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INFRASTRUCTURE IMPACTS CALCULATOR: AN INFRASTRUCTURE ASSESSMENT TOOL USING CO-BENEFIT APPROACH

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ABSTRACT: The 1992 United Nations Conference on Environment and Development recognized the concept of sustainable development which balances the economic, social, and environmental factors to meet our needs and the future. Succeeding climate actions such as the Clean Development Mechanism, Nationally Appropriate Mitigation Actions, Green Climate Fund, Intended Nationally Determined Contributions, and the Paris Agreement reinforce the support for co-benefits. The co-benefits approach considers both development and climate benefits in a single policy. The Sustainable Technology Assisted Route Planning for Region VI, funded by the Department of Science and Technology – Philippine Council for Industry, Energy, and Emerging Technology Research and Development, considers this approach. It aims to support the development of a sustainable Local Public Transport Route Plan (LPTRP) that integrates the road and maritime transport network of Region VI through the use of developed technologies for the transport sector while considering its social, economic, and environmental impacts. The LPTRP is crucial in the implementation of the Public Utility Vehicle Modernization Program launched in 2017. In this regard, an Excel-based assessment tool compatible with a transport simulation tool is developed and presented. The tool facilitates a swift processing of information from the simulation results of different scenarios to the comparative assessment of transport infrastructure proposals and policies. It enhances the capabilities of local staff and researchers in assessing the effects of transport projects and programs using co-benefit analysis. This endeavor hopes to foster better local decision-making related to transportation planning and management affecting not only the economy but also the environment.

Keywords: Co-benefit analysis, Transportation planning, Impact assessment tool, Sustainability

1. INTRODUCTION

The 1992 United Nations Conference on Environment and Development recognized the concept of sustainable development which balances economic, social, and environmental factors to meet our needs and the future. Succeeding climate actions such as the Clean Development Mechanism, Nationally Appropriate Mitigation Actions (NAMAs), Green Climate Fund (GCF), Intended Nationally Determined Contributions (INDCs), and the Paris Agreement reinforce the support for co-benefits. This approach aims to consider both development and climate benefits simultaneously in a single policy.

The transportation sector links the different sectors of our economies. Investments in the transportation sector affect the country's development. The movement of people, goods, and services almost always require the use of transportation. In this regard, being able to improve and optimize the transportation sector is critical to sustain economic growth. Public health should never be overshadowed by the pursuit of economic growth. The strong relationship between transportation and health necessitates a more inclusive approach - one that would cover the interests of both the stakeholders and the society. In light of the broad evidence that climate change is occurring with potentially expensive and far-reaching health consequences, urgent and substantial actions are needed. Several researchers have employed the co-benefits (CB) framework to assess transport projects and policies beyond just the transportation metrics [1]–[3]. Its use has become a predominant concept in scientific writing that focuses on reconciling the environmental and the developmental goals. This appears to be very promising for developed economies and emerging economies, as it offers a way of not compromising economic growth while still allowing environmental aspects to be taken into account. The literature is abundant with transportation and traffic studies offering various solutions for the many problems that face the transport sector. Experiences of other countries and best practices all over the world are now readily available. With these information, local planners are given the opportunity to learn from previous mistakes and follow or even improve on the success of others for local projects implementations.

Back in 2018, local transportation planning specialists were commissioned to conduct a twoweek hands-on training to municipal, city, and provincial representatives of Local Government Units (LGUs) to develop the Local Public Transport Route Plan (LPTRP). The expected output of the capacity building activity is the submission of LPTRPs. However, only a few LGUs were able to achieve this. The LPTRP is an important document for the LGUs in order for the Public Utility Vehicle Modernization Program (PUVMP) to be implemented. The training has shown that the participants had limited exposure to both QGIS for spatial land-use planning and JICA STRADA v.3.5 for public transport planning. JICA STRADA software is highly complex and thus, participants were not able to utilize this tool in developing their respective route plans. A more user-friendly transportation planning software is proposed.

Transportation plans and policies crafted from sound and holistic approaches are needed in identifying a sustainable transportation development roadmap that would cater to the needs of all stakeholders. This research is part of an ongoing research program entitled Sustainable Technology-Assisted Route Planning for Region VI (STARPLANVI) which is funded by the Department of Science and Technology – Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD). The STARPLAN program aims to support the development of a sustainable Local Public Transport Route Plan (LPTRP) that integrates the road and maritime transport network of Region VI through the use of developed technologies for the transport sector.

