Development of Variable Toll Pricing Strategy to Manage Traffic Congestion at Metro Manila Skyway

Queen Jean Flores, Bien Carlo Realon, Lindley Bacudio, and Giselle Joy Esmeria*
Industrial Engineering Department
De La Salle University
Manila, Philippines
giselle.esmeria@dlsu.edu.ph

Abstract

The rapid growth of real estate development in the Southern Luzon (Philippines) has fundamentally affected the traffic condition at Metro Manila Skyway. The lack of efficient public transport system from the South has led many residents to acquire their own vehicles to conveniently transport them from home to their respective destinations. This has contributed to the significant increase of both public and private vehicles traveling from South to the metropolis. Despite the government efforts to build alternative infrastructures and regulations to minimize the traffic condition, the traffic becomes even worse in recent years. This study has been conducted to develop an alternative solution to alleviate traffic condition at Metro Manila Skyway that connects South Luzon to Manila. Variable pricing strategy has been applied to different industries in the Philippines, especially in regulating oil prices but has not been applied to address the worsening traffic condition in the country. This paper aims to simulate variable toll pricing strategies to reduce traffic congestion in Metro Manila Skyway (MMS) and determine the optimal revenue generated from the best price strategy. In addition, the study seeks to find out the public acceptability of the best pricing strategy for Metro Manila Skyway. The results of the study have shown that 44% of the respondents chose to use the Elevated road during peak hours with heavy traffic despite paying a higher toll rate, while 42% chose to leave earlier or later the peak hours at a lower toll rate. The rest of the respondents chose to use At-Grade road during rush hours or Elevated road when traffic is moderate with both normal toll rates.

Keywords
Variable Pricing; Sensitivity Analysis; Customer Acceptability; Traffic Congestion

1. Introduction

Traffic congestion, in which the demand for road space exceeds the supply and the transport system approaches to capacity (Abanes, Maniago J.M., & Jos , 2017) is becoming a serious problem throughout the world especially those countries with populated cities (Wang, Chen, & Li, 2014). In the Philippines, the critical zone for traffic congestion is in Metro Manila with the daily commute time of 90 to 150 minutes and can cost the country up to P2.4 billion a day (more than 10% of the gross regional domestic product) (Santiago, 2016). Moreover, to ease this problem, the government built infrastructures and rules which can reduce traffic and satisfy the demand of the people in transportation such as expressway system (Suarez, 2016), Unified Vehicular Volume Reduction Program (UVVRP) also known as number coding (Regidor & Tiglao, 2014), truck ban and U-turn scheme (Regidor & Tiglao, 2014) together with the establishment of elevated expressway system or skyways (Ganiron, 2014) and recently the 3-digit coding scheme during Christmas season (Montenegro, 2016). However, it seems that traffic still continues to grow especially in Metro Manila due to rapid increase of motor vehicles (Santiago, 2016).

With the Philippines economy continuously increasing, Metro Manila's transportation problem continues to worsen as more and more people chose to drive their own cars. Economists have claimed that congestion pricing is the most efficient solution to heavy traffic, but its implementation seemed to be more complicated in early years. With recent technological advancements and continuous research, many cities in the world applied the concept and have proven to be effective (Cramton & Geddes, 2017). Pricing plays an important role in this concept for it can be the factor to easily forecast the number of road users who will choose to travel in a particular time with corresponding toll price. The study aimed to simulate different scenarios of traffic volume in order to generate the best pricing strategy using variable pricing and to determine the preferences of the road users with respect to the schedule of travel.

2. Review of Related Literature

2.1. Tolling System

In the Philippines, a study by Hermoso (2015) presented the different tolling systems used in the different tolling roads in the country. Moreover, another study discussed the use of technology in tolling systems, like the first use of RFID technology in tolling roads in the Philippines in CAVITEx (Luces, 2014). The other tolling roads then followed the trend of using RFID, just like SLEX and Metro Manila Skyway [8]. The density of toll roads in the country is measured by passenger car per lane per 300m (pcplp300m) to describe whether the traffic is light, moderate, or heavy (Diaz-Garin, 2017). The Epifanio de los Santos Avenue (EDSA) has been found to be the most congested road in Metro Manila. With the research findings, the Metropolitan Manila Development Authority (MMDA) is considering using congestion pricing, that has been modeled from Singapore, to control the traffic in EDSA (Gotinga, 2017). However, there are a lot of requirements before implementing this concept in the real system that hinders the MMDA in executing the project (Ramirez, 2017). There are still no toll roads in the country that utilizes the congestion pricing to regulate traffic. However, one paper (Laforteza, 2015) proposed a congestion charge policy in the Philippines to lessen the traffic and road congestion in the country.

