Journal of Engineering and Applied Technology
Vol. 4, No. 2, August 2023, pp. 87-97

Online ISSN 2716-2265
Printed ISSN 2716-2257

Evaluation of capacity and number of gates for delays and fuel consumption in the FTSP UII parking area

Muhamad Abdul Hadi[1,*], Muhammad Kennyzyra Bintang[2], Ad Zulfa Geofani Firdaus[3], Ghina Hanifah Farza[4]

[1,2,3,4] Department of Civil Engineering, Universitas Islam Indonesia, Indonesia
E-mail: muhamad.abdul.hadi@uii.ac.id *
* Corresponding Author

ABSTRACT

One of the goals of campus development is to provide more adequate facilities for campus residents. This is caused by the increase in vehicles and a large traffic movement that will result in parking users having difficulty parking and causing congestion. This study was devoted to examining the capacity of the FTSP UII motorcycle parking area. Data in this study was obtained by conducting a survey at the research location. The research results will be obtained by comparing the capacity of the FTSP UII parking area in the existing conditions and the next 5 years as well as comparing the value of fuel consumption. Based on the research that has been carried out, the existing parking lot can still accommodate vehicles. Furthermore, in the next 5 years, the parking lot can no longer accommodate vehicles. In addition, it can be concluded that the addition of parking gates can reduce the queue length by 56%, delay by 19%, and fuel consumption by 19%.

ARTICLE INFO

Article history
Received:
03 April 2023
Revised:
15 August 2023
Accepted:
20 August 2023

Keywords
capacity
delay
fuel consumption
gate
parking

1. Introduction

The university is a place that offers several facilities such as classrooms, offices, libraries, and sports venues. Over time, several campuses began to develop, either facilities or the addition of new buildings. One of the goals of this development is to provide more adequate facilities for campus residents. Thus, the phenomenon of increasing the number of students can be found. This is inseparable from the Faculty of Civil Engineering and Planning (FTSP) at the Islamic University of Indonesia (UII). FTSP UII is one of the oldest campuses in UII. Based on data from the Higher Education Database (PDDikti), there was an increase in the number of students at FTSP UII by 9.9% from 2020 to 2021, with details of the increase in the number of students from 2019 to 2020 by 9% and the increase in the number of students from 2020 to 2021 by 10%. The increase in the number of students caused an increase in the number of vehicles [1]. In addition, the increase in the number of students also has an effect on increasing the need for facilities and transportation [2]. The increase in the number of students resulted increase in vehicles and in a large traffic movement [3][4]. If the increase in vehicles is not balanced by an increase in facilities, especially parking facilities, it will result in parking users having difficulty parking and causing congestion, especially during peak hours on workdays [5]. Thus, the impact of traffic and parking can be considered one of the main problems within any region and can increase additional costs for universities [6]. Therefore, it is necessary to provide facilities and infrastructure for traffic flow control in the form of a flow circulation system and parking management [7] [8].

Parking is a state of immobility from a vehicle that is not temporary [9]. Parking can also be interpreted as any vehicle that stops at a certain place whether stated by traffic signs or not. In addition to its condition, it has almost experienced over capacity. Another problem found is the queue of vehicles when entering or leaving the parking area. This is due to the inadequate number of gates or access available. Something like this happened to the motorcycle parking area in the FTSP UII area. Based on observations of existing conditions, there is often a phenomenon of long queues of vehicles when going out or entering the parking area. This causes the vehicle to be required to wait longer. Furthermore, queuing activities make vehicles experience time delays [10]. By making efforts to reduce delays, it has an impact on reducing fuel consumption and exhaust emissions [11].

Based on the conditions and phenomena that have been described, the results of this study will be presented in the form of evaluating capacity and evaluating the number of gates or access in the FTSP UII parking area to measure the effectiveness of parking facilities. Measurements are carried out in current conditions and in next 5 years conditions. In addition, this study would also contain a comparison of fuel consumption in conditions before and after adding access in and out of the FTSP UII parking area.

