,8
9	Basuki Rahmat Krian street (Indomart until Persebaya Store)	Rp 1.019,2
Average		Rp 953,88

4.4.11 Service Level

Service level tells about the worthiness of the parking service from the amount of parking levy that the user paid. In the questionnaire the respondent was asked in the figure 4.11.


Apabila tarif parkir untuk motor Rp 2000 dan mobil Rp 3000, menurut pendapat anda berapa % dari tarif tersebut sepadan untuk service yang didapatkan pada parkir digital? (Mohon untuk melihat deskripsi pada bagian sebelumnya untuk petunjuk pengisian) *

contoh: 10% dari tarif mobil yaitu Rp 300. Maka, Rp 300 ini merupakan besaran uang yang pantas dibayarkan untuk pelayanan parkir yang diberikan. Karena parkir digital belum dilaksanakan, maka Anda bisa membayangkan dari sistem parkir digital yang sudah dijelaskan pada section sebelumnya.

Short answer text

Apabila tarif parkir untuk motor Rp 2000 dan mobil Rp 3000, menurut pendapat anda berapa % dari tarif tersebut sepadan untuk service yang didapatkan pada parkir offline? (Mohon untuk melihat deskripsi pada bagian sebelumnya untuk petunjuk pengisian). *

contoh: 10% dari tarif mobil yaitu Rp 300. Maka, Rp 300 ini merupakan besaran uang yang pantas dibayarkan untuk pelayanan parkir yang diberikan.

Short answer text

Figure 4.11 Questionnaire of Service Level

In order to set the same understanding, the level of quality of the service is defined in 7 points of Likert scale (Orgajensek & Gal, 2011). Therefore, the Likert scale is transformed into percentage as the multiplication of the parking levy. The definition of the scale explained below,

0%-15% = very unsatisfied

15%-30% = unsatisfied

30%-45% = somewhat unsatisfied

45%-50% = neutral

50%-65% = somewhat satisfied

65%-80% = satisfied

80%-100% = very satisfied

Figure 4.12 Digital Parking Information Image

For conventional parking system, the parking users can rely on their experience. While for digital parking, which is new system that soon to be implemented, the parking users can estimate the service level from the description, as shown in figure 4.12, of the digital system in the questionnaire. Overall, the average service level for each location is described in table 4.24.

Table 4.25 Service Level

Vehicle	Location Index	Service Level	
		Digital	Offline
Car	1	0,36	0,21
	2	0,39	0,27
	3	0,49	0,20
	4	0,25	0,16
	5	0,52	0,15
	6	0,41	0,16
	7	0,23	0,40
	8	0,32	0,27
	9	0,46	0,17
Motorcycle	1	[redacted]	
	2	0,22	0,24
	3	0,38	0,36
	4	0,30	0,30
	5	0,45	0,34

Vehicle	Location Index	Service Level	
		Digital	Offline
	6	0,20	0,21
	7	0,33	0,27
	8	0,22	0,22
	9	0,37	0,29

It can be seen from the survey result that users' perspective regarding the parking service is still very low. The highest average of offline parking is from the Gajahmada street with 40% service level for car users. The interesting fact is that the users still see the digital parking will give the same service level as the offline. This is acceptable since they do not have any experience on the new system. Moreover, perceived quality from the parking service in traditional market is lower than the other areas.

CHAPTER 5
PARKING ZONING OPTIMIZATION RESULT ANALYSIS

This chapter contains analysis on the optimization result from both parking service provider model and parking user model and continue with sensitivity analysis of some parameters.

5.1 Optimization Model Result

In this sub chapter explains the analysis of optimization result from parking service provider model and parking user model.

5.1.1 Parking Service Provider Model

The result of decision variable can be found in the table 5.1. The maximum profit earned for parking service provider is Rp 901.405.100. The total revenue obtained is Rp 4.394.965.000 subtracted by total cost Rp 2.997.094.000, lost sales Rp 374.336.900 and leakage Rp 122.129.000. The areas selected for mixed system are in front of Porong market, new Tulangan market, and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo). Apparently, this optimization result fulfilled all the company's constraints, which are the maximum operational cost, Rp 3.000.000.000; the minimum 30% of full digital zone; and the maximum 30% mixed system zone.

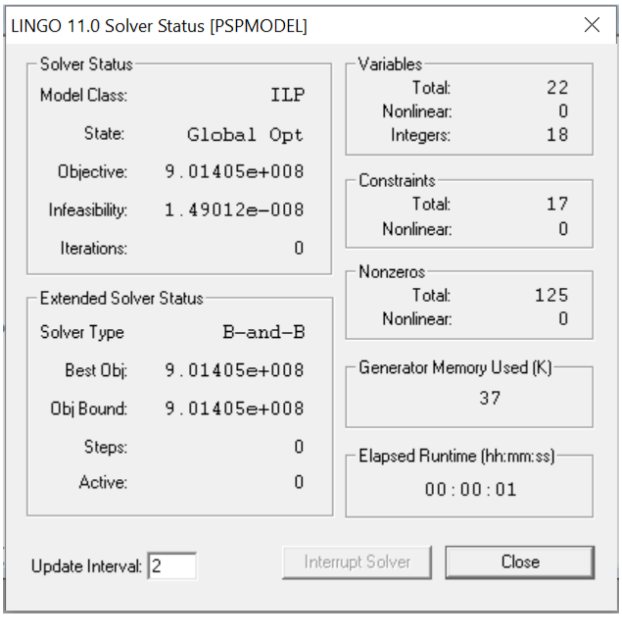


Figure 5.1 PSP Model Solver Status

Figure 5.1 above is the solver status for parking service provider which appear right when the solver finish finding the best solution. In this case, the solver terminates the model in "Global Optimum" state, whereas the current solution is the best or at the peak. Moreover, LINGO identifies the model as ILP (Integer Linear Programming), which is fit to the plan. Then, the objective field gives value of 9,01405 $x\,10^8$. However, a value in the infeasibility field of 1,49 $x\,10^{-8}$ indicates that constraints in the model are violated by, though the value is nearly zero. In addition, iterations field shows how many times LINGO does operation until the solution found. In parking service provider model, the number of iterations is zero which implies that the solver directly solves the optimization. This also explains the short running time.

Table 5.1 Optimization Result Parking Service Provider Model

Parking Location	Location Index	Full Digital	Mixed
Puskesmas Sidoarjo	1	1	-
Dispenduk Capil Office Sidoarjo	2	1	-
In front of Sidoarjo train station	3	1	-
In front of Larangan market	4	1	-
In front of Porong market	5	-	1

Parking Location	Location Index	Full Digital	Mixed
New Tulangan market	6	-	1
Gajahmada street (Sop Ayam Klaten until UFO)	7	1	-
Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	-	1
Basuki Rahmat Krian street (Indomart until Persebaya Store)	9	1	-

Another window called solution report will be created containing more details about the solution of the model. Another information that can be discovered is from slack or surplus column. Figure 5.2 presents the slack or surplus column for parking service provider model. The column informs about how close the model to satisfy a constraint as an equality. The fourth row has negative value which indicates violation of the objective function component lost sales. Moreover, the sixth row is the constraint of operational cost, therefore, this row is Rp 103.580.000 from being satisfied as an equality. While for the row number 7 it is from minimum full digital areas selected.

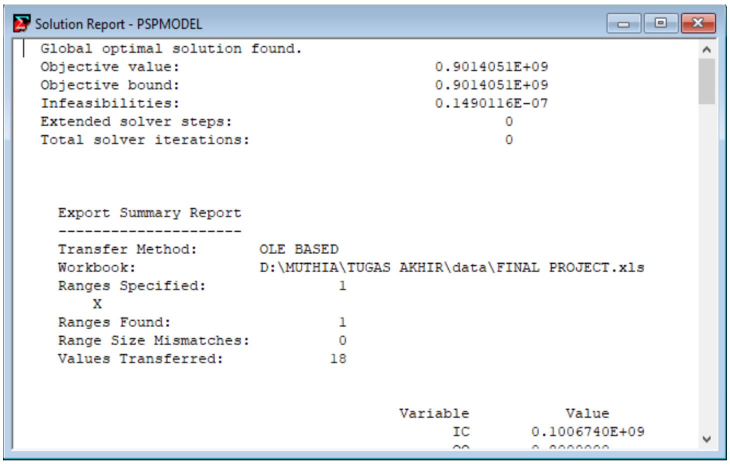
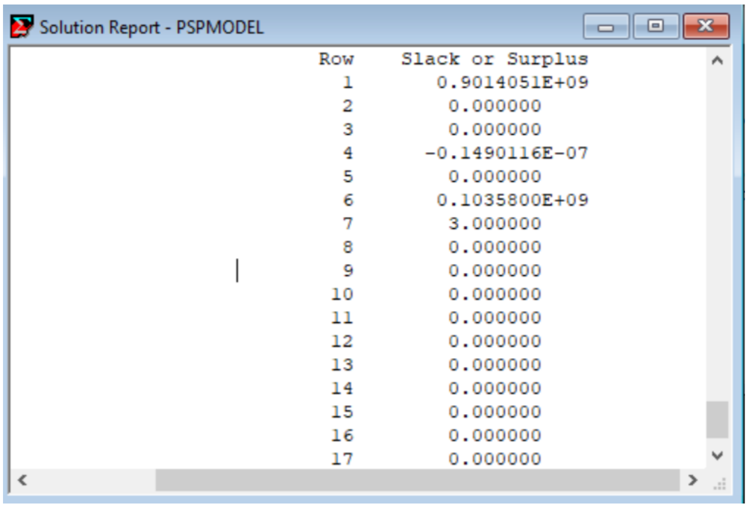


Figure 5.2 PSP Model Solution Report



Solution Report - PSPMODEL

Row	Slack or Surplus
1	0.9014051E+09
2	0.000000
3	0.000000
4	-0.1490116E-07
5	0.000000
6	0.1035800E+09
7	3.000000
8	0.000000
9	0.000000
10	0.000000
11	0.000000
12	0.000000
13	0.000000
14	0.000000
15	0.000000
16	0.000000
17	0.000000

Figure 5.3 PSP Model Solution Report (2)

In fact, those areas selected have low customer willingness level which resulting in high lost sales. While for the implication of type of location, 2 out of 3 areas are from traditional market. Therefore, it is better to accommodate the low customer willingness with implementing mixed parking system where parking users still have choice for conventional parking.

5.1.2 Parking User Model

The result for parking user model with objective function to minimize the total cost is shown in table 5.2. All locations are chosen to be in full digital system. The minimum total cost spend by parking users is Rp 44.006,7. This is the minimum total cost paid for both car and motorcycle users in 9 areas. The result obtained from total cost car Rp 25.302,95 and total cost motorcycle Rp 18.703,73. Therefore, it fulfilled all the constraints determined before such as the minimum 30% of digital parking zone, maximum 30% of mixed parking zone and the minimum willingness 50% for digital zone.

Overall, perceived quality of conventional parking service is still very low. The highest service level surveyed is from Gajahmada street whereas car parking user on average think that 40% or Rp 1200 worth for service given. Though the survey result of digital parking service level is much lower than the author's expectation, it is slightly higher than offline parking service level. This factor makes the decision is to implement full digital parking in all areas.

