Dynamic analysis of on-street-parking impact on road capacity

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Abstract. On-street-parking research has resulted in and conclusions to improve road capacity. The aims of this study to determine the existing condition of road capacity based on-street-park. Dynamic on-street-parking influenced by two indicators, space and time, as well as the scenarios needed if the road capacity does not support. Dynamic analysis was conducted twice, the first one is the study of the traffic volume on-road section with the dynamic parking and queue in each of the three zones in drop-off and pick-up areas. The parking analysis has already used to many studies [1] [2]. Whereas the equations have improved from traffic behaviour approach[3], and dynamic queuing equation model [4] are used for queue analysis [5]. From the results of the analysis, DS values for the road sections before and after the drop-off pick-up area were 0,044, while in the drop-off and pick-up area was 0,155. From the queue analysis, the value of $\rho < 1$ is obtained for all zones. Based on a study location that has 4 lanes in direction, the road configuration scenario is not yet needed, but the road sections before and after the drop-off pick-up area will have a DS value of 0,75 in 2050, while the drop-off pick-up area in 2036. Further research needs to be done by calculating the road’s effective-width due to vehicle parking manoeuvres.

1. Introduction

The most common problem arising in the people on transportation system is on street parking at the transportation terminal, including Ahmad Yani International Airport, Semarang. From the data of PT Angkasa Pura I (Persero), Ahmad Yani International Airport Semarang has served as many as 5.1 million passengers (January to December 2018), which increased by 4.4 million passengers or around 17% from 2017.

In the process of airport traffic movement and park, there is an up-and-down activity of passengers carried out by vehicles in the airport drop-off and pick-up area [6]. Drop-off and pick-up activities, hereinafter referred to as dynamic parking activities, are able to influence the capacity of existing road sections in terminal area of Ahmad Yani International Airport Semarang, so it is necessary to study the effect of dynamic parking activities on the existing road segment capacity.
2. Research Methodology
In this research, it is necessary to have a method to identify problems and formulate solutions precisely. The method used in this research is descriptive analysis method. To obtain the primary data needed, field observations are conducted, while secondary data are obtained from previous literature studies and administrative data. Dynamic analysis was conducted twice, the first one is the study of the traffic volume on-road section with the dynamic parking and queue in each of the three zones in drop-off and pick-up areas. The parking analysis has already used to many studies [1] [2]. Whereas the equations have improved from traffic behaviour approach[3], and dynamic queuing equation model [4] are used for queue analysis [5].

3. Analysis and Result

3.1. Moving Car Observer (MCO)
Moving car observer method is used to obtain value of traffic volume, travel time, and travel speed on the road before and after drop-off and pick-up area. From survey, the results of analysis are as shown in Table 1.

| Observation | Traffic Volumes | Average Time | Average Speed |
|-------------|----------------|--------------|---------------|
|             | q (pcu/sec.)   | t (sec.)     | v (m/s)       |
| 1           | 0.053          | 191.80       | 0.043         | 11.09 | 39.94 |
| 2           | 0.088          | 319.35       | 0.046         | 10.47 | 37.68 |
| 3           | 0.051          | 185.71       | 0.041         | 11.89 | 42.80 |
| 4           | 0.071          | 258.17       | 0.045         | 10.68 | 38.45 |
| 5           | 0.047          | 169.41       | 0.046         | 10.58 | 38.10 |
| 6           | 0.134          | 482.40       | 0.041         | 11.71 | 42.16 |
| Average     | 0.074          | 267.81       | 0.040         | 11.07 | 39.86 |

3.2. Dynamic Parking
For dynamic parking analysis that occurs at on-street drop-off and pick-up area, the calculation is carried out in several stages as follows:
3.2.1. Static Capacity (SC), based on Transportation Department regulations [7] the Park Space Unit (PSU) value at the airport drop off and pickup area is taken at 2.50 x 5.00 m. As for the effective length of land, the value is based on observations in the field. From the analysis results, the static capacity values obtained are as in Table 2.