2. Method

This research on parking capacity evaluation of FTSP UII is included in the quantitative type of research because this research uses data in the form of numbers. The parking capacity evaluation research focused on the motorcycle parking area in the FTSP UII area. In addition, the method used to obtain data on this study is by conducting a survey which will then be analyzed to get conclusions from the research carried out. The data collection survey was conducted on Tuesday and Friday at 07:00-17:00 WIB. The choice of the two days was because on both days the phenomenon of long queues in the FTSP UII parking area was longer than other days. The conclusion of this study is in the form of a comparison of the capacity of the FTSP UII parking area in existing conditions and the next 5 years as well as a comparison of fuel consumption values based on delays. The scheme of the research method of this study can be seen in Fig. 1 as follows.

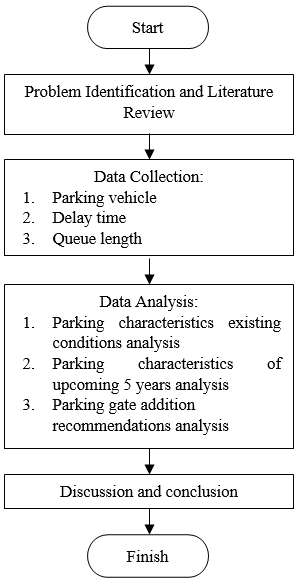

Fig. 1. Scheme of research method

The location of this study can be seen in Fig. 2 as follows.

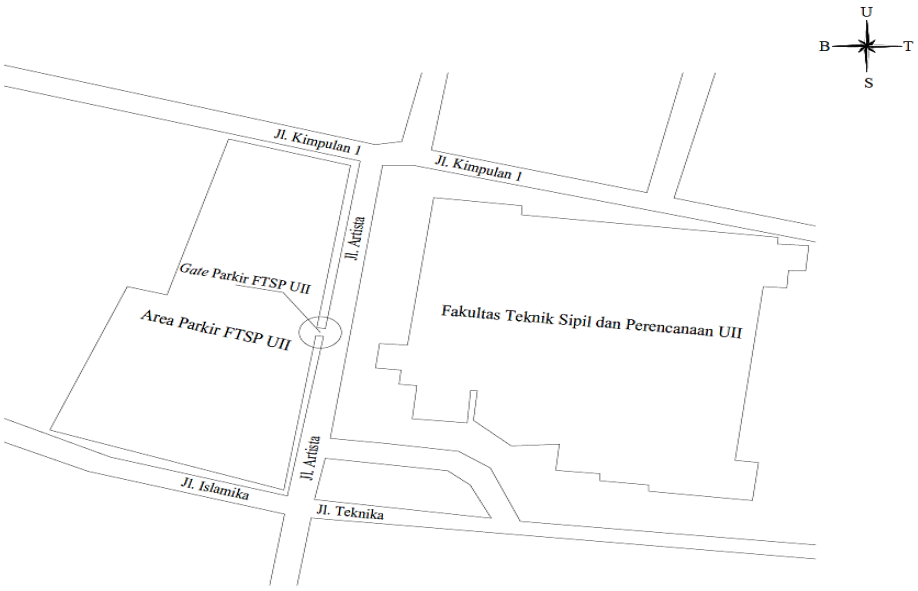

Fig. 2. Research location

3. Results and Discussion

3.1. Parking Characteristics Existing Conditions Analysis

Parking characteristics include parking duration, parking accumulation, parking volume, parking index, parking capacity, parking turnover, and parking occupancy. Supporting data were obtained from surveys at the research site. The discussion on aspects of parking characteristics is as follows.

1. Parking Duration
   The duration of parking is the length of time it takes for vehicles to enter the parking lot until they leave the parking lot. The graph of the duration of parking in existing conditions can be seen in Figure 3 as follows.

