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SIMULATION OF TOLL COLLECTION SYSTEM IN SURABAYA-GEMPOL TOLLWAY

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Abstract: Toll collection can have an open or closed system. In an open system, the users pay the toll in either entrance or exit gate, while in a closed system, they take a ticket in the entrance gate and pay the toll in the exit gate. The structure of open and closed toll collection systems can be simulated to get optimum locations that would generate the highest revenue. Secondary data from the Tollway Authority was used to construct an OD matrix. Elasticity of demand by changing the price was used to model the reduced demand due to change in structure of the toll collection. Several scenarios of structure changes were proposed, simulated and evaluated. Evaluation concludes that two open systems were the best scenarios for the tollway and improvement in the toll collection of about 8% compared with the existing condition.

1. BACKGROUND

The collection system in a tollway can be an open or closed system. In the open toll collection system, the road user usually pays in entrance gate or exit gate, while in the closed toll collection system, the road user takes the ticket in the entrance gate and pays the toll in the exit gate. The structure of open and closed toll collection system can be simulated to get optimum locations that would generate highest toll for the operator. Changing the location of closed and open systems can readjust the toll collection structure. However, the change in the structure may reduce the traffic volume due to the increase in the toll price. If the traffic volume reduction is big, there are possibilities that the change in the structure will reduce the income of toll operator. Moreover, the location of the tollgate that needs to be changed as an open or closed system need to be evaluated and simulated so that the optimum location is found.

As a case study, the simulation was done for the Surabaya-Gempol Tollway. The tollway has been in operation since 1986 with a 43-km length and nine tollgates. Two toll collection systems are used, an open collection system from Dupak to Waru and a closed system from Waru to Gempol. Figure 1 shows the location of both systems.

The growth of Surabaya City, and its surrounding areas, such as Sidoarjo, Porong, and Gempol has led to an increase in the volume of the toll road users. This increase has presented great demands on the present toll collection system so a toll collection readjustment is needed.

The purpose of this study is to get the optimum location where the toll operator can get the maximum benefit. To do this, specific objectives have been set-up as follow:

- to determine the reduction of volume of vehicles due to the change in the structure of the toll collection system
- to simulate and determine the optimum location
- to have a financial analysis for the optimum location

The study only assesses the change in structure of the open and closed toll collection system. It does not include the detailed design, social and political impacts of the alternatives recommended. The analysis is for the toll operator's side. Change of user benefits due to the change in the toll collection structure is negligible.

Figure 1. The Existing Toll Collection System

2. METHODOLOGY

Description of working steps in the study is shown in Figure 2. The main steps can be categorized into 4 parts: First, determination of OD model based on the OD matrix and distance matrix. Based on the model, an elasticity model was developed which produces an elasticity matrix. Second, the average travel distance of toll users is calculated based on distance matrix and projected OD. The average travel distance is the basis for the change in the structure of toll collection system. Since the basic toll price is assumed to be fixed, the toll price is calculated based on average travel distance. The third step is to calculate the change in volume due to the structure change and total revenue. Lastly, financial analysis was done for the best scenario that passes the third step.

3. MODEL OF THE TOLLWAY

The Indonesian Tollway Authority provided the data for the study (Jasa Marga (1998)). Origin destination (OD) data was available only for the closed system, while OD data for the open system was adjusted by survey. The survey was done on 13-15 September 1997. The average volume of the three days survey was used to get an average OD volume of

September 1997. We call this data as Base-OD. The vehicles were classified into three types. Vehicle type I: composed of passenger cars, jeeps, mini buses, mini trucks and medium size buses. Vehicle type IIA: medium trucks or buses with two axles and Vehicle type IIB: big trucks or buses with more than two axles.

