Assessing the Impact of Road Maintenance Investment to Commuter Safety in a Developing Country Using System Dynamics: The Case of Metro Cebu, Philippines

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Abstract

Commuter safety continues to be one of the major problems in road transportation especially in urban cities of developing countries. Although road maintenance investments have been established to maintain and improve the quality of roads, only limited studies of its assessment towards commuter safety under the sustainability framework have been conducted. Because the pillars of sustainability – namely economy, environment and society – need to be concurrently considered in the assessment, a systems dynamics approach is used. This is used to develop the relationship of sustainable transportation pillars that are relevant to the current transportation system in Metro Cebu relative to incidences of road fatalities. A causal loop diagram is initially made to identify the key components and their interrelationships as basis in developing a stock-and-flow diagram of the model. The simulation was run from 2024 to 2040, and the results show an increase of road maintenance budget by about 10% yielded a practically higher and more stable road maintenance-to-decreased fatality ratio starting 2032. Although increasing the budget yields a more stabilized ratio, its trend is slower. These results can help policymakers develop better strategies to improve safety without much compromise to other aspects of a sustainable transportation system.

Keywords  
Commuter Safety, Road Maintenance Investment, Sustainable Transportation and System Dynamics

1. Introduction

As the rate of urbanization continues to increase globally, so does population. The United Nations reports that the population all over the world has reached about 7.6 billion, with majority residing in urban areas (United Nations, 2018b). Moreover, it is projected to increase even further, from 55% in 2018 to 68% by 2050 (United Nations, 2018a). With the gradual shift of people living from rural to urban cities, the increasing demand for housing and transportation is apparent.

It is widely known that urbanization paves the way for further economic progress. However, it has also shown to adversely impact the environment and the society. With increased economic activity in urban cities, more jobs are created, attracting people to migrate despite uncertainly in employment (Glaeser, Kahn, & Rappaport, 2008). Inevitably, the demand for transportation also increases. Having more vehicles on the roads translates to an increase in air pollution. This is a real problem that most countries face, which inspired the United Nations to develop the sustainable development goals in 2015 (United Nations, 2015b).

The 17 goals were created to contribute to the overall realization of the sustainability agenda with specific targets. One of these goals pertain to sustainable cities, and among its targets aim at providing “safe, affordable, accessible
and sustainable transport systems for all (United Nations, 2015a).” While it is paramount to ensure an affordable and accessibility transport systems for all, the safety of its stakeholders, primarily the commuters or passengers, is vital as well. Recent reports show that incidences of road fatalities continue to increase worldwide, with low- and middle-income countries reported higher cases than high-income countries (World Health Organization, 2018a). The World Health Organization (2018b) reported that while the Philippines has shown progress in the prevention of road fatalities, the number of incidences still continue to increase and is still considered a major problem.

In most sustainability studies on urban transportation systems, the environmental and economic components are particularly of major interest. The social aspect, especially commuter safety or road fatalities, receives minor interest, with even lesser attention in developing countries. Moreover, these studies have focused on interventions and policies that refer to driving behavior and road rules (Katko, 2006; B.-M. Yang & Kim, 2003). These occurrences have been known to occur from the constant increase in volume of vehicles as a consequence of urbanization and economic growth (Dimitriou, Nikolaou, & Antoniou, 2017; Padam & Singh, 2004).

This study seeks to investigate the effect of road maintenance investment and simulate its effect to incidences of traffic accident-related deaths with the sustainable transportation framework. The study focused on Metro Cebu as a case study to characterize an urban city of a developing country having mixed traffic with no formal mode of transportation. A systems dynamics modelling approach was used to simulate the effect of increasing road maintenance investment to fatalities over a period of several years. The results can serve as reference to the extent of level and allocation of investment in road maintenance to facilitate in minimizing road fatalities and how it can be translated into policies.

1.1 Objectives
This research intends to determine how different configurations of road maintenance investments can influence road fatalities through simulation with systems dynamics. Particularly, it aims to: 1. Develop a systems dynamics model that is suitable for a transportation system of a developing country with mixed modes of informal transportation, 2. Simulate the effect of different values of road maintenance investment to road fatalities over a period of time, and 3. Determine an ideal and practical scenario that promotes reduced road fatalities.