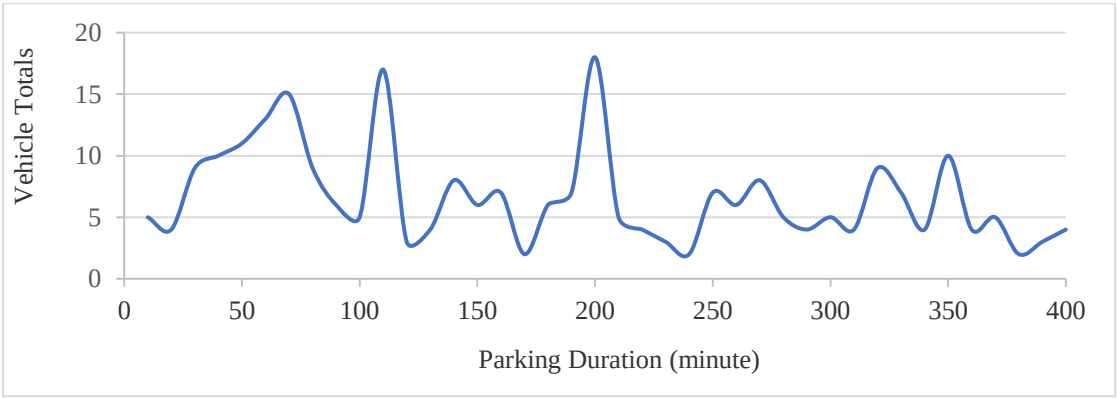

Fig. 3. Parking duration of existing conditions

After obtaining a parking duration chart as shown in Fig. 3, the durations of each vehicle can be grouped. The calculation of the duration of self-parking can be used to calculate the amount of parking revenue at the location if paid parking is applied. The parking duration is 200 minutes with the number of vehicles as many as 18 vehicles. From the calculation of the duration, it can be determined the maximum duration of 400 minutes and the average duration of 198 minutes.

2. Parking Accumulation

Parking accumulation is needed to find out the number of vehicles that are in a parking lot at a certain interval of time. The recapitulation of the results of the calculation of accumulated parking in existing conditions can be seen in Table 1 as follows.

Table 1. Parking Accumulation Existing Conditions

Number	Time	Incoming Vehicle	Vehicle Out	Accumulation
1	<07:00	78	0	78
2	07:00-08:00	114	2	190
3	08:00-09:00	140	20	310
4	09:00-10:00	257	44	523
5	10:00-11:00	259	104	678
6	11:00-12:00	219	199	698
7	12:00-13:00	241	291	648
8	13:00-14:00	229	60	817
9	14:00-15:00	154	106	865
10	15:00-16:00	177	104	938
11	16:00-17:00	177	477	638
12	>17:00	114	410	342

The maximum accumulation based on Table 1 is 938 vehicles, occurring from 15:00 to 16:00.

3. Parking Volume

Parking Volume is the number of vehicles that have used parking space in a certain parking lot in a certain unit of time. The recapitulation of the results of the calculation of the existing condition parking volume can be seen in Table 2 as follows.

Table 2. Parking Volume Existing Conditions

No	Time	Volume
1	<07:00	78
2	07:00-08:00	114
3	08:00-09:00	140
4	09:00-10:00	257
5	10:00-11:00	259
6	11:00-12:00	219
7	12:00-13:00	241
8	13:00-14:00	229
9	14:00-15:00	154
10	15:00-16:00	177
11	16:00-17:00	177
12	>17:00	114
	Total	2159

Table 2 shows that the maximum volume for parking is 259 vehicles/hour at 10.00 – 11.00.

4. Parking Index
   The parking Index is a percentage of the accumulated number of vehicles at a given time interval divided by the available parking spaces multiplied by 100%. Based on the analysis, a parking index of 93% was obtained. This means that the vehicles in the parking lot are smaller than the capacity that has been provided. Therefore, it can be concluded that the capacity of the parking lot in existing conditions can still accommodate vehicles.