| Area / Zone | Effective Length of Land | PSU | Static Capacity |
|-------------|-------------------------|-----|-----------------|
| (0)         | (1)                     | (2) | (3) = (1) / (2) |
| DO/1        | 60.2 m                  | 2.5 x 5 m | 12 PSU |
| DO/2        | 52.7 m                  | 2.5 x 5 m | 10 PSU |
| DO/3        | 107 m                   | 2.5 x 5 m | 21 PSU |
| PU/1        | 69.3 m                  | 2.5 x 5 m | 13 PSU |
| PU/2        | 55.3 m                  | 2.5 x 5 m | 11 PSU |
| PU/3        | 90.3 m                  | 2.5 x 5 m | 18 PSU |

3.2.2. Dynamic Capacity (DC), from survey results during peak hours, the average parking duration are obtained then processed to find value of dynamic capacity. From the analysis results, it is obtained the value of dynamic capacity as in Table 3.

| Area / Zone | SC | Week day | Week end |
|-------------|----|----------|----------|
| (0)         | (1) | (2)      | (3) = (1)*(2)/(4) | (5) | (6)      | (7) = (1)*(5)/(6) |
| DO/1        | 12  | 6.25     | 0:01:47 | 2500 | 6 | 0:01:40 | 2571 |
| DO/2        | 10  | 6        | 0:01:52 | 1935 | 6 | 0:01:25 | 2500 |
| DO/3        | 21  | 6.5      | 0:07:38 | 1075 | 6 | 0:07:55 | 955  |
| PU/1        | 13  | 6.5      | 0:02:27 | 2061 | 6 | 0:02:35 | 1814 |
| PU/2        | 11  | 6.5      | 0:02:39 | 1625 | 6 | 0:03:38 | 1082 |
| PU/3        | 18  | 6.6      | 0:02:23 | 2925 | 6 | 0:02:25 | 2700 |

3.2.3. Parking Space Needs, the number of vehicles parked and average parking duration are obtained from survey results. From analysis results, it is obtained value of parking space needs as in Table 4. (T: time survey; Y: volume in pcu/hour; D: stopping time; Z: Park Space Unit).

| Area / Zone | Week day | Week end |
|-------------|----------|----------|
| (0)         | (1)      | (2)      | (3) = (1)*(2)/(4) | (5) | (6)      | (7) = (1)*(5)/(6) |
| DO/1        | 6.25     | 664      | 0:01:47 | 3.187 | 6 | 0:01:40 | 2.352 |
| DO/2        | 6        | 380      | 0:01:52 | 1.963 | 6 | 0:01:25 | 1.436 |
| DO/3        | 6.5      | 106      | 0:07:38 | 2.071 | 6 | 0:07:55 | 1.320 |
| PU/1        | 6.5      | 224      | 0:02:27 | 1.413 | 6 | 0:02:35 | 1.297 |
| PU/2        | 6.5      | 284      | 0:02:39 | 1.922 | 6 | 0:03:38 | 2.084 |
| PU/3        | 6.6      | 233      | 0:02:23 | 1.434 | 6 | 0:02:25 | 0.987 |

To find out whether or not the parking space capacity is met, it is necessary to make a comparison between the value of parking capacity and number of parking space needs as shown in Table 5.
### Table 5. Comparison of parking capacity and parking needs

| Area / Zone | SC     | Week Day | Difference | Week End | Difference |
|-------------|--------|----------|------------|----------|------------|
|             | (0)    | (1)      | (2)        | (3) = (1) – (2) | (4)        | (5) = (1) – (4) |
| DO/1        | 12     | 3.187    | +8.8130    | 2.352    | +9.6480    |
| DO/2        | 10     | 1.963    | +8.0370    | 1.436    | +8.5640    |
| DO/3        | 21     | 2.071    | +18.929    | 1.320    | +19.680    |
| PU/1        | 13     | 1.413    | +11.587    | 1.297    | +11.703    |
| PU/2        | 11     | 1.922    | +9.0780    | 2.084    | +8.9160    |
| PU/3        | 18     | 1.434    | +16.566    | 0.987    | +17.013    |

3.2.4. Parking Space Turnover, from analysis of parking volume and static capacity, turnover can be calculated as shown in Table 6.

