A SYSTEMS APPROACH TO DESIGN BUS RAPID TRANSIT SYSTEM IN VIENTIANE (LAO PDR)*

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1. Introduction

Vientiane is a moderate city with population growth rate of 4.7 per annual (estimated in 2007). Besides, the growth of population, the growth in industrialization requires the needs of labor demands and commutes. The increase in high volume of travel resulted in traffic congestion and longer travels time. Since more automobiles are engaged in commuting, this resulted in problems of road traffic accidents and air pollution. In order to solve the above mentioned problems, and to provide economic, social and environmental benefits to commuters as well as to encourage regional economic development, Bus Rapid Transit (BRT) is introduced as an alternative mode on the existing road infrastructure between Urban districts via Centre Business District for the total length of 23 km. This research attempts to find an optimal design of BRT system, measure benefits from deployment, and estimate the feasibility and profitability from project implementation.

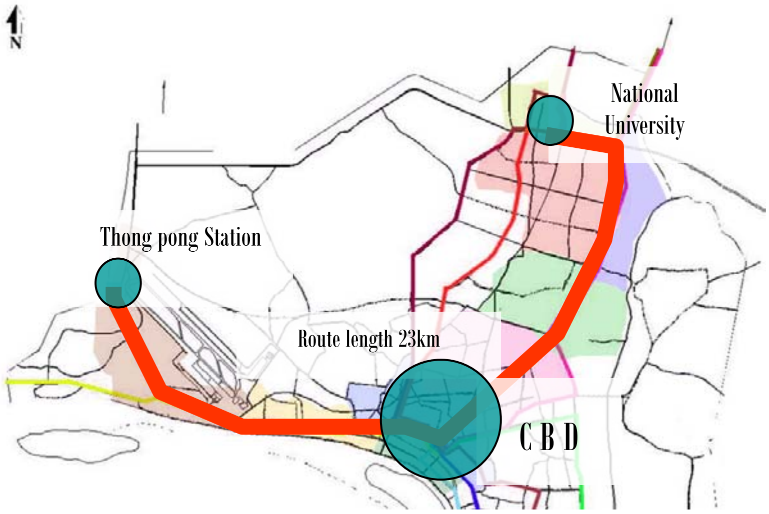

Figure 1: Map of Study Area (Northern Part of Vientiane)

2. Modeling System Optimization Approach, and Analysis of BRT System

A BRT system differs from more traditional rail and bus services by its features that combine most of the qualities of light rail transit (LRT) with highly flexible service and advanced technologies to improve customer convenience and system reliability. BRT can be described as a high quality bus-base rapid transit system that provide fast, comfortable and cost effectiveness within urban mobility with the combination of vehicles, stations, running way, and Intelligent Transportation Systems (ITS) elements into a fully integrated system with a unique identity. [1)]

(1) Modeling System Optimization Approach

System optimization approach is used in this study to decide an optimal design and planning through a broad view of BRT system. It was explained by Vuchic (2005) that system approach represents a broad view of an object, system, and process with attention thorough understanding of its characteristics and functions.[2)] In order to optimize the BRT system, selection appropriate elements of BRT is very important. There are numerous BRT elements available for transit

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agencies to choose to equip their BRT systems. Different system combinations of BRT elements display different service levels and reflect different budgetary constraints. Upon deciding to invest in BRT, a transit agency must select a combination of elements that maximize the cost-benefit of operation.

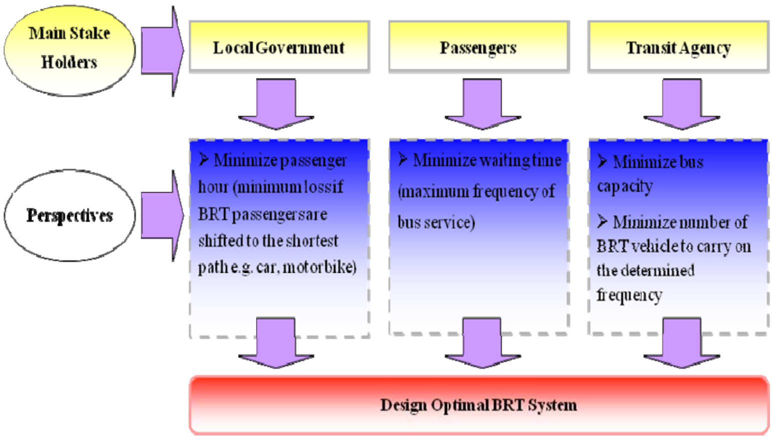

Figure 2: Multi-objective Optimization and Optimal BRT

The objective functions set forth into account of three perspectives: passengers, operator and community. The first objective is to minimize waiting time. This is strictly the perspective of BRT users. The second and third are to minimize the unused seat capacity as to allow for a more viable BRT service and the third objective is to minimize the number of BRT vehicles to carry on the determined frequencies. These are the operator perspective. The forth objective is to minimize passenger hours. This objective attempts to take into account the comparison between the BRT, car, and motorbike mode. This objective represents the perspectives of the government and can also be a perspective of BRT passengers. Figure 2, in order to determine all requirements and to satisfy all objectives, the multi-objective optimization methodology is carried out to determine the optimal design of BRT system.