5. Parking Capacity
   Parking capacity is divided into two types, namely static capacity and dynamic capacity as follows.
   a. Static capacity
      Static capacity is the number of parking spaces available in a parking lot. The static capacity for the parking area is 1012 SRP.
   b. Dynamic capacity
      Dynamic capacity is the ability of a parking lot to accommodate vehicles that have different parking characteristics. The dynamic capacity for the parking area is 431 vehicles.

6. Parking Turnover
   Parking turnover is the turnover rate obtained from the number of vehicles that have utilized the parking lot at a certain time interval divided by the available parking space. From the results of the analysis, a turnover value of 2.133 was obtained. Therefore, it can be concluded that during the observation time, each SRP experienced an average turnover of 2.133 times.

7. Parking Occupancy
   Parking occupancy is the accumulation of vehicles at a certain interval of time divided by the available parking spaces multiplied by 100%. The recapitulation of the results of the calculation of parking occupancy in existing conditions can be seen in Table 3 as follows.

Table 3. Parking Occupancy Existing Conditions

No	Waktu	Accumulation	Occupancy (%)
1	<07:00	78	8
2	07:00-08:00	190	19
3	08:00-09:00	310	31
4	09:00-10:00	523	52
5	10:00-11:00	678	67
6	11:00-12:00	698	69
7	12:00-13:00	648	64
8	13:00-14:00	817	81
9	14:00-15:00	865	85
10	15:00-16:00	938	93
11	16:00-17:00	638	63
12	>17:00	342	34

   Based on the table above, a maximum occupancy of 93% was obtained at 15.00 – 16.00.

8. Parking Space Needs
   Parking space needs (PSN) are the number of parking spaces needed for a parking lot. Based on the results of the analysis, the PSN value was obtained in the existing condition of 331 Parking Space Unit (PSU).

From the calculation analysis, the results of the need for PSN were obtained for 331 PSU. When compared to the existing static capacity of 1012 PSU and 72.8 PSU, this means that the vehicles in the parking lot are less than the capacity that has been provided (Static Capacity and the Directorate General of Land Transportation, 1996). Therefore, it can be concluded that the capacity of the parking lot in the existing conditions can still accommodate vehicles.

3.2. Parking Gate Addition Recommendations Analysis

The addition of a parking gate is necessary because there have been often queues of vehicles, especially during peak hours when vehicles leave the parking area. Simulation of adding parking gates was carried out with the PTV VISSIM Application. The scheme of adding gates can be seen in Fig. 5 on the next page. After that, a gate modelling simulation was carried out on the VISSIM PTV Application.

Fig. 5. Research Location

Based on observations at the study site, the highest queue length value was 28.9 m and occurred in the afternoon at 16:00-17:00. A recapitulation of the queue length values can be seen in Table 4 on the next page.

Table 4. Queue Length Value Comparison

Queue Length (m)				
n	**Observation**	**VISSIM**	**Average VISSIM**	**(y'-y)/y**
1	28.9	15.52	12.68	0.463
2	28.9	12.49		0.568
3	28.9	10.04		0.653
		Total		1.683
		MAPE (%)		34

Table 4 shows a MAPE value of 34% with the meaning of modelling acceptable (<50%). In addition, Table 4 also shows that with the addition of parking gates, the average queue length value becomes 12.68 m. Therefore, it can be interpreted by adding a gate the value of the queue length is reduced from 28.9 m to 12.68 m or decreased by 56%.

Based on observations at the study site, the highest delay value was 20 seconds and occurred in the afternoon at 16:00-17:00. A recapitulation of the delay duration values can be seen in Table 5 as follows.

Table 5. Delay Value Comparison

Delay (second)				
n	**Observation**	**VISSIM**	**Average VISSIM**	**(y'-y)/y**
1	20	18.2	16.27	0.090
2	20	17.4		0.130
3	20	13.2		0.340
		Total		0.560
		MAPE (%)		11

Table 5 shows a MAPE value of 11% with the meaning of modeling acceptable (<50%). In addition, Table 5 also shows that with the addition of parking gates, the average delay value becomes 16.22 seconds. Therefore, it can be interpreted by adding a gate the queue length value is reduced from 20 seconds to 16.27 seconds or decreased by 19%.

