Public Transportation and Private Car: A System Dynamics Approach in Understanding the Mode Choice

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ABSTRACT

While there is a general agreement that the use of public transportation should be encouraged, it has also been reported that the willingness and tendency to use the public transportation is dominated by the propensity of private car use. Consequently, the persistent increase in the modal share of private car has been a matter of concern in the context of growing cities. This research starts with the understanding that the entire state of the modal share in a city would be the collective reflection of the mode choice behaviour of individuals who populate the large population mass in the city. A causal feedback loop model is developed to study the individual mode choice behaviour in the context of a city. The model is then translated into a system dynamics simulation model. The context of Dubai has been considered in order to operationalise the simulation model. The simulation experiments revealed that it would be challenging to motivate individuals in using the public transportation in the city where private car has already been a dominant mode. It is also found that the very desire of individuals to own and use private car is one of the key points that should be addressed properly if the mode choice is to be influenced.

KEYWORDS

Dubai, the Mode Choice, Private Car, Public Transportation, Sustainable Transportation, System Dynamics

1. INTRODUCTION

Modal share in urban transportation has been one of the major concerns as it affects the very functionality and sustainability of transportation system in growing cities. Promotion and use of public transportation is often emphasised, but at the same time excessive private car ownership and usage has been reported to be one of the persistent challenges (Steg, 2005; Kitamura, 1989). Plenty of research have been done to understand the mode choice behaviour and consequent status of the modal share. For instance, some majority of the studies in this area use the common approach of mode choice analysis such as binary and multinomial logit modelling (Mintesnot and Takano, 2007). Other statistical (Scheiner and Holz-Rau, 2010; Anable and Gatersleben, 2005; Lu and Pas, 1999) and qualitative (Beirao and Cabral, 2007; Stone et al., 2003; Hiscock et al., 2002) approaches have also been used to analyse empirical data on mode choice. Studies also have been done with the use of panel data to observe the mode choice behaviour over time (Kitamura, 2009). These different methodologies and approaches help to develop substantial understanding in the subject area. However the literature also point out some shortcomings related to the methodology, and they also indicate directions for further research. Kitamura (2009) argued that the static approach based on cross-sectional data might lead to unreliable analysis results, and thus panel data could be used for better...
result and understanding of mode choice behaviour over time. Mokhtarian (2009) observed that the analysis of behaviour over time would provide more meaningful insights but there are limitations of panel data analysis. The forecasting-based panel data analysis tool in fact could not accommodate many variables and the relevant dynamic simulation was based on the replication of past behaviour of limited number of variables. On the side of directions for further research, some of the literature indicate the need to include soft variables in the mode choice behaviour studies. Cao and Mokhtarian (2005) stated that in reality the mode choice behaviours are influenced by a large variety of qualitative and experiential variables that are seldom considered and measured. Scheiner and Holz-Rau (2010) and Fujii and Kitamura (2003) emphasised that the travel behaviour would not only be affected by hard objective factors, but it would also be influenced by subjective and psychological factors. Bamberg et al. (2011) recommended for further research in the line of improving the theory of causal determinants of car use. Stern and Richardson (2005) asserted that most of the travel behaviour models lack a cognitive explanatory mechanism explaining the individual’s choice process. There is a sense of consensus that the whole set of individual level behaviour have not been fully understood in the context of transportation (McFadden, 2007). In this paper, an attempt has been made to study the mode choice behaviour at an individual level in the context of a city. The tool of system dynamics has been used in this study (see Sterman (2000), Morecroft (2007) or Azar (2012) for details on the systems thinking and system dynamics approach). The tool helps to develop understanding on the mode choice behaviour from a holistic systems perspective. Especially the tool helps to conceptualise the mode choice behaviour in terms of feedback loops that comprise circular causal relationships between a number of relevant hard and soft variables. The conceptualised feedback loops can be used to develop a simulation model on which experiments can be done to learn why and how one individual would make choice on the mode of transport over time.

In this research, the city of Dubai has been taken as a case city in order to contextualise an urban area. A basic assumption is that the entire state of modal share in a city would be the collective reflection of the mode choice behaviour of individuals who populate the large population mass in the city. The assumption is relevant to a city such as Dubai where large majority of population mass include working-class individuals. Another assumption is that there are only two dominant modes of transportation – namely private car and public transportation – in a city. The bi-modal assumption is valid in the context of Dubai where other modes such as walking and cycling are usually not preferred.

In this paper, first, using the principles of systems thinking a conceptual feedback loop model has been developed by assimilating the literature review based knowledge on private car ownership and usage, and public transportation choice and usage. Then the feedback loop model was operationalised into a system dynamics simulation model. The context of Dubai has been taken to operationalise the parameters of the model. Numbers of simulation experiments on the model were carried out, out of which some key outputs of the experiments have been discussed, and then at the end, some pertinent conclusions of this research have been drawn.

2. CONCEPTUAL FEEDBACK LOOP MODEL

2.1. Private Car Ownership and Usage

Private car in general would be a preferred choice for transportation in modern urban life if one can afford to own and use it. This proposition is largely supported by most of the literature in car psychology and behavioural mode choice. Private car is taken as a sovereign mode of transportation that can provide protection, convenience, flexibility and reliability to make private trips (Hiscock et al., 2002). There are other numerous literature (such as Innocenti et al., 2013; Gatersleben and Uzzell, 2007; Mann and Abraham, 2006; Steg et al., 2001) that describe why the concept of private car is intrinsically related to the attachment to consume its possession and use. In addition to that, there is a distinct set of theoretical arguments on why people own and use car. Steg (2005) and Steg
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