ARTICLE IN PRESS

Engineering xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Engineering

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

Research
Sustainable Infrastructure—Article

Estimation of the Impact of Traveler Information Apps on Urban Air Quality Improvement

Wenke Huang [a,b], Mingwei Hu [a,*]

[a] Department of Transportation Engineering, Shenzhen University, Shenzhen 518000, China
[b] Shenzhen Nanshan Urban Planning and Land Resource Research Center, Shenzhen 518000, China

ARTICLE INFO

Article history:
Received 4 November 2017
Revised 3 December 2017
Accepted 3 January 2018

Keywords:
Real-time traffic information
Mobile devices
Environmental benefits
Agent-based model

ABSTRACT

With the rapid growth of vehicle population and vehicle miles traveled, automobile emission has become a severe issue in the metropolitan cities of China. There are policies that concentrate on the management of emission sources. However, improving the operation of the transportation system through apps on mobile devices, especially navigation apps, may have a unique role in promoting urban air quality. Real-time traveler information can not only help travelers avoid traffic congestion, but also advise them to adjust their departure time, mode, or route, or even to cancel trips. Will such changes in personal travel patterns have a significant impact in decreasing emissions? If so, to what extent will they impact urban air quality? The aim of this study is to determine how urban traffic emission is affected by the use of navigation apps. With this work, we attempt to answer the question of whether the real-time traffic information provided by navigation apps can help to improve urban air quality. Some of these findings may provide references for the formulation of urban traffic and environmental policies.

1. Introduction

The transportation sector plays a vital role in every nation's economy. With the rapid development of China's economy, there has been a boom in road transportation, which is one of the largest sources of air pollution. Since the contradictions between the rapid growth in the number of vehicles and the limited transportation infrastructure resources are increasingly serious, many cities—and particularly metropolises—are facing traffic congestion and severe air pollution. These issues will result in huge economic losses to society and will restrict the sustainable development of these cities [1,2]. As an effective approach to solve urban traffic problems, intelligent transportation systems (ITSs) improve traffic system efficiency and air quality to a certain degree [3].

With the development of information communications technology (ICT) and the popularity of smart phones, traveler information apps are widely used in ITS [4–6]. These apps include electronic maps, navigation aids, parking guidance, and more. Among the navigation apps that are available in China, the most popular are Auto Navi Map and Baidu Map. Travelers can obtain a great deal of information through apps on their mobile devices, allowing them to know the current enroute (or even pre-trip) traffic conditions on the roads ahead. As a result, travel plans (e.g., travel mode, departure time, and travel route) can be adjusted to increase travel efficiency. Therefore, the potential capacity of the whole network can be better utilized and fuel consumption can be saved; emissions can also be reduced. In summary, the environmental benefits of traveler information apps are a key topic to be explored both now and in the near future. However, little research is available on the influence of traffic information on urban air quality. Although abundant research exists on the impact of traffic information on urban traffic, most of these studies still focus on traditional traffic information-dissemination approaches, such as radio, television, variable message signs, and Internet websites. However, such approaches are not the best way to acquire real-time traffic information, especially during trips. In the past two or three years, the use of apps to acquire traffic information has been popularized and promoted. However, little research exists on this kind of real-time information release, and even less on its environmental benefits.

Using multimethod modeling, a traveler-behavior model, a traffic simulation model, and an emissions model were integrated through the AnyLogic simulation platform and the MOVES (short

* Corresponding author.
E-mail address: humw@szu.edu.cn (M. Hu).

https://doi.org/10.1016/j.eng.2018.03.003

Please cite this article in press as: Huang W, Hu M. Estimation of the Impact of Traveler Information Apps on Urban Air Quality Improvement. Eng (2018), https://doi.org/10.1016/j.eng.2018.03.003

for Motor Vehicle Emission Simulator) emission model. An agent-based model (ABM) was built to simulate travelers' behavior under real-time traffic information provided by navigation apps. The traffic model simulates the agents' behaviors within the network, and the emission model calculates the emission inventories at the project level. This study focuses on the relationship between traveler's behaviors and environmental benefits, and can provide a reference for the formation of urban traffic policies.

2. Methods

2.1. Model summary

A comprehensive model combining traveler behavior prediction, traffic simulation, and emission calculation was developed in order to analyze the environmental performance of traveler information apps on a dynamic space-time scale. Fig. 1 presents the schematic of the comprehensive model. First, we built an ABM of traveler behavior, considering the impact of traffic information. We then built a microscopic traffic simulation model to simulate changes in trip production, trip attraction, distribution, model split, and traffic assignment, as influenced by diverse travelers' behavior. The data of each vehicle (e.g., position, speed, and accelerated speed at each time stamp) were collected and stored in a database as the input of the next step. Finally, we calculated the quantities of several pollutants using a project-level emissions model.