3.3. Analysis of Fuel Consumption Value Comparison

The comparison of fuel consumption values before and after the addition of parking gates can be known using the LAPI-ITB Eq. (1) as follows [12].

$$F = 3.889 \times 10^{-4} \times \text{Delay (liter)} \quad (1)$$

So the value of fuel consumption before the addition of the gate is 0.0078 litres and the value of fuel consumption after the addition of the parking gate is 0.0063 litres. Therefore, it can be concluded that with the reducing value of delay based on the addition of parking gates, the value of fuel consumption can decrease by up to 19%.

3.4. Parking Characteristics Of Upcoming 5 Years Analysis

Analysis of parking characteristics in the next 5 years is carried out by forecasting vehicle data. Forecasting was done using Eq. (2) on the next page.

$$Pn = Po \times (1+i\%)^n \quad (2)$$

The determination of the i grade was carried out by looking at the number of FTSP UII students from 2019 to 2021 with details of the increase in the number of students from 2019 to 2020 by 9% and the increase in the number of students from 2020 to 2021 by 10%. Thus, an i value of 9.9% was obtained. The discussion on aspects of parking characteristics in the next 5 years can be seen as follows.

1. Parking Duration
   A graph of the duration of parking in the next 5 years can be seen in Figure 4 as follows.

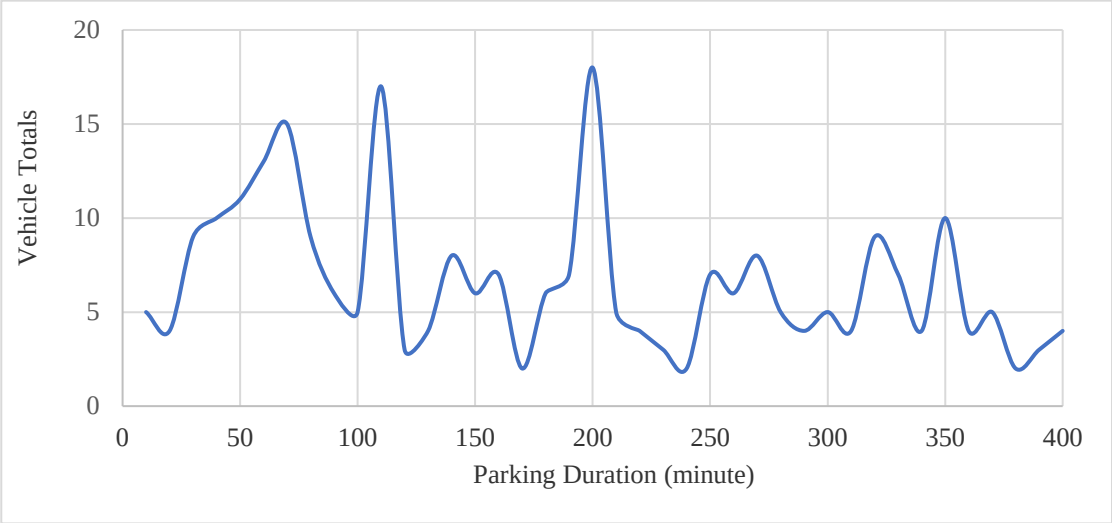

Fig. 4. Graph of Parking Duration for the Next 5 Years

After obtaining a parking duration chart as shown in Figure 4 above, the durations on each vehicle can be grouped. The calculation of the duration of self-parking can be used to calculate the amount of parking revenue at the location if paid parking is applied. The parking duration is 200 minutes with the number of vehicles as many as 18 vehicles.

2. Parking Accumulation
   A recapitulation of the results of the calculation of accumulated parking conditions for the next 5 years can be seen in Table 6 as follows.

