Journal of Environmental Management xxx (2018) 1–11

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

System dynamics model of taxi management in metropolises: Economic and environmental implications for Beijing

Hao Wang [a,*], Kai Zhang [a], Junhua Chen [a], Zhifeng Wang [a], Guijun Li [b], Yuqi Yang [a]

[a] School of Management Science and Engineering, Central University of Finance and Economics, Beijing, China
[b] Research Department, Central University of Finance and Economics, Beijing, China

ARTICLE INFO

Article history:
Received 30 November 2017
Received in revised form
5 February 2018
Accepted 7 February 2018
Available online xxx

Keywords:
Taxi management
Travel characteristics
System dynamics
Pricing mechanism
Economic implications
Environmental implications

ABSTRACT

Taxis are an important component of urban passenger transport. Research on the daily dispatching of taxis and the utility of governmental management is important for the improvement of passenger travel, taxi driver income and environmental impacts. However, urban taxi management is a complex and dynamic system that is affected by many factors, and positive/negative feedback relationships and nonlinear interactions exist between each subsystem and variable. Therefore, conventional research methods can hardly depict its characteristics comprehensively. To bridge this gap, this paper develops a system dynamics model of urban taxi management, in which the empty-loaded rate and total demand are selected as key factors affecting taxi dispatching, and the impacts of taxi fares on driver income and travel demand are taken into account. After the validation of the model, taxi operations data derived from a prior analysis of origin−destination data of Beijing taxis are used as input for the model to simulate the taxi market in Beijing. Finally, economic and environmental implications are provided for the government to optimise policies on taxi management.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

The development of public transport is an inevitable choice for metropolises to alleviate traffic-related and environmental problems such as traffic congestion and vehicle exhaust pollution. As a principal means of infrequent travel, taxi transport is a useful complement to public transport in a city. However, the efficiency of taxi use is always unsatisfactory, and the taxi empty-loaded rate remains high (e.g., over 38% in Beijing), which leads to a waste of taxi resources in many cities. In particular, the growing use of car-hailing service applications based on the internet such as Didi and Uber has made the situation worse in recent years. For example, if many empty taxi cars cruise around the road network this may increase traffic load, waste fuel energy and even increase greenhouse gas (GHG) emissions. Therefore, research on taxi travel characteristics and operational simulations are significant for the efficient management of urban taxis.

Taxi travel characteristics are usually divided into basic characteristics and the temporal and spatial distribution of travel, etc., which can be derived from origin−destination (OD) data. In practice, taxi OD data are mainly collected from the management information systems of taxi companies and cover the daily operational records of all operating taxis, which include information on car ID, pick-up points, drop-off points, pick-up times and drop-off times, etc. The analysis of taxi OD data can help reveal the basic situation of taxi operations. However, the current research question is a dynamic problem, namely, how is the efficiency of taxi services affected when taxi fare rates are adjusted? The main objective of this research is to investigate how taxi pricing mechanisms affect the efficiency of taxi services. Therefore, to comprehensively understand the development trends and existing problems of the urban taxi market, a systematic approach, i.e., system dynamics (SD) modelling, could be used for the simulation of taxi systems via the analysis of OD data.

SD is a quantitative approach to analysing causal relationships between various factors in a system and is designed to extract the internal causes and feedback mechanisms from complex phenomena (Anand et al., 2006; Shepherd, 2014). An urban taxi system is a multi-variable, multi-feedback and nonlinear complex traffic system that is restricted by many factors in terms of traffic, the economy and policy. Urban taxi operations can be simulated and predicted by building a dynamic model of a taxi system that considers all associated factors together. Besides, taxi-related research

* Corresponding author.
E-mail address: holy.wong@connect.polyu.hk (H. Wang).

https://doi.org/10.1016/j.jenvman.2018.02.026
0301-4797/© 2018 Elsevier Ltd. All rights reserved.

emerged decades ago, and its focus has shifted over time.

On the basis of an analysis of travel characteristics, this paper develops an SD model of taxi operations to simulate and predict the possible conditions of taxi operations under different scenarios so as to provide a quantitative reference and theoretical support for establishing more efficient and integrated taxi dispatching mechanisms in metropolises. Taxi dispatching is defined as guiding and moving taxi cars according to actual demand and supply. Taking Beijing city as a case study, the proposed model is used to run an SD simulation using taxi OD data for Beijing. The empty-loaded rate is used to represent the efficiency of taxi operations, and the efficiency of taxi management in Beijing is analysed and measured via the simulation. In addition, scenario simulations on changes in taxi fares are conducted to analyse a series of effects caused by the fare changes. Finally, the findings of this research can provide a scientific reference and recommendations for taxi operations and management in metropolises.