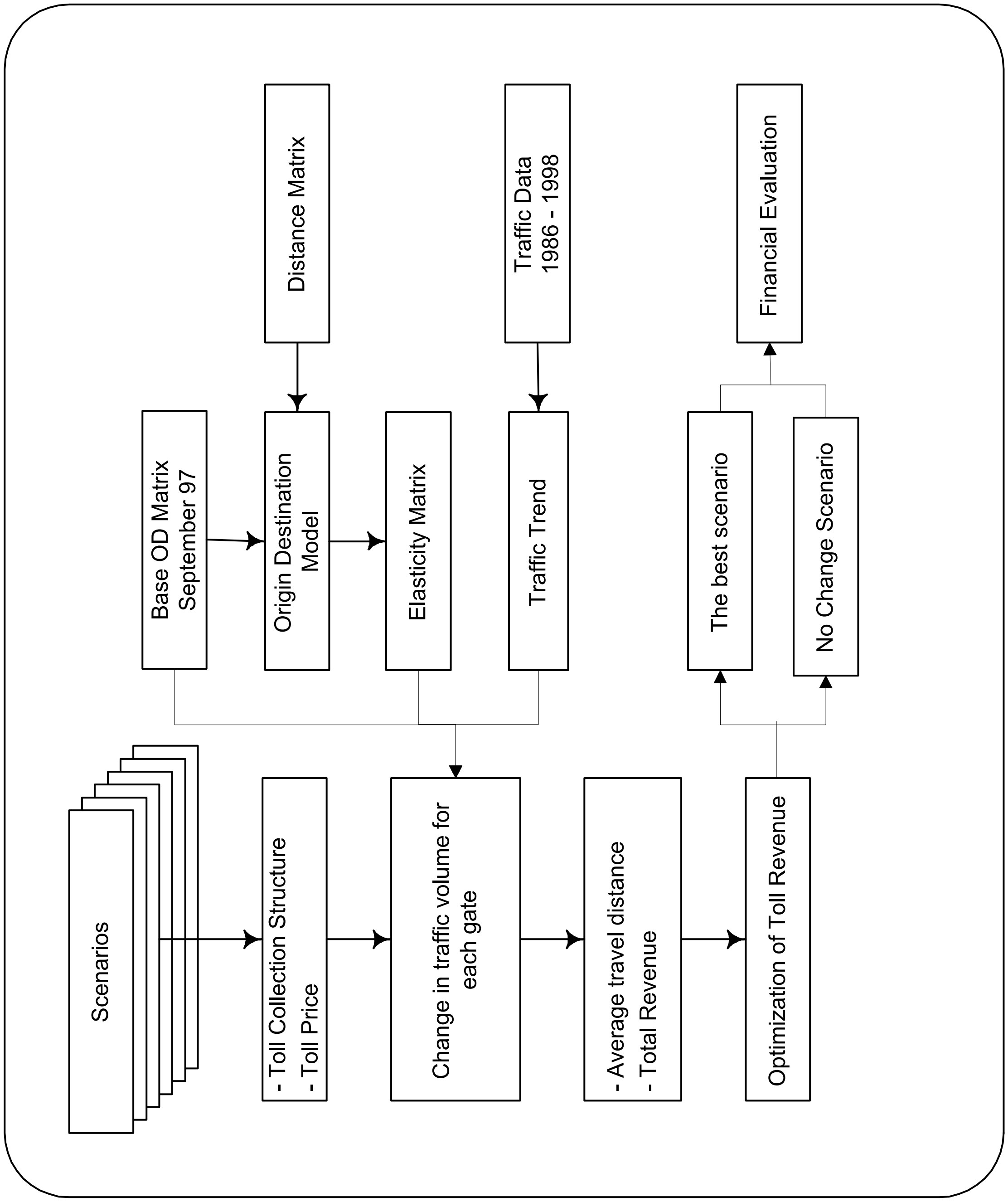

Figure 2. Working Structure of the study

To predict future vehicular volume, mathematical models need to be developed. Traffic volume distribution from and to tollgate can be modeled by a doubly constraint gravity model (Ortuzar and Willumsen (1990)). The model explains that traffic volume between two toll-gate locations depending on the volume of entry gate and exit gate and the generalized cost between the gates, or formulated as:

$$T_{ij} = A_i . B_j . O_i . D_j . f(c_{ij}) \quad (1)$$

where,

T_{ij} = traffic volume from location i to j
O_i = traffic volume of entry gate i
D_j = traffic volume of exit gate j
A_i, B_j = Constant
$f(c_{ij})$ = generalized cost function from location i to j

Index i and j state the location of toll-gate, where value 1 to 9 is Perak, Dupak, Banyu Urip, Satelit, Gunung Sari, Waru, Sidoarjo, Porong and Gempol, respectively.

The model was calibrated to be able to get the constant and cost function that satisfied the condition for the Surabaya-Gempol Tollway. The volume data from each gate was used to calibrate equation (1). The generalized cost uses travel distance for simplification since no other cost data is available. Table 1 shows the distance from one gate to another in a matrix form.