2. Literature Review
The increase in urbanization over the years has consequentially led to a growth in population along with more demand for transportation and movement. As a result, the cases of road fatalities have shown to increase as well. These fatalities are caused by varying factors, including the degrading quality of roads.

2.1 Road Fatalities
One of the known primary factors in road fatalities has to do with the driver. The most common involve driving under influence of alcohol (Olojede, Daramola, & Olufemi, 2017; B.-M. Yang & Kim, 2003), age restriction policies (Walton, Jenkins, Thoreau, Kingham, & Keall, 2020), or speeding (Oluwole, Rani, & Rohani, 2013; Shen et al., 2011). Although not all cases involve the death of a commuter, driving without seatbelts or helmets for two-wheeled vehicles (Hordofa, Assegid, Girma, & Weldemarium, 2018) has certainly contributed to its increase. Regardless of the causes, driving behavior is regulated through enforced policies such as imposition of penalties to restrain bad driving (Mphela, 2011).

While these factors are attributed to behavior that the driver has control over, other factors are noteworthy. One of these is the geographical location and its weather (Michener & Tighe, 1992). Despite the best efforts of a driver to drive safely, inclement weather conditions can negatively affect driving, leading to crashes and fatalities (Eisenberg & Warner, 2005; Saha, Schramm, Nolan, & Hess, 2016), with increased severity in weather causing more accidents compared to fine weather (Edwards, 1998). The reality of adverse weather condition is that it causes eventual degradation of road conditions (Malin, Norros, & Innamaa, 2019), leading to road accidents. Especially in tropical and developing countries such as the Philippines where rainfall is abundant and road conditions are relatively poor, this continues to be of concern. To reduce or prevent road deterioration, road maintenance is implemented. Unlike developed countries where road maintenance funds are well-established and adequate, the contrary can be said in low- or even middle-income where investments in maintaining roads are relatively lower (The World Bank, 1988), developing countries (Asian Development Bank, 2003) due to limited fiscal capacity (Sperling & Clausen, 2004).

2.2 System Dynamics and Sustainable Transportation
Systems dynamics modelling was developed based on systems theory that seeks to analyze the cause-and-effect
relationship of components in a system. Usually called SD, the method was developed by Forrester to study the relationship of organization structure and policies on industrial activities (J. Forrester, 1961). Due to the success of this method, it was then used to study the interaction of housing, population growth and business activities in an urban city. With the prominent success of the method in predicting the behavior of a system and its individual components, Forrester later used SD to a global extent – the socio-economic system has shown to be impacted undesirably with the continued increase in population growth and exploit of natural resources (J. W. Forrester, 1971).

At present, the application of SD has expanded to any study that involves interaction of elements in a system. From waste management (Georgiadis, 2013; Mao et al., 2013; Poles, 2013), to industrial, transportation and logistics application (Egilmez & Tatari, 2012; Vafa-Arani, Jahani, Dashh, Heydari, & Moazen, 2014), and even urban planning (Onat, Egilmez, & Tatari, 2014), the literature of SD still continues to grow. Because of the nature of SD modelling method, this has become an ideal approach in sustainability studies, including sustainable transportation.

As with any sustainability study, sustainable transportation is generally viewed as a system that involves the interaction of the transportation system to the economy, environment, and population to represent the three pillars of sustainability. Policy scenarios are incorporated in an SD model to determine its impact to a reference mode that pertains to the objective of the study. Policies are proposed in different forms, majority of which are targeted towards benefitting the environment, such as interventions towards reduction in air pollution using energy-efficient vehicles (Cheng, Chang, & Lu, 2015; Ercan, Onat, & Tatari, 2016; Velazquez, Munguia, Will, Zavala, & Verdugo, 2015), electric or low-carbon vehicles (Haghshenas, Vaziri, & Gholamialam, 2015; Jia, Liu, & Yan, 2019; Y. Yang, Zhang, & Ni, 2014), the use of alternative fuels (Rees, Stephenson, Hopkins, & Doering, 2017), or implementation of pollution charging fees (Jia et al., 2019). While these policies are associated with and have been demonstrated to affect the economic aspect of the SD model, such as pollution charging fee, increased public transport usage, or public investment in mass transit, the social aspect is mostly focused on the population, with a few studies considering commuter or passenger fatalities.

