ANALYSIS OF OPTIMAL NUMBER OF MANUAL AND E-TOLL SERVICE GATES AT LAEM CHABANG PORT

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Introduction

Transportation is a major component that affects to supply chain competitiveness. Traffic situation, especially at Laem Chabang port (LCP), is also very important for export since LCP is Thailand's largest port. The major transportation mode in LCP is truck which is approximately 90 percent. Based on the volume of haulage trucks and cars at the LCP in year 2000, average daily traffic is about 7,000 vehicles (Laem Chabang port, 2010). These vehicles cause a serious traffic jam that a queue is sometimes occurred at the front of entrance gates around 3 kilometres as Figure 1.

Figure 1: Traffic jam around the entrance gates

The attention of management and operations analysts for this queueing problem has considered for a number of years. To reduce the length of queue, there are many methods such as increasing the market share of other transportation modes, increasing the efficiency of the Tolls. However, the effective methods to be implemented in LCP are still challenged since the number of vehicles is moderately increasing. Statistics of Import-Export Cargo Containers through Laem Chabang Port, Fiscal Year 2008-2012 is illustrated in Figure 2.

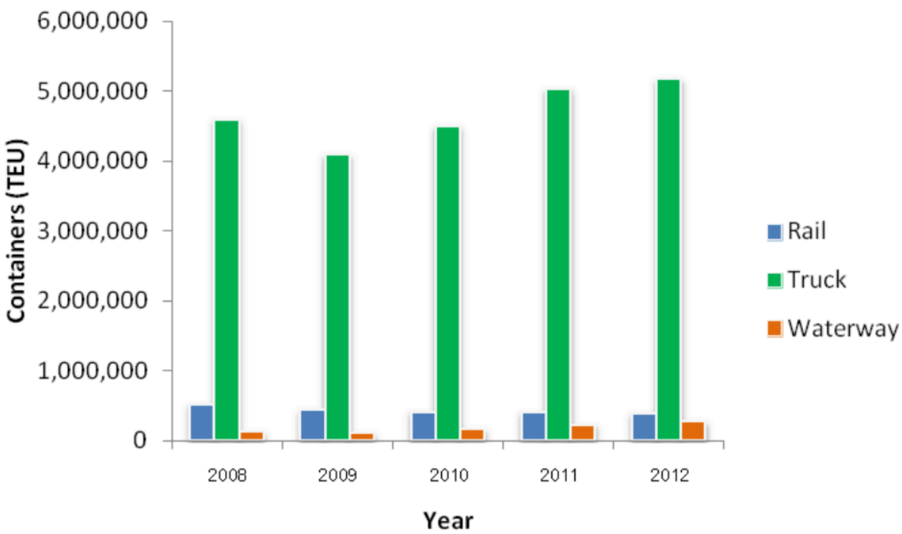

Figure 2: Statistics of Import-Export Cargo Containers through Laem Chabang Port, Fiscal Year (Modified from Laem Chabang Port, 2013)

In this paper, we propose a simulation for analysing the toll systems at LCP as the main contributes. We aim to determine the suitable number of manual toll collections and electronic tolls (e-toll) collections.

Literature Review

There are many existing researches that consider the queueing problems for improving both management and operations. Several attempts involve analytical treatments (Heindl and Telek, 2002; Kim, 2005; and Rabta, 2009). However, the more sophisticated mathematics models will increase the more difficult in analyst to the real world queueing problems. Rabta (2013) pointed out that there are no general accurate formulas for computing the mean waiting time in general multiple server queues.

Simulation is one of the most popular approaches to measure the performance of complex systems as discussed in Cruz, Smith, and Medeiros (2005). Niea, et al. (2012) also utilized a simulation-based optimization to assign passengers for designing selectee lane queueing. Woensela, et al. (2008) applied the queueing theory approach to analyse the travel times due to traffic congestion. They illustrated the appropriateness of the approach to capture travel times. Therefore, this research utilizes the advantage of the simulation to determine the optimal number of both manual and electronics toll collections.

Methodology

The procedures for using simulation in this research are described as Figure 3. There are 7 toll gates in this case study as depicted in Figure 4. We firstly collect data on October, 2012 and then we attempt to focus on the most vehicle volume.