Table 1. Real Distance Matrix (km)

	Perak	**Dupak**	**Banyu Urip**	**Satelit**	**Gn Sari**	**Waru**	**Sidoarjo**	**Porong**	**Gempol**
Perak	0	3.5	5.5	9	12	17	28	37	43
Dupak	3.5	0	2	5.5	8.5	13.5	24.5	33.5	39.5
Banyu Urip	5.5	2	0	3.5	6.5	11.5	22.5	31.5	37.5
Satelit	9	5.5	3.5	0	3	8	19	28	34
Gn Sari	12	8.5	6.5	3	0	5	16	25	31
Waru	17	13.5	11.5	8	5	0	11	20	26
Sidoarjo	28	24.5	22.5	19	16	11	0	9	15
Porong	37	33.5	31.5	28	25	20	9	0	6
Gempol	43	39.5	37.5	34	31	26	15	6	0

An iterative procedure was done to determine the generalized cost function and the constants A_i and B_j. The calibrated T_{ij} was compared with the T_{ij} data. Sheppard (1986) suggested that a trial and error process should be done to minimize the root mean square error (RMSE). The difference between the T_{ij} model and T_{ij} data was the error. The square root of the summation of the square of the error is called RMSE (root mean square error), or

$$\text{RMSE} = \sqrt{(T_{ij} - T_{ij}^{'})^2} \quad (2)$$

where:

RMSE = root mean square of error

T_{ij} = Calibrated traffic volume from location i to j

T'_{ij} = Data traffic volume from location i to j

Table 2 shows the results of the trial error for vehicle type I. It can be seen that a logistic-product function with two parameters give the smallest RMSE among all trials and we use this type of function for the Surabaya-Gempol Tollway.

Table 2. Trials of Generalized Cost

f(cij)	Function Name	a	b	rmse
1/(cij^b)	Product		-0.05597	234,090
Exp(cij*b)	Exponential		0.01927	310,108
1/(1+exp(cij*b)	Logistic		-1034676.641	267,712
1/(1+(cij^b)	Logistic product		-24.6	229,799
1+b*cij	Linear		-0.05317	589,234
1/(1+a*(cij^b)	Logistic product	-1.00037	0.02137	212,871
1/(1+a*exp(cij*b)	Logistic	-4657.11061	-0.01926	310,110

The calibration was done for all vehicle types. A maximum of 20 iterations can give the value for A_i and B_j. The result of OD model calibration for logistic-product with two parameters is shown in Table 3.

Table 3. Results of OD Model Calibration.

	Veh. Type I	Veh. Type IIA	Veh. Type IIB
a	-1.0004	-0.9826	1.5439
b	0.0214	0.0364	-1.1906
rmse	212871	29490	22549
A1	-1.783E-08	-1.981E-07	3.817E-06
A2	-2.265E-08	-2.147E-07	5.304E-06
A3	-1.182E-08	-8.824E-08	4.276E-06
A4	-1.821E-08	-1.897E-07	4.476E-06
A5	-1.611E-08	-1.516E-07	4.033E-06
A6	-2.580E-08	-3.645E-07	4.225E-06
A7	-2.327E-08	-2.344E-07	3.400E-06
A8	-2.114E-08	-2.156E-07	3.376E-06
A9	-3.407E-08	-4.509E-07	3.607E-06
B1	9.265E-01	9.207E-01	9.782E-01
B2	9.470E-01	8.632E-01	1.088E+00
B3	6.465E-01	4.763E-01	9.323E-01
B4	8.544E-01	7.118E-01	8.900E-01
B5	6.916E-01	6.059E-01	9.157E-01
B6	1.535E+00	2.088E+00	1.501E+00
B7	1.004E+00	8.712E-01	8.272E-01
B8	9.516E-01	8.280E-01	8.372E-01
B9	1.489E+00	1.705E+00	8.661E-01

Comparing the real OD data with the Base OD, the total error was 2.94%. After it was modeled, the error was 7.89% compared with the real data. The error was considered acceptable.