2.2. Toll Matrices of Metro Manila Skyway

In understanding the toll matrices implemented in the toll roads of the Metro Manila Skyway, it is necessary to understand the factors that may have affected these costs. The study of Botlikova & Cemerkova (2012) describes that the toll amount collected on these toll roads may be influenced by different factors like number of registered vehicles, road transport performance and intensity of traffic. In the government funded transportation infrastructures, the toll collection is a major source of revenue and can be used as basis to determine the capacity of the government for further developments on transport infrastructures (Botlikova & Cemerkova, 2012). In most of the third world countries, like the Philippines, the lack of state funding forces the government to partner with private investors in order to pursue on the transport infrastructure developments. For the Metro Manila Skyway, with the right balance of the realizing the private investor's realistic rate of return and the interest of the public consumers, the Toll Regulatory Board approved a toll price matrix. The price matrixes depend on the distance of the entrance and exit points starting from the South Luzon Expressway up to the Metro Manila Skyway and vice versa. Moreover, the toll rates implemented in the Skyway are fixed, meaning it is not affected by traffic congestion, the time frame, and other factors. As of 2017, the toll price matrices implemented for class 1 vehicles are shown in Table 1 below.

Table 1. Class 1 toll prices as of 2017 (Skyway O&M Corporation, 2016)

CLASS 1 (Cars, Jeepney, Pick-ups, Vans)						
ENTRY/EXIT POINTS	**SKY**	**MAG**	**C-5**	**BIC**	**SUC**	**ALA**
Merville		49.00				
Bicutan	72.00	49.00	49.00			
Sucat	118.00	84.00	84.00	34.00		
Alabang	164.00	118.00	118.00	69.00	34.00	
Filinvest	168.00	122.00	122.00	73.00	38.00	4.00
Muntinlupa-Cavite Exp	196.00	150.00	150.00	101.00	66.00	32.00
Susana Heights	179.00	133.00	133.00	84.00	49.00	15.00
San Pedro	185.00	139.00	139.00	90.00	55.00	21.00
Southwoods	198.00	152.00	152.00	103.00	68.00	34.00
Carmona	204.00	158.00	158.00	109.00	74.00	40.00
Mamplasan	213.00	167.00	167.00	118.00	83.00	49.00
Sta. Rosa	221.00	175.00	175.00	126.00	91.00	57.00
ABI/Greenfield	232.00	186.00	186.00	137.00	102.00	68.00
Cabuyao	239.00	193.00	193.00	144.00	109.00	75.00
Silangan	244.00	198.00	198.00	149.00	114.00	80.00
Calamba	260.00	214.00	214.00	165.00	130.00	96.00

2.3. Monte Carlo Simulation

This paper utilizes Monte Caro Simulation. Monte Carlo is a simulation technique which uses internally generated (pseudo) random numbers. It defines a domain of possible inputs, generates a deterministic computation on the inputs and performs a deterministic computation on the inputs (Li, 2015). Using this, random numbers are generated for the assumed numbers of vehicles in different traffic scenarios which are based from the performance measure of Metro Manila Skyway that indicates the traffic density of the road according to its traffic condition. Given below is the traffic performance measure of Manila Skyway (Diaz-Garin, 2017), in which the density is measured as passenger cars per lane per 300 meters (pcplp300m), according to its traffic description.

Table 2. Performance measure of traffic condition (Skyway O&M Corporation, 2016)

Density (pcplp300m)	***LOS***	***Traffic Description***
0-5	A	Light
6-10	B	Moderate
11-45	C	Heavy

2.4. Elasticity-Response To Price Change

Price elasticity of demand is the measure of consumer's sensitivity to price which is the proportionate to change in demand given a change in price. It is said that for consumer goods and services, the price elasticity is between 0.5 and 1.5. If the price elasticity is 1.0, it is a commonly used rule of thumb or "unitary elastic" which means that the change in price of that product or service causes an equal change in quantity demanded. Meanwhile those products or services with a price elasticity stronger than negative one is "elastic" in which demand for a product is sensitive to price changes such as if the selling price increases, there is a tendency that fewer units will be sold and if the price elasticity is smaller or even closer to zero than negative one, then it is "inelastic" which states that demand for a product is not sensitive to price changes (Anderson , McLellan, Overton, & Wolfram, 1997). Based from (Mulugeta, Greenfield, Bolen, & Conley, 2013), price elasticity can be computed using the following formula.