In the few sustainable transportation studies that included road safety in their SD model, its representation as a reference mode is varied, such as number of deaths (Haghshenas et al., 2015; Y. Yang et al., 2014). López, Monzón and Pfaffenbichler (2012) went further to include traffic noise as a measure of safety. Although emphasis on safety was presented in these studies, the policy scenarios in their SD models were geared largely towards the environment and transportation infrastructure. Understandably, these studies were done in developed countries where their priorities are different from developing countries. While arguably the importance of the environment is a paramount concern, the fact that numerous studies dedicated to it makes commuter safety, being one of the social pillars, a least explored matter. It is in fact a matter of chief concern, as a study conducted by Mayo and Taboada (Mayo & Taboada, 2020) in Metro Cebu showed safety as the highest priority for commuters over cost of travel, comfort, accessibility and concern for the environment. Ranking safety as the highest preference were also found to be consistent regardless of demographic and socio-economic factors.

3. Methods
3.1 Metro Cebu, Philippines

This study was conducted in Metro Cebu, Philippines which consists of three highly urbanized cities: Cebu City, Lapu-Lapu City, and Mandaue City. Metro Cebu has a combined land area from the three cities of about 407.97 sq. km. and is located along the central part of the island of Cebu and Mactan Island. Cebu City and Mandaue City are both found in the same island of Cebu while Lapu-Lapu City is found in Mactan Island. The two islands are connected by two bridges: Marcelo Fernan Bridge and Osmeña Bridge.

The three urban cities are distinguished from other neighboring cities by its high economic activities. Cebu City houses large malls and major hotel chains, as well as big schools and universities. In Mandaue City, big business establishments and factories can be found, while in Lapu-Lapu City, processing zones, domestic and international airport, and large beach resorts are found.

Whereas in Metro Manila, the country’s biggest metropolitan, there is a formal mass transportation system (the Light Rail Transit and the Metro Rail Transit), Metro Cebu only has informal public transportation, such as Public Utility Jeepney (PUJ or Jeepney for short), Multicabs (smaller version of a Jeepney), city buses, taxis, ride-hailing cars and motorcycles, cycle rickshaw and auto rickshaw. Unlike most formal transportation that run on dedicated lanes or infrastructure, the informal modes of transportation in Metro Cebu all share the same road.
3.2 Causal Relations of a Sustainable Transportation System in Metro Cebu

The general structure of the system dynamics model is primarily developed to serve as a framework in developing a stock and flow diagram in the later section and is shown in Fig. 1.

![Causal loop diagram of a sustainable transportation system in Metro Cebu incorporated with road maintenance investment (author’s interpretation)](image)

The three pillars of sustainability are integrated in the causal loop. The Gross Regional Domestic Product represents the economic pillar, air pollutants for the environment, and population for social. Based on the causal loop, four feedback loops were identified:

a. B1: \( \text{POP} \rightarrow \text{TRAVEL VOL.} \rightarrow \text{ACCIDENTS} \rightarrow \text{POP} \)

The first balancing loop involves the population that affects travel volume. With an increase in population, the need for travel in the metropolitan is also expected to increase. As more people travel, cases of accidents also increase, which causes the population to decrease.

b. \( \text{POP} \rightarrow \text{TRAVEL VOL.} \rightarrow \text{ROAD QUALITY} \rightarrow \text{ACCIDENTS} \rightarrow \text{POP} \)

A second balancing loop also involve the population, wherein its increases also cause an increase in travel volume. With an increased travel volume, the road experiences more which eventually decreases its quality and may lead to more accidents and in turn decreases population.

c. B3: \( \text{ECONOMY} \rightarrow \text{TNV} \rightarrow \text{PM} \rightarrow \text{ECONOMY} \)

A third balancing loop involves the economy, wherein an increase in the economic strength is an indication that more people can afford to buy their own vehicles. As more vehicles ply the road, it causes an increase in air pollution, contributing to a decrease in the economy.

d. R1: \( \text{POP} \rightarrow \text{TRAVEL VOL.} \rightarrow \text{ROAD MAINTENANCE INVESTMENT} \rightarrow \text{ROAD QUALITY} \rightarrow \text{ACCIDENTS} \rightarrow \text{POP} \)

The last loop is reinforcing wherein an increase in population causes an increase in travel volume. Since more vehicles utilize the roads, an increase in road maintenance is needed to maintain or improve road quality. When roads become better, it lessens incidence of road accidents.