4. AVERAGE TRAVEL DISTANCE

The average travel distance of toll users times the basic price determines the toll price. The basic price is assumed to be a constant, Rp. 100/km. Average distance of toll users is a value that represents the summation of distance that each user traveled, divided by the traffic volume. It can be determined by

$$d_{pq} = [\ \Sigma_{i=p..q}\ \Sigma_{j=p..q}\ (T_{ij}\ .\ d_{ij})\ ]\ /\ [\Sigma_{i=p..q}\ \Sigma_{j=p..q}\ (T_{ij})] \qquad (3)$$

where

d_{pq} = average travel distance between an origin gate p and a destination gate q

T_{ij} = trips between an origin gate i to a destination gate j

d_{ij} = distance between an origin gate i and a destination gate j

Gate i and j lies within gate p and q. For example, distance between Perak to Satelit (p=1, q=4), will examine all the gates within those sections (i=1 to 4 and j=1 to 4). Using the distance matrix in table 1, the average travel distance is determined. The calculated result of average travel distance is shown in Table 4. Column 2 to 4 is the average distance for each vehicle type. Column 5 is the average for all vehicle types. However, only the average distance categorized by vehicle type is used for the simulation.

Table 4. Average Travel Distance of Each Section (Km) 1998

Section	Km Veh. I	Km Veh. II A	Km Veh. II B	Average Distance	Real Dist.	Rp Veh. I	Rp. Veh IIA	Rp. Veh IIB
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Perak-Gempol	15.5	17.6	15.5	16.2	43.0	1500	2000	3000
Perak-Satelit	5.5	5.3	5.2	5.3	9.0	500	500	1000
Perak-Waru	8.6	9.3	9.8	9.3	17.0	1000	1500	2000
Perak-Sidoarjo	9.6	9.7	10.1	9.8	28.0	1000	1500	2000
Perak-Porong	10.2	10.5	11.4	10.7	37.0	1000	1500	2000
Satelit-Waru	6.1	6.5	7.0	6.5	8.0	500	500	1000
Satelit - Sidoarjo	8.6	7.6	7.6	7.9	19.0	1000	1500	2000
Satelit -Porong	9.9	10.1	11.1	10.4	28.0	1000	1500	2000
Satelit-Gempol	18.0	21.7	18.2	19.3	34.0	2000	3000	4000
Waru - Sidoarjo	11.0	11.0	11.0	11.0	11.0	1000	1500	2000
Waru - Porong	12.7	15.9	16.7	15.1	20.0	1500	2000	3000
Waru- Gempol	20.8	24.6	22.7	22.7	26.0	2000	3000	4000
Sidoarjo - Porong	9.0	9.0	9.0	9.0	9.0	1000	1500	2000
Sidoarjo - Gempol	14.0	13.6	12.0	13.2	15.0	1500	2000	3000

Columns 7 to 9 show the toll price for each vehicle type. It is calculated by multiplying the average distance with the basic price Rp 100/km. Then, it is rounded off to the nearest 500 rupiahs for practical operational reasons. The toll prices of vehicle type II A and II B are 1.5 and 2 times that of vehicle type I, respectively.

5. SIMULATION CONCEPT

The change in structure of toll collection will affect the toll price for part of the users. Changing the structure from a closed to an open system, will make part of the users who travel a relatively shorter distance than the total distance of open system suffer losses, and decide to use arterial road. Tollway is an alternative road to the arterial. The changing structure may increase or reduce the tollway volume and affect the total income of the operator.

Changing the structure from closed system to open system will increase the toll price and reduce the volume of the system. However, the revenue of the operator may increase or reduce, depending on the location. How much volume reduction will have a maximum revenue and in which locations?

To know the volume reduction due to the change in toll-price and the distance of the open system, we need the concept of volume elasticity toward toll-price (Manheim(1980)). Volume elasticity toward toll-price is the percentage of change in traffic volume because of a 1% change in the toll price. If the absolute value of elasticity is between 0 and 1, the change in volume is smaller than the change in toll-price. When the absolute value of elasticity is greater than one, the change in toll price will be very sensitive, and will affect the traffic volume. Negative values of elasticity means that the traffic volume reduces as the toll price increases.

The volume elasticity toward toll-price can be formulated as:

$$E = \frac{d\left(T_{ij}\right)/T_{ij}}{dX \;/\; X} = \frac{d\left(T_{ij}\right)}{dX} \cdot \frac{X}{T_{ij}} \qquad (4)$$

where:

E	=	Elasticity
X	=	toll price which identical to travel distance from gate i to j
T_{ij}	=	trips between an origin gate i to a destination gate j

From equation 1, we let the expression Ai . Bj . Oi . Dj = h = constant for each (i,j) pair, then Tij = h . f(cij). The best generalized cost function was found to be logistic-product function **f(cij) = 1 / [(1+a*(cij^b)]** , with two parameters **a** and **b**, so the elasticity can be derived to be:

$$E = b/X \;.\; ((Tij\;/\;h\;) - 1) \qquad (5)$$

The elasticity value for each vehicle type is shown as a matrix in table 5. The elasticity values are between zero to negative one. It means that the percentage of volume reduction due to increase of toll price, which happens because of the changing structure from closed system to open system, will always be smaller than the percentage of change in toll price. In other words, the open toll collection system will always be better than the closed system for the toll operator.