$$Ed = \%\Delta QA / \%\Delta PA \quad (1)$$

Where:
Ed = Price Elasticity of demand
(%ΔQA)) = Percent change in quantity (Q) of product A computed as
[(QA (w) – QA (w-1)) / (QA (w-1) + QA (w)) / 2]
(%ΔPA) = Percent change in price (P) of product A computed as
[(PA (w) – PA (w-1)) / (PA (w-1) + PA (w)) / 2]
w and (w-1) refer to current and previous weeks, respectively.

2.5. Standard Logit Model

Using Standard Logit Model, the probability of choosing alternative i among all alternatives will be determined (Morgul, 2010). In here, the researchers will know the most preferred route of road customers, between the graded and elevated, as the price changes in elevated. The formulas are given below for further information.

$$P_{in} = \frac{\exp(V_{in})}{\sum_{i=1}^{J} \exp(V_{in})} \quad (2)$$

Where
$V_{in} = \alpha C_{in} + ɣT_{in} + \varepsilon_{in}$; the observable part of the utility; Logit Model
C_{in} = the monetary cost of travel
T_{in} = the monetary cost of travel time for using alternative i for an individual
α and ɣ = the parameters
ε_{in} = the unobserved portion of the utility which is assumed identically and independently distributed (IID) with extreme value distribution

2.6. Sensitivity Analysis

Sensitivity Analysis can demonstrate impacts of changes to inputs, determine the most and least influential inputs, test the impacts of extreme events and estimate reasonable high and low prices (Jammalamadaka, Jarmarwala, Hirunyanitiwattana, & Mokkapati, 2011). In addition, it attempts to provide a ranking of the model's input assumptions with respect to their contribution to model output variability or uncertainty and the measures mainly proposed for this method are the partial rank correlation coefficient and standardized rank regression coefficient (EPA, 1997). In a much wider perspective, the conclusion of sensitivity depends on the degree of change pertaining to the models, data and assumptions.

3. Gap Analysis and Synthesis

Throughout the years, the Philippine government established different infrastructures and rules and regulations to minimize traffic congestion in the Philippines such as the expressway systems, Unified Vehicular Volume Reduction Program (UVVRP), number coding, truck ban, U-turn scheme, and the 3-digit coding scheme during Christmas season. However, the effectiveness of those infrastructures and rules continue to diminish as time goes by because the number of the vehicles increases annually (Regidor, 2013). Aside from these infrastructures and rules, several researches utilizing mathematical models were also conducted to help lighten the traffic problem. However, there are only few studies existing in the Philippines. Abanes, et al (2107) conducted a study on the application of graph theory to determine traffic-congested areas along Taft Avenue. A study by Intal et al (2015) focuses on the optimization of bus schedules along EDSA (Epifanio Delos Santos Avenue) using fuzzy rule-based system. In addition, De Guzman & Sigua (2009) developed a knowledge–based expert system to Development of a Knowledge-Based diagnose traffic congestion within road intersections. Based on the literature reviewed, variable pricing as a strategy to reduce traffic congestion was not yet considered. Using this, the optimal pricing strategy can be generated for the different time periods of the day and the corresponding traffic volumes to distribute the excessive traffic volumes during rush hours to other time periods with light or moderate traffic. Currently, the Metro Manila Skyway is experiencing traffic congestion especially during rush hours due the increasing volume of road users yearly. With respect to this, it defeats its purpose which is to give faster and better travel condition for road customers.

Moreover, with the literature review and analysis done, specific findings had been gathered.

- *Variable pricing can be a good solution to the traffic congestion of the Philippines, but it might be limited due to the lenient implementation of Philippine traffic laws and regulations with the agencies involved.*

- *There is a need for further research to conduct measures in order to assess the needs of the motorists*

4. Methodology

4.1. Research Flowchart

The stages in research methodology are presented in Figure 1.