Table 1: Sets of Combinations for BRT System

Elements / Combination	Exclusive Median Lane	Stop / station	Pre paid Fare system	Signal Control System	AVL & Real time system
Basic-Improved	Applied	Applied	×	×	×
Semi-Moderate	Applied	Applied	Applied	×	×
Moderate	Applied	Applied	×	Applied	×
Enhanced	Applied	Applied	Applied	Applied	×
High-Enhanced	Applied	Applied	Applied	Applied	Applied

The flow of this study conducted in 5 major steps: Firstly, conducted Stated Preference survey. Secondly, obtain optimal BRT system from optimization methodology. Thirdly, passengers forecast for BRT based on travel simulation model. Fourthly, benefit analysis from implementing BRT, and finally financial simulation in order to realize the project's feasibility and profitability. Prior conducting any estimation, the set of element combinations (Table 1) was based on the consideration of improving existing level of service and reducing costs, technical feasibility, institutional constraints, and the use of elements that provide travel time reduction and increase features to encourage more riders.

(2) Analysis of BRT System

In this stage, the optimization functions are set forth in order to find an optimal BRT system for Vientiane Capital. The following equations are optimization functions used for calculation of optimal BRT system: The optimization methodology was conducted based on the

Figure 3: Optimization Equations to Calculate Optimal BRT System

$$Maximization: Cost_{combination\_i} / Utility_{brt\_i}$$

$$Cost_{combination\_i} = ay_{vehicle\_i} + by_{station\_i} + C_{facility\_i}$$

$$Utility_{brt\_i} = \beta_1 X_{access\_brti} + \beta_2 X_{invehicle\_time\_brti} + \beta_3 X_{headway\_brti} + \beta_4 X_{fare\_brti}$$

Where: $X_{access\_brti} = f(y_{station\_i})$; $X_{invehicle\_time\_brti} = f(C_{facility\_i})$

$$X_{headway\_brti} = f(y_{vehicle\_i}; y_{staion\_i})$$

$$X_{invehicle\_time\_brti} = \{C_{facility\_A}, C_{facility\_B}, C_{facility\_C}, C_{facility\_D}, C_{facility\_E}\}$$

setting of five element combinations (Basic Improved, Semi-Moderate, Moderate, Enhanced, and High Enhanced system), setting of possible headway-based schedule time (from 2, 3, 4,… 10 min) which are designed based on determining utility/cost ratio of optimization, and fare price based on the SP survey (3,000kip to 6,000kip with 1,000kip increment). As the expected result of this optimization methodology, there will be one highest point based on utility-cost ratio to determine the optimal value of the system.

After deriving total cost and utility of each combination, the selection of optimal element combination is based on the calculation of utility-cost ratio. Figure 4 shows the result of the optimal element combination of combination “Enhanced” provide the optimal utility-cost ratio for the value of 0.0458 with headway of 5-minute and fare price of 3,000kip.