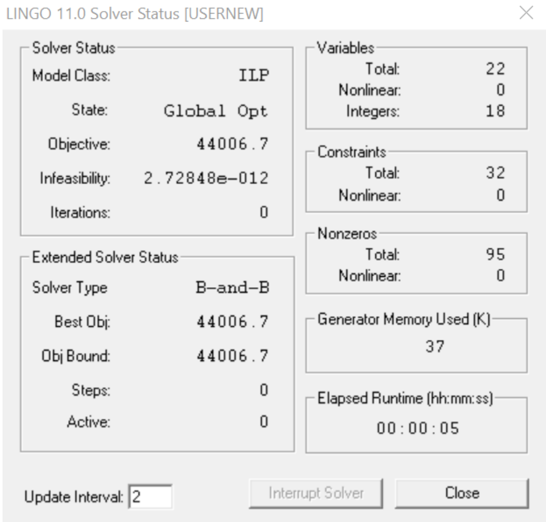


Figure 5.4 Parking User Solver Status

Solver status is a typical LINGO optimization result that shows information about the linear programming model. For parking user model, the model class is Integer Linear Programming (ILP) and the state of the solution is global optimum. Global optimum indicates the solution is at the peak. Moreover, there is very small value of infeasibility in this model for about $2{,}7284\ x\ 10^{-12}$. The solver needs no iteration to obtain the optimum result.

Table 5.2 Optimization Result Parking User Model

Parking Location	Location Index	Full Digital	Mixed
Puskesmas Sidoarjo	1	1	0
Dispenduk Capil Office Sidoarjo	2	1	0
In front of Sidoarjo train station	3	1	0
In front of Larangan market	4	1	0
In front of Porong market	5	1	0
New Tulangan market	6	1	0
Gajahmada street (Sop Ayam Klaten until UFO)	7	1	0
Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	1	0

Parking Location	Location Index	Full Digital	Mixed
Basuki Rahmat Krian street (Indomart until Persebaya Store)	9	1	0

Figure5.5 shows the solution report of parking user model. The upper column tells the same information as the solver status report. Therefore, at the bottom side, there is column named slack or surplus that informs about how close the model to satisfy a constraint as an equality. Based on figure 5.6, start from row 17 until row 32 the value of slack or surplus column is more than zero. Refer back to the model, row 17 until 32 is constraint of minimum customer willingness which all areas have average more than 50% willingness. Hence, those values are considered as surplus.

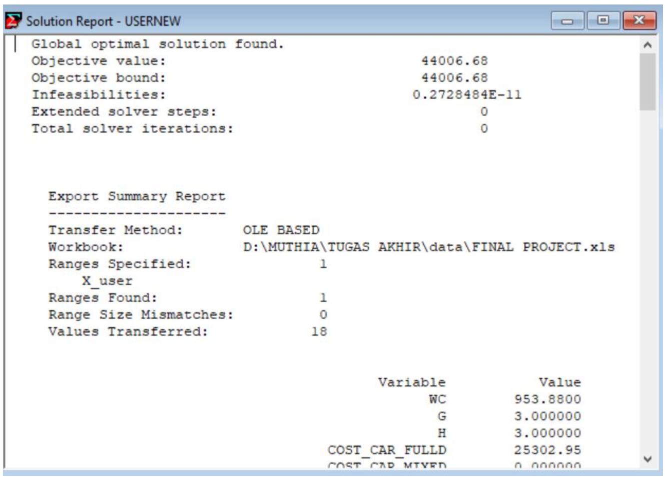


Figure 5.5 Parking User Solution Report

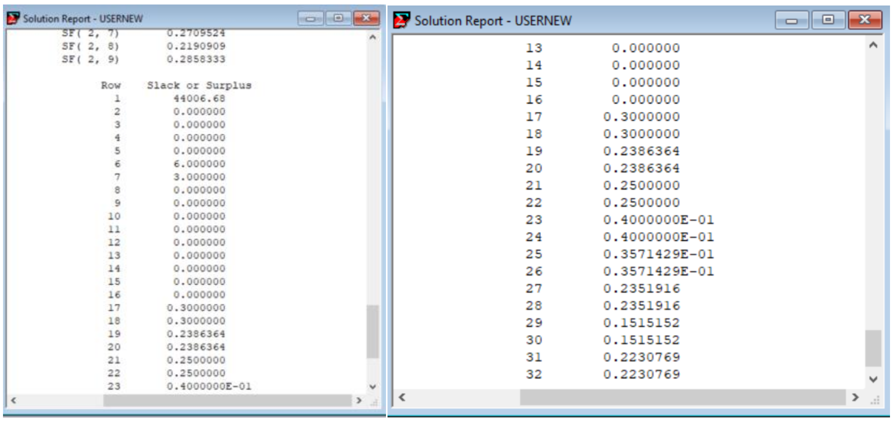


Figure 5.6 Parking User Solution Report (2)

This is an important finding to understand about how parking users perceived the quality of service given. Due to the low level of service, selecting mixed parking system is not preferable in this model. However, compared with the result from previous model, it can be pointed out that both have different result.

5.2 Sensitivity Analysis

Several parameters have uncertain value, therefore sensitivity analysis must be done to see the effect of disparity of the variable and the effect to the decision variable and objective function. There are 6 parameters in total. Customer willingness, parking proportion, demand, and rejection mixed system are corresponding to parking service provider’s model. While service level and waiting time are for parking user model. Sensitivity analysis is done by changing the variable into a certain range.

5.2.1 Customer Willingness

The author changes the value of customer willingness to implement digital parking into 5 different values, ranging from 50% lower until 50% higher than the initial value. Customer willingness parameter will affect the rejection rate for the full digital parking system, and furthermore resulting in different profit as shown in figure 5.7. Willingness level has positive correlation with the profit. The higher the willingness level indicates lower rejection rate, hence the profit will also be higher. Moreover, the slope of the line from -25% to 0% is getting bigger due to changing in the decision variable. The difference between the upper bound and the lower bound is Rp 1.143.484.100.

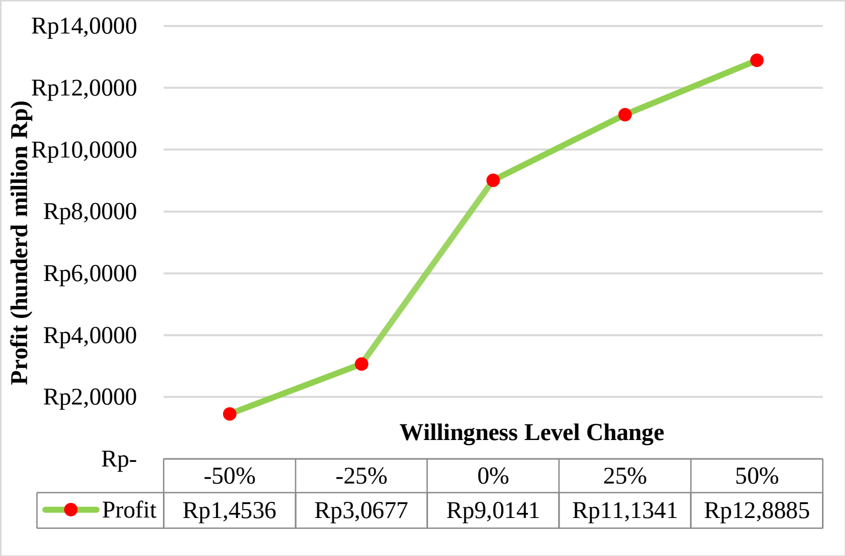


Figure 5.7 Customer Willingness Sensitivity Analysis

From the decision variable result, when the willingness level is half of the initial value, three areas that chosen to implement mixed are in front of Larangan market, in front of Porong market, and in Basuki Rahmat Krian street. This suggest that having 5% of lost sales is more profitable than losing customers for full digital parking. Meanwhile when the willingness level is 50% higher than the initial value, areas are chosen to implement mixed parking are Puskesmas Sidoarjo and Basuki Rahmat Krian street.

Table 5.3 Decision Variable of Customer Willingness -50% Sensitivity Analysis

Parking Location	Location Index	Full Digital	Mixed
Puskesmas Sidoarjo	1	1	-
Dispenduk Capil Office Sidoarjo	2	1	-
In front of Sidoarjo train station	3	1	-
In front of Larangan market	4	-	1
In front of Porong market	5	-	1
New Tulangan market	6	1	-

Parking Location	Location Index	Full Digital	Mixed
Gajahmada street (Sop Ayam Klaten until UFO)	7	1	-
Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	1	-
Basuki Rahmat Krian street (Indomart until Persebaya Store)	9	-	1

Table 5.4 Decision Variable of Customer Willingness 50% Sensitivity Analysis

Parking Location	Location Index	Full Digital	Mixed
Puskesmas Sidoarjo	1	-	1
Dispenduk Capil Office Sidoarjo	2	1	-
In front of Sidoarjo train station	3	1	-
In front of Larangan market	4	1	-
In front of Porong market	5	1	-
New Tulangan market	6	-	1
Gajahmada street (Sop Ayam Klaten until UFO)	7	1	-
Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	1	-
Basuki Rahmat Krian street (Indomart until Persebaya Store)	9	1	-

5.2.2 Demand

One approach to know parking demand is calculating based on parking turnover each day. Parking turnover is the rate of occupancy one parking slot in one day. In average, the daily occupancy of one parking slot is 3 times for car and 2 times for motorcycle. Moreover, the sensitivity analysis will use the occupancy rate from 1 time a day to 8 times a day.

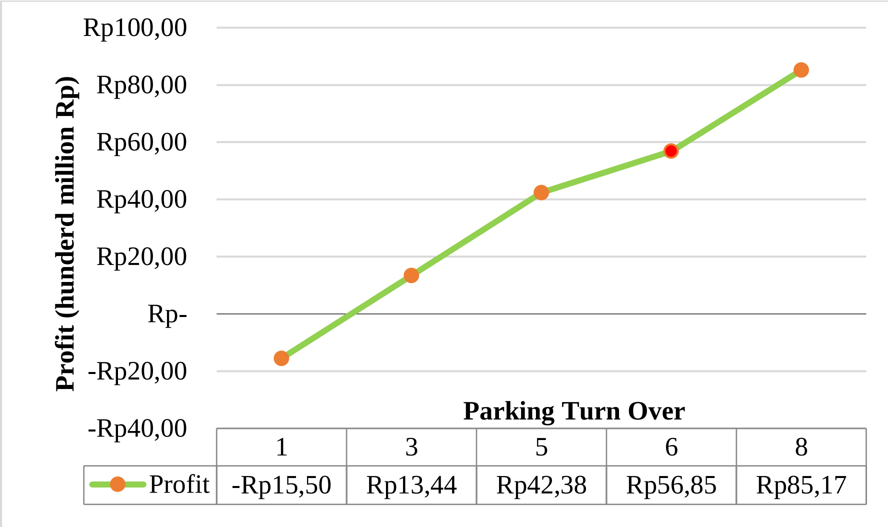


Figure 5.8 Parking Turn Over Sensitivity Analysis

Figure 5.8 is the visualization of the profit changes when variating the value of parking turn over. The higher the parking turnover rate causing the overall demand increase then the profit will increase significantly.

If the parking turn over for each parking slot is 1 time a day, the parking service provider will not generate any profit. As for the decision variable, all conditions have the same results, area in front of Porong market, new Tulangan market, and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo) are selected to implement mixed parking system. The only difference is the profit generated. The deviation of profit between the lowest and highest demand is Rp 10.067.054.000. In addition, every additional 1 value of parking turn-over, the profit will change for Rp 1.447.088.500.