### Table 6. Parking space turnover value in each area and zone

| Area / Zone | Week Day | Week End |
|-------------|----------|----------|
|             | Ks       | Peak Hour | Maximum Turnover |
|             | (0)      | (1)      | (2) = (2)/(1)   | (3) = (4)/(1) |
| DO/1        | 12       | 7:31 - 7:45 | 62.00     | 55.333 |
| DO/2        | 10       | 12:01 - 12:15 | 35.900   | 38.000 |
| DO/3        | 21       | 16:46 - 17:00 | 2.857    | 5.048  |
| PU/1        | 13       | 16:46 - 7:45 | 13.923   | 17.231 |
| PU/2        | 11       | 11:46 - 12:00 | 18.636   | 25.818 |
| PU/3        | 18       | 7:01 - 7:15  | 8.222    | 12.944 |

3.2.5. Parking Accumulation, data are grouped every 15 minutes in order to facilitate the determination of maximum value parking accumulation. The results of parking accumulation data analysis can be seen in Table 7.

### Table 7. Parking accumulation in each area and zone

| Area / Zone | Week day | Week end |
|-------------|----------|----------|
|             | Max. Accumulation | Peak Hour | Max. Accumulation | Peak Hour |
| DO/1        | 9        | 7:31 - 7:45 | 6           | 7:16 - 7:30 |
| DO/2        | 6        | 12:01 - 12:15 | 5           | 7:16 - 7:30 |
| DO/3        | 9        | 16:46 - 17:00 | 5           | 12:16 - 12:30 |
| PU/1        | 4        | 7:31 - 7:45  | 4           | 16:46 - 17:00 |
| PU/2        | 6        | 11:46 - 12:00 | 8           | 17:01 - 17:15 |
| PU/3        | 5        | 7:01 - 7:15  | 5           | 12:46 - 13:00 |

3.2.6. Parking Index. From the analysis, results of parking accumulation and parking capacity can be used to calculate parking index values as shown in Table 8.
Queuing analysis is carried out to find out whether the road sections in drop off and pick up areas can accommodate the queues of vehicles that occur[5]. This analysis is carried out by taking peak hour data on arrival patterns and queuing services during the main survey, then the data is distributed every 5 minutes to determine the frequency of vehicles in drop off and pick up areas. After that, checked the data based on steady state analysis and distribution of arrival and service patterns, then the queuing performance values are determined based on existing geometric formulas. For the results, it can be seen in Table 9 and Table 10.

Table 8. Parking index in each area and zone

| Area/ Zone | Ks | Week day Accumulation | Index (%) | Week End Accumulation | Index (%) | Max. Index |
|------------|----|----------------------|-----------|----------------------|-----------|------------|
| DO/1       | 12 | 9                    | 75.00     | 6                    | 50.00     | 75.00      |
| DO/2       | 10 | 6                    | 60.00     | 5                    | 50.00     | 60.00      |
| DO/3       | 21 | 9                    | 42.86     | 5                    | 23.81     | 42.86      |
| PU/1       | 13 | 4                    | 30.77     | 4                    | 30.77     | 30.77      |
| PU/2       | 11 | 6                    | 54.55     | 8                    | 72.73     | 72.73      |
| PU/3       | 18 | 5                    | 27.78     | 5                    | 27.78     | 27.78      |