The LPTRP is crucial in the implementation of the Public Utility Vehicle Modernization Program of the Philippine government which was launched in 2017. STARPLAN will specifically train and provide both the software and hardware public transport planning tools to the local government staff and university faculty and staff for their use to sustain the public transport planning and management of Region VI. Through the STARPLAN VI, several computers installed with the necessary public transport planning tools and trainings are provided to the local government staff and partner educational institutions for their use to sustain the public transport research, planning, and management of Region VI. The program objective is very timely and appropriate as various projects are being constructed and many are still in the planning process. In this light, the trainings provided to the staff are quite apt. The level of understanding of the various concepts of the transportation planning process and the skills are further enhanced. In the various trainings, different participants have different level of understanding of the transportation planning concepts. In order to further streamline this process, the Traffic Infrastructure Impacts Calculator was conceived. This will facilitate LGU personnel and researchers to easily estimate the effects of certain policies and proposals from their simulations. The tool facilitates a swift processing of information from the simulation results of different scenarios to the comparative assessment of the proposals and policies for the region using Co-benefit Analysis. This endeavor hopes to foster better local decision-making related to transportation planning and management. To adopt a more systems-oriented approach and considering the archipelagic nature of the country, it is essential to plan towards an interconnected maritime and road transport network. Noting the case of Region VI wherein maritime transport services are available to provide linkages between the islands.

The targeted audience of the TIIC are LGUs, specifically those who are in charge of making local policies, transport projects and infrastructure. STARPLAN VI also provides training in various project-developed transportation tools and software to Region VI LGU staff and providing the TIIC tool can provide huge benefit to them. This is because the TIIC can provide LGUs a way to quickly test and assess policies and proposals on their own.

2. REVIEW OF RELATED LITERATURE

Urban areas are generally centers of economic growth. Rapid development and expansion of these areas require a massive amount of investment in infrastructure and transportation for sustainability. The transportation sector is next to the industrial sector in terms of energy consumption accounting for about 30% of the world's total delivered energy. The transportation sector guzzles around 60% of the global oil demand and is responsible for approximately 22% of the CO2 emission in 2008 globally. Moreover, road vehicles account for around 81% of the total transportation energy demand [4]. In a research in Delhi, India, co-benefits was used in order to determine the effects of mode shifting to a non-polluting mass transit system. The study was motivated by the increasing population in the city resulting in an escalation of transportation demand and thus the problems of congestion and emissions from road vehicles [5].

In another study in Manila, Philippines, co-benefit analysis was also applied in determining the effect of mode choices of commuters along EDSA when hypothetical improvements are made with respect to the access and egress modes to MRT3. The difference of these scenarios in terms of environmental effects from baseline and hypothetical scenarios were examined [6]. The same research team also did a cobenefit analysis for the proposed Panay-Guimaras-Negros Bridge in Western Visayas Region [7]. A study made in Beijing also looked into cobenefits. The study specifically looked into the effect of promoting NEVs (new energy vehicle) on energy consumption [8]. There are quite a lot of studies concerning the use of co-benefits to assess the effects of various proposed transportation projects and policies. Mayrhofer and Gupta [9] accredits the co-benefits approach as a positive and constructive "win-win" way to operationalize how economic, environmental, and social aspects can be integrated within the concept of sustainable development, instead of framing them in terms of trade-offs.

The co-benefits framework can be used to evaluate transportation initiatives and regulations in a way that considers the environment as well as the transportation sector. The policy evaluation process can take into account the interests of both the stakeholders and the community by combining the advantages of reduced travel time and operating costs with the key co-benefits of reduced CO2, SOx, NOx, and PM emissions. The method used provides an all-inclusive long-term assessment to identify the best development roadmap that caters to enhancing transport operation efficiency without compromising the general public's well-being by capturing more than just the fundamental traffic characteristics [10].

In this study, by incorporating the benefits of travel time and vehicle operating cost (VOC) reduction with the primary CB of savings in accident losses and emission costs, an all-inclusive and long-term assessment will be performed, aiming to determine the optimum development roadmap that caters to the interests of both the industry and the community.