5.2.3 Lost Sales in Mixed Parking System

Lost sales number in mixed system cannot be predicted precisely, therefore sensitivity test is necessary. The lower bound for this parameter is 0%, meaning that there will be no lost sales in all area that implement mixed parking system. And the upper bound is 15% of the customers will not be able to park in mixed parking system. Moreover, the decision variables of all scenarios are the same. Area in front of Porong market, new Tulangan market, and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo) are selected to implement mixed parking system. This analysis found evidence for negative correlation between lost sales level and profit. The profit difference from the lowest rejection level and the highest one is Rp 130.852.500. The result now provides evidence to change 1% of mixed system lost sales system will result in profit change for Rp 8.723.500.

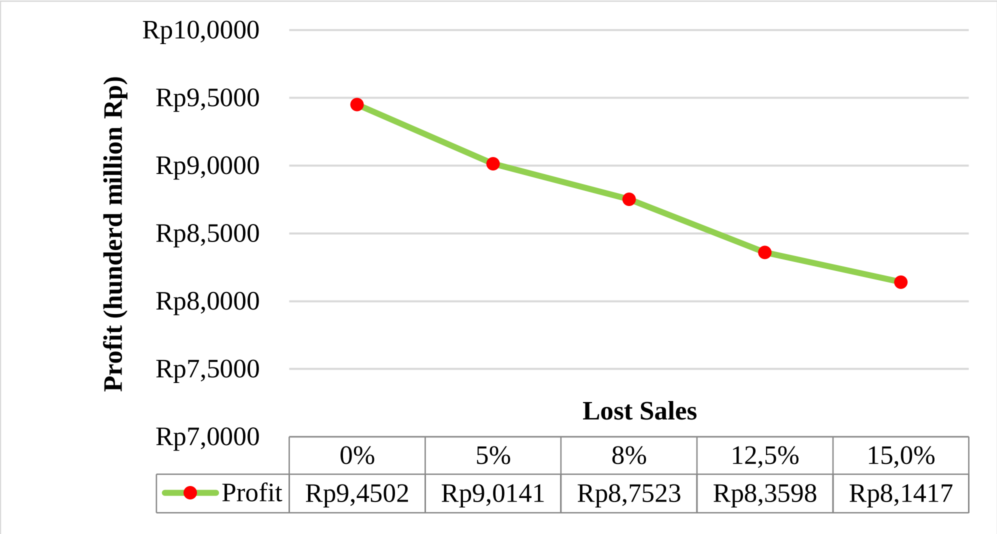


Figure 5.9 Rejection Mixed System Sensitivity Analysis

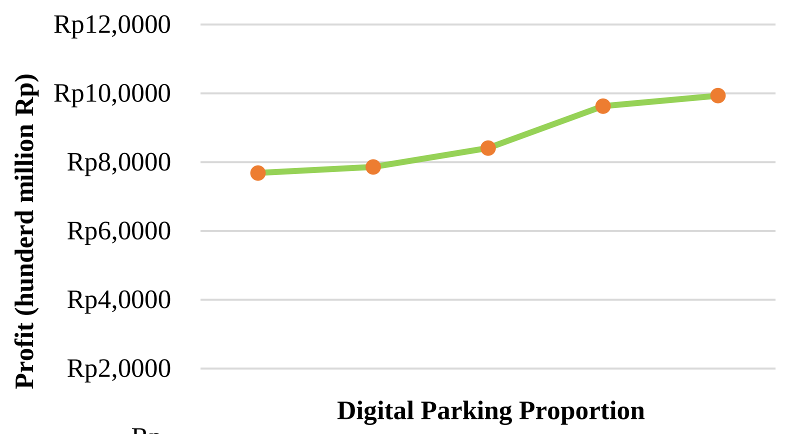
5.2.4 Parking System Proportion

In this section, the next parameter to be observed is parking system proportion. The value that was used previously in optimization model is 80% of digital parking system and 20% offline parking system. Therefore, this was only assumption because it has not yet determined.

Table 5.5 Parking System Proportion Changes

No	System	Proportion	Profit
1	Digital	50%	Rp 768.468.700
	Offline	50%	
2	Digital	60%	Rp 785.638.300
	Offline	40%	
3	Digital	70%	Rp 840.341.000
	Offline	30%	
4	Digital	90%	Rp 962.470.000
	Offline	10%	
5	Digital	95%	Rp 993.002.000
	Offline	5%	

As is presented in the table 5.8, the digital parking proportion is positively correlated with the total profit. Figure 5.10 also visualize the effect of changing parking proportion to the total profit. Therefore, the decision variable for scenario number one, where the digital filled 50% of the parking space, area Puskesmas Sidoarjo and Tulangan market are chosen to implement mixed system. When the proportion increased by 10%, additional mixed parking system for in front of Porong market. However, when the proportion of digital parking reached 70%, Puskesmas Sidoarjo no longer chosen as mixed parking system, instead in Jaksa Agung Suprapto street is selected as mixed parking simultaneously with Tulangan market and Porong market. Moreover, the sensitivity analysis found that every 1% change in digital proportion resulted in profit change for Rp 6.106.400, only if there is no change in decision variable.



	50%	60%	70%	90%	95%
Profit	Rp7,684	Rp7,856	Rp8,403	Rp9,624	Rp9,930

Figure 5.10 Parking Proportion Sensitivity Analysis

The change of Puskesmas Sidoarjo's arking system is because the willingness in Jaksa Agung Suprapto street generates higher lost sales compared to Puskesmas Sidoarjo. Therefore, in Puskesmas Sidoarjo only car parking slot that available. The Author also found that when the digital parking proportion passed down until 20%, all areas are selected to implement mixed parking system.

5.2.5 Waiting Time

The next parameter to be analyzed is the waiting time for each parking system. Waiting time parameters are divided into two, the waiting time of digital system (WO) and offline system (WF). For WO, due to unknown value, the range for sensitivity analysis is from 50% shorter to 150% longer than initial waiting time. While for WF, the value ranges from 50% faster than initial WF value until 50% longer than initial value.

Table 5.6 Digital Waiting Time Changes

Digital Waiting Time Changes	Cost
-50%	Rp 35.899
0%	Rp 44.007
50%	Rp 52.115
100%	Rp 59.670
150%	Rp 66.722

For digital system waiting time, the variations causing different total cost according to the table 5.9. Increasing digital waiting time, causing the total cost moves upward. It is conspicuous that total cost has cost of waiting that depends on waiting time. For the decision variable, all areas are chosen to be full digital system until the waiting time for digital system is 2 minutes. Area in front of Sidoarjo train station and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo) are selected to implement mixed parking. Which means average digital and offline waiting time is less than 2 minutes. The deviation from the lowest value and highest value is Rp 30.823. This indicates every 1% of digital waiting time, contributes to total cost for Rp 162.

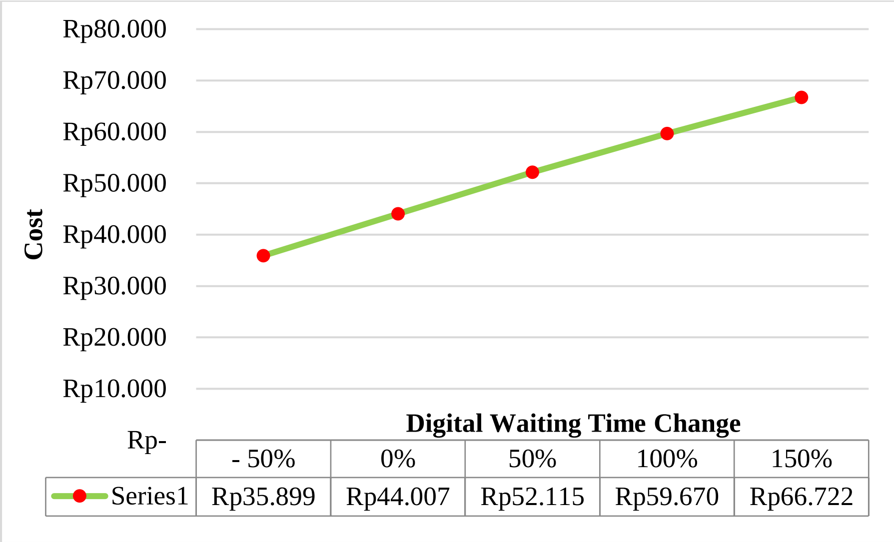


Figure 5.11 Digital System Waiting Time Sensitivity Analysis

On the other hand, the changing value of offline parking system waiting time not always changing the total cost. The clear evidence can be seen in figure 5.12. From 25% faster waiting time, the cost paid is constant until the waiting time is 50% longer. This is due to the decision variable which choose all parking areas to be full digital since when the waiting time set 25% faster.

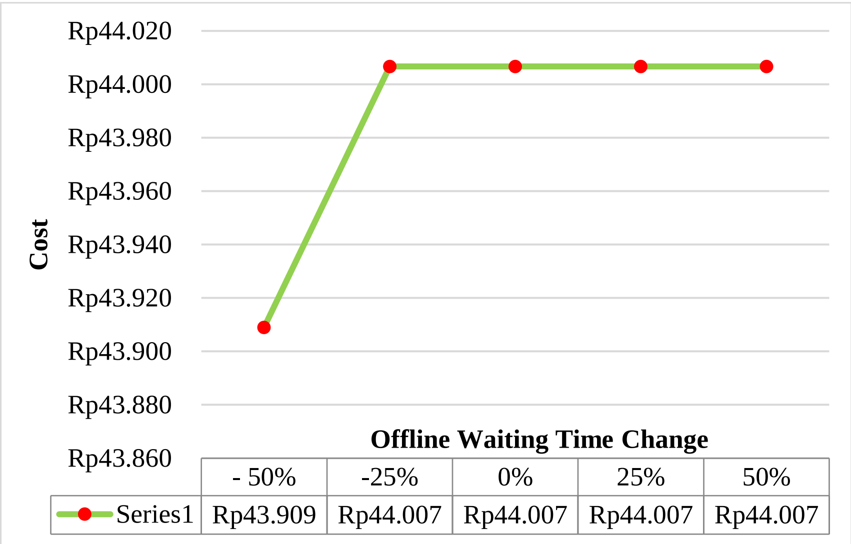
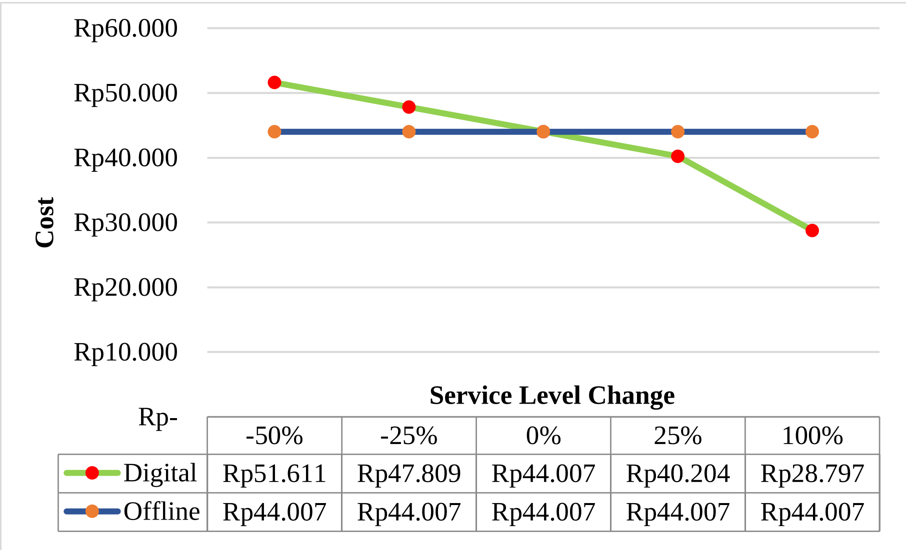


Figure 5.12 Offline Waiting Time Sensitivity Analysis

5.2.6 Service Level

Parameter of service level also has 2 types, service level for digital parking system and service level for offline parking system. Both parameters will have sensitivity analysis with changing the value from 50% lower until 100% higher value. The effect to the total cost paid by parking user shown in the figure 5.13. When digital service level rises up, the total cost also grow. While changing in offline service level, the total cost remains. This is due to the unchanging decision variable, which select full digital for all areas.