3.3 Proposed System Dynamics Model

With the causal loop developed, a stock and flow diagram can be established. The elements and their interaction were identified based on the causal loop diagram. Appropriate equations were created to rationalize the relationships of the elements. Although ideally a system dynamics model is crafted as closest possible to the actual system, the unavailability of raw or historical data to represent certain elements has prompted the authors to utilize a proximate alternative. Adjustments in the revision of stock and flow diagram were made, and the final flow chart is presented in Fig. 2.
The Gross Regional Domestic Product (GRDP) is the indicator for the economy submodel. It is balanced by increments in decrements in GRDP. The decrease in GRDP is partly due to economic loss from air pollution (Shrivastava, Neeta, & Geeta, 2013; The Lancet Commission on Health and Pollution, 2017). The positive (GRDPi) and negative (GRDPd) economic growth are based on the how the current economy is doing, as shown by a feedback loop of GRDPi and GRDPd to the stock GRDP. Historical data of GRDP for Region VII (Philippine Statistics Authority, 2018a) is used to represent economic status of Metro Cebu.

The population of Metro Cebu is the indicator for the population submodel. Births (POPi) and deaths (POPd) balance the stock level of population. When the population increases, the number of vehicles also increase to meet transportation demand. In turn, transport volume (TV) also increases. The Philippine Statistics Office provides access to historical data on population in the Philippines (Philippine Statistics Authority, 2018b).

The level of CO₂ is used as an indicator to represent the environment submodel. Vehicular emissions of CO₂ are caused by the number of vehicular trips (TV). The authors used the published reports from the Japan International Cooperation Agency for Metro Cebu (Japan International Cooperation Agency, 2015a, 2015b; Japan International Cooperation Agency & Department of Transportation, 2019) as bases for trip rates and volume since said data from local government agencies are locally unavailable inaccessible.

The transportation submodel is based on total number of vehicles (TNV) that is affected by the population (POP) and GRDP per capita (GPC). An increase in the population causes an increase in number of vehicles and travel volume (TV) due to more demand for transportation. The Land Transportation Office reports the total number of registered vehicles in the country, and although they have published their data, it has shown inconsistency in the details (such as vehicle types). As this can pose a challenge in mathematically modelling the trend in population, the authors have opted to use the total number of registered vehicles since is the only information shown to be consistent in all their reports.

The road maintenance submodel uses Regional Budget for Road Maintenance (RBRM) as the indicator. Factors that affect it are the state of the economy through the GPC and the extent of transportation movement through TV. Growth in GPC enables more funding for road maintenance (Gwilliam et al., 2008). And as volume of transportation increases, financial support to maintain the quality of roads also increase. Road maintenance budget is needed to maintain or improve the quality of roads (RQ) and corresponding road quality index (RQI)to eventually help prevent road fatalities (Albalate, Fernández, & Yarygina, 2013). The quality of roads is affected both by TV and the amount invested to maintain it.

The safety submodel uses transport accident-related deaths as the indicator. Incidence of road-related fatalities are due

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to the quality of road and the transport volume. With more vehicles running on the roads, accidents and fatalities also tend to increase. The quality of road can also affect road fatalities, wherein with lower road quality, more accidents are expected (Odero, Khayesi, & Heda, 2003; Persson, 2008).

3.4 Mathematical Simulation
The simulation of the SD model can be done by establishing first the mathematical relationships of the elements through regression analysis. Once determined, the simulation was conducted using a simulation software, Stella v.9.0. One of the major benefits of using a simulation software is the convenience of incorporating mathematical equations to stocks, flows and converters and conduct fast complex mathematical calculations. The regression analysis was made using historical data.

3.5 Model Validation
In order to effectively simulate the real-world behavior and characteristics of a sustainable transportation in Metro Cebu, it is crucial to primarily validate the structure and behavior of the SD model. By validating the model, it is ensured that the results of the simulation are acceptable and realistic. This study adapts the process used by Qudrat-Ullah and Seong (Qudrat-Ullah & Seo, 2010) which was based on the previous work of Barlas (1996) that is still widely used in simulation model validation. The validation process in this study involves the structure and behavior of the SD model.