Table 6. Parking Occupancy for the Next 5 Years

Number	Time	Incoming Vehicle	Vehicle Out	Accumulation
1	<07:00	125	0	125
2	07:00-08:00	183	3	305
3	08:00-09:00	224	32	497
4	09:00-10:00	412	71	838
5	10:00-11:00	415	167	1087
6	11:00-12:00	351	319	1119
7	12:00-13:00	386	467	1039
8	13:00-14:00	367	96	1310
9	14:00-15:00	247	170	1387
10	15:00-16:00	284	167	1504
11	16:00-17:00	284	765	1023
12	>17:00	183	657	548

The maximum accumulation based on Table 4 is 1504 vehicles, occurring from 15:00 to 16:00.

3. Parking Volume
   A recapitulation of the results of the calculation of parking volume in the next 5 years can be seen in Table 7 as follows.

Table 7. Parking Volume for the Next 5 Years

No	Waktu	Volume
1	<07:00	125
2	07:00-08:00	183
3	08:00-09:00	224
4	09:00-10:00	412
5	10:00-11:00	415
6	11:00-12:00	351
7	12:00-13:00	386
8	13:00-14:00	367
9	14:00-15:00	247
10	15:00-16:00	284
11	16:00-17:00	284
12	>17:00	183
	Total	3461

Table 7 shows that the maximum volume for parking is 415 vehicles/hour at 10.00 – 11.00.

4. Parking Index
   Based on the results of the analysis, a parking index of 149 % was obtained. This means that the vehicles in the parking lot are larger than the capacity that has been provided. Therefore, it can be concluded that the capacity of the parking lot in the next 5 years conditions no longer able to accommodate vehicles.

5. Parking Capacity
   Parking capacity is divided into two types, namely static capacity and dynamic capacity as follows.
   a. Static capacity
      Static capacity is the number of parking spaces available in a parking lot. The static capacity for the parking area is 1012 SRP.
   b. Dynamic capacity
      Dynamic capacity is the ability of a parking lot to accommodate vehicles that have different parking characteristics. The dynamic capacity for the parking area is 431 vehicles.

6. Parking Turnover
   From the analysis, a turnover value of 3.419 was obtained. Therefore, it can be concluded that during the observation time, each SRP experienced an average turnover of 3.419 times.

7. Parking Occupancy
   A recapitulation of the calculation results of parking occupancy for the next 5 years' conditions can be seen in Table 8 on the next page.

Table 8. Parking Occupancy for the Next 5 Years

No	Waktu	Accumulation	Occupancy (%)
1	<07:00	78	12
2	07:00-08:00	190	30
3	08:00-09:00	310	49
4	09:00-10:00	523	83
5	10:00-11:00	678	107
6	11:00-12:00	698	111
7	12:00-13:00	648	103
8	13:00-14:00	817	129
9	14:00-15:00	865	137
10	15:00-16:00	938	149
11	16:00-17:00	638	101
12	>17:00	342	54

Based on the table above, a maximum occupancy of 93% was obtained at 15.00 – 16.00.

8. Parking Space Needs
   Parking space needs (PSN) are the number of parking spaces needed for a parking lot. Based on the results of the analysis, the PSN value was obtained in the existing condition of the 1654 parking space unit (PSU).

From the calculation analysis, the need for parking spaces (KRP) was obtained, namely 1654 SRP. When compared to the existing static capacity of 1012 SRP and 72.8 SRP, this means that the vehicles in the parking lot are more than the capacity that has been provided (Static Capacity and Directorate General of Land Transportation, 1996). Therefore, it can be concluded that the capacity of the parking lot in the next 5 years is no longer able to accommodate vehicles. So, a collaboration with professional parking management companies or an ITS application area can be applied to solve parking issues in the future.

4. Conclusion

Based on the research that has been carried out, the following conclusions were obtained.