Moreover, with the applied changing range of service level, decision variable unchanged with all implement full digital parking. The difference total cost for digital service change is Rp 22.814. Moreover, 1% of service level change will contribute to total cost for Rp 152.



	-50%	-25%	0%	25%	100%
Digital	Rp51.611	Rp47.809	Rp44.007	Rp40.204	Rp28.797
Offline	Rp44.007	Rp44.007	Rp44.007	Rp44.007	Rp44.007

Figure 5.13 Service Level Sensitivity Analysis

5.3 Managerial Implications

The provided sensitivity analysis from the previous sub chapter here are some implications that can be taken for managerial decision.

a. The result of PSP optimization model implies that public facility parking area and main roads tend to have greater value of customer willingness therefore selected to implement full digital parking system. On the other hand, traditional market parking user still have low willingness to use digital parking.

Figure 5.14 Tornado Diagram of PSP Model

b. From the perspective of profit, the most sensitive variable is demand as shown in tornado diagram in figure 5.14. If the demand can increase, so can the profit. However, increasing the demand seems nonviable, the second most sensitive variable is customer willingness. If the government could attract more customer to use digital parking, it would be a great advantage for them.

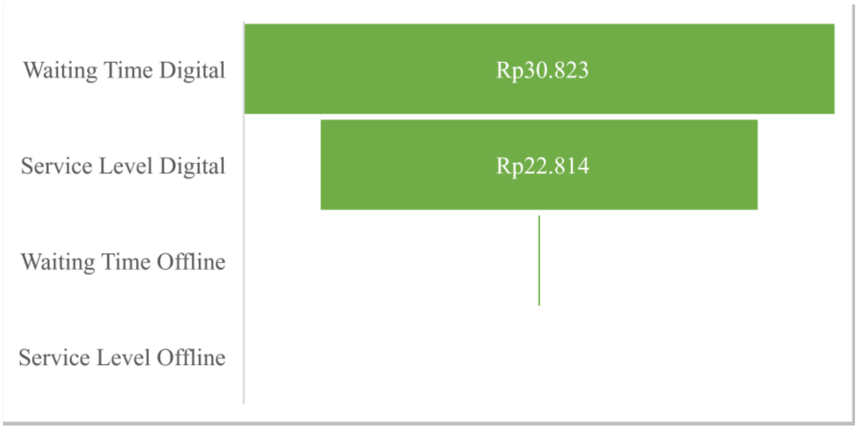


Figure 5.15 Tornado Diagram of Parking User Model

c. From the tornado diagram in figure 5.15, the most sensitive variable for parking user model is digital waiting time. On average, every additional 1 minute of waiting, parking users are adding more loss for about Rp 16.000. Nonetheless, the government as well as parking service provider should maintain the digital parking waiting time low to avoid increasing total cost paid by the users.

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CHAPTER 6

DECISION MAKING OF PARKING ZONING

This chapter provides fully cooperative game and vertical Nash equilibrium as the methods for decision making.

6.1 Fully Cooperative Game

In the previous chapter, solution from both parties' point of view are different. Profit wise, area index 5,6 and 8 better to implement mixed parking system for the first year of implementation due to low willingness of customer. Meanwhile, cost wise, it is cheaper to fully implement digital parking system across 9 areas. To tighten the gap, a fully cooperative game approach is going to be used. By sharing openly about the objective and trying to solve simultaneously, a better solution will be derived. To do this, both models will be combined into one optimization model. The objective function of the model is described below,

$$\text{Max}\, Z = (revenue - cost - lost\ sales - leakage) - total\ cost$$

Whereas the model constraints are the same with the initial models. With this formulation, the solver will generate result that maximize the profit and at the same time minimize the total cost. Optimal decisions need to be taken in the presence of trade-offs between the objectives. After checking the error in the model, the model runs to find optimal solution.

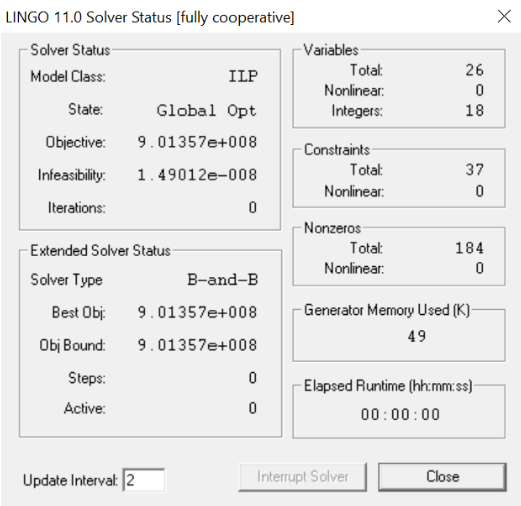


Figure 6.1 Solver Status Fully Cooperative Game

Based on the optimization result, the areas chosen to implement mixed parking system are in front of Porong market, new Tulangan market and in Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo). It can be clearly observed that the result of fully cooperative game is the same with the parking service provider optimization model. This happens because of the objective function's unit difference. For parking service provider, it is the profit, which value in millions rupiah, on the other hand parking user cost value in tens of thousands rupiah. So it is more like profit has greater power than total cost. While the total profit remains the same as the result of PSP optimization model, the total cost is slightly increased become Rp 47. 575,53.

Table 6.1Decision Variable Fully Cooperative Game

Parking Location	Location Index	Full Digital	Mixed
Puskesmas Sidoarjo	1	1	-
Dispenduk Capil Office Sidoarjo	2	1	-
In front of Sidoarjo train station	3	1	-
In front of Larangan market	4	1	-
In front of Porong market	5	-	1
New Tulangan market	6	-	1
Gajahmada street (Sop Ayam Klaten until UFO)	7	1	-
Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo)	8	-	1
Basuki Rahmat Krian street (Indomart until Persebaya Store)	9	1	-

6.2 Vertical Nash Equilibrium

Another approach to help decision maker is using game theory. Normal form of game will be used to obtain vertical Nash equilibrium. Therefore, vertical means the power structure of the players. Young (1991) stated that vertical integration is preferable than rivalry although the result might be smaller than fully cooperative.

Parking service provider as the government representative has higher position than parking user. So, in this game for vertically player relation, the solution from Nash equilibrium will be obtained. The players of this game are parking service provider and parking user. Moreover, there are three identical strategies for each player as shown in table 6.2.

Table 6.2 Strategies for Each Player

No	Strategies
1	Mixed parking system for area number 5
2	Mixed parking system for area number 6
3	Mixed parking system for area number 8

Those strategies were formed with the acknowledge of the solution from previous processes. The gap between PSP's solution and parking user's is the system of those three areas. Hence, this stage will find the feasible combination of two areas or only one area. The solution of all areas number 5,6 and 8 implement mixed parking system will not be possible. If doing so, parking user will have to pay higher cost. Otherwise, for parking service provider with strategy all areas implement digital parking system, profit will be lower. Furthermore, total cost paid by parking user is used as the payoff value for parking user, while total profit is for parking service provider. Table 6.3 describes the payoff matrix of the game.

Table 6.3 Payoff Matrix

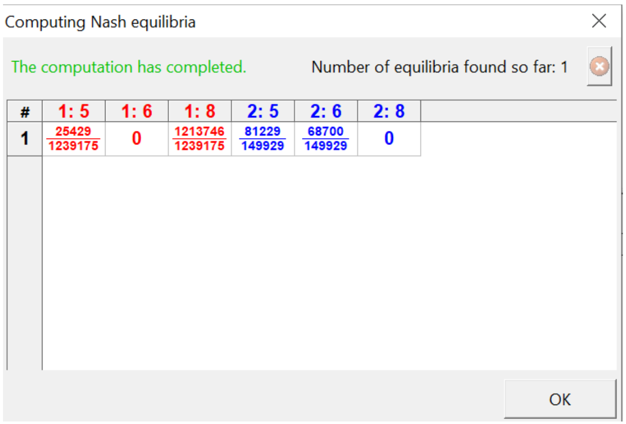
		Parking Service Provider					
		5		6		8	
Parking User	5	-Rp 45.506	Rp 798.691.994	-Rp 46.889	Rp 859.379.294	-Rp 46.193	Rp 840.717.762
	6	-Rp 46.889	Rp 859.379.294	-Rp 45.389	Rp 797.420.544	-Rp 46.076	Rp 839.446.312
	8	-Rp 46.193	Rp 840.717.762	-Rp 46.076	Rp 839.446.312	-Rp 44.694	Rp 728.759.012

The payoff matrix then being inserted to Gambit software. In the figure 6.2 the red shaded numbers are payoff for parking user, while blue shaded numbers are for parking service provider.

Parking User Payoff: / PSP Payoff:	5		6		8	
5	-45506	798691994	-1172213/25	859379294	-46193	840717762
6	-1172213/25	859379294	-2269459/50	797420544	-4607623/100	839446312
8	-46193	840717762	-4607623/100	839446312	-4469373/100	728759012

Figure 6.2 Payoff Matrix in Gambit Software

After computation, Gambit software found one Nash equilibrium. The solution result is mixed strategies with the probability as shown in figure 6.3. Player 1 or parking user mixed strategy is to choose area 5 as mixed system 2% of its time and 98% area 8. Whereas, for player 2 or parking service provider mixed strategy is to choose area 5 as mixed system 54% of its time and choose area 6 46% of its time. With this solution, the expected value of the game for parking user is – Rp 46.139,5. Meanwhile, for parking service provider the expected value of the game is Rp 839.855.355. Hence, the possible scenario of combination areas implementing mixed system are area 5, area 6, area 5 and 6, area 5 and 8, area 6 and 8.



#	1: 5	1: 6	1: 8	2: 5	2: 6	2: 8
1	25429/1239175	0	1213746/1239175	81229/149929	68700/149929	0

Figure 6.3 Nash Equilibrium Output in Gambit

CHAPTER 7
CONCLUSION AND RECOMMENDATION

In this chapter explains the conclusions that align with the objectives which previously had been determined and recommendations for future research.

7.1 Conclusion

After the series of stages to achieve the research’s objectives, below are the author’s findings along the processes,

1. This research had derived the mathematical model of binary integer linear programming in determining the parking zoning for early stage of digital parking system implementation. Parking service provider, as the government representation, determined parking zoning across the regency not solely based on their advantage but also from parking users’ perspective. Therefore, there are two integer programming models, for parking service provider with the objective of maximizing profit and for parking user with the objective of minimizing cost. In order to maximize profit, several components are to be considered such as revenue, operational cost, lost sales, and leakage potential. Whereas parking levy, waiting time and service level are parameters to describe cost. Moreover, after solving the model independently, the results demonstrate two things. First, the maximum profit for Rp Rp 901.405.100 achieved by selecting areas in front of Porong market, new Tulangan market, and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo) as mixed parking system zone. Second, in parking user model the result is to implement full digital zone in all areas with total cost Rp 44.006,7. These findings demonstrate clear evidence of different result.
2. Sensitivity analysis is an important process in the understanding of the uncertainty of the parameters. For PSP model the parameters are customer willingness, parking proportion, lost sales in mixed system and demand. Customer willingness, as the second most sensitive

parameter, have difference profit value Rp 1.143.484.000 from the upper bound and lower bound. Then for the changing parking proportion parameter, the difference between 95% and 50% digital parking portion is Rp 224.533.300. The initial value of lost sales is 5%. Therefore, by lowering the lost sales become 0%, the total profit will increase 4,8% or Rp 43.617.500. When the value become 15%, total profit will decrease Rp 87.235.000. Meaning that every 1% contribute to Rp 8.723.500 change in the profit. While for demand, every additional 1 value of parking turn-over, the profit change is the biggest for Rp 1.447.088.500, so it is the most sensitive parameter. On the other hand, parking user model parameters that are used in sensitivity analysis are waiting time and service level. As the most sensitive parameter for parking user model, it suggests that every 1% increase in digital parking waiting time will increase the total cost for Rp 162, vice versa. As for offline waiting time, the total cost remains stagnant from 25% shorter waiting time. Next is sensitivity analysis for service level. For digital parking service level, every 1% increase in digital parking service level will decrease the total cost for Rp 152 and vice versa. Meanwhile for offline parking service level, the total cost remains the same starting 50% lower until 100% higher service level.