For this study, the AnyLogic simulation platform and the MOVES emission model were chosen to build the comprehensive model. The theoretical basis of AnyLogic is complex system theory; this platform supports three modeling methods in any combination: system dynamics (SD), ABMs, and discrete-event models (DEMs) [7,8]. In our model, an ABM and a DEM were combined to simulate travelers' behavior and traffic operation, respectively—a combination that is difficult to establish using traditional traffic simulation software. This innovation brings the simulation results quite close to reality. The microscopic emission model was built using the US. Environmental Protection Agency (EPA)'s MOVES model, which is an advanced motor vehicle emission simulator that is used around the world.

2.2. Traveler-behavior modeling

ABM provides an effective method of simulating behavior by building the whole system from the bottom up. ABM regards each entity in the system as an agent, and attempts to describe the system in terms of the behavior and interactions of agents. Compared with the traditional aggregate model, which simulates a system from the top down, ABM carries the advantages of being closer to reality and having greater efficiency, maneuverability, and portability [7–9].

AnyLogic was used to develop an ABM of traveler behaviors. The process of developing the ABM comprised three main steps. First, the agents—that is, the objects of the simulation—were chosen. Second, the behavior of the agents was defined. Complex behaviors, including dynamically changing departure times, travel modes, and routes, can be simulated by the ABM of travelers, in addition to basic attributes (e.g., gender, age, and probability of using apps to obtain traffic information) and driving attributes (e.g., preferred speed, maximum acceleration, maximum deceleration, and frequency of changing lanes). Finally, the agents were put into the simulation environment and allowed to interact with each other and the environment. Thus, the presentation of the simulation is a combination of many agents' behaviors [7,8].

The belief–desire–intention (BDI) agent model is an event-driven execution model. Taking the BDI model as a reference [10–12], environmental and traffic facilities were set as the *belief* of the traveler. The destination arrival was set as the *desire* of the traveler, and the *intention* of the traveler comprised behaviors, such as searching for an optimal route, perceiving other vehicles, changing lanes, avoiding, overtaking, waiting, and so on. At the beginning of each simulation step, the traveler agent chooses certain behaviors from the *intention* set as the activities in the next step, as presented in Fig. 2.

2.3. Traffic simulation modeling

A newly added software library in AnyLogic 8, the Road Traffic Library, allows modelers to build professional traffic simulation models [13]. Compared with other traffic simulation software, AnyLogic has an open system architecture and compatibility with

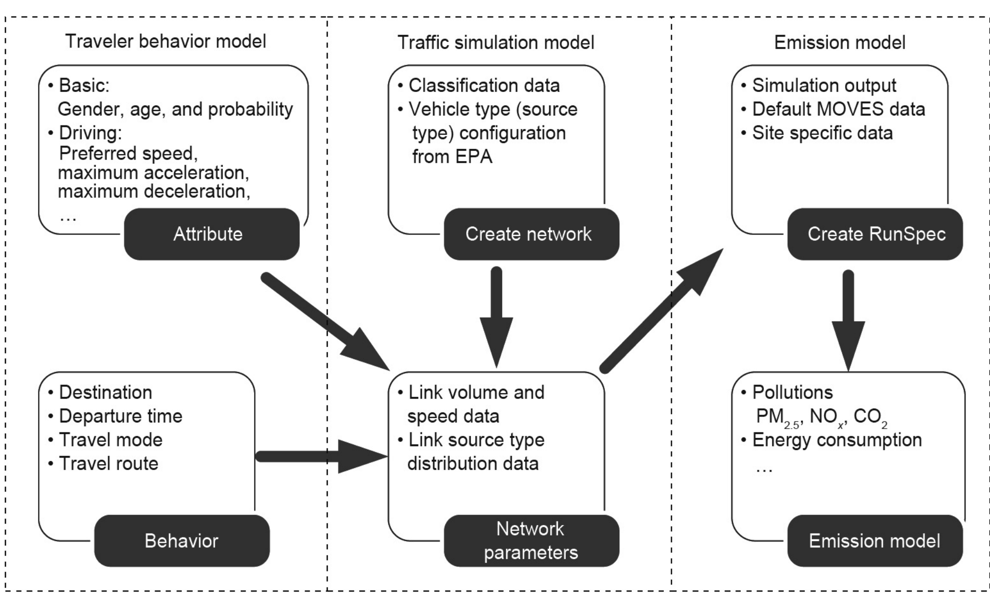

Fig. 1. Schematic of the comprehensive model. RunSpec: run specification.