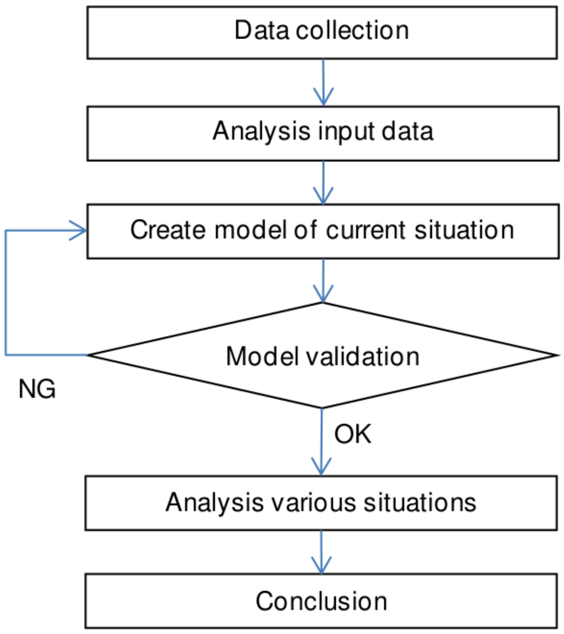

Figure 3: Methodology

Figure 4: Current operations (manual toll collections)

Nevertheless, in this paper, we do not restrict our analysis for processing time at the toll collections to the exponential distribution. We aslo consider the queuing model as illustrated in Figure 5. All arrival vehicles are sequentially assigned into the the several toll collections or based on a first come, first served basis.

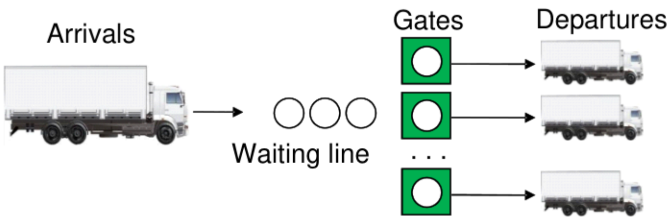

Figure 5: Characteristics of a queueing model

From Figure 5, the current processes of manual toll collections are presented as Figures 6.

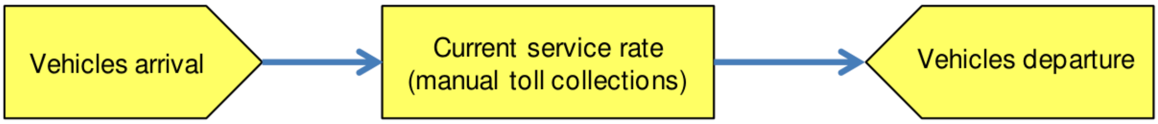

Figure 6: Simulation model for manual toll collections

The model is validated by comparing a number of arrival vehicles, a number of departure vehicles, and a number of vehicles in the queue, respectively. To find the optimal solutions of improvements, various approaches of toll collections are simulated and modelled as Figure 7. The proposed model considers both manual toll and e-toll collections.

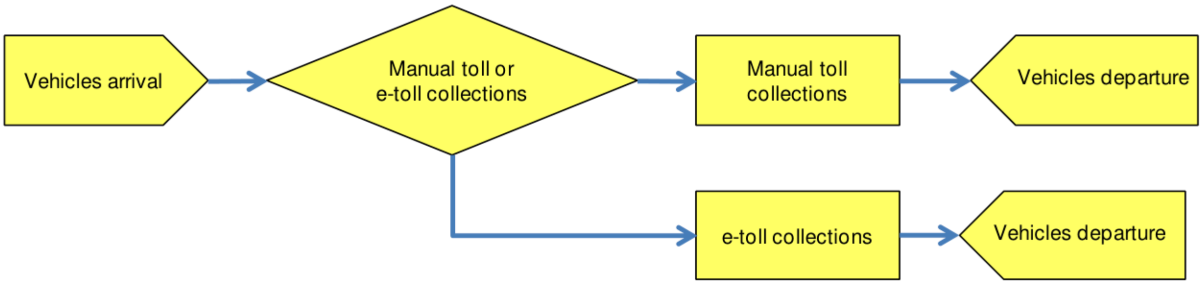

Figure 7: Simulation model for both manual tolls and e-toll collections

Improvement approaches for finding the optimal number of both manual toll and e-toll collections are proposed and simulated as Tables 1 and 2. Table 1 only considers the operations of the manual toll collections. Table 2 consider the case of increasing the number of e-toll whereas decreasing the number of manual toll collections. However, possible solutions from Table 1 may face some difficulties in implementation because of limitation in space requirements.