1. In the existing condition, the value of parking space needs (PSN) was obtained, which was 331 PSU. When compared to the static (existing) capacity of 1012 PSU, the current parking lot can still accommodate vehicles.
2. In the existing condition, the highest queue length value is 28.9 m and the delay value is 20 seconds. With an alternative scheme in the form of adding 1 parking gate, a queue length value of 12.68 m and a delay value of 16.27 seconds were obtained. Therefore, the addition of parking gates can reduce the queue length by 56% and delay by 19%.
3. The addition of parking gates affects the value of fuel consumption. The value of fuel consumption before and after the addition of parking gates is 0.0078 litres and 0.0063 litres. Therefore, the addition of parking gates can reduce fuel consumption by 19%.
4. In the next 5 years, the value of parking space needs (PSN) is obtained, which is 1654 PSU. When compared to the static (existing) capacity of 1012 PSU, the existing parking lot is no longer able to accommodate vehicles because there is a shortage of 642 PSU. Thus, a recommendation was obtained, namely the opening of a new parking lot. By looking at the need for parking spaces, the addition of a high-rise parking building for motorcycles is necessary to be planned.

Acknowledgement

We would like to express our gratitude to the Directorate of Research and Community Service (DPPM) of Universitas Islam Indonesia as the funder for this research. We also thank all parties who have helped the sustainability of this research.

References

[1] Simanjuntak, Nova Riyanti, and Sutan Parasian Silitonga, "Evaluasi Kapasitas Areal Parkir Kampus Universitas Palangka Raya Berdasarkan Kebutuhan Satuan Ruang Parkir (SRP)," *Jurnal Teknika: Jurnal Teoritis dan Terapan Bidang Keteknikan*, vol. 3., no. 2, pp. 136-148, 2020.

[2] Herdiansyah, Herdis, et al, "Capacity analysis of parking lot and volume of vehicle toward sustainable parking convenience," *IOP Conference Series: Earth and Environmental Science*. vol. 88, no. 1, 2017.

[3] Mahmugi, Imam, and Eti Sulandari, "Evaluasi Kebutuhan Lahan Parkir pada Fakultas Teknik universitas Tanjungpura Pontianak," *JeLAST: Jurnal PWK, Laut, Sipil, Tambang*, vol. 5, no. 3, 2017.

[4] Sulistio, Harnen, and Agus Suharyanto, "Evaluasi Kebutuhan Ruang Parkir Di Kampus Universitas Brawijaya," *Media Teknik Sipil*, vol. 13, no. 1, pp. 79-90, 2015.

[5] Gurbuz, Okan, and Ruey Long Cheu, "Survey to explore behavior, intelligent transportation systems needs, and level of service expectations for student parking at a university campus," *Transportation Research Record*, vol. 2674, no.1, pp. 168-177, 2020.

[6] Abbood, Abdulkareem N., Abdul RI Ahmed, and Harith KK Ajam, "Evaluation of parking demand and future requirement in the urban area," *Civil Engineering Journal*, vol. 7, no. 11, pp. 1898-1908, 2021.

[7] Genel, Vokan, *Parking management in smart built environment: evaluation of METU Campus*, MS thesis, Middle East Technical University, 2020.

[8] Moeinaddini, Mehdi, et al, "A practical method for evaluating parking area level of service," *Land Use Policy*, vol. 33, pp. 1-10, 2013.

[9] Direktorat Jendral Perhubungan Darat, "Pedoman Teknis Penyelenggaraan Fasilitas Parkir", 1996.

[10] Putra, Arief Permana, and Agus Sumarsono, "Analisis Hubungan Kinerja Simpang Bersinyal Terhadap Konsumsi Bahan Bakar di Kota Surakarta," *Matriks Teknik Sipil*, vol. 1, no.1, 2012.

[11] Al-Arkawazi, Shamil Ahmed Flamarz, "Measuring the influences and impacts of signalized intersection delay reduction on the fuel consumption, operation cost and exhaust emissions," *Civil Engineering Journal*, vol. 4, no. 3, pp 552-571, 2018.

[12] Lembaga Afiliasi dan Penerapan Industri ITB bekerjasama dengan PT. Jasa Marga, 1996. "Laporan Akhir Studi Perhitungan Biaya Operasi Kendaraan",1996.