3. Previous result from binary linear programming may raise concern about the absence of agreement which then be addressed by conducting fully cooperative game and vertical Nash. The difference lies between the approach used to create agreement of parking zoning. In fully cooperative game, both models are combined into one. This method found that the optimum result is the same with solution from parking service provider model. Afterwards, using normal form of game theory to find vertical Nash equilibrium. A mixed strategy for parking user to choose area in front of Porong market 2% of the time and Jaksa Agung Suprapto street (Bank Jatim until Badan Kepegawaian Daerah Sidoarjo) 98% of the time, with value of the game is Rp 46.139,5. While for parking service provider, mixed strategy to choose 54% of the time area

in front of Porong market and 45% of the time area in new Tulangan market, with value of the game (profit) Rp 839.855.355.

7.2 Recommendation

Recommendations that will be useful for the future research are:

1. Conduct the parking user survey through direct interview to get more accurate and representative data.
2. After a year of implementation, conduct evaluation for further policy about digital parking.
3. In this research, all parameters data are assumed to be deterministic, it could be better if stochastic data is used to make the result more representative.
4. There are many problems that need to be solved in the future research to complete this research regarding the implementation of digital parking. Such as strategy to highlight action plan and time motion study of digital parking service.

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APPENDIX

Appendix 1 Questionnaire Google Form 1

Appendix 2 Questionnaire Google Form 2

Berapakah usia Anda? *

Short answer text

Jenis kendaraan apa yang paling sering Anda gunakan? *

- Motor
- Mobil

Dari beberapa kawasan di bawah ini, pilihlah 1 kawasan yang paling sering anda kunjungi *

kawasan parkir berikut adalah yang termasuk dalam on-street parking (parkir tepi jalan)

- Depan Pasar Larangan
- Depan Pasar Porong
- Pasar Tulangan
- Puskesmas Sidoarjo
- Kantor Dispenduk capil
- Depan stasiun KA
- JL.Gajahmada (area sop ayam sampai UFO)
- JL. Jaksa Agung Suprapto (area depan BKD sampai bank Jatim)

Appendix 3 Questionnaire Google Form 3

Berapa lama anda biasanya menunggu sampai mendapat parkir? *

menunggu bisa diartikan menunggu dilayani juru parkir atau waktu dihabiskan untuk mencari tempat parkir yang kosong.
contoh: 2 menit.

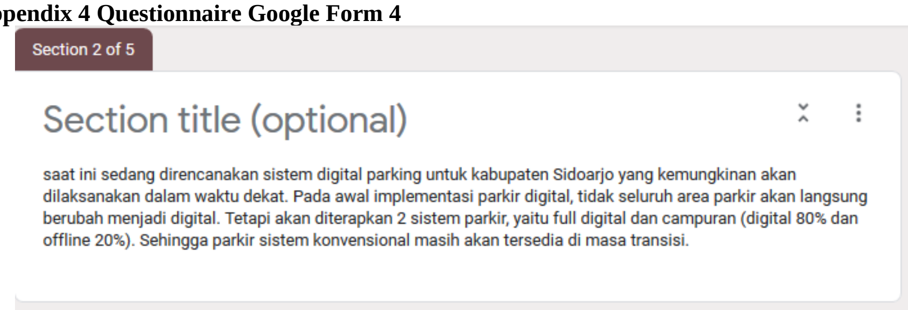
Short answer text

Jika waktu tunggu tersebut bisa dikuantifikasikan dengan nilai uang (rupiah), maka berapa rupiah yang terbuang untuk menunggu selama 1 menit? *

contoh: Rp 1000 untuk setiap 1 menit menunggu.

Short answer text

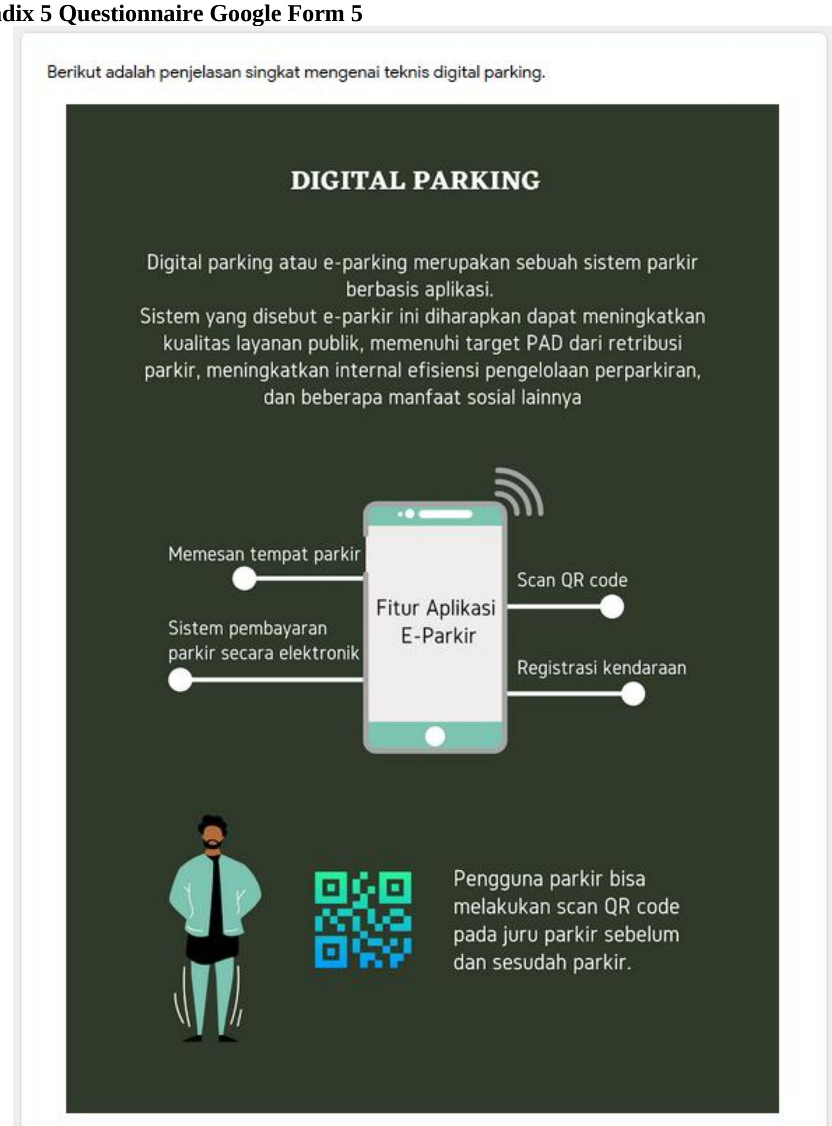
Appendix 4 Questionnaire Google Form 4


Section 2 of 5

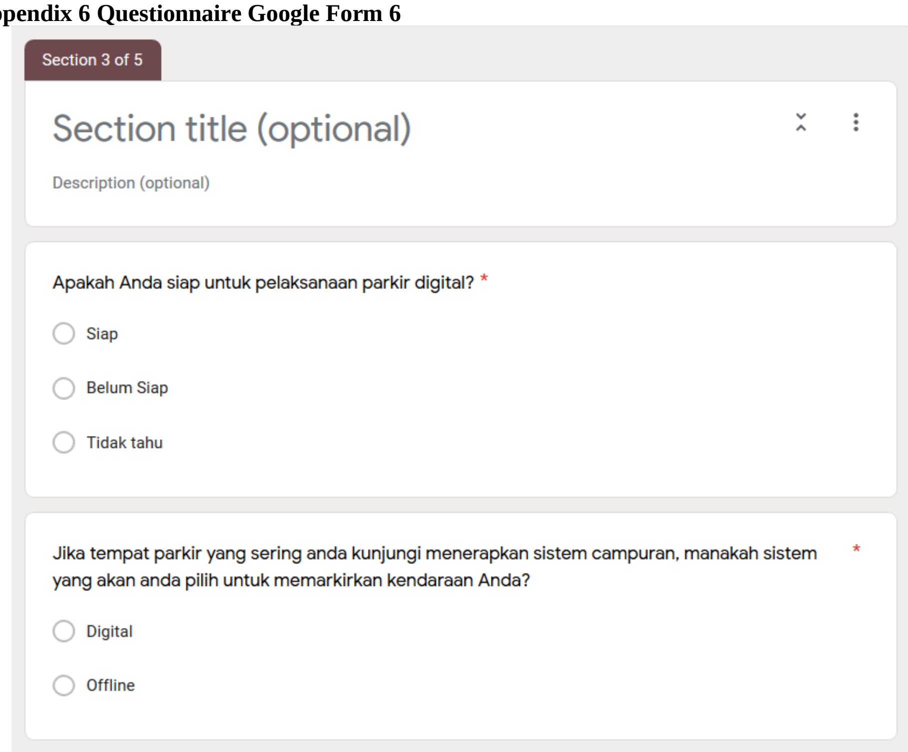
Section title (optional)

saat ini sedang direncanakan sistem digital parking untuk kabupaten Sidoarjo yang kemungkinan akan dilaksanakan dalam waktu dekat. Pada awal implementasi parkir digital, tidak seluruh area parkir akan langsung berubah menjadi digital. Tetapi akan diterapkan 2 sistem parkir, yaitu full digital dan campuran (digital 80% dan offline 20%). Sehingga parkir sistem konvensional masih akan tersedia di masa transisi.