3.5.1 Structural Validation
The structure of the model concerns its configuration in relation to the actual system being studied. By developing a causal loop diagram, an overview of the key variables in the system and their inter-relationship is created. The process of developing a causal loop diagram of this study was initially based on existing literature in sustainable transportation. Together with first-hand observation of the actual transportation system in Metro Cebu, an appropriate causal relationship was developed, as shown in Fig. 1. Closed feedback loops with reinforcing or balancing relationship are indicated.

Having identified the feedback loops, a corresponding stock-and-flow diagram was developed, as presented in Figure 2. The elements in this diagram were based on the causal loop diagram. They were then inputted in Stella v.9.0 and tested to see the results of the simulation. Once the model produced results that were expected of the system, the model is considered structurally acceptable.

Extreme conditions and scenarios were also tested in the model to ensure that the model does not produce negative results. The parameters were identified using different regression analysis methods, and the best fit was used. However, since the model utilizes actual historical data for its elements, adjustments were made in the model by substituting it with the closest approximation.

3.5.2 Behavioral Validation
Behavioral validation ensures that the model produces simulated results that are closest possible to reporter historical data with the least error. When the difference between actual and simulated data and Mean Squared Error (MSE) are both 5% or less, the behavior is acceptable (Wackerly, Mendenhall, & Scheaffer, 2014).

Run specifications included setting $dt=1$ year with the integration method set to Euler’s Method as this configuration yielded the least error. The authors compared actual and simulated values of POP, GRDP, RBRM, RQI and TARD as references for behavioral validation. It should be noted that available data provided by the Philippine Statistics Authority for population were only available for the years 1990, 1995, 2000, 2007, 2010 and 2015 while values for GRDP, RBRM and TARD were only available starting 2010; since there were unavailable data for 1990, 1995, 2000 and 2007, their entries were denoted with a dash as shown in Table 3 in section 5.3

Calculation of residual for RQI is done differently. Since RQI values are between 1 as minimum to 7 as maximum, and reported ratings are presented with one decimal place, changes in ratings are only done in 0.1 increments. Therefore, calculation of residual between actual and simulated are shown in the equation below:

$$Residual = \frac{|Actual\ RQI - Simulated\ RQI|}{(Max\ RQI - Min\ RQI)} \times 100 = (100/6) \times |Actual\ RQI - Simulated\ RQI|$$
4. Data Collection

Raw data for the elements in the systems dynamics model were collected from relevant government agencies. For example, the population for Metro Cebu was obtained from the website of the Philippine Statistics Authority, and data for registered vehicles were from the Land Transportation Office.

5. Results and Discussion

5.1 Numerical Results

The baseline data is initially determined by setting RMIF = 0. Scenarios are then introduced during simulation by setting values of RMIF={0.05, 0.1, 0.2, 0.5, 1.0}. These values represented percentage increase of road maintenance investments. Simulation runtime is set to begin in 2010 and end in 2040. Implementation of RMIF values were programmed to execute in 2024. Simulated TARD from 2024 to 2040 using all RMIF values are shown in Table 1.

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Upon the start of implementation of changes in RMIF in the year 2024, we can now determine the change in differences in TARD values until 2040 using different values of RMIF. By dividing these values to its corresponding RMIF, we are able get their ratio. The results are summarized in Table 2.

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</table>
5.2 Graphical Results

Figure 3 shows the trend of traffic accident-related deaths every year from 2024 to 2040 using different values of RMIF. Common among all trends is that it is constantly increasing every year. Notably, however, the trend for RMIF=1.0 tend to exhibit a slower increase compared to lower values of RMIF. But when we consider the ratio of decrease in changes in TARD and its corresponding RMIF, we see a different behavior of trends, shown in Figure 4.

We do this by dividing the decrease in TARD by its corresponding RMIF. The relative decrease in TARD for each RMIF was with reference to the simulated baseline data. Although we can easily see that RMIF=1.0 yielded the lowest TARD compared to lower RMIF values, we also need to consider the extent of its decrease. Since having a bigger reduction in TARD is considered favorable, then a higher ratio is favorable as well. The individual ratios for each RMIF value are detailed in Table 2.