Table 5. Matrix of Volume Elasticity toward Toll price

To / From	Perak	Dupak	Banyu Urip	Satelit	Gn Sari	Waru	Sidoarjo	Porong	Gempol
VEHICLE TYPE I									
Perak	0.000	-0.120	-0.169	-0.104	-0.132	-0.027	-0.002	-0.002	-0.001
Dupak	-0.197	0.000	-0.421	-0.154	-0.168	-0.031	-0.002	-0.002	-0.001
Banyu Urip	-0.648	-0.552	0.000	-0.166	-0.125	-0.021	-0.014	-0.048	-0.002
Satelit	-0.181	-0.110	-0.144	0.000	-0.420	-0.040	-0.010	-0.008	-0.005
Gn Sari	-0.060	-0.085	-0.532	-0.318	0.000	-0.035	-0.007	-0.005	-0.003
Waru	-0.005	-0.029	-0.029	-0.044	-0.039	0.000	-0.048	-0.033	-0.018
Sidoarjo	-0.003	-0.016	-0.015	-0.019	-0.012	-0.033	0.000	-0.090	-0.027
Porong	-0.002	-0.013	-0.011	-0.014	-0.008	-0.025	-0.142	0.000	-0.004
Gempol	-0.002	-0.007	-0.006	-0.008	-0.005	-0.016	-0.029	-0.004	0.000
VEHICLE TYPE II									
Perak	0.000	-0.190	-0.356	-0.177	-0.257	-0.023	-0.008	-0.003	-0.002
Dupak	-0.829	0.000	-0.886	-0.262	-0.328	-0.026	-0.009	-0.003	-0.002
Banyu Urip	-0.671	-0.579	0.000	-0.873	-0.762	-0.053	-0.190	-0.189	-0.005
Satelit	-0.380	-0.231	-0.332	0.000	-0.763	-0.033	-0.042	-0.010	-0.005
Gn Sari	-0.141	-0.199	-1.383	-0.663	0.000	-0.017	-0.013	-0.004	-0.002
Waru	-0.007	-0.039	-0.043	-0.054	-0.054	0.000	-0.044	-0.040	-0.018
Sidoarjo	-0.007	-0.040	-0.040	-0.042	-0.030	-0.011	0.000	-0.304	-0.028
Porong	-0.005	-0.029	-0.028	-0.028	-0.019	-0.026	-0.334	0.000	-0.006
Gempol	-0.002	-0.007	-0.007	-0.007	-0.005	-0.018	-0.031	-0.006	0.000

When the elasticity from Eq. (5) is considered as point elasticity, where $d(Tij)/dX = \Delta(Tij)/\Delta X$, then the volume changing due to toll price can be calculated as

$$\Delta(Tij) = \Delta X \cdot (Tij_o / X_o) \cdot E \qquad (6)$$

where:

$\Delta(Tij)$ = changing of traffic volume from i to j due to changing of toll-price
ΔX = changing of toll price
Tij_o = original traffic volume from i to j
X_o = original toll price
E = volume elasticity toward toll-price

By changing the location of open and closed system, the toll price change and the volume change can be determined.

7. SIMULATION SCENARIOS AND RESULTS

The purpose of the study was to evaluate the change in the toll collection system. However, there are hundreds of combination possibilities for the open and closed system. For each direction, the link between two consecutive gates can be an open (O) or closed (C) system. For example the existing condition, from Perak to Waru, can be symbolized as OOOOOCCC. The total link number for each direction is eight links, so the total combination of toll collection system is 2^8 = 256 possibilities.