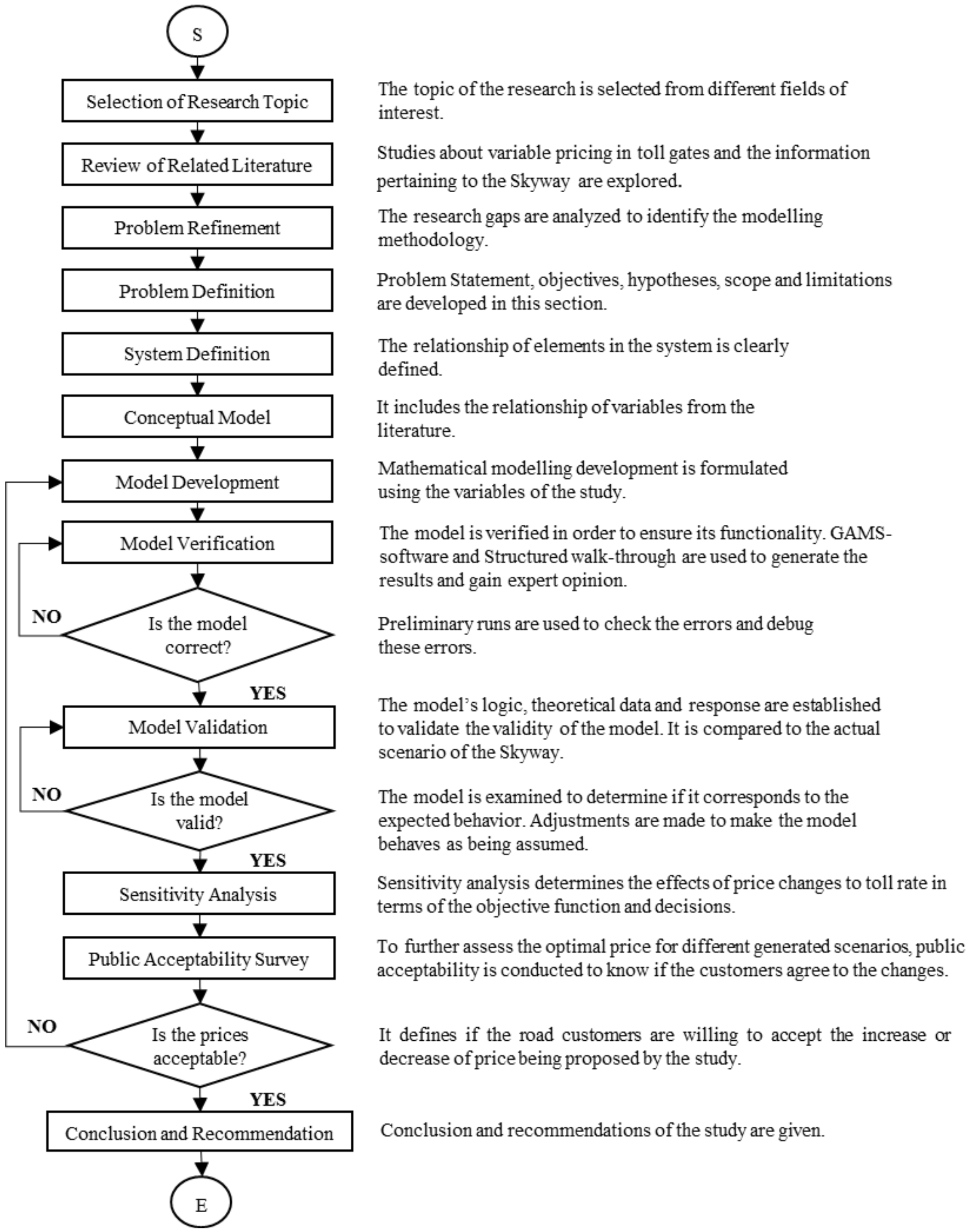

Figure 1. Research Flowchart

4.2. Model Development

4.2.1. Assumptions

- Metro Manila Skyway has a fixed capacity despite the increasing number of vehicles.
- Road customers pass through their usual route and time with only two choices, the graded or elevated.
- The speed of the vehicles is ignored.
- There is an increase in toll prices upon the occurrence of heavy traffic
- Usual toll prices are implemented upon the occurrence of moderate traffic.
- There is a decrease in toll prices upon the occurrence of light traffic

4.2.2. Indices

Index	Description
d	Individual
e	Entrance
h	Hour
i	Route Choice (elevated/graded)
n	New Quantity/Price
o	Old Quantity/Price
y	Traffic Scenario