In this light, useful tools are required in order to further facilitate and improve transportation planning towards sustainability. A growing consensus among planners regarding the interaction between the integrated land-use and the transport policies results in better outcomes [11]. The researchers mentioned that accessibility planning is a key strategy in maximizing environmental sustainability and quality of life in urban areas brought about by more efficient transport systems. In this particular study, they developed a tool which assesses the location choices of new activities in Rome based on accessibility changes. This tool aids planners in assessing the effects of new location choices on mobility and the environment in monetary terms. Another study by Mateichyk et al [12] also developed a tool in the facilitation of the processes and analysis for EIAs in Ukraine. Their web-based tool was proven to work starting from encoding to reports generation to supervisory state agency. These tools aid in the planning and could therefore aid in achieving the various sustainability goals through the proper assessment of various projects and policies.

In the Philippines, one of the flagship projects of the current administration is the PUVMP. To shed more light on the importance of this program, based on an LTO report, there are more than 12 million motor vehicle units registered as of 2019 where around 18% are PUJs [13]. Buses and PUJs serve around 67% of the demand in Metro Manila. The PUVMP is not just about modernizing the PUJs as it also aims to consolidate the operators into cooperatives, reduce emission, encourage mode shift through improved services, and enhance the living standards of the PUJ industry/sector [13]. The new body make of the modernized vehicles which costs at least 1.6 million pesos, minimum of EURO IV emission standards, global navigation satellite system (GNSS), automatic fare collection, free WIFI, CCTVs, speed limiters, dashboard cameras, and easy accessibility for PWDs are some of those which have been required by LTFRB. Under the modernization, the units will achieve being comfortable, accessible, reliable, environment-friendly, and sustainable (CARES) with due consideration to PWDS and the elderly. It is worth noting that 90% of the total PUJs nationwide are at least 15 years old [13]. The timeworn units contribute largely to air pollution and are getting more obsolete. In order to aid the drivers and operators in this program, the Land Bank of the Philippines and the Development bank of the Philippines are providing special loan packages to cooperatives where the 5% equity or down payment of 80,000PHP can be shouldered by the government [13]. However, one of the requirements for the loan is to secure the Local Public Transportation Route Plan (LTPRP) from the LGUs which is also a problem due to the non-submission of LGUs [14]. In the current fragmented set-up which is characterized by disorganized dispatching and on-street competition, drivers tend to be more aggressive in order to increase their profit. Jeepney units also stop anywhere causing congestion [15].

3. RESEARCH SIGNIFICANCE

A tool will be developed in this study. The tool will aid in aggregating the expected benefits of a proposed transportation project or policy. This will be contrasted against the expected costs of the project and determine whether the project proposal is advantageous or not in terms of the co-benefits. Forecasts are essential in transportation planning since the social benefits are distinguished from the different associated costs. Thus, the tool may aid in the technical aspect of policy or transport infrastructure recommendations. This kind of study benefits the decision makers in carrying out sensible decisions to make the most out of the limited public resources.

4. METHODOLOGY

Majority of the work to be accomplished covers the design of the tool to be developed. With personnel from the Planning Divisions of LGUs and/or Regional Offices as one of the envisioned users, the tool needs to be designed to be as user-friendly as possible, usable by even those with little technical expertise. Using traffic modeling results as an input to the tool, users will be given an estimate of the impacts, which they may utilize in the development of transport policies. Users may no longer need to perform the calculations and with this tool the infrastructure assessment process is streamlined.

The TIIC uses both Excel's and Visual Basic for Applications (VBA) Userform functions. The tool uses input based around EMME's output which are the Average speed of the network, Total VDT, and VHT in order to do the Co-benefits analysis. The output of the analysis would be in billions of Philippine Pesos per year for Time Savings, Vehicle Operating Cost, and Environmental Cost Savings. This enables a simple comparison among alternatives. Note that all the computations shall be done in 2020 prices. It shall be assumed that the average inflation rate towards the modeling year 2020 is applicable in projecting values. The Co-Benefits approach will also be limited to the calculation of savings in vehicle-operating costs, value of time, and environmental costs of the pollutants CO2, NOx, SOx, and SPM.