Appendix 5 Questionnaire Google Form 5



Appendix 6 Questionnaire Google Form 6



Section 3 of 5

Section title (optional)

Description (optional)

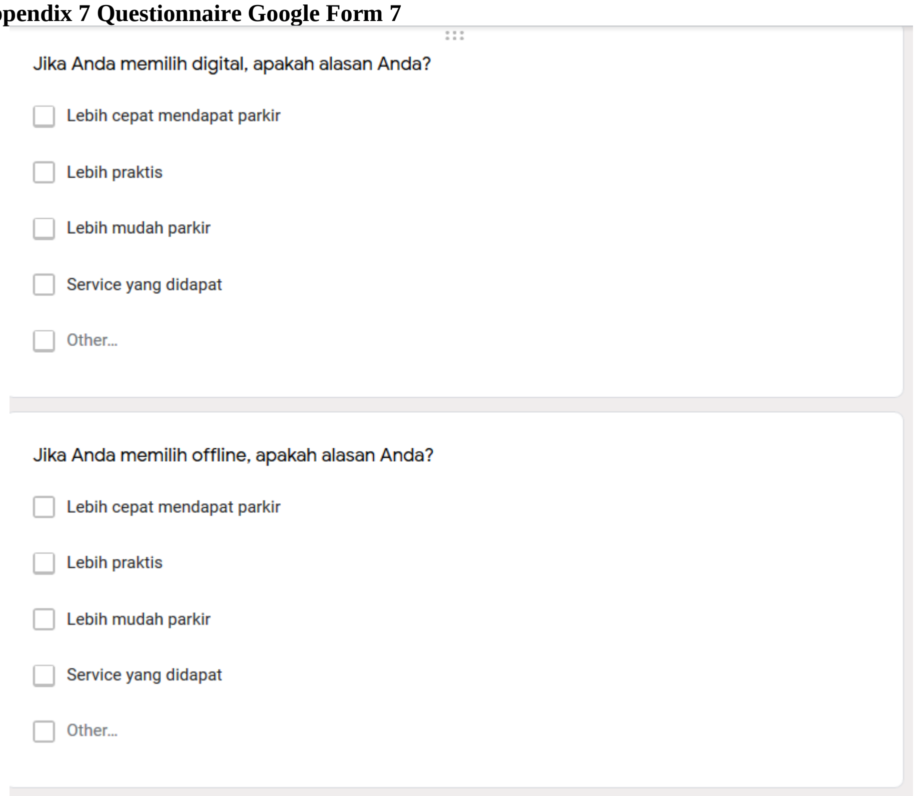
Apakah Anda siap untuk pelaksanaan parkir digital? *

- ○ Siap
- ○ Belum Siap
- ○ Tidak tahu

Jika tempat parkir yang sering anda kunjungi menerapkan sistem campuran, manakah sistem yang akan anda pilih untuk memarkirkan kendaraan Anda? *

- ○ Digital
- ○ Offline

Appendix 7 Questionnaire Google Form 7



Jika Anda memilih digital, apakah alasan Anda?

- ☐ Lebih cepat mendapat parkir
- ☐ Lebih praktis
- ☐ Lebih mudah parkir
- ☐ Service yang didapat
- ☐ Other...

Jika Anda memilih offline, apakah alasan Anda?

- ☐ Lebih cepat mendapat parkir
- ☐ Lebih praktis
- ☐ Lebih mudah parkir
- ☐ Service yang didapat
- ☐ Other...

Appendix 8 Questionnaire Google Form 8

Apakah anda setuju bila tarif parkir digital dan offline dibedakan? *

- ◯ Ya
- ◯ Tidak
- ◯ Tidak tahu

Jika iya, manakah yang seharusnya memiliki tarif lebih tinggi?

- ◯ Digital
- ◯ Offline

Appendix 9 Questionnaire Google Form 9

Section 4 of 5

Section title (optional)

Berikut ini adalah panduan untuk mengisi pertanyaan selanjutnya terkait tingkat pelayanan parkir di Kabupaten Sidoarjo

0%-15% = sangat tidak baik
15%-30% = tidak baik
30%-45% = agak tidak baik
45%-50% = netral
50%-65% = agak baik
65%-80% = baik
80%-100% = sangat baik

Apabila tarif parkir untuk motor Rp 2000 dan mobil Rp 3000, menurut pendapat anda berapa % dari tarif tersebut sepadan untuk service yang didapatkan pada parkir digital? (Mohon untuk melihat deskripsi pada bagian sebelumnya untuk petunjuk pengisian) *

contoh: 10% dari tarif mobil yaitu Rp 300. Maka, Rp 300 ini merupakan besaran uang yang pantas dibayarkan untuk pelayanan parkir yang diberikan. Karena parkir digital belum dilaksanakan, maka Anda bisa membayangkan dari sistem parkir digital yang sudah dijelaskan pada section sebelumnya.

Short answer text

Appendix 10 Questionnaire Google Form 10

Apabila tarif parkir untuk motor Rp 2000 dan mobil Rp 3000, menurut pendapat anda berapa % dari tarif tersebut sepadan untuk service yang didapatkan pada parkir offline? (Mohon untuk melihat deskripsi pada bagian sebelumnya untuk petunjuk pengisian). *

contoh: 10% dari tarif mobil yaitu Rp 300. Maka, Rp 300 ini merupakan besaran uang yang pantas dibayarkan untuk pelayanan parkir yang diberikan.

Short answer text

Saran untuk pengelolaan parkir digital di Kabupaten Sidoarjo

Long answer text

After section 4 Continue to next section

Section 5 of 5

Terimakasih!

Peneliti mengucapkan terimakasih yang sebesar-besarnya atas kesediaan Anda menjawab seluruh pertanyaan dalam kuesioner ini.
Apabila ada pertanyaan/kritik/saran pada Peneliti, bisa langsung menghubungi contact person di bawah ini:
e-mail: rahmasari.muthia@gmail.com

Appendix 11 Questionnaire Result for Puskesmas Sidoarjo

1	2	3	4	5	6	7	8	9
20	Motorcycle	Puskesmas Sidoarjo	10	Rp 500	Not Ready	Offline	20%	40%
26	Motorcycle	Puskesmas Sidoarjo	0	Rp -	Ready	Digital	78%	69%
20	Car	Puskesmas Sidoarjo	2	Rp 1.000	Do not know	Offline	10%	10%
18	Car	Puskesmas Sidoarjo	4	Rp 5.000	Do not know	Offline	0%	10%
21	Car	Puskesmas Sidoarjo	3	Rp 1.000	Not Ready	Offline	50%	50%
23	Car	Puskesmas Sidoarjo	1	Rp 2.000	Ready	Digital	0%	0%
28	Car	Puskesmas Sidoarjo	6	Rp 2.000	Ready	Digital	0%	10%
56	Car	Puskesmas Sidoarjo	1	Rp 2.000	Ready	Offline	20%	0%
23	Car	Puskesmas Sidoarjo	2	Rp 500	Ready	Digital	87%	50%
35	Car	Puskesmas Sidoarjo	3	Rp 1.000	Ready	Digital	10%	40%
22	Car	Puskesmas Sidoarjo	3	Rp 1.000	Ready	Digital	20%	50%
30	Car	Puskesmas Sidoarjo	5	Rp 1.000	Not Ready	Offline	50%	20%
28	Car	Puskesmas Sidoarjo	3	Rp 2.000	Not Ready	Offline	30%	10%

1	2	3	4	5	6	7	8	9
34	Car	Puskesmas Sidoarjo	2	Rp 1.500	Ready	Digital	80%	20%
41	Car	Puskesmas Sidoarjo	2	Rp 2.000	Not Ready	Offline	40%	10%
30	Car	Puskesmas Sidoarjo	3	Rp 1.000	Ready	Digital	67%	20%
32	Car	Puskesmas Sidoarjo	1	Rp 2.000	Not Ready	Offline	40%	10%
35	Car	Puskesmas Sidoarjo	1	Rp 1.500	Not Ready	Offline	50%	30%
35	Car	Puskesmas Sidoarjo	1	Rp 500	Ready	Digital	62%	20%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 12 Questionnaire Result Office for Dispenduk Capil

1	2	3	4	5	6	7	8	9
21	Car	Office Dispenduk capil	3	Rp 1.000	Ready	Digital	50%	40%
23	Motorcycle	Office Dispenduk capil	0	Rp 2.000	Ready	Digital	10%	81%
23	Motorcycle	Office Dispenduk capil	1	Rp -	Ready	Digital	100%	50%
22	Motorcycle	Office Dispenduk capil	1	Rp -	Ready	Digital	3%	10%
17	Motorcycle	Office Dispenduk capil	0	Rp 500	Not Ready	Offline	30%	40%
24	Motorcycle	Office Dispenduk capil	5	Rp 1.000	Ready	Digital	20%	10%
54	Car	Office Dispenduk capil	3	Rp 5.000	Ready	Digital	10%	20%
29	Car	Office Dispenduk capil	0	Rp 4	Ready	Digital	1%	20%
35	Car	Office Dispenduk capil	2	Rp 500	Ready	Digital	50%	40%
29	Car	Office Dispenduk capil	1	Rp -	Do not know	Offline	10%	10%
29	Motorcycle	Office Dispenduk capil	0	Rp 1.000	Ready	Digital	10%	10%
51	Car	Office Dispenduk capil	3	Rp 1.000	Ready	Digital	78%	50%
29	Car	Office Dispenduk capil	0	Rp 5.000	Do not know	Digital	50%	20%
29	Car	Office Dispenduk capil	6	Rp 2.000	Ready	Digital	30%	30%
49	Motorcycle	Office Dispenduk capil	1	Rp 4	Ready	Offline	6%	0%
27	Motorcycle	Office Dispenduk capil	5	Rp 1.000	Ready	Digital	10%	10%
28	Car	Office Dispenduk capil	3	Rp 5.000	Ready	Digital	1%	10%
23	Motorcycle	Office Dispenduk capil	1	Rp 500	Ready	Digital	7%	0%
40	Motorcycle	Office Dispenduk capil	7	Rp 2.000	Ready	Digital	20%	30%
29	Car	Office Dispenduk capil	2	Rp 4.000	Do not know	Digital	50%	20%
45	Car	Office Dispenduk capil	3	Rp 5.000	Ready	Digital	100%	40%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 13 Questionnaire Result for In Front of Sidoarjo Train Station

1	2	3	4	5	6	7	8	9
22	Motorcycle	In front of Sidoarjo train station	0	Rp 2.000	Ready	Digital	20%	20%
20	Motorcycle	In front of Sidoarjo train station	1	Rp 2.000	Ready	Digital	57%	62%
22	Motorcycle	In front of Sidoarjo train station	1	Rp -	Not Ready	Offline	10%	50%
23	Motorcycle	In front of Sidoarjo train station	2	Rp -	Do not know	Offline	85%	50%
23	Motorcycle	In front of Sidoarjo train station	1	Rp 1.000	Not Ready	Offline	20%	30%
22	Motorcycle	In front of Sidoarjo train station	0	Rp 1.500	Ready	Digital	50%	0%

1	2	3	4	5	6	7	8	9
23	Motorcycle	In front of Sidoarjo train station	1	Rp -	Ready	Digital	30%	50%
22	Motorcycle	In front of Sidoarjo train station	2	Rp 1.500	Ready	Digital	50%	89%
21	Motorcycle	In front of Sidoarjo train station	1	Rp 500	Ready	Digital	10%	5%
22	Motorcycle	In front of Sidoarjo train station	3	Rp 500	Ready	Digital	30%	10%
34	Motorcycle	In front of Sidoarjo train station	0	Rp 4.000	Ready	Digital	50%	20%
28	Car	In front of Sidoarjo train station	9	Rp 2.000	Ready	Offline	30%	30%
36	Car	In front of Sidoarjo train station	1	Rp 1.000	Ready	Digital	97%	20%
29	Car	In front of Sidoarjo train station	0	Rp 1.500	Not Ready	Offline	30%	56%
20	Car	In front of Sidoarjo train station	1	Rp 1.000	Ready	Digital	40%	4%
32	Car	In front of Sidoarjo train station	1	Rp 1.000	Ready	Digital	50%	3%
24	Car	In front of Sidoarjo train station	3	Rp 1.000	Not Ready	Offline	40%	20%
25	Car	In front of Sidoarjo train station	1	Rp 500	Ready	Digital	93%	20%
23	Car	In front of Sidoarjo train station	2	Rp 1.500	Ready	Digital	50%	6%

1	2	3	4	5	6	7	8	9
41	Car	In front of Sidoarjo train station	1	Rp 1.000	Ready	Digital	15%	17%
41	Motorcycle	In front of Sidoarjo train station	2	Rp 1.000	Ready	Digital	50%	50%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 14 Questionnaire Result for In front of Larangan Market