Approach	Existing manual toll (gates)	Manual toll increasing	Total manual toll (gates)
Current	7	0	7
1	7	1	8
2	7	2	9
3	7	3	10
4	7	4	11
5	7	5	12

Table 1: Increasing the number of manual toll collections

Approach	Existing System (gates)		Proposed system (gates)		Total tolls (gates)	
	Manual toll	e-Toll	Manual toll decreasing	e-Toll Increasing	Manual toll	e-Toll
Current	7	-	-	-	7	-
1	7	-	1	1	6	1
2	7	-	2	2	5	2
3	7	-	3	3	4	3

Table 2: Increasing the number of e-toll whereas decreasing the number of manual toll collections

Moreover, we also proposed to apply the e-toll collections without any using manual toll collections although this approach may not be flexible for the users and operators. In this case, all stakeholders have to change their working processes and require more time for both training and learning.

Finally, the paper performed a questionnaire survey about possible difficulties of e-toll collections implementation. We applied a face-to-face interview to two focused groups of stakeholders that are some staffs from both terminal operators at LCP and truck carriers. There are 10 people responded to this interview.

Results and discussions

Current situation

The sampling data based on October 2012 were collected at the main entrance gate as shown in Figure 8. The periods of high volume of arrival vehicles are focused for performing simulations.

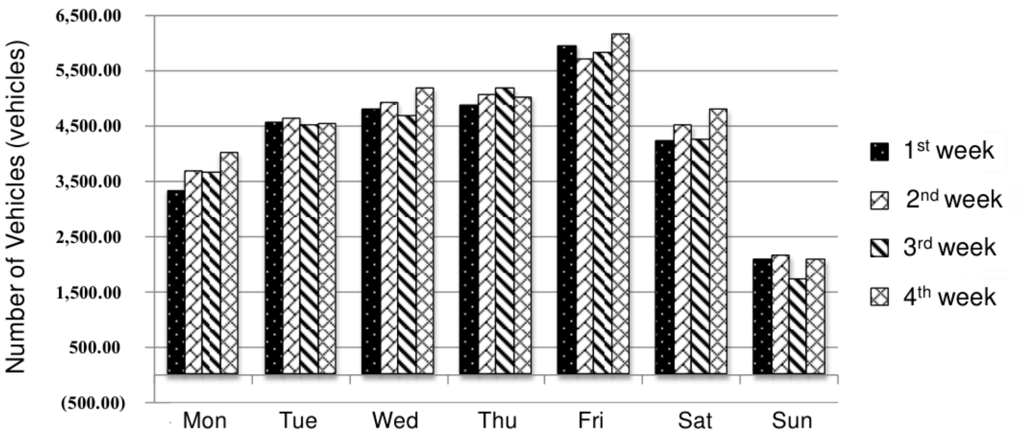

Figure 8: Distribution of sampling data

Based on Figure 8, most of the cars come to the LCP on Friday. Then, this research focused on every Friday to select the most impact periods. The result of distribution of vehicles is illustrated as Figure 9.

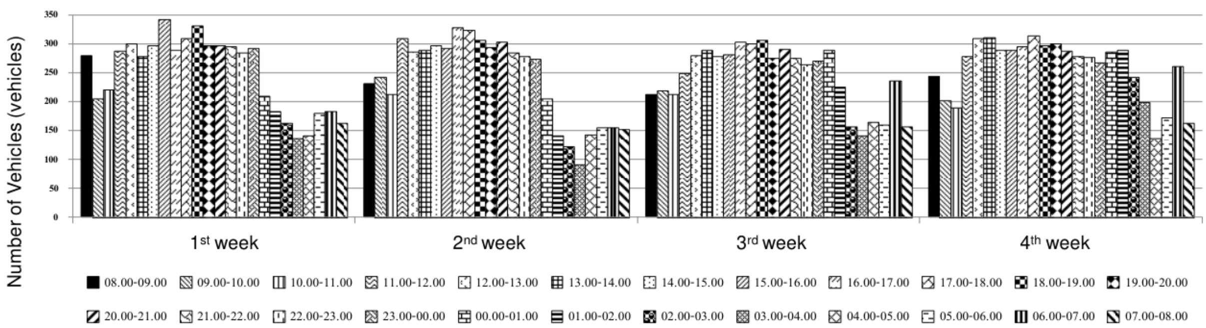

Figure 9: Distribution of vehicle on every Friday

From Figure 9, it illustrates that most of the trucks came during 11:00 A.M. to 01:00 A.M. as shown in Table 3.