The Institute for Global Environmental Strategies (IGES) has promoted the use of the co-benefits approach to incorporate both the climate and development issues in project evaluations. The co-benefit analysis is a tool which provides invaluable information to policy makers. It incorporates savings in travel time, vehicle operating costs, traffic safety, and environmental emissions [16].

The fundamental goal of using co-benefits is to understand a topic's many facets outside of its intended use and benefit. Through the incorporation of various features and objects into the project design, the cobenefits approach considers the relationship between the existing local issues, such as traffic congestion, greenhouse gas emissions, and pollution, and their future global consequence, which is climate change [16]. Additionally, the transport cobenefits will be used in this study to support the estimation and analysis of the quantitative data that will serve as the foundation for developing policies, building infrastructure, and minimizing transportation costs. The quantitative data will be derived through the examination of the major variables influencing travel behavior, such as the expenses associated with journey time, vehicle operation, and emissions. These data will be used to execute the appropriate solutions, such as estimating the reduction in greenhouse gas emissions, shortening trip distances, and lowering travel costs.

The travel time savings is quantified by taking the difference between the total travel cost of travellers with and without the proposed project. The total travel time costs for the scenarios are computed as follows:

$$\boldsymbol{BT_i} = \sum_j \sum_l \left(\boldsymbol{Q_{ijl}} \times \boldsymbol{T_{ijl}} \times \boldsymbol{\alpha_j}\right) \times \mathbf{365} \quad (1)$$

where

$\boldsymbol{BT_i}$ − total travel time cost with/without the project

$\boldsymbol{Q_{ijl}}$ −traffic volume for j vehicle type on link l, with/without the project (vehicle/day)

$\boldsymbol{T_{ijl}}$ − average travel time for j vehicle type on link l, with/without the project (min)

$\boldsymbol{\alpha_j}$ − value of time for j vehicle type

$\boldsymbol{i}:\ \boldsymbol{i} = \boldsymbol{w}$ **with project**; $\boldsymbol{i} = \mathbf{0}$ **without project**

The vehicle operating cost reduction is quantified by taking the difference between the vehicle operating costs between the two scenarios. The computation for the savings is shown as follows:

$$\boldsymbol{BR_i} = \sum_j \sum_l \left(\boldsymbol{Q_{ijl}} \times \boldsymbol{L_l} \times \boldsymbol{\beta_j}\right) \times \mathbf{365} \quad (2)$$

where

$\boldsymbol{BR_i}$ − total vehicle operating cost with/without the project

$\boldsymbol{Q_{ijl}}$ −traffic volume for j vehicle type on link l, with/without the project (vehicle/day)

$\boldsymbol{L_l}$ − link length of link, l (km)

$\boldsymbol{\beta_j}$ − value of vehicle operating cost for j vehicle type

$\boldsymbol{i}:\ \boldsymbol{i} = \boldsymbol{w}$ **with project**; $\boldsymbol{i} = \mathbf{0}$ **without project**

The environmental emissions are quantified using the top-down approach where the amount of fuel used for the scenarios are first quantified. This provides the basis for taking the difference in the emissions generated between the baseline and the with-project scenarios. The emissions included are the SOx, CO2, NOx, and the PM which are also monetized using the various marginal costs per air pollutant. Monetizing all the benefits enable the comparison of scenarios using a single unit. The overall savings provide policy makers an overview of the costs and benefits associated with the scenarios involving policy changes or project proposals being evaluated.

5. RESULTS AND DISCUSSION

In this particular research, Roxas City has been chosen as the pilot city to implement the TIIC. Roxas City, as seen in Fig.1, is in the island of Panay in the Western Visayas Region where the STARPLAN VI project is currently deployed.

Fig. 1 Roxas City Location

Roxas City has been chosen because they were among the first to gather data for their LPTRP. In this regard, the data which includes traffic counts, trip origin and destination information, public transport routes, and other relevant information gathered were used in order to develop the EMME model for the baseline scenario. The various traffic counts were used to calibrate the baseline model to replicate the current traffic scenario along the existing links in the network. This is done in order to generate realistic simulations when hypothetical changes are introduced onto the road network.