4.2.3. System Parameter

Parameter	Description
PRICEMIN	Minimum price of the skyway for each entrance
PRICEMAX	Maximum price of the skyway for each entrance
α	Parameter for the monetary cost of travel before choosing alternative i
ɣ	Parameter for the monetary cost of travel time for using alternative i for an individual
εid	The unobserved portion of the utility which is assumed identically and independently distributed (IID) with extreme value distribution

4.2.4. Variables

4.2.4.1. Decision Variables

Variable	Description
PRICEhye	Price strategy offered by the skyway for hour h per scenario y per entrance e

4.2.4.2. System Variables

Variable	Description
VUFid	Utility function upon choosing alternative i, between graded and elevated, of an individual
PEGid	Probability of choosing alternative i, between graded and elevated, of an individual
EOD	Elasticity of demand
DEMPhye	Demand proportion for hour h per scenario y per entrance e
ADhye	Assumed demand for hour h per scenario y per entrance e
PRICEhye	Price Strategy p per scenario y
PEOD	Price elasticity of demand
Qn	Newly generated demand
Cid	The monetary cost of travel before choosing alternative i
Tid	The monetary cost of travel time for using alternative i for an individual

4.2.5. Objective Functions

The objective function is the maximization of revenues in which it includes the summation of price strategy p per scenario y and the assumed demand per hour h per scenario y. The two variables will be multiplied to get the revenue for each scenario and price strategy. The price strategy with the highest revenue will be chosen as the best pricing strategy of the Skyway.

$$\text{Max } R = \Sigma\, (\text{DEMPhye} * \text{PRICEhye}) \quad (3)$$

4.2.6. Constraints

4.2.6.1. Price Limit Constraint

Toll Regulatory Board of the Philippines is the one deciding the maximum and minimum limit of the toll prices of Metro Manila Skyway. Hence, the Citra Metro Manila Tollways Corporation (CMMTC) and Skyway O & M Corporation (SOMCO) cannot have very high or very low price so the price is bounded by a certain upper and lower limit.

$$PRICEhye <= PRICEMAX; \quad \forall h,y,e \quad (4)$$
$$PRICEhye >= PRICEMIN; \quad \forall h,y,e \quad (5)$$

4.2.6.2. Demand Captured Equation

This equation determines the number of customers who will pass through the Skyway depending to the price strategy for hour h per scenario y per exit. It will be used since there are two alternative routes, which are the graded and elevated.

$$DEMPhye = PEGid * ADhye \quad (6)$$

4.2.6.3. Standard Logit Model

The research generates random numbers for the assumed demand of the original price of the Skyway. It is based from the performance measure or the density per traffic condition of the Skyway. In order to get the elasticity of demand that will be used to know if the price strategy can increase or decrease the demand of the vehicles, the ɣ which is the parameter of monetary cost of travel time for using alternative i for an individual must be computed using the utility function given below:

$$VUFid = \alpha Cid + \gamma Tid + \varepsilon id \quad (7)$$
$$EOD = \gamma (Po/Qo) \quad (8)$$
$$Qn = Qo – EOD (Pn-Po) (Qo/Po) \quad (9)$$

Using the utility function, the probability of choosing alternative i is determined. It helps the researchers to know if the price strategy is effective upon implementation. The formula below illustrates the Standard Logit Model.

$$PEGid = exp(VUFid)/(\sum(exp(VUFid)) \quad (10)$$

In addition, to know the sensitivity of newly generated demand and new price over the assumed demand, from random numbers, and old price, price elasticity of demand is used. If the price elasticity is 1.0, it means that the change in price of that product or service causes an equal change in quantity demanded while if the price elasticity is stronger than -1.0 then the product/service is sensitive to price change and there is a tendency that the demand will decrease though if the price elasticity is smaller or even closer to zero than negative one, it states that demand for a product is not sensitive to price changes. Given below is the formula for the price elasticity of demand.

$$PEOD=(((Q_n-Q_o)/(Qn+Qo))/(2))/(((Pn-Po)/(Pn+Po))/(2)) \quad (11)$$

4.2.6.4. Non-negativity Constraint

In order to ensure that all the variables being solved by the model will turn out to be positive, non-negativity constraint is added.