It is not feasible to evaluate all the possibilities, which we are sure cannot be used. In the other extreme, if only one possibility is evaluated, the validity of that possibility is questionable. Not all possibilities were considered because most of them are not feasible. The elimination process was done by several assumptions:

- Consecutive gates will not change from open to closed system or reverse. The relatively small distances will not have much effect compared to the rounding off value of the toll price. The toll price is rounded off to Rp 500 rupiahs for operational reasons. The main tollway users are long distance travelers.
- The maximum number of gates where users usually pay or take a ticket from Perak to Gempol is three. This number is considered to maintain the comfortability of users. The increase in number of gates will increase the number of times users need to stop.
- Open system is preferable to closed system due to the finding that the absolute number of elasticity of the tollway is smaller than one.
- The basic price is assumed to be constant, Rp 100/km. The assumption is taken because the user benefit (such as time reduction or vehicle operating cost) will not significantly change with the change in structure of toll collection system
- The determination of toll price is based on average travel distance of toll users. Some sections, such as Porong-Gempol and reverse, originally do not allow users to be used, so the average travel distance of those sections cannot be calculated. Then, those sections will not be included in the scenarios.
- For convenient operation of the tollway, and reduction of gate modification cost, both directions are considered as one link.

Considering those assumptions, Table 6 lists seven scenarios to be evaluated. Scenario zero is the no change scenario, the existing condition as a basis to evaluate other scenarios. When any scenario is not better than scenario zero, that change cannot be used.

Scenario 1 is developed based on existing condition with minor modification, which is to move the closed system up to Sidoarjo. This scenario extends the length of the open system. The extension based on findings that for this toll road, the open system has always a better revenue than the closed system. Scenarios 2 to 6 use more open systems. Development of up to three open systems is based on maximum paying gate number. Determination of Satelit, Waru and Sidoarjo as point of change is considered because of the strategic locations of those three gates, they are not so close to each other. The other gates will make the distance between paying gates too close to each other, and will disturb the comfortability of the users.

Optimizing the toll revenue toward the scenarios means that a search for the highest revenue among the scenarios is needed. The toll revenue can be calculated by matrix multiplication of toll price and modeled volume OD. The modeled volume OD is the existing OD volume, which have been reduced by the change in volume due to change in toll price. The change in toll price is based on average travel distance. The average travel distance depends on the volume. The simulation of each scenario imitates the real condition to calculate total toll revenue per year and compares it with the total revenue of the existing condition.

Table 6. Scenarios of Toll Collection System

Scenario Number	**Explanation**
0	Existing condition: Open system Perak to Waru, closed system Waru to Gempol
1	Extending one open one closed system : Open system Perak to Sidoarjo, closed system Sidoarjo to Gempol
2	One open system : Perak to Gempol
3	Two Open Systems Open system 1: Perak to Waru Open System 2: Waru to Gempol
4	Two Open Systems Open system 1: Perak to Sidoarjo Open system 2: Sidoarjo to Gempol
5	Three Open Systems Open System 1: Perak to Satelit Open system 2: Satelit to Waru Open System 3: Waru to Gempol
6	Three Open Systems Open System 1: Perak to Satelit Open system 2: Satelit to Sidoarjo Open System 3: Sidoarjo to Gempol

Table 7 shows the results of the simulation for each vehicle type for each scenario. The percentages in the last column are the comparison between total revenue of each scenario with total revenue of scenario zero (no change). Scenario 2, which simulates one open system from Perak to Gempol (the longest system), and scenario 5 which represents three open systems Perak-Satelit, Satelit-Waru, and Waru-Gempol do not produce better revenue compared with existing condition. The toll price of both scenarios is smaller than existing condition in some sections.

Table 7. Simulated Revenue for each scenario (Rp x 10^6)

Scenario	**Veh. Type I**	**Veh. type II A**	**Veh. Type II B**	**Total**	**Percentage**
0	42,623	7,441	9,475	59,540	100%
1	42,921	7,749	9,533	60,204	101%
2	42,928	6,297	9,667	58,892	99%
3	46,518	7,727	9,898	64,142	108%
4	43,443	7,804	9,770	61,017	102%
5	41,492	7,090	8,890	57,472	97%
6	45,374	7,934	10,686	63,993	107%

Scenarios 1, 3, 4 and 6 produce higher revenue compared with the existing condition. It is clear from the percentage of total revenue, that scenario 3 with two open systems Perak-Waru and Waru - Gempol is the best scenario. Changing the structure into two open systems up to Sidoarjo (scenario 4), only produces 2% higher revenue for the toll operator. It can be seen that longer distances between gates will not usually produce higher revenue.