1	2	3	4	5	6	7	8	9
22	Motorcycle	In front of Larangan market	7	Rp 1.000	Not Ready	Offline	20%	20%
22	Motorcycle	In front of Larangan market	0	Rp -	Ready	Offline	50%	76%
21	Motorcycle	In front of Larangan market	2	Rp 5.000	Ready	Digital	50%	50%

22	Motorcycle	In front of Larangan market	1	Rp	3.000	Do not know	Digital	56%	0%
16	Motorcycle	In front of Larangan market	0	Rp	2.000	Not Ready	Offline	10%	10%
22	Car	In front of Larangan market	7	Rp	500	Ready	Digital	50%	50%
20	Motorcycle	In front of Larangan market	10	Rp	2.000	Do not know	Digital	10%	10%
19	Motorcycle	In front of Larangan market	8	Rp	-	Ready	Digital	50%	50%
30	Car	In front of Larangan market	7	Rp	-	Ready	Offline	10%	0%
29	Motorcycle	In front of Larangan market	7	Rp	1.000	Ready	Digital	10%	10%
19	Motorcycle	In front of Larangan market	8	Rp	500	Ready	Digital	53%	62%
23	Motorcycle	In front of Larangan market	6	Rp	4.000	Ready	Digital	50%	50%
21	Motorcycle	In front of Larangan market	6	Rp	1.000	Ready	Offline	50%	50%
27	Motorcycle	In front of Larangan market	6	Rp	2.000	Not Ready	Digital	50%	50%
20	Motorcycle	In front of Larangan market	10	Rp	1.000	Ready	Offline	30%	50%
24	Motorcycle	In front of Larangan market	9	Rp	2.000	Ready	Digital	6%	8%
23	Car	In front of Larangan market	7	Rp	3.000	Ready	Digital	80%	20%

28	Car	In front of Larangan market	10	Rp	-	Ready	Digital	2%	2%
24	Car	In front of Larangan market	7	Rp	4.000	Ready	Digital	6%	5%
31	Car	In front of Larangan market	8	Rp	3.000	Ready	Digital	8%	10%
33	Car	In front of Larangan market	9	Rp	4.000	Ready	Digital	9%	2%
26	Motorcycle	In front of Larangan market	9	Rp	1.000	Do not know	Offline	10%	8%
29	Motorcycle	In front of Larangan market	7	Rp	2.000	Do not know	Digital	20%	20%
46	Motorcycle	In front of Larangan market	8	Rp	1.000	Not Ready	Offline	8%	10%
29	Motorcycle	In front of Larangan market	10	Rp	2.000	Do not know	Digital	20%	20%
29	Motorcycle	In front of Larangan market	6	Rp	2.000	Do not know	Digital	20%	20%
46	Car	In front of Larangan market	10	Rp	5.000	Ready	Digital	10%	10%
50	Car	In front of Larangan market	5	Rp	1.000	Do not know	Offline	50%	50%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system

4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 15 Questionnaire Result for In front of Porong market

1	2	3	4	5	6	7	8	9
22	Motorcycle	In front of Porong market	0	Rp 1.000	Not Ready	Offline	50%	50%
21	Motorcycle	In front of Porong market	15	Rp 500	Not Ready	Offline	80%	50%
22	Motorcycle	In front of Porong market	3	Rp 1.000	Do not know	Offline	50%	20%
22	Motorcycle	In front of Porong market	2	Rp -	Not Ready	Offline	2%	0%
20	Motorcycle	In front of Porong market	1	Rp 500	Ready	Digital	65%	50%
21	Motorcycle	In front of Porong market	3	Rp -	Do not know	Offline	50%	50%
22	Motorcycle	In front of Porong market	1	Rp 1.000	Ready	Digital	10%	2%
28	Motorcycle	In front of Porong market	1	Rp 2.000	Ready	Digital	50%	50%
47	Car	In front of Porong market	2	Rp -	Not Ready	Offline	30%	30%
42	Car	In front of Porong market	4	Rp 1.000	Not Ready	Offline	40%	10%
22	Car	In front of Porong market	5	Rp 1.000	Ready	Digital	75%	10%
27	Car	In front of Porong market	2	Rp 1.000	Ready	Digital	40%	0%
21	Car	In front of Porong market	3	Rp 1.500	Ready	Digital	50%	20%
21	Car	In front of Porong market	1	Rp 1.000	Ready	Digital	62%	10%
31	Car	In front of Porong market	2	Rp -	Ready	Digital	50%	10%
40	Car	In front of Porong market	0	Rp 500	Ready	Digital	56%	30%

1	2	3	4	5	6	7	8	9
33	Car	In front of Porong market	2	Rp 1.500	Ready	Digital	62%	10%
34	Car	In front of Porong market	1	Rp 2.000	Not Ready	Offline	50%	20%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 16 Questionnaire Result for Tulangan Market

1	2	3	4	5	6	7	8	9
21	Motorcycle	Tulangan Market	1	Rp 3.000	ready	Digital	10%	5%
21	Motorcycle	Tulangan Market	0	Rp 1.000	do not know	Digital	30%	50%
21	Motorcycle	Tulangan Market	1	Rp 4.000	ready	Digital	8%	8%
23	Motorcycle	Tulangan Market	1	Rp 3.000	not ready	Offline	55%	50%
19	Motorcycle	Tulangan Market	3	Rp 1.500	not ready	Digital	20%	10%
21	Car	Tulangan Market	1	Rp 1.000	do not know	Digital	20%	5%
49	Car	Tulangan Market	4	Rp -	ready	Offline	60%	10%
34	Motorcycle	Tulangan Market	3	Rp 10.000	ready	Digital	5%	10%

1	2	3	4	5	6	7	8	9
20	Car	Tulangan Market	2	Rp 1.000	do not know	Offline	5%	50%
24	Motorcycle	Tulangan Market	4	Rp 500	ready	Digital	10%	10%
24	Car	Tulangan Market	1	Rp 500	not ready	Offline	50%	0%
36	Car	Tulangan Market	2	Rp 1.500	ready	Digital	70%	10%
24	Car	Tulangan Market	3	Rp 2.000	ready	Digital	40%	20%
34	Car	Tulangan Market	3	Rp 2.000	not ready	Offline	30%	10%
23	Car	Tulangan Market	1	Rp 1.000	ready	Digital	50%	20%
18	Motorcycle	Tulangan Market	3	Rp 1.000	ready	Digital	25%	25%

1 How old are you?
2 What type of vehicle do you use?
3 Where do you usually park?
4 How long does it take to wait when you about to park? (It can also wait to be served by the officer)
5 How much do you think the cost of waiting per minute?
6 Are you ready to implement digital parking system?
7 If in the parking area applies mixed parking system, which one will you choose?
8 Service level of digital parking system
9 Service level of offline parking system

Appendix 17 Questionnaire Result for Jl. Gajahmada (area sop ayam until UFO)

1	2	3	4	5	6	7	8	9
46	Car	JL.Gajahmada (area sop ayam until UFO)	1	Rp 2.000	ready	Digital	20%	5%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp 500	ready	Digital	58%	55%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	not ready	Offline	50%	53%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	ready	Digital	67%	20%
21	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 1.000	ready	Digital	40%	10%
21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	ready	Digital	8%	0%
22	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 2.000	ready	Digital	50%	50%
21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp -	ready	Digital	72%	30%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 1.000	ready	Digital	10%	20%
21	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 500	not ready	Offline	20%	50%
23	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	4	Rp 2.000	not ready	Offline	20%	58%
21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	tidak bisa dibandingkan	not ready	Offline	50%	0%
21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp -	ready	Offline	10%	70%

21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 1.000	ready	Digital	50%	10%
40	Car	JL.Gajahmada (area sop ayam until UFO)	8	Rp 1.000	ready	Digital	20%	6%
20	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp 1.000	ready	Offline	10%	10%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 1.000	ready	Digital	50%	65%
22	Car	JL.Gajahmada (area sop ayam until UFO)	4	Rp 1.000	not ready	Digital	50%	20%
23	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 500	ready	Digital	30%	10%
23	Car	JL.Gajahmada (area sop ayam until UFO)	5	Rp 1.500	ready	Digital	10%	70%
28	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 2.000	Do not know	Digital	10%	10%
22	Car	JL.Gajahmada (area sop ayam until UFO)	7	Rp 500	ready	Digital	9%	1%
25	Car	JL.Gajahmada (area sop ayam until UFO)	4	Rp 1.000	ready	Digital	54%	75%
45	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	ready	Digital	50%	50%
21	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp 500	ready	Offline	10%	20%
21	Car	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	ready	Offline	10%	30%
20	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	not ready	Offline	10%	8%

23	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp -	ready	Digital	70%	65%
24	Car	JL.Gajahmada (area sop ayam until UFO)	7	Rp -	ready	Digital	5%	6%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	9	Rp 2.000	Do not know	Offline	5%	4%
22	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 500	ready	Offline	10%	10%
32	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 500	Do not know	Offline	Entahlah	
55	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 500	ready	Digital	3%	10%
22	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	ready	Offline	30%	20%
23	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 500	ready	Digital	40%	10%
22	Car	JL.Gajahmada (area sop ayam until UFO)	6	Rp 4.000	ready	Digital	10%	5%
23	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	ready	Digital	55%	50%
20	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	7	Rp 1.000	ready	Offline	30%	60%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	ready	Offline	10%	20%
22	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 1.000	ready	Digital	62%	50%
21	Car	JL.Gajahmada (area sop ayam until UFO)	0	Rp -	not ready	Offline	70%	70%

22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	4	Rp 1.000	ready	Digital	30%	20%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	3	Rp 500	ready	Digital	50%	50%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 1.000	ready	Digital	50%	10%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	8	Rp 500	not ready	Offline	10%	10%
21	Car	JL.Gajahmada (area sop ayam until UFO)	7	Rp 2.000	ready	Digital	20%	50%
21	Car	JL.Gajahmada (area sop ayam until UFO)	0	Rp 2.000	Do not know	Digital	10%	3%
22	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 3.000	ready	Digital	20%	10%
21	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 1.000	Do not know	Digital	10%	10%
22	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 500	Do not know	Digital	5%	2%
47	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	8	Rp -	ready	Digital	10%	0%
28	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp 500	ready	Digital	65%	10%
28	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	7	Rp 3.000	ready	Digital	30%	10%
22	Car	JL.Gajahmada (area sop ayam until UFO)	0	Rp 500	ready	Digital	10%	10%
34	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 500	Do not know	Offline	10%	30%

23	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp 1.000	ready	Digital	30%	20%
45	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp -	ready	Digital	5%	10%
29	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	8	Rp 2.000	ready	Digital	10%	20%
28	Car	JL.Gajahmada (area sop ayam until UFO)	5	Rp 1.000	ready	Digital	70%	67%
46	Car	JL.Gajahmada (area sop ayam until UFO)	5	Rp 2.000	ready	Digital	10%	30%
26	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	not ready	Offline	8%	0%
28	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 3.000	Do not know	Digital	5%	10%
56	Car	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	Do not know	Offline	20%	20%
33	Car	JL.Gajahmada (area sop ayam until UFO)	15	Rp 4.000	ready	Digital	10%	10%
32	Car	JL.Gajahmada (area sop ayam until UFO)	6	Rp 3.000	not ready	Offline	10%	10%
54	Car	JL.Gajahmada (area sop ayam until UFO)	1	Rp -	ready	Digital	50%	50%
43	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 2.000	ready	Digital	30%	50%
57	Car	JL.Gajahmada (area sop ayam until UFO)	5	Rp -	ready	Digital	5%	10%
57	Car	JL.Gajahmada (area sop ayam until UFO)	5	Rp -	ready	Digital	6%	0%

34	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	not ready	Offline	20%	30%
40	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	0	Rp 4.000	ready	Digital	50%	30%
26	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	4	Rp 2.000	ready	Digital	50%	40%
26	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	4	Rp 2.000	ready	Digital	50%	40%
26	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 2.000	ready	Digital	50%	40%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	2	Rp 1.500	ready	Digital	50%	50%
22	Motorcycle	JL.Gajahmada (area sop ayam until UFO)	4	Rp 1.500	ready	Digital	50%	50%
44	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 650	ready	Digital	5%	5%
43	Car	JL.Gajahmada (area sop ayam until UFO)	10	Rp 10.000	ready	Digital	100%	67%
43	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 2.000	ready	Digital	10%	33%
30	Car	JL.Gajahmada (area sop ayam until UFO)	0,5	Rp 1.000	ready	Digital	20%	20%
44	Car	JL.Gajahmada (area sop ayam until UFO)	3	Rp 650	ready	Digital	5%	5%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?