$$\text{all var} >= 0 \quad (12)$$

5. Results and Discussion

With a 9.6% of margin of error for the initial survey, 85% of the road customers prefer the Skyway Elevated as road choice, and only 15% prefer the Skyway At-Grade. Additionally, 47 percent of the respondents prefer the Php26-Php30 of price change for the variable toll pricing of the Skyway Elevated, only 20 percent and 17 percent preferred the Php16-Php20 and Php21-25 price change respectively. With this, the 5 pricing strategies were determined to range from +/-Php 26 up to +/-Php30. From the initial survey, the peak hours of the Metro Manila Skyway were discovered to start at 7:00 AM and end at 9:00 AM in the morning and start at 5:00 PM and end at 7:00 PM in the afternoon. These findings were validated from the two months' worth of hourly traffic condition updates of the Skyway SOMCO. From these data, 10 traffic condition scenarios were created with different traffic condition per hour presented in Table 3 below.

Table 3. Generated scenarios for the 17 time periods

Time Period	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
5:00-6:00	L	L	L	L	L	L	L	L	L	L
6:00-7:00	L	L	H	H	L	H	L	H	L	H
7:00-8:00	H	L	L	H	H	H	H	H	L	L
8:00-9:00	M	M	M	L	L	M	H	H	L	H
9:00-10:00	L	L	L	L	L	L	L	L	L	L
10:00-11:00	L	L	L	L	L	L	L	L	L	L
11:00-12:00	L	L	L	L	L	L	L	L	L	L
12:00-1:00	L	L	L	L	L	L	L	L	L	L
1:00-2:00	L	L	L	L	L	L	L	L	L	L
2:00-3:00	L	L	L	L	L	L	L	L	L	L
3:00-4:00	L	L	L	L	L	L	L	L	L	L
4:00-5:00	L	H	H	H	L	L	H	H	L	L
5:00-6:00	H	H	H	L	H	L	L	H	L	H
6:00-7:00	H	L	H	L	L	H	H	H	L	H
7:00-8:00	L	L	L	L	L	L	L	L	L	L
8:00-9:00	L	L	L	L	L	L	L	L	L	L
9:00-10:00	L	L	L	L	L	L	L	L	L	L

With the regression analysis, the significant relationship between a dependent variable and independent variable is determined. Likewise, from the Standard Logit Model of the study, regression analysis determines the coefficient for toll rate of Skyway-Elevated which is being compared to the coefficient for toll rate of Skyway-Graded to know the demand proportion of road customers who are most likely prefer the Skyway Elevated. Table 4 shows a 0.42 coefficient for the toll rate of Skyway-Elevated though the p-value is only 0.31. Having a confidence interval of 95%, it means that the toll rate of Skyway-Elevated does not show any significance to the total cost being spent by the road customers upon travelling to Manila.

Table 4. Regression result for toll rate of skyway elevated vs. total cost

	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	527.11	88.43	5.96	0.00	351.68	702.54	351.68	702.54
X Variable	**0.42**	0.41	1.01	**0.31**	-0.40	1.24	-0.40	1.24

Nevertheless, Table 5 indicates the result for the regression analysis between toll rate of Skyway-Graded and total cost being spent by road customers upon travelling to Manila. It shows a coefficient of 0.06. Meanwhile, the p-value is 0.84 which does not also show any significance to the total cost being spent by the road customers with a confidence interval of 95%.

Table 5. Regression result for toll rate of skyway graded vs. total cost

	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	607.09	43.30	14.02	0.00	521.20	692.99	521.20	692.99
X Variable	**0.06**	0.28	0.21	**0.84**	-0.49	0.61	-0.49	0.61

For the price elasticity, since the result showed a negative elasticity for all scenarios and every price strategy, this means that the demand is sensitive to price change. In the sensitivity analysis, four parameters were created to test the changes on the results of the model. The model responded to the changes brought by the four parameters and the revenue changes of the 10 scenarios also were altered. Meanwhile, demand proportion is the percentage that road customers are most likely prefer to pass through Skyway Elevated based from their total spending cost upon travelling to Manila. Using this, the researchers can estimate somehow the expected road customers based from the assumed demand. The demand proportion was calculated to be 0.875 or 88%.