2. Related work

Taxi services have increasingly attracted researchers' attention in the field of urban transport, and many previous studies on urban taxi operations, dispatching and management have been conducted in recent years. For example, Rodriguez-Valencia (2014) investigated the differences in taxi operations between day and night in Bogotá, Colombia on the basis of surveys of drivers in the city. Wang et al. (2014) proposed a taxi dispatch policy comprising linking several taxi trips with demand time points to improve the existing systems used by taxi companies in Singapore. Conway et al. (2012) evaluated taxi dispatching procedures using kerbside data and interviews at a particular traffic hub, namely, JFK Airport in New York City. Furthermore, a few researchers have focused on simulations of taxi services in urban areas by modelling the environments of taxi operations as a whole to help decision-makers better manage the taxi market (Bischoff and Maciejewski, 2014; Grau and Maria, 2013; Grau and Romeu, 2015).

Taxi services were initially investigated from the perspective of economy, i.e., price (Arnott, 1996; Douglas, 1972), and regulating prices was recognised as an effective way to improve services and reduce waiting time. With the development of the taxi industry in many cities, researchers started to examine the industry from other points of view, including taxi demand and supply (Cooper and Faber, 2010), the performance of taxi operation systems (Chen and Zhao, 2011), evaluations of taxi-sharing systems (D'Orey et al., 2012) and urban taxis and air pollution (An et al., 2011). Because big data theory is widespread in current society, big traffic data have been widely used for the management and optimisation of transport. For instance, large-scale taxi OD data can be used not only to optimise taxi operations (Yang et al., 2015) but also to estimate urban link travel times (Zhan et al., 2013). In addition, the development of information and communications technology (ICT) has enabled people to manage taxi service operations more accurately and conveniently (Liao, 2011), and internet technology has also reshaped taxi service modes and the taxi industry (Anderson, 2014; Li, 2016).

SD is a systematic and holistic approach based on the science of complexity that is suitable for dealing with complex interrelationships among various factors in complex systems and quantitatively simulating the future development of these systems (Liu et al., 2015a, 2015b). An urban traffic/transport system is a typical giant complex system, as so many constituent elements such as people, cars and roads are interrelated in the system. To probe such complex systems, SD modelling has been widely used in urban transport research (Shepherd, 2014). For instance, Haghani et al. (2003) attempted to use SD simulation modelling in the simultaneous treatment of land use and interactions in a transport system between a large number of physical, socioeconomic and policy variables. Cao and Menendez (2015) modelled the SD of urban traffic on the basis of parking-related states to evaluate the interactions between urban traffic and parking systems. Lewe et al. (2014) created an SD model of multimodal intercity transport that integrated socioeconomic factors, mode performance, aggregate demand and capacity. Similarly, Xia and Jiang (2014) established an SD model for the prediction of transport and socioeconomic factors that considered passenger transport capacity, cargo capacity, population, GDP and other major factors in the whole system. In addition, some researchers applied SD models to urban traffic congestion problems in different places (Jahed Shiran, 2014; Yang et al., 2013), and other researchers adopted an SD approach to analyse the effects of transport policies on energy consumption and GHG emissions (Liu et al., 2014, 2015b; Vafa-Arani et al., 2014). Although an SD approach has been employed to understand individual behaviour in mode choice between public transport and private cars in the context of a city (Bajracharya, 2016), few studies have focused on the problems of urban taxi operations from a holistic viewpoint using SD (Song, 2014), let alone systematic taxi dispatching and the empty-loaded rate.

Therefore, to bridge this research gap, this research employs an SD approach to model the holistic system of urban taxi operations and analyse taxi dispatching using the empty-loaded rate in different scenarios.

3. SD model

3.1. Description of taxi system

3.1.1. Aim of system modelling

With the rapid development of the urban economy, the urban taxi industry has grown progressively to make a significant contribution to the travel of residents and accounts for a large share of overall urban traffic. However, this rapidly growing industry has brought about great pressure on urban traffic, and inappropriate control measures proposed by some local governments have further worsened the situation. Phenomena referred to as 'difficult to call a taxi' and 'empty-loaded cruising', etc., have emerged in many cities, such as Beijing and Shenzhen, which indicates low efficiency and problems in taxi dispatching. Therefore, it is essential to examine the dispatching and control mechanisms of taxi systems. An overall taxi system is a complex system that includes not only taxis themselves but also other factors in terms of travel demand, taxi supply and taxi policies, which are directly or indirectly associated with taxis within the city. Research refers to the travel route arrangements of all taxis in a city during a working day as the taxi dispatching system, and the main factors that affect taxi routes are referred to as the dispatching mechanism. Because modern taxis are equipped with global positioning system (GPS) devices and unified voice communication platforms, taxi drivers can receive real-time information such as taxi high-demand areas and traffic jam areas, etc., in a timely manner and adjust their driving routes accordingly, which implies that supply and demand theory can be used to interpret taxi dispatching. In the urban taxi system modelled in this paper, the total taxi demand (demand) and empty-loaded rate (supply) are selected as the two key factors in taxi dispatching, on which the research on taxi dispatching and associated problems is based.

In addition, the management of the taxi market by governments mainly comprises macro-management, including quantity control and price control, etc., which is defined as taxi market regulation in this paper. In considering the conditions of balancing taxi supply and demand, this research develops an SD model of an urban taxi

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات