IATSS Research 39 (2016) 121–129

Contents lists available at ScienceDirect

IATSS Research

Potential for modal shift by passenger car and motorcycle users towards Bus Rapid Transit (BRT) in an Asian developing city

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ARTICLE INFO

Available online 8 April 2015

Keywords:
Bus Rapid Transit
Stated preference
Logit model
Car user
Motorcycle user
Asian developing city

ABSTRACT

Many developing Asian cities consider a Bus Rapid Transit (BRT) system in their public transport planning because of its advantages, offering lower investment cost and flexible implementation over rail systems. The objective of this research is to assess the potential of BRT for attracting travelers from passenger cars and motorcycles. Three different BRT systems were designed for the main corridor passing through Khon Kaen City in Thailand. The study developed modal split models for predicting the choices of passenger car users and motorcycle users. The models were developed based on a Stated Preference (SP) survey. It was found that BRT could attract significantly private vehicle users to change mode choice. The proportion of motorcycle users shifting is higher than passenger car users. However, the majority of private vehicle users still prefer their own private vehicles. Both travel time and travel cost affects the mode choice, in which travel time has a highly significant effect on passenger car users' choice of BRT, but travel cost has a highly significant effect on motorcyclists' choice. Some socio-economic factors, including gender, age, driving license holding and residence location also influence the choice of BRT.

1. Introduction

Bus Rapid Transit (BRT) has become a popular worldwide transit mode, especially in Europe, South America, and particularly in Asia, due to its value for money, service capacity, affordability, relative flexibility, and network coverage [1]. Many case studies have shown that BRT can be a cost-effective way to provide a high-performance transport service [2,3]. Some developing Asian cities also consider BRT in their public transport planning because of its advantages of lower investment cost and flexible implementation over rail systems [4]. In addition, BRT is recommended to realize the low carbon society target for Asian developing cities since BRT would shift private vehicle users to a transport sector which emits lower CO_2 [5,6]. There are however several urban characteristics of Asian developing cities which are different from the successful BRT implementing cities, such as Latin American cities, which should be carefully considered to achieve a successful implementation of a BRT project, for example, urban sprawl (caused by poor city planning) and high private vehicle usage (due to poor existing public transport). Many previous studies have proposed integrated strategies with BRT systems to cope with urban sprawl in developing Asian cities. For example, the case studies of accumulating demands from urban sprawl to the BRT corridor by paratransit feeder in Bangkok [7–9] and a case study of integrating a BRT System with Rickshaw in Dhaka [10].

Due to the poor service of existing public transport and cheap motorcycle use, many developing Asian cities have a very high private vehicle share, especially for motorcycles. Hanoi and Ho Chi Minh cities in Vietnam have recorded motorcycle shares of 81%, and 90%, respectively, of all motorized trips [11,12]. The car was recorded as 40% of mode share in Malaysia [13]. In many provincial cities of Thailand, the motorcycle share accounts for approximately a half of all travel trips, e.g. 51% of all trips in Khon Kaen City [14]. Surveyed annual VKT of motorcycles in Khon Kaen city (6247 km) was higher than that in Bangkok (4015 km) [15]. Thus, it is very challenging to encourage modal shift from motorcycle to BRT. Previously, there are some studies [e.g., 16,17] that proposed policies and planning of bus systems in motorcycle-dominated communities.

It is not easy to achieve high modal shift to BRT in developing countries where an increase in wealth profile is making private vehicles a more affordable means of transport, as well as conferring elements of status causing a high passenger car (PC) and motorcycle (MC) share.

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Peer review under responsibility of International Association of Traffic and Safety Sciences.

http://dx.doi.org/10.1016/j.iatssr.2015.03.002

Some passenger car users from high-income families prefer their existing mode because of comfort, privacy and status considerations. It is very difficult to shift them to use the public transport, even if a highly efficient public transit is provided. Motorcycle use is rather cheap and provides high accessibility, even though it is unsafe and uncomfortable. However, there is a lack of previous research studying a comparison of car users' and motorcycle users' choice behavior on BRT, as well as the effects of different BRT systems on choice behavior.

Therefore, the objective of this research is to assess potentials of BRT in shifting travelers from private vehicles (both car and motorcycle). The case study is in Khon Kaen City in Thailand, where three different BRT systems were designed and proposed to travelers. The study is based on stated preference (SP) data from which modal split models were developed for predicting the choices of passenger car users and motorcycle users to use BRT.

In this paper, the next section outlines the literature on the effectiveness of BRT. Section 3 describes the research methodology. Section 4 presents the model results and discussions. Section 5 presents the application of the developed models for BRT planning in the city, followed by the conclusions and recommendations in Section 6.