Time	Arrival rate (vehicles)	Passing Vehicle (vehicles)	Cumulative Queueing (vehicles)
11:00-12:00	316	280	36
12:00-13:00	330	295	71
13:00-14:00	343	320	94
14:00-15:00	322	308	108
15:00-16:00	410	316	202
16:00-17:00	430	332	300
17:00-18:00	383	313	370
18:00-19:00	368	316	422
19:00-20:00	317	295	444
20:00-21:00	366	294	516
21:00-22:00	348	295	569
22:00-23:00	370	298	641
23:00-24:00	249	287	603
24:00-01:00	207	318	492

Table 3: Distribution of vehicles arriving during 11:00 A.M. to 01 A.M. interval time

From Table 3, the maximum cumulative vehicles in the waiting line were 641 vehicles. That means the length of queue was around 3 kilometres occurred at the front of the entrance gates. Then, the schedule of the arrival vehicles was assigned in the simulation model during 11:00 A.M. to 01 A.M. period as Figure 10.

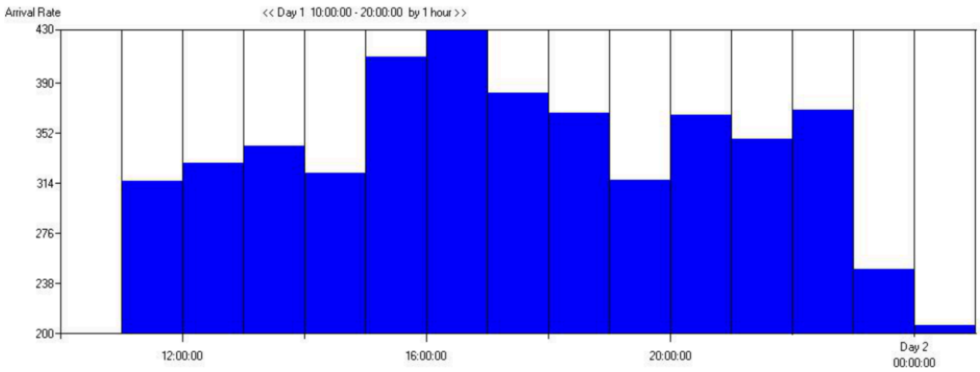

Figure 10: Vehicles arrival schedule in the situation model

The operation time for e-toll collection is around 25 – 30 seconds/vehicle. Then, the distribution of this operation is assigned as a uniform distribution. The minimum and the maximum values of service times at the gates are approximately 25 and 30 seconds, respectively. On the other hand, the operation times for all manual gates are collected to calculate the average operation times.

Model validation

This paper found that a triangular distribution can represent the distribution of current arrival rate at 95 percent significance level or tria(46,75,127) in the simulation program. This distribution is then utilized in the simulation to perform validation analysis. Therefore, the result of model validation was demonstrated as Table 4 by comparing the number of arrival vehicles, the number of departure vehicles and the maximum number of vehicles in the queue, respectively.

Factors	Actual (vehicles)	Model (vehicles)	Difference (vehicles)	Difference (%)
The number of arrival vehicles	4,759	4,759	0	0%
The number of departure vehicles	4,267	4,247	20	0%
Maximum number of waiting vehicles	641	676	-35	-5%

Table 4: Model validation

Results from Table 4 demonstrated the satisfied results of the model since all different values were less than 10 percent. Additionally, the maximum error from the proposed model was around 5 percent. Consequently, the proposed model can be utilized to evaluate other situations.

Results of the simulation model

This research attempts to improve the service rate of the manual toll collections by increasing a number of tolling gates. The maximum additional tolling gate is five gates. Therefore, the results of the simulation model are demonstrated in Table 5 to Table 7.

Factors	Total manual tolls (gates)						Unit
	7	8	9	10	11	12	
The number of arrival vehicles	4,759	4,759	4,759	4,759	4,759	4,759	veh
The number of departure vehicles	4,247	4,759	4,759	4,759	4,759	4,759	veh
Average total time in the system	66.85	27.29	4.83	1.75	1.53	1.48	min/veh
Average waiting time	65.58	25.91	3.45	0.38	0.15	0.10	min/veh
The average number of waiting vehicles	211	82	11	1.20	0.48	0.31	veh
Maximum Waiting Time	130.13	49.54	13.42	4.00	2.18	1.82	min/veh
Maximum Number of Waiting	676	291	90	32	20	18	veh
Utilization	100	97.97	87.08	78.37	71.25	65.31	Percent

Remark: veh is vehicles and min is minute

Table 5: Results of improvement by increasing the number of manual toll collections

From Table 5, the simulations show that the current system or 7 manual toll collections cause the average waiting time and the average number of waiting vehicles around 65.58 minutes/vehicle and 211 vehicles, respectively. The optimal number of manual toll collection should be at least 9 gates because both waiting time and number of waiting vehicles are only 3.45 minutes/vehicle and 11 vehicles, respectively. Increasing two manual toll collections can reduce a large amount of average waiting time. However, the users may prefer 10 manual toll collections because the average waiting time is around 0.38 minutes/vehicle whereas utilization of the service provider is 78.37 percent.