Table 6. Maximum and minimum revenue of all entry points for each price strategy

Price Strategy	***Max (+)***	***Min (-)***
26 Pesos	62,782,222.00	12,166,097.00
27 Pesos	62,980,182.00	12,093,953.00
28 Pesos	63,178,694.00	12,021,809.00
29 Pesos	63,377,206.00	11,949,665.00
30 Pesos	63,575,718.00	11,877,521.00

Table 6 indicates that increasing or decreasing 30 pesos in the original price of each entry point means gaining the highest possible revenue from the assumed demand for the Skyway compared from other prices. However, as the price range increases, the chance to get the lowest possible revenue also increases though, the lowest revenue can only be obtained if the traffic condition remains to be light all throughout the day which is most unlikely to happen knowing the gathered traffic scenarios from SOMCO. In this case, the researchers chose this price to increase or decrease the original price of the toll depending to the traffic condition of the Skyway. Using this price strategy, the objectives can be achieved which is to get the near optimal price strategy that can generate the possible maximum revenue of the Skyway and reduce the traffic volume.

Table 7. Average Percentage Difference of the Original Revenue and the Near Optimal Pricing Strategy

Price Strategy	***S1***	***S2***	***S3***	***S4***	***S5***	***S6***	***S7***	***S8***	***S9***	***S10***
1	5.04%	1.95%	7.26%	4.57%	2.33%	4.72%	6.96%	8.76%	-18.35%	6.23%
2	5.21%	2.01%	7.51%	4.74%	2.41%	4.90%	7.21%	9.05%	-19.25%	6.47%
3	5.39%	2.07%	7.75%	4.92%	2.49%	5.05%	7.45%	9.35%	-20.16%	6.67%
4	5.57%	2.13%	8.00%	5.08%	2.59%	5.21%	7.69%	9.65%	-21.11%	6.90%
5	5.75%	2.18%	8.23%	5.23%	2.64%	5.37%	7.95%	9.95%	-22.05%	7.10%

With a 9.5% margin of error for the final survey, the public acceptability of the selected best pricing strategy for the variable toll pricing of the Skyway Elevated was determined. The road customer respondents reacted positively with the proposed pricing strategy of +/-Php30 on the toll fees depending on the traffic condition during the hourly time periods. 44 percent of the respondents chose to still use the Elevated road during peak hours with heavy traffic condition, even if they have to pay Php30 more than the normal toll rates. While, 42 percent of the respondents chose to leave earlier or later the peak hours, in order travel during light traffic, and use the Elevated road in order to have a Php30 decrease in their toll fees. Whereas, only 8 percent of the respondents chose to use At-Grade road during rush hours and pay normal At-Grade toll rates. Only 7 percent of respondents chose to wait for moderate traffic condition to pay the normal toll rates of the Elevated road.

6. Conclusion

Although the Philippine Government already has provided several solutions to the immense traffic congestion in the National Capital Region, the crowding of roads still continuously worsen each year. Furthermore, there are few studies tackling the traffic congestion problem in the Philippines, more specifically applying the concept of variable pricing on the issue, which means that there is a clear need for this study. There is also a robust proof that this concept needs to be applied on the Metro Manila Skyway; as it serves as the passageway of Southern Luzon to some of the chokepoints of the metropolis, and with the recent trend of heavy traffic congestion in the elevated tolled road, the purpose of the Skyway to provide faster travel time is being defeated. The researchers hypothesized that simulating different scenarios of traffic conditions can generate best pricing strategy which can be acceptable for the road customers, for the revenue of the Skyway, and for the distributing the traffic volume to other time periods.

From the results of the model using GAMS, the increase or decrease of Php30 in the toll prices can generate the maximum revenue compared to the other pricing strategies used. However, this pricing strategy also has the highest risk of revenue loss, if there is light traffic condition all throughout the time periods of the day. The revenues of the different scenarios are varying because of the different hourly traffic condition in each scenario. It can be inferred that the increase in revenue is directly proportionate with the number of time periods with heavy traffic congestion, as this means that a Php30 increase in the toll fees are warranted. Only Scenario 9 produced the high risk of revenue loss as compared to the normal revenue with the normal actual tolling of Skyway. The negative change in the revenue ranges from -18.36% up to -22.04%. However, based on the actual data from the hourly traffic condition updates by Skyway SOMCO, the possibility of Scenario 9 where all of the time periods have a light traffic condition is very low.