2. Experiences of modal shift to BRT

The planning of BRT is intended to increase the attractiveness of bus transport and affect modal shift from private vehicles. Some empirical data is supportive of the case that BRT has generally similar performance to light rail in the perceptions of passengers. Currie [18] examined the relative passenger attractiveness of BRT systems compared to other transit modes by using a trip attribute approach. The study examined how passengers valued trip attributes for on-street bus, BRT, and light rail and heavy rail systems in passenger behavior researches conducted in many countries. The study found that passengers valued trip attributes for BRT and rail modes in a broadly similar manner. The BRT systems should be as effective as rail in generating patronage when developed to replace on-street bus services. The lower costs for BRT systems compared to rail may be used to claim cost effectiveness advantages for BRT. In Thailand, from the attitude survey, it was also found that all aspects of BRT can compete with an on-street rail-based system and BRT systems can be effective in attracting passengers much more than the current public transport [4].

In Jakarta, Indonesia, Alvinsyah et al. [19] observed the attitude of public transport users due to the introduction of a new public transport system. The BRT systems with and without a feeder service under various fare and time savings were proposed. This study found that there are differences in peoples' perception and their probability of choosing a better service. Ernst [20] surveyed the mode shift to the Jakarta BRT in Indonesia, during the first month of operation, and found that 20% of BRT riders previously were private vehicle users (14% from private car user and 6% from motorcycle user).

Although many studies confirm that BRT is attractive to travelers, in practice the level of mode shift is uncertain. Levinson et al. [2] reviewed the BRT case studies around the world and reported that up to 72% of BRT riders in Houston were diverted from cars and 20% of BRT riders in Vancouver previously used cars. The mode shift of the Nantes BRT (BHLS, Buses with High Level of Service) in France was 29% from private cars [21]. This was rather high because the busway was deployed in a previously poorly served area and public space was reorganized to restrict car use. Only 18% of BRT (Orange Line) riders in Los Angeles were shifted from private cars [22]. In China, on the Beijing BRT Line 1, only 12.4% of riders previously were private car users [23].

The different results of modal shift are likely because of different system characteristics and performance, personal perceptions and characteristics, and local circumstances. For example, McDonnell et al. [24] analyzed the scheme of bus priority measures in Dublin, Ireland. The results indicate that respondents are willing to pay large amounts for large improvements in journey times and for improved comfort attributes. McDonnell and Zellner [25] examined the effectiveness of different BRT schemes. Various scenarios focused on the difference between the environment with and without BRT, and the ancillary policies, including exclusive bus lane, off-boarding ticket machines, express bus stops and improved bus frequency. The model results showed that all integrated measures can achieve up to 50% of bus share, while bus share was only 20% for the base case of bus with no exclusive bus lane and the ancillary measures. The modal shift is rather high; however, for this result it should be noted that bus travel time is much lower than car travel time for all scenarios tested. This leads to a question about how many travelers would switch to BRT if private vehicles (car and motorcycle) travel times were lower than or equal to BRT travel time.

In developing countries, Nurdden et al. [13] evaluated the policies encouraging public transport use in Malaysia, and found that apart from simply travel time, age, gender, car ownership, travel cost, and household income are also significant factors in influencing individual's mode choice. However, the most important policies encouraging public transport are a reduction of travel time from home to public transport stations and subsidized fare.

In summary, the proportions of modal shift from private vehicle users to BRT have a very wide range depending on various factors. Currently, in Asian developing countries, cars and motorcycles are much more convenient than other travel modes. Their support infrastructures are also well developed. It was suggested that the BRT system should be developed on high density corridors, or on corridors that are poorly served by existing buses. This system would be a high-quality bus system with rapid transit based operation (exclusive and priority lane with high frequency and reliability). Even if this infrastructure and service is developed, it is still uncertain to achieve a high modal shift to BRT, particularly in a private vehicle dominated community.

3. Case studies and methodology

3.1. Case study

Khon Kaen City in Thailand was selected as a case study of an Asian developing city because it is a private vehicle-dominated city similar to many developing cities in Asia where public transport is losing modal share. Khon Kaen City has 81% of all trips by private modes (51% by MC and 30% by PC) [14]. Less than 20% of all trips are by Song Thaew (the existing public pickup truck). The existing Song Thaew is not popular because of poorly designed service routes, delayed and unpunctual service, uncomfortable vehicles and unsafe driving. Khon Kaen city currently has a plan to operate a BRT system along its main corridor (called the Friendship Highway) passing though the middle of Khon Kaen City [26]. The BRT line on this corridor is called the Red Line, aligned from the north to the south of the city. This Red Line is the first phase among a total of five lines for the full BRT plan in Khon Kaen City. The Red Line has 17 stations along its 30 km corridor as displayed in Fig. 1.

3.2. Design of Bus Rapid Transit System

To explore various types of BRT system influencing the choice of private vehicle users, in this study, different BRT systems were designed with different efficiency levels to propose to private vehicle users. The design concept is to propose BRT systems suitable with the conditions of Asian developing cities, which have limited investment budget, urban sprawl and high private vehicle usage. The three different BRT systems are:

1) The minibus (MNB): the small air-conditioned bus is operating along a mixed traffic lane, i.e. an on-street bus. This system provides bus stops along the service route. This system is proposed for Asian