In case of using the e-toll collections together with the manual toll collections, the single e-Toll collection and 6 manual toll collections provided a satisfied result as revealed in Table 6. Therefore, the remaining average waiting time of vehicles is 5.26 minutes/vehicle and the average queue length is only 5 vehicles. Additionally, two e-toll collections provide a better average waiting time or around 0.96 minute/vehicle whereas utilization of the service provider is 72.40 percent.

Factors	Current system	Change manual toll collections to be e-toll collections (gates)			Unit
		1	2	3	
Number of vehicles arriving	4,759	4,759	4,759	4,759	veh
Number of vehicles departure	4,247	4,759	4,759	4,759	veh
Average total time in the system	66.85	6.33	2.07	1.85	min/veh
Average waiting time	65.58	5.26	0.96	0.95	min/veh
Average number of waiting vehicles	211	5	2	1	veh
Maximum waiting time	130.13	20.12	4.39	2.02	min/veh
Maximum number of waiting vehicles	676	45	17	7	veh
Utilization	100	84.40	72.40	56.72	Percent

Table 6: Results of increasing the e-Toll collections whereas decreasing the manual toll collections

Factors	e-Toll collections (gates)							Unit
	1	2	3	4	5	6	7	
Number of vehicles arriving	4,759	4,759	4,759	4,759	4,759	4,759	4,759	veh
Number of vehicles departure	1,831	3,655	4,755	4,759	4,759	4,759	4,759	veh
Average total time in the system	257.58	115.78	2.86	0.54	0.48	0.46	0.46	min/veh
Average waiting time	257.27	115.38	2.40	0.08	0.02	0.01	0.00	min/veh
Average number of waiting vehicles	895	388	7.61	0.27	0.08	0.02	0.01	veh
Maximum waiting time	534.08	238.59	9.94	1.57	0.63	0.37	0.33	min/veh
Maximum number of waiting vehicles	2,964	1,267	65	14	7	6	4	veh
Utilization	100	100	100	81.43	51.93	43.28	37.10	Percent

Table 7: Results of using e-Toll system only

From Table 7, it can notice that four e-toll collections can service all arrival vehicles with a very satisfied waiting time. The average waiting time is only 0.08 minute/vehicle whereas the utilization of the system is 81.43 percent. Therefore, it seems that the e-toll collection is one of the best alternatives to increase the efficiency of the service time at the entrance gates. However, the e-toll collection implementation is still not successful. Thus, this paper surveys some opinions of two groups of stakeholders as summarized in Table 8. The minimum positions for the responders are assistant managers or equivalent positions.

Stakeholders	Opinions
Terminal operators	- Lack of sufficient enforcement for using e-toll collections - Insufficient of collection gates
Truck carriers	- Insufficient of public relationship accomplishment - Less flexibility for making payment such as the users have to prepaid every 1,000 baht as the minimum payment - High risk in spending more waiting time i.e. if some companies do not use the e-toll system or some error at e-toll collections occurs, the trucks in waiting lines have to spend more time - Need more details in using report because the users have to make a financial report to their customers and related stakeholders

Table 8: Summarized of important opinions from two groups of stakeholder

Conclusion

The simulation method is a good tool for evaluating the optimal number of manual and e-Toll collections. However, this approach has some limitations because it is based on several assumptions especially the distributions of arrival vehicles, departure vehicles and service time. In case of loose approximations, output of our simulation can significantly deviate from actual performance values. This research attempts to improve the service time at the entrance gates at LCP. The first approach is to increase the number of manual toll collections. The second approach is to change some manual toll collections to be e-toll collections. The last approach is to utilize only e-toll collections. Based on the minimum utilization at 80 percent, simulation results show that we should use 9 manual toll collections for the first approach. The second should implement 6 manual toll gates together with an e-toll collection. The last approach is to use only 4 e-toll collections. However, this research still does not consider the behaviour of the drivers and the effect of traffic from other area that should be focused for the future research.

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