We can see that an increase in road maintenance budget by just 10 (RMIF=0.1) yielded a consistently higher ratio compared to other RMIF. However, it also showed fluctuating ratios that are similar to RMIF = 0.05. It can also be observed that as RMIF values increase, the fluctuation tends to stabilize, and while this is ideal, this also tells us that considerably increasing the budget does not necessarily translate to bigger reduction in benefits. The benefits in this case refer to the extent of reduction in TARD.
### 5.3 Validation

This section shows a comparison of simulated and historical data of selected elements in the model. Their differences, represented as residuals, are also indicated. As mentioned, a maximum residual of 5 is deemed acceptable. The results are shown in Table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>Population, in thousands</th>
<th>GRDP, in million PHP (Gross Regional Domestic Product)</th>
<th>RBRM (Regional Budget for Road Maintenance)</th>
<th>RQI (Road Quality Index)</th>
<th>TARD (Transport Accident-Related Deaths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>936.89</td>
<td>902.56</td>
<td>3.66</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1995</td>
<td>1030.78</td>
<td>1055.85</td>
<td>2.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000</td>
<td>1195.68</td>
<td>1210.66</td>
<td>1.26</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2005</td>
<td>1,410.86</td>
<td>1429.97</td>
<td>1.35</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2010</td>
<td>1,547.91</td>
<td>1,526.2</td>
<td>1.40</td>
<td>538.56</td>
<td>536.62</td>
</tr>
<tr>
<td>2011</td>
<td>1,557.57</td>
<td>1,557.9</td>
<td>0.91</td>
<td>590.91</td>
<td>592.34</td>
</tr>
<tr>
<td>2012</td>
<td>1,589.71</td>
<td>1,621.6</td>
<td>2.74</td>
<td>672.24</td>
<td>653.81</td>
</tr>
<tr>
<td>2013</td>
<td>1,653.55</td>
<td>1,653.5</td>
<td>5.17</td>
<td>737.74</td>
<td>721.62</td>
</tr>
<tr>
<td>2014</td>
<td>1,693.55</td>
<td>1,684.7</td>
<td>0.51</td>
<td>822.44</td>
<td>796.41</td>
</tr>
<tr>
<td>2015</td>
<td>1,717.57</td>
<td>1,717.5</td>
<td>7.50</td>
<td>867.16</td>
<td>878.89</td>
</tr>
<tr>
<td>2016</td>
<td>1,749.61</td>
<td>1,749.6</td>
<td>3.56</td>
<td>1,033.3</td>
<td>1,070.1</td>
</tr>
<tr>
<td>2017</td>
<td>1,781.84</td>
<td>1,781.8</td>
<td>4.20</td>
<td>1,156.5</td>
<td>1,180.8</td>
</tr>
</tbody>
</table>

Note: Table entries denoted with dash (“-”) indicate unavailable data.

### 6. Conclusions

This study has presented and proposed a systems dynamic model that suits urban cities of developing countries, with emphasis on those cities with no formal modes of transportation. Metro Cebu, one of the biggest metropolitans in the Philippines, has ironically no formal modes of transportation in place, making it an ideal subject for this study. The results of this study that for an urban city in a developing country, the concept of increasing the use of a limited resource may not necessarily translate to better results, and that appropriate considerations must be made. The said resource perhaps can be allocated to other means of improving safety. In this case, a 10 increase in road maintenance...
investment may be considered practical. The results of this study can help policymakers develop better strategies to improve safety without much compromise to other aspects of a sustainable transportation system. One approach can be in the form of policy to control the number of vehicles plying the roads in the metropolitan. Another consideration could be how to control ownership of private vehicles. Because transportation in Metro Cebu is only reliant on informal modes, a mass formal mode of transportation should seriously be considered. The Japan International Cooperation Agency have been conducting feasibility studies of a mass transportation system in Metro Cebu (Japan International Cooperation Agency, 2015a; Japan International Cooperation Agency & Department of Transportation, 2019) recently to help improve its worsening traffic condition. Because emphasis was given to improving traffic and logistic movement, the findings of this study can complement their findings.

Acknowledgements
The authors would like to thank the Department of Science and Technology – Engineering Research and Development for Technology (DOST-ERDT) and the University of San Carlos for providing scholarship and research grants to the corresponding author.

References

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