EMME software was used to plot the volume of vehicles on links for the baseline scenario, where the thicker lines indicate more traffic. Using this transport model, two hypothetical scenarios were formulated for this study. The first one is related to the introduction of a circumferential road whereas the other scenario involves adding the same circumferential road with other new local roads. These were proposed to provide better traffic circulation in the area.

The traffic is forecasted for the 5, 10, and 20 year projections shown below. Projections were made based on the traffic growth rate equation formulated by JICA. It is calculated using several factors obtained from regional sources such as population growth rate, per capita income growth rate, and transport demand elasticity per vehicle type which has been established by the DPWH in its Highway Planning Manual. The comparison of the baseline scenario against the other two hypothetical scenarios are based on the projections shown in Fig.2.

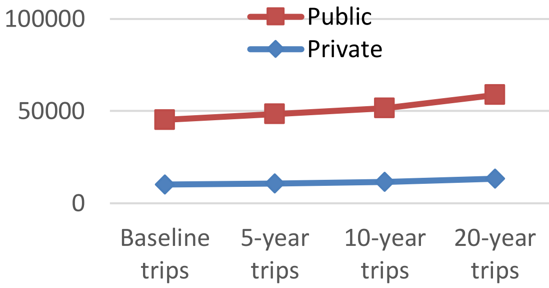

Fig. 2 Baseline and forecasted traffic

The different scenarios were separately simulated and were compared with the baseline scenario. Shown in Table 1 is the summary of the scenarios simulated in the EMME software. It can be seen that overall, the proposed scenarios will improve the current situation due to the enhancement in average zone to zone travel time and speed. This reduction implies a positive effect of the proposed projects in the study area. The volume-capacity ratio (VCR) also shows a significant improvement brought about by the proposed roads. The provision of the proposed roads also shows reductions of around 30% in the current VCR values of the baseline scenario, which is quite significant.

Table 1 EMME Scenario modeling summary

Scenarios	Ave. zone-zone travel time (min)	VCR	Ave. speed (kph)	VDT (veh-km)	VHT (veh-hr)
baseline	23.55	0.16	26.75	63010.38	2306.13
with circum-ferential roads	20.86	0.11	28.10	60090.06	1779.55
with circum-ferential and additional road links	20.54	0.11	28.15	59512.49	1750.47

EMME outputs can show the scenario comparison output of the baseline vs with-circumferential road and the comparison between baseline and with-circumferential plus other local roads. Green-colored links in EMME show reduction in traffic volume while those in red show increase in volume. The scenario comparison from the model generated have shown the impact of the provision of the proposed roads. Through this tool, planners can visualize the extent of the effect of the projects, the TIIC can aid in accurately comparing the effects of these scenarios in terms of the co-benefits.

After incorporating the two scenarios in EMME, separate simulations were prepared for each of them. After each run, results were exported and compiled. The information were directly fed into the TIIC. The information can either be encoded manually or imported from the worksheet output of EMME. Once all the information is fed to the TIIC, the calculation may be started and several charts and a table can be seen in the output tab of the tool.

Fig.3 contains charts for the different savings calculated. For travel time savings, the hypothetical scenarios are each compared with the baseline scenario and the savings are calculated based on the reduction in travel time for the entire network. The minimum wage rate is used to convert the travel time savings to monetary units. The next co-benefit included in the TIIC is the vehicle operating cost savings. This is computed based on link speeds and estimated using equations developed by JICA [17].

Due to improved speed in the network, the vehicle operating cost for the scenarios indicate savings. More savings can be derived from the circumferential plus other local roads scenario due to better average speed in the network. The reduction in NOx, CO, CO2, SOx, and PM were considered for the environmental savings. The reduction also derived from the changes in speed and quantified through the values obtained from Clean Air Asia Initiatives. Figure 7 shows a similar result where scenario B involving the provision of the circumferential road along with other local roads yield the larger amount of savings.

As shown in this section, the TIIC tool is able to perform co-benefit analysis in line with the outputs of EMME which is the transportation planning software used in the project. The tool streamlines the process of being able to compare various scenarios that are introduced in EMME through co-benefit analysis that is integrated in the TIIC tool. This tool can either accept imported EMME CSV data or through manual encoding. Co-benefit analysis has been utilized as it not only looks into vehicle operating costs and value of travel time savings as well as environmental emission savings.