For the price elasticity, the results showed that for all scenarios and every price strategy the demand is not sensitive to the price change of the toll fees. This can prove that the demand of the road customers is far too complicated to determine the increase or decrease that can be brought by changing the toll prices. There need to be more factors to be considered and incorporated in the model of the study. In the sensitivity analysis, the model responded to the changes brought by the four parameters and the revenue changes of the 10 scenarios also were altered. From the result of the public acceptability survey, there is an almost 50/50 result on the chosen action of the road customers. The main choices were whether road customers leave early to travel using Skyway Elevated and pay Php 30 less than usual, or still leave during the peak hours, use the Skyway Elevated and pay an additional Php 30 to their toll fees. With this result, it can be deduced that there is a positive reaction of the road customers with regards to the variable toll pricing of the Metro Manila Skyway. It can also be assumed that the strategic pricing of the toll rates is effective as almost half of the respondents are willing to leave earlier or later the peak hours, which can lessen the traffic volume during these times, significantly.

7. Areas for Further Studies

This paper on using variable toll pricing that can be acceptable to the public in alleviating the traffic congestion in the Skyway Elevated, while providing the maximum possible revenue for Metro Manila Skyway, is important for the traffic congestion researchers and practitioners in the Philippines. However, this study does not have all the solutions to the traffic congestion problem. The researchers recommend for future researches to focus on the technologies necessary for the implementation of the variable toll pricing on Metro Manila Skyway and any other major tolled roads in the country. It is also recommended to conduct a broader scope on the study of the scenarios of the traffic conditions and collecting more respondents to have a better and more accurate set of data to determine the peak time and preferred price change for the toll prices. Moreover, in order to better analyze the response of the system with the different pricing strategies, it is recommended to consider more pricing strategies with a greater price disparity to acquire the reaction of the road customers. Additionally, it is also important for future studies to also consider the other possible routes of the roads going to Metro Manila as route options for the road customers. Furthermore, the variable toll pricing of the Metro Manila Skyway can only be effective if the road customers have real-time updates of the traffic condition in the tolled roads, in order for them to modify their travel decisions in time. With this, it is recommended to partner up with the Toll Regulatory Board and the Skyway Operations and Management Corporation in order to include the necessary services and legalities needed in the study. Lastly, this research can be applied in lessening the traffic condition of tolled roads in other major economic cities in the Philippines.

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Biographies

Queen Jean Flores received Bachelor of Science in Industrial Engineering from De La Salle University Manila – Laguna Campus, Philippines. She was an academic scholar in high school under the scholarship program of Lasallian Mission Office called Lingap Foundation and became a centennial scholar in college. She was part of different organizations such as Environmental Conservation Organization and Industrial Engineering Guild; likewise, a consistent dean's lister.

Bien Carlo Realon earned Bachelor of Science degree in Industrial Engineering from De La Salle University in Manila, Philippines. Since high school, he was an academic scholar of the LaSallian Mission Office and the LINGAP Foundation. He has produced notable projects and worked with different organizations in the university including the Harlequin Theater Guild, Council of Student Organizations, Environmental Conservation Organization, Student LaSallian Animators, and Rotaract Club of Nuvali.

Lindley Bacudio is former fulltime faculty and program coordinator of Industrial Enginnering Department at De La Salle University Science and Technology Complex. He holds Bachelor of Science and Masteral of Science in Industrial Engineering from University of the Philippines, Diliman. He has taught courses in operations research, operations management, and statistics. He has published journals and conference papers in multi-criteria decision making, simulation, and operations research. Mr. Bacudio is currently pursing project management graduate certificate in Toronto, Canada. He is a member of Project Management Institute (PMI) and Engineering Intern (EIT) program of Professional Engineers Ontario (PEO). He is also a volunteer mentor of Engineer-In-Residence program PEO.

Giselle Joy Esmeria is currently a fulltime Assistant Professor at the Department of Industrial Engineering of De La Salle University Manila - Laguna Campus. She holds a Bachelor of Science degree in Industrial Engineering from Mapua Institute of Technology and a Master of Engineering Management with specialization in systems management from University of the City of Manila. She is a Certified Professional Industrial Engineer with more than 8 years experience in manufacturing industry. She has taught courses in quality management, statistics, production operations management and other related engineering and business courses. Her research interests include optimization, manufacturing and disaster management. She is a member of the Philippine Institute of Industrial Engineering and currently pursuing a degree in Doctor of Philosophy in Industrial Engineering at De La Salle University Manila, Philippines.