Level of Service Analysis of Toll Plazas in Bangkok and Surabaya

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1. Introduction

A toll plaza constitute a potential bottleneck and the congestion can be serious enough that alternative plaza designs and operating strategies need to be considered. To measure the toll plaza performance, level of service has been studied by several researchers.

The first study on toll plaza was done by WOOD & HAMILTON (1955). And several other researchers have also studied toll plaza capacity (BALD & UNDERWOOD, 1977; HALL & DAGANZO, 1983; RUBENSTEIN, 1983; GRIFFITHS & WILLIAMS, 1984). However, the first researchers that studied the level of service of toll plaza were WOO & HOEL (1991). The criteria they suggested are based on aggregated measures of traffic density and volume to capacity ratio (V/C). Aggregated V/C ratio for an entire toll plaza is convenient to use, but density is not practical to measure, since it has a difficult procedure to calculate it. Later, LIN & SU (1994) studied the level of service of toll plaza on the Chung-San Freeway, Taiwan, based on their Toll Plaza Simulation Computer Program. They used average queue length and average time in system as a measure of effectiveness for designing the level of service for toll plaza.

These previous studies already proposed some parameters as a measure of effectiveness in analyzing the toll plaza's level of service. However, the relationship between the V/C ratio and average time in queue, average time in system and average number of vehicles in system has not been clarified yet. This relation is important because if the V/C ratio increases, there will be an increase also in the average time in queue, average time in system and average number of vehicles in system.

The purpose of this study is to propose the level of service standard for toll plaza in Bangkok, Thailand and Surabaya, Indonesia, as a guideline to improve the operataion and performance of toll plaza in both two cities. The traffic flow data was collected from two toll plazas in Bangkok and three plazas in Surabaya through video camera (photographics technique).

2. Level of Service Analysis of Toll Plaza

Service time analysis has been differentiated by the type of vehicle. Service time for vehicle type 1 (car) in study area was ranging from 7.2 seconds to 10.7 seconds with the mean of 8.3 seconds. The service time for vehicle type 2 (6-wheel vehicle) on

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Table-1 Duration of Observation in Each Study Area

No.	Location	Date	Total Time of Observation	Time of Observation	
				First	Second
1.	Din Daeng, Bangkok	11-08-1994	1 hrs 25 mins	10.35-11.00	12.15-13.15
2.	Tha Rue 1(Port), Bangkok	10-08-1994	2 hrs	10.00-11.00	12.00-13.00
3.	Waru 2, Surabaya	19-09-1994	1 hr	15.00-16.00	
4.	Dupak 1, Surabaya	20-09-1994	2 hrs	10.40-11.40	13.30-14.30
5.	Dupak 3, Surabaya	19-09-1994	2 hrs	10.20-11.20	13.10-14.10

Table-2 Comparison of Service Time by Type of Vehicle and Toll Booth

No.	Location	Toll Booth	Type of Payment	Vehicle Type 1		Vehicle Type 2		Vehicle Type 3	
				Service time (Seconds)	No's	α 2	No's	α 3	No's
1.	Din Daeng	1	N	10.10	228	1.21	101	1.34	76
		2	E	7.66	278	1.25	164	1.29	21
		3	E	7.39	399	1.17	65	0.98	4
		4 **	E	7.48	540	—	—	—	—
		5 **	E	7.23	551	—	—	—	—
		6 **	E	7.45	519	—	—	—	—
2.	Tha Rue 1 (Port)	1	N	8.67	102	1.15	104	1.37	135
		2	E	8.39	341	1.06	20	1.01	10
		3**	E	9.04	392	—	—	—	—
3.	Waru 2	2	N	7.84	93	1.56	84	2.13	84
		3	N	7.63	136	1.58	87	1.92	44
		4	N	8.18	153	1.09	62	1.45	26
4.	Dupak 1	1	N	10.73	44	1.27	80	1.73	109
		2	N	8.64	95	1.45	120	2.02	115
		3	N	9.07	186	1.22	131	1.75	66
		4	N	7.91	165	1.20	78	2.00	45
5.	Dupak 3	1	N	8.23	291	1.58	118	2.10	46
		2	N	8.77	301	1.33	128	1.90	42
		3	N	8.28	243	1.21	108	2.02	45
		4	N	7.74	122	1.23	82	1.64	19

N = for non exact payment
E = for exact payment
** = for type 1 only
Due to small number

the average was 1.31 times the service time of vehicle type 1. The service time for vehicle type 3 (vehicles with more than 6 wheels) on the average was 1.76 times the service time of vehicle type 1.