This promotes the concept of sustainability which is essential especially during these times were climate change is a pressing issue. Roxas City, Philippines was chosen to be the pilot implementation of the TIIC. Two EMME scenarios were formulated and were separately compared with the baseline scenario. Not only can this tool accept various scenarios but it can also accept various projections from each scenario. It was determined that the second case will provide the more co-benefits to the city. Through this tool, this research is able to achieve its goal of assisting the LGUs in their task of crafting sustainable transport infrastructure projects and programs in Region VI.

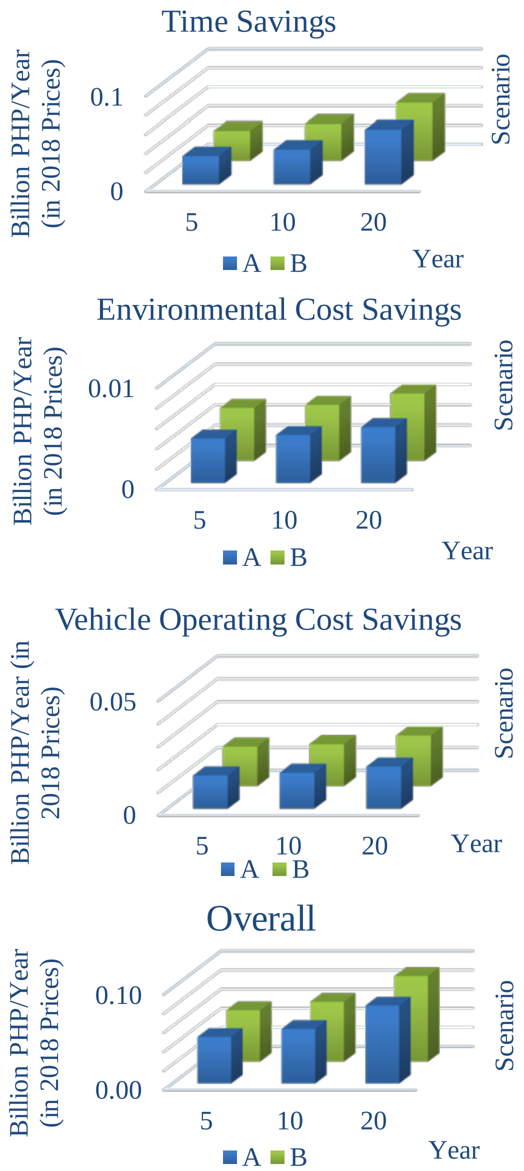

Fig. 3 TIIC comparison of various scenarios

6. CONCLUSIONS

This study is part of the government-funded research program STARPLAN VI which aims to support the development of the LPTRPs of various LGUs that integrates the road and maritime transport network of Region VI using the developed technologies for the transport sector.

To aid government staff in assessing proposed transport projects, the TIIC was conceived. The TIIC tool is able to perform co-benefit analysis in line with the outputs of EMME. The tool streamlines the process of being able to compare various scenarios that are introduced in EMME through co-benefit analysis that is integrated in the TIIC tool. This tool can either accept imported EMME CSV data or manual encoding. Co-benefit analysis has been utilized as it not only looks into vehicle operating costs and value of travel time savings as well as environmental emission savings. This promotes sustainability which is essential now when climate change is a pressing issue.

In this paper, Roxas City, Philippines was chosen to be the pilot implementation of the TIIC. Two EMME scenarios were formulated and were separately compared with the baseline scenario. Not only can this tool accept various scenarios but it can also accept various projections from each scenario. It was determined that the second case will provide the more co-benefits to the city. Through this tool, this research aims to assist LGUs in their task of crafting sustainable transport infrastructure projects and programs in Region VI.

This developed tool was also demonstrated to the target audience in Region 6. Based on the surveys conducted from the trainings, the LGU personnel and partner SUCs appreciate the relevance of the tool in their tasks. Majority of the participants found it easy and most of the comments provided were already considered and incorporated in the latest version. Though the current version only accepts inputs from EMME, the researchers added an option for the users to contact the researchers for possible revisions in order to accommodate certain requests and other software output formats.

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