Table 8. Cumulative Toll Price of the best Scenario

Vehicle Type I

To From	perak	dupak	Banyu	satelit	gn sari	Waru	Sido	porong	gempol
Perak	0	1,000	1,000	1,000	1,000	1,000	3,000	3,000	3,000
Dupak	1,000	0	1,000	1,000	1,000	1,000	3,000	3,000	3,000
Banyu	1,000	1,000	0	1,000	1,000	1,000	3,000	3,000	3,000
Satelit	1,000	1,000	1,000	0	1,000	1,000	3,000	3,000	3,000
gn sari	1,000	1,000	1,000	1,000	0	1,000	3,000	3,000	3,000
Waru	1,000	1,000	1,000	1,000	1,000	0	2,000	2,000	2,000
Sido	3,000	3,000	3,000	3,000	3,000	2,000	0	2,000	2,000
Porong	3,000	3,000	3,000	3,000	3,000	2,000	2,000	0	0
Gempol	3,000	3,000	3,000	3,000	3,000	2,000	2,000	0	0

Vehicle Type IIA

To From	perak	dupak	Banyu	satelit	gn sari	waru	Sido	porong	gempol
Perak	0	1,500	1,500	1,500	1,500	1,500	4,500	4,500	4,500
Dupak	1,500	0	1,500	1,500	1,500	1,500	4,500	4,500	4,500
Banyu	1,500	1,500	0	1,500	1,500	1,500	4,500	4,500	4,500

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8. FINANCIAL ANALYSIS

The best scenario means the highest revenue for the operator, but it does not mean it will be financially feasible. If the cost to change the structure is more expensive than additional revenue that it gains from the existing condition, the scenario is not feasible. If the best scenario is not financially feasible, the financial evaluation will turn to the second scenarios and so on until the scenario that gains more revenue than the existing condition.

Table 9 is the summary of financial analysis for the first year (1998). The unit price is based on the Tollway Authority's basic price in 1998. The table shows a rough estimate of the costs and benefits incurred when using the best scenario generated in Table 7. For the cost component, demolition of the gates means the removal of the gates, which are not needed, with the change of the toll structure. Gates modification means the widening of the road approaching the gates and unusable toll equipment are the signals and other equipment, which will be taken away with the demolition of the unneeded tollgates.

Table 9 Financial Analysis

COST COMPONENT	**Unit**	**Unit Price**	**Count**	**Cost**
Demolition of toll gates	Rp /unit	7,500,000	10	75,000,000
Construction of new gates	Rp /unit	100,000,000	2	200,000,000
Gates modification	Rp/gate	20,000,000	1	20,000,000
Unusable Toll equipment	Rp/gate	1,375,000,000	3	4,125,000,000
		Total		**4,420,000,000**

BENEFIT COMPONENT	**Unit**	**Unit Price**	**Count**	**Cost/ year**
Reduction of toll collectors	Rp/person/month	1,600,000	26	499,200,000
Reduction of Gate supervisors	Rp/person/month	2,250,000	3	81,000,000
Reduction of Gate management staff	Rp/person/month	3,000,000	3	108,000,000
Reduction of gate and equipment's maintenance cost	Rp/gate/month	550,000	8	52,800,000
Additional Toll Revenue	Rp/year	4,602,570,000	1	4,602,570,000
		Total		**5,343,570,000**

The benefits incurred from the change in structure are also shown. Total toll revenue for the best scenario (scenario 3) for year 1998 is Rp 64,142,290,000 while the existing scenario produces a total revenue of Rp 59,539,720,000. The difference, 4.6 billion rupiahs is the additional toll revenue due to the change in structure.

It can be seen that even for the first year, benefit component is higher than cost component. The benefit cost ratio, BCR =1.209 higher than one and positive net present value, NPV = Rp. 923,570,000. This result states that the change in structure from the existing condition to two open systems from Perak to Waru is financially feasible.

9. CONCLUSIONS AND RECOMMENDATIONS

Based on the study, the structure of open and closed toll collection system can be simulated to get optimum locations that would generate highest revenue for the toll operator. Elasticity of demand by changing the price was used to model the reduced demand due to a changed toll collection structure. Several scenarios of the changing structure were proposed, simulated and evaluated. Evaluation concludes that two open systems were the best scenarios for the tollway and it will improve the toll collection by about 8% compared with the existing condition. Further study is needed to consider social impacts due to the change in the system.

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