On the average, the service time provided by the operator in Bangkok (8.15 seconds) was shorter than that in Surabaya (8.46 seconds), while the conversion factor is also higher in Surabaya. Conversion factors in Bangkok were 1.17 and 1.25 for vehicle type 2 and type 3, respectively. In Surabaya, the conversion factors were 1.34 for vehicle type 2 and 2.09 for vehicle type 3.

Mostly, there was no significant difference between service time for vehicle type 2 and vehicle type 3 in Bangkok. The exact payment system was not effectively implemented in Tha Rue 1 (Port) Toll Plaza, so there is no significant difference for different types of payment (exact and non exact) here. Din Daeng Toll Plaza shows that

there is a significant difference between exact payment and non-exact payment. The capacity of exact payment toll booth is 37% higher than the capacity of non-exact payment.

Consequently, since the service time in Bangkok is shorter than in Surabaya, the capacity in Bangkok (446 vehicles) is higher than that in Surabaya (429 vehicles).

Three models have been selected for four parameters that are studied here.

(1)Relation between V/C Ratio and Average Time in Queue:

Average Time in Queue

= exp (-1.23632 + 4.04583 (V/C ratio))

(2)Relation between V/C Ratio and Average Time in System:

Average Time in System

= exp (1.95478 + 1.24176 (V/C ratio))

(3)Relation between V/C Ratio and Average Number of Vehicle in System:

Average number of Vehicles in System

= exp (-1.9532 + 2.98461 (V/C ratio))

From those three relations the level of service has been proposed for toll plaza, as can be seen in Table-3.

Table-3 Proposed Level of Service for Toll Plaza in Bangkok and Surabaya

Level of Service	Average Number of Vehicle in System (Vehicles)	V/C Ratio	Average Time in Queue (seconds)	Average Time in System (seconds)
A	$0 < n \leq 1$	$0 < r \leq 0.65$	$0 < q \leq 4$	$0 < s \leq 16$
B	$1 < n \leq 2$	$0.65 < r \leq 0.90$	$4 < q \leq 11$	$16 < s \leq 22$
C	$2 < n \leq 3$	$0.90 < r \leq 1.00$	$11 < q \leq 17$	$22 < s \leq 24$
D	$n > 3$	$r \rightarrow 1.00$	$q > 17$	$s > 24$

Notes:
n = average number of vehicles in system (vehicles)
r = v/c ratio
q = average time in queue (seconds)
s = average time in system (seconds)

3. Toll Plaza Simulation Analysis

The simulation model developed in this research, which was applied to analyze the toll plaza in study area, is an appropriate representation of actual vehicle movement in each of toll plaza.

The simulation model was built so that it is adaptable to analyze vehicle movement in any toll plaza under several different conditions, by changing relevant values of input parameters.

Adjusting the simulation model with the real situation is time consuming, this is one of the disadvantage of GPSS/PC that was faced by the researcher.

4. Conclusion

Two toll plazas in Bangkok and three toll plazas in Surabaya have been analyzed in this research. Furthermore, the level of service design standards for toll plaza

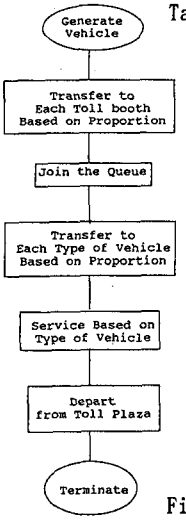

Figure-1 Flow Chart of Toll Plaza Simulation

Table-4 Comparison of Observed and Simulated Results in Waru Toll Plaza

Parameter	Observed	Simulated
1. Number of Vehicles		
- Toll booth 2	261	276
* Vehicle Type 1	93	96
* Vehicle Type 2	84	92
* Vehicle Type 3	84	88
- Toll booth 3	267	277
* Vehicle Type 1	136	143
* Vehicle Type 2	87	89
* Vehicle Type 3	44	45
- Toll booth 4	241	242
* Vehicle Type 1	153	152
* Vehicle Type 2	62	64
* Vehicle Type 3	26	26
2. Average Time in Queue, sec		
- Toll booth 2	9.54	9.27
- Toll booth 3	6.09	5.80
- Toll booth 4	3.8	4.17

have been developed. These findings are summarized and presented in the following subsections.

4.1 Level of Service Analysis of Toll Plaza

Three models have been developed: first the relationship between average time in queue and v/c ratio; second, the relationship between average time in system and v/c ratio; third, the relationship between average number of vehicle in system and v/c ratio. Furthermore, the level of service standards for toll plaza have been developed by defining into four level based on those three models.

4.2 Toll Plaza Simulation

The simulation model developed in this research using GPSS/PC Software, which was applied to analyze the toll plaza in study area, is an appropriate tool to predict the operating condition of toll plaza after some improvement measures has been applied.

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