3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 18 Questionnaire Result for Jl. Jaksa Agung Suprapto (BKD area until Bank Jatim)

1	2	3	4	5	6	7	8	9
21	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 500,00	0	Do not know	Offline	50%	10%
21	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp -	1	Ready	Digital	7%	10%
25	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 4.000,00	2	Ready	Digital	40%	40%
19	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 2.000,00	2	Ready	Digital	80%	60%
20	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp -	3	Ready	Digital	10%	10%
33	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp -	2	Do not know	Offline	10%	3%
19	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 1.000,00	4	Ready	Digital	30%	20%
20	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 500,00	3	Ready	Offline	75%	30%

24	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	500,00	0	Not Ready	Offline	10%	10%
23	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	-	1	Ready	Digital	20%	50%
21	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	-	1	Ready	Digital	4%	8%
26	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	-	2	Do not know	Digital	10%	50%
49	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	3.000,00	4	Ready	Digital	10%	5%
28	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	1.000,00	8	Ready	Digital	6%	0%
30	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	2.000,00	0	Ready	Digital	10%	20%
42	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	1.000,00	4	Do not know	Digital	20%	10%
25	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	2.000,00	2	Ready	Digital	50%	50%
25	Motorcycle	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	1.000,00	0	Do not know	Offline	30%	50%
52	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	-	1	Ready	Offline	20%	20%
38	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	-	0	Ready	Digital	30%	30%
29	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	3.000,00	9	Do not know	Offline	80%	65%
26	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp	2.000,00	1	Ready	Digital	8%	8%

29	Car	JL. Jaksa Agung Suprapto (BKD area until Bank Jatim)	Rp 1.000,00	2	Not Ready	Offline	7%	2%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 19 Questionnaire Result for Jl. Basuki Rahmat Krian (area Indomaret until Persebaya Store)

1	2	3	4	5	6	7	8	9
21	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	3	Ready	Digital	55%	30%
22	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 4.000	2	Ready	Digital	70%	10%

22	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	0	Ready	Digital	10%	10%
20	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	0	Do not know	Offline	50%	53%
19	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	4	Ready	Digital	40%	50%
23	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 4.000	6	Ready	Digital	70%	30%
21	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	1	Not Ready	Digital	60%	80%
20	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	0	Do not know	Offline	10%	10%
20	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	0	Do not know	Offline	50%	50%
21	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	3	Not Ready	Offline	50%	50%
30	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	5	Ready	Digital	20%	20%

27	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	2	Ready	Digital	10%	10%
22	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 500	2	Not Ready	Offline	Sejujurnya saya tidak paham maksudnya.	Sama
29	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	1	Ready	Offline	kurang paham	kurang paham
28	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	4	Ready	Digital	6%	0%
49	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 500	2	Ready	Digital	30%	50%
26	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	0	Ready	Digital	10%	10%
30	Motorcycle	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	1	Ready	Digital	Jika Motorcycle 2rb, seharusnya Car >2x lipat harga parkir Motorcycle, Car kendaraan	50%

							yg memakan lahan parkir 3-5Motorcycle.	
41	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	2	Ready	Digital	60%	10%
26	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 500	2	Ready	Digital	50%	10%
23	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 3.000	1	Not Ready	Offline	40%	20%
22	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp -	1	Ready	Digital	50%	20%
22	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 500	2	Ready	Digital	50%	20%
22	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	2	Ready	Digital	50%	10%
25	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.500	1	Not Ready	Offline	30%	10%

40	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	6	Ready	Digital	50%	10%
26	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 2.000	2	Ready	Digital	70%	10%
29	Car	JL. Basuki Rahmat Krian (area Indomaret until Persebaya store)	Rp 1.000	0	Ready	Digital	50%	10%

1	How old are you?	6	Are you ready to implement digital parking system?
2	What type of vehicle do you use?	7	If in the parking area applies mixed parking system, which one will you choose?
3	Where do you usually park?	8	Service level of digital parking system
4	How long does it take to wait when you about to park? (It can also wait to be served by the officer)	9	Service level of offline parking system
5	How much do you think the cost of waiting per minute?		

Appendix 20 LINGO Model for Parking User Optimization

```
sets:
vehicle/1,2/:PO,PF;
!1=car
2=motor
PF = price of parking digital
PO = price of parking offline;
location/1..9/:;
system/1,2/:;
!1= digital
2=offline;
link1(location,system):x;
!x= decision variable;
link2(vehicle,location):WL,WF,WO,SO,SF;
!WL = Willingness level
WF = Waiting time offline
WO = Waiting time digital
SO = Service level digital
SF = Service level offline;
endsets
data:
PO = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','PO');
PF = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','PF');
WO = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','WO');
WF = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','WF');
SO = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','SO');
SF = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','SF');
WL = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','WL');
@OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','X_user') = x;
WC = 953.88;
g = 3;
h = 3;

enddata
min = (cost_car_fullD + cost_car_mixed) + (cost_mtr_fullD + cost_mtr_mixed);
```

```
        cost_car_fullD=    @sum(link2(i,j):@sum(link1(j,k)|i#EQ#1    #and#    k#EQ#1:(PO(i)*x(j,k))    +
(WC*WO(i,j)*x(j,k))-(SO(i,j)*PO(i)*x(j,k))));
        cost_car_mixed=          @sum(link2(i,j):@sum(link1(j,k)|i#EQ#1          #and#          k#EQ#2:
((0.5*(PO(i)+PF(i)))*x(j,k))+ ((0.5*(WF(i,j)+WO(i,j)))*WC*x(j,k)) -
        (0.5*((SO(i,j)*PO(i))+(SF(i,j)*PF(i)))*x(j,k))));
        cost_mtr_fullD=      @sum(link2(i,j):@sum(link1(j,k)|i#EQ#2      #and#      j#NE#1      #and#
k#EQ#1:(PO(i)*x(j,k))+(WC*WO(i,j)*x(j,k))-(SO(i,j)*PO(i)*x(j,k))));
        cost_mtr_mixed= @sum(link2(i,j):@sum(link1(j,k)|i#EQ#2 #and# k#EQ#2:((0.5*(PO(i)+PF(i)))*x(j,k))
+ ((0.5*(WF(i,j)+WO(i,j)))*WC*x(j,k)) -
        (0.5*((SO(i,j)*PO(i))+(SF(i,j)*PF(i)))*x(j,k))));


        @sum(link1(j,k)|k#EQ#1:x(j,k)) >= g;
        @sum(link1(j,k)|k#EQ#2:x(j,k)) <= h;
        @for(location(j):x(j,1)+x(j,2)=1);
        @for(link1(j,k):@BIN(x(j,k)));
        @for(link1(j,k)|j#NE#1:(0.5*(WL(1,j)+WL(2,j)))>= 0.5*x(j,1));
```

Appendix 21 LINGO Model for PSP Optimization

```
sets:
vehicle/1,2/:PO,PF;
!1=car
2=motor
PF = price of parking digital
PO = price of parking offline;
location/1..9/:;
system/1,2/:;
!1= digital
2=mixed;
link1(location,system):x,OC,LP;
!LP = leakage potential
X= decision variable
OC = operational cost;
```

```
link2(vehicle,location,system):D,LS;
!LS = rejection
D = Demand;
endsets

data:
PO = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','PO');
PF = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','PF');
LP = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','LP');
D = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','D');
IC = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','IC');
OC = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','OC');
LS = @OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','LS');
@OLE('D:\MUTHIA\TUGAS AKHIR\data\FINAL PROJECT.xls','X') = X;
QO = 0.8;
g = 3;
h = 3;
b = 3000000000;
enddata

max = revenue - cost - lost_sales - leakage;
revenue = @sum(link1(j,k):@sum(link2(i,j,k)|k#EQ#1:D(i,j,k)*PO(i)*x(j,k))) +
@sum(link1(j,k):@sum(link2(i,j,k)|k#EQ#2:x(j,k)*(((QO)*D(i,j,k)*PO(i))+((1-
QO)*D(i,j,k)*PF(i)))));
cost = IC + @sum(link1(j,k):OC(j,k)*x(j,k));
lost_sales=
@sum(link1(j,k):@sum(vehicle(i):@sum(link2(i,j,k)|k#EQ#1:LS(i,j,k)*x(j,k)*PO(i)*D(i,j,k)))) +
@sum(link1(j,k):@sum(vehicle(i):@sum(link2(i,j,k)|k#EQ#2:LS(i,j,k)*x(j,k)*PF(i)*D(i,j,k)))) ;
leakage = @sum(link1(j,k):@sum(link2(i,j,k):LP(j,k)*(1-QO)*D(i,j,k)*PF(i)*x(j,k)));

@sum(link1(j,k):OC(j,k)*x(j,k))<= b;
@sum(link1(j,k)|k#EQ#1:x(j,k)) >= g;
@sum(link1(j,k)|k#EQ#2:x(j,k)) <= h;
@for(location(j):x(j,1)+x(j,2)=1);
@for(link1(j,k):@BIN(x(j,k)));
```

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Muthia Rahmasari is an undergraduate student at Industrial and System Engineering, Institut Teknologi Sepuluh Nopember (ITS). She was born in Bandung on July 1st, 1998. The author academic journey started in Al-Fajar kindergarten in Bekasi (2002-2004) then continued to Al-Fajar elementary school until 4th grade before moved to Angkasa XII elementary school in Halim. The author then pursued secondary school in 81 Junior High School in east Jakarta from 2010 until 2013 and continued to 48 Senior High School from 2013 until 2016.

As a college student, the author had actively involved in several activities and organizations non academically. In the second year of college (2017-2018), the author participated as Steering Committee for freshman orientation and staff of Academia Department in Society of Petroleum Engineers (SPE) ITS Student Chapter. In middle of the year 2018, the author assigned as Head of Division of Community Outreach in Society of Petroleum Engineers (SPE) ITS Student Chapter. At the same time, she was accepted as laboratory assistant in Quantitative Modelling and Industrial Policy Analysis (QMIPA) Laboratory, where she further developed her interest in related field of knowledge. The author had work experience as Purchasing department intern at PT.Omron Manufacturing Indonesia for 2 months. The author also had actively participated as events committee such as in Industrial Engineering Games (IE Games) as event staff, and Red Euphoria Month (REM) BEM FTI ITS as volunteer. The author can be reached through email rahmasari.muthia@gmail.com.