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Notes and comments

Environmental impact and travel time savings of a new monorail system in colombo's commuting traffic

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ABSTRACT

This study estimates the environmental impact and the value of travel time savings for commuters who travel to Colombo city in traffic congestion when the proposed monorail system is in place. The model considers an introduction of a monorail into a mono-centric city with symmetrically distributed radial highways converging toward the central business district (CBD), with an inelastic commuter demand. We compare the CO_2 emission amount as well as aggregate travel time savings from different monorail scenarios, with the introduction of a toll as a necessary condition to generate an efficient outcome. The results show that for a monorail running at an average speed of 40 km/h a length of 26.8 km from the CBD will optimize investment and contribute travel time savings of 105 million Rs. per day or 189 million USD per year to the Sri Lankan economy, resulting in the CO_2 emission reduction by 42%. A sensitivity analysis is conducted to evaluate the effects of monorail speed, commuter income, and population growth.

1. Introduction

This study investigates the environmental impact and the value of travel time savings for commuters who travel to the Colombo city center, when monorail system is introduced to one of city's seven major corridors. Sri Lankan government is now planning to introduce mass transit systems in these corridors. To describe this situation we establish a mono-centric city model with symmetrically distributed radial highways where traffic congestion is present. In particular, we evaluate the impacts of introducing a monorail along a highway by comparing the total CO_2 emission as well as aggregate travel time savings from different monorail scenarios. Our results show that for a monorail running at an average speed of 40 km/h a length of 26.8 km from the central business district (CBD) will optimize investment and contribute travel time savings of 105 million Rs. per day or 189 million USD per year to the Sri Lankan economy, resulting in the CO_2 emission reduction by 42%.

This finding has policy relevance from the perspective of climate change mitigation. A large part of the carbon budget will be consumed by the transportation sector especially in the developing mega cities like Colombo where rapid urbanization is taking place. It is expected that without any effective measures the amount of global emissions from transportation sector will at least double by 2050. One major contributor to the greenhouse gas emissions is the road transport. Economic growth and increasing purchasing power in developing world induce motorization, implying increased congestion and

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environmental externalities especially in urbanized areas. The first-best policy to these externality is a Pigouvian tax equivalent to the marginal external costs of each trip. Possibility of modal shift enhances its effectiveness in alleviating greenhouse gas emission from urban commuting that is essentially price-inelastic and traditionally dominated by private auto travels.

Besides, the majority of transport investments bring benefits to transport users in terms of the value of travel time savings. Commuting takes up a large portion of an individual's time allocated for transportation, and traffic congestion increases it significantly. As saving travel time is the key parameter in benefit-cost analysis of transport projects as discussed by Small (2012) and many others, the proposed monorail system in Sri Lanka is expected to do the same. Theoretical arguments and empirical evidence on passenger transport confirm that people place value on travel time savings. Mackie et al. (2001) found that value of travel time savings accounts for approximately 80% of the monetized benefits in major road schemes in the UK. It also became an acute problem in many cities in developing countries such as Colombo, the commercial capital of Sri Lanka. As a result of urban development and economic growth, the Colombo metropolitan area has dramatically increased in size during the last few decades. This rapid urban expansion has led to suburbanization, a longer average journey length for commuters, and increased use of private vehicles. This resulted in severe traffic congestion with speeds as low as 8 km/h during the peak congestion period at the CBD. At present, 70% of commuting trips to Colombo metropolitan area start 20–40 km away from the city center and enter the city through seven key corridors. It is estimated that current travel demand will increase by 75% by 2035. As the share of the higher income group is estimated to increase from 7.6% in 2012 to 56.3% in 2035, it is expected that the number of commuters using private vehicles will increase by approximately 2.5 times while the number of passengers using public transport will remain at a roughly static value.[1] As a result, current commuters are conscious about saving travel time.

Accordingly, policies to promote public transport and to alleviate urban traffic congestion were emphasized in the CoMTrans Urban Transport Master Plan by Ministry of Transport of Sri Lanka (2014a). In translating the policies into reality, mass transit projects are undergoing simultaneously along all the major corridors that connect the CBD to the suburban areas in greater Colombo. There are seven major corridors in greater Colombo metropolitan area. Proposed mass transit projects along these corridors are listed in Table 1.[2] Among them is the Malabe corridor that connects CBD to the western suburb, along which the construction of a monorail is suggested. This paper thus identifies the optimal monorail system along this corridor and evaluates quantitatively the impacts of its introduction on both the transportation and environmental costs.

The remainder of this paper is organized as follows. In Section 2 we present the theoretical framework of the analysis. Section 3 conducts numerical simulation analysis and calibrates the model using different parameters for the monorail speed, income, and population to compare the key variables with those in the case without the monorail. Finally, Section 4 concludes.

2. Theoretical framework

Here, we choose the ring-radial travel model developed by Anas and Moses (1979) to demonstrate traffic flows throughout the corridor. The model stipulates a circular city with radial highways connecting the suburbs with the CBD.[3] In these authors' work, assuming that radial highways are evenly distributed around the circular city, the serving area – which is also called the market area – of each highway is demarcated to divide the area between two adjacent radial highways into two equal sub-areas. In this circular city, the width of the serving area in a given travel corridor increases linearly with the radial distance, and this tends to decrease the density. We found that the model used by Yoshida (2011), which gives a relationship between flow volume and cost of a highway is directly applicable in our study to calculate the cost at a given location with a different flow volume.

We then consider a situation where a mass transit system is introduced along each of these highways as an alternative commuting mode, in particular, a case of introducing a monorail. Highway extends indefinitely while the monorail along it has finite length that is endogenously optimized. As we assume circular symmetry as for the geography of the city, we limit our analysis to a single market area along a highway which is an arc. It is assumed that the capacity of the highway and the speed of the monorail are constant throughout the corridor, and hence that the highway is capacity-constrained and congestible while the monorail is not.

2.1. Demand

We consider a morning rush hour where people who travel along the highway to the CBD are all commuters, and therefore their travel demand is inelastic to trip price. Trip price is consisted of user's time cost and if any, monetary cost e.g. toll.

The commuter can access the highway or the monorail at any point along them, but the exit will be only at the CBD. The commuters reach the highway or the monorail from their residences traveling circumferentially.[4] There are three types of commuters in this city: those who drive all the way, those who take the monorail, and those who drive to the monorail terminal

[1] CoMTrans Urban Transport Master Plan Executive Summary: Final Report 2014.
[2] These are also found in CoMTrans Urban Transport Master Plan by Ministry of Transport of Sri Lanka (2014a,b).
[3] Size of CBD is assumed to be negligible.
[4] We assume that cost of circumferential access travel is fixed and negligibly positive.