Table 9. Queuing analysis in drop off and pick up area on week day

| Area | Arrival Rate (λ) | Services Rate (μ) | Probability of Busy Period (p) | Queue Length (Lq) | Queue Line Length (L) | Waiting Time in System (Ws) | Waiting Time in Queue (Wq) |
|------|------------------|-------------------|--------------------------------|--------------------|-----------------------|----------------------------|---------------------------|
|      | vehicles/5 min. | vehicles/min.     |                                | vehicles/min.      | 1.27                  | 1.93                      | 1.22                      | 0.80                     |
|      | 7.905            | 1.58              | 2.40                           | 0.66               |                       |                           |                           |                          |
|      | 4.524            | 0.90              | 1.00                           | 0.90               | 8.60                  | 9.50                      | 10.50                     | 9.50                     |
|      | 1.262            | 0.25              | 1.40                           | 0.18               | 0.04                  | 0.22                      | 0.87                      | 0.16                     |
|      | 2.929            | 0.59              | 1.40                           | 0.42               | 0.30                  | 0.72                      | 1.23                      | 0.51                     |
|      | 3.821            | 0.76              | 2.20                           | 0.35               | 0.18                  | 0.53                      | 0.70                      | 0.24                     |
|      | 3.060            | 0.61              | 2.00                           | 0.31               | 0.13                  | 0.44                      | 0.72                      | 0.22                     |

Table 10. Queuing analysis in drop off and pick up area on week end

| Area | Arrival Rate (λ) | Services Rate (μ) | Probability of Busy Period (p) | Queue Length (Lq) | Queue Line Length (L) | Waiting Time in System (Ws) | Waiting Time in Queue (Wq) |
|------|------------------|-------------------|--------------------------------|--------------------|-----------------------|----------------------------|---------------------------|
|      | vehicles/5 min. | vehicles/min.     |                                | vehicles/min.      | 1.32                  | 1.99                      | 1.66                      | 1.10                     |
|      | 5.988            | 1.20              | 1.80                           | 0.67               |                       |                           |                           |                          |
|      | 4.250            | 0.85              | 1.00                           | 0.85               | 4.82                  | 5.67                      | 6.67                      | 5.67                     |
|      | 0.714            | 0.14              | 1.00                           | 0.14               | 0.02                  | 0.17                      | 0.17                      | 0.17                     |
|      | 2.238            | 0.45              | 1.60                           | 0.28               | 0.11                  | 0.39                      | 0.87                      | 0.24                     |
|      | 2.857            | 0.57              | 1.60                           | 0.36               | 0.20                  | 0.56                      | 0.97                      | 0.35                     |
|      | 2.643            | 0.53              | 1.00                           | 0.53               | 0.59                  | 1.12                      | 2.12                      | 1.12                     |
3.4. Road Capacity Prediction
In previous analysis, the existing condition shows that road capacity is still fulfilling. However, it is necessary to know when the road capacity is no longer eligible. This is useful for future design preparation, so that problems in the field can be anticipated.

3.4.1. Growth Rate, the passenger growth rate of Ahmad Yani International Airport is obtained from PT Angkasa Pura I (Persero), because the number of passengers has represented the number of flights and the number of vehicles entering the airport area. The analysis carried out in the form of regression analysis to determine magnitude of growth rates[8]. From the results of regression analysis as in Fig. 3, a growth value of 9.52% is obtained.

![Passenger growth regression chart](image)

Figure 2. Passenger growth regression chart

3.4.2. Degree of Saturation Prediction, to predict degree of saturation value, at first predicted volume value in n year with formula:

\[ Q_n = Q \times (1 + i)^n \]  \hspace{1cm} (1)

In this analysis, look for in what years (n) the DS value ≈ 0.75, so the formula used is:

\[ DS_n = \frac{Q_n}{c} \rightarrow 0.75 = \frac{Q_n}{c} \rightarrow Q_n = 0.75c \]  \hspace{1cm} (2)

\[ Q_n = Q \times (1 + i)^n \]

0.75C = Q x (1 + i)^n

\[ n = \frac{(1+i)^n}{\log\left(\frac{0.75C}{Q}\right)} \]  \hspace{1cm} (3)

From calculation results, the road segments before and after drop off / pick up area will have a DS value of 0.75 for next 31 years or in 2050, while for the drop off / pick up area for next 17 years or in 2036. So that as these years approach, it is necessary to plan anticipate problems steps that can arise in the field.

4. Conclusion
This paper proposes an improved procedure to produce dynamic parking optimum according to requirements and can be used as a research reference to simulate models of events that might not occur. The research resulted in: (i) analysis of road section capacity and parking space capacity at
drop-off and pick-up area on street (ii) prediction of future road performance, so that further planning is needed.

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