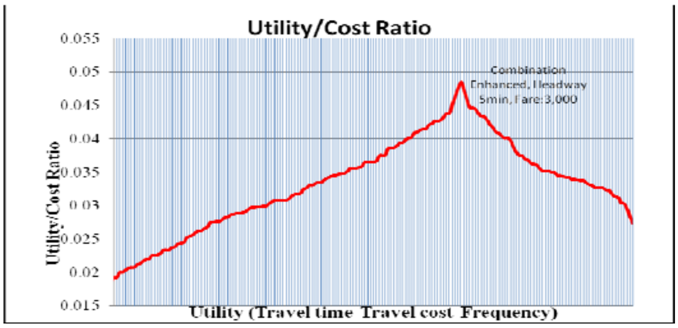

Figure 4: Optimal BRT System Based on Utility-Cost Ratio

3. Evaluation of Benefit from Implementing BRT

Key benefits that we expected to result from implementing BRT system divided into three categories: Economic, Social, and Environmental benefit. Firstly, economic benefit is consumer benefits based on travel time and cost saving when current bus and automobile users shift to BRT. In order to measure time value benefit, the value of time spent traveling needs to be monetized. The generally accepted methods for doing so set forth the value of time depending on a few factors including: (1) the different portions of a commute (i.e., in-vehicle travel time, access time, and waiting time), and (2) the value of traveling which multiplied the gross average hourly wage rate in the relevant region by the specific factor. [3)] In order to measure travel cost reduction from automobile to transit use, a marginal cost associated with each Vehicle Miles Travel (VMT) is estimated. Components of the marginal cost include fuel, oil, tire deterioration, maintenance, and vehicle depreciation. Average annual marginal cost from car and bike users, and average travel distance were used in our estimation. Finally, we derived marginal cost for car and motorcycle at the rate of US$0.0675 and US$0.15 per km respectively. Secondly, social benefit can be obtained from the reduction in accident costs when travel distance from automobile users is reduced. The average annual number of accidents is definitely related to Vehicle Mile Travel. Using data provided by the Department of Transportation, we calculated the average accident cost at the value of $0.00625 per km. Lastly, environmental benefit can be achieved from the reduction in air emissions. Litman (2002) suggested that for an average car, air pollution costs are $0.04 per vehicle mile.[4)] Because Vientiane city is considered not having much air pollution problem from mobile sources. Therefore, we suggested the value of $0.02 be used in our preferred model as a mean value obtained from reference sources.

Table 2: Benefits from Implementing BRT

Year	Time value saving (US$)	Automobile users cost reduced (US$)	Accident cost saving (US$)	Air Emission reduced (US$)
2015	863,853	$101,710,011	$1,688,957	5,404,662
2020	1,082,269	$127,966,741	$2,124,966	6,799,890
2025	1,357,071	$161,001,721	$2,673,532	8,555,302
2030	1,702,812	$202,564,775	$3,363,712	10,763,877

From the result, we derived the benefits in monetary values as shown in Table 2. Cost reduction from automobile users shifting to BRT is the main economic saving gained from the system with 93 % followed by air emission and accident cost reduction respectively. However, the air pollution cost shows 3 times greater than accident cost saving. Since pollution and accident are related to number of vehicle miles travel, we tried to find an appropriate ratio of the air pollution and accident. Based on the reference source *(Transport 2020 Bus Rapid Transit-A Cost Benefit Analysis)* we found the ratio of pollution and accident cost is 2.5. However, we already used the low pollution cost rate in the estimation. Therefore, we considered the pollution cost and accident cost reduced are appropriate for the study area.

For further estimation, we estimated the amount of saving for passengers who used the system. The benefits from time value, new user cost reduction and benefits from reducing accident cost were used for the estimation. When comparing the Gross Domestic Product (GDP) of the country as shown on Figure 5, we used the average annual GDP growth rate of 6.5 percent to calculate the increase of GDP and compared with the cost saving per capita. We found that the cost saving from the utilization of BRT can save approximately 14% of the total GDP per capita.

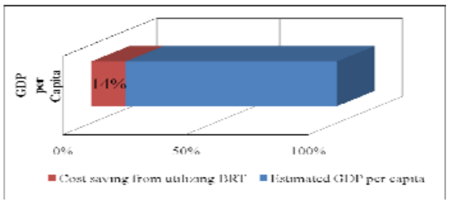

Figure 5: Cost Saving per Capita from Implementing BRT

4. Feasibility Analysis from Financial Aspect

Based on the input of costs and income data of financial simulation, it was found that the BRT project applied for Vientiane capital is feasible and highly profitable without any subsidy from the Government. Due to the simple layout of system, the easiness of construction, the low cost of investment, operation and maintenance, and the most significant solution that could make the project profitable is the high volume of the forecasted BRT passengers. As shown in Figure 6, the result of simulation shows that BRT project would take 14 year in debt while the remaining years represent profitability.

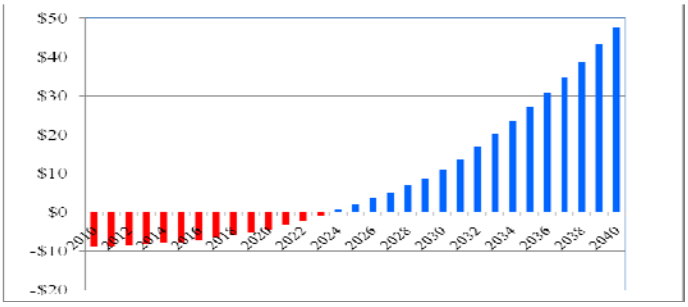

Figure 6: Accumulative Financial Balance (US$mill)

5. Conclusions

Utilizing transit would provide commuters and non-commuters benefits: economic, social and environmental benefits. Operation based on the optimal design can help achieving maximization of the system. Financial simulation of the project is very important to ensure the feasibility if the project is implemented. However, operating transit service alone cannot maximize transit investment benefits unless support strategies and appropriate policy such as Transit Oriented Development, transit priority, and parking management are introduced. Since BRT provides such great cost-effectiveness and encourage low-income mobility and individual cost saving, future expansion of BRT project is considered throughout all regions to provide more accessibility, and regional development.

References

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