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RESEARCH PAPER

Analysis of Micro-cars' Influence on Traffic Network Using a Microscopic Simulator

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Abstract: The environmental effects and network performance of mixed traffic, consisting of micro-cars and conventional cars, on a small network are investigated using microscopic simulations. After calibrating the simulation model, the effects of three assumptions concerning micro-car speeds are investigated using the model. First, the parameters needed for network performance evaluation are determined iteratively. The power required to meet total travel demand is then computed to predict emissions. A higher ratio of micro-cars in the traffic reduces emissions, as does a lower micro-car speed. To investigate travel efficiency, the main parameters used are average speed, total travel time and total delay time. The results suggest that a higher ratio of micro-cars has a positive effect on the network when their speed is the same as or a slightly lower than that of conventional cars, while a higher ratio of micro-cars has a negative effect when their speed is close to the average traffic speed of the base model. To obtain a suitable balance between desired environmental effects and road network performance, we recommend that the desired speed of micro-cars be set to 40–45 km/h on a small urban traffic network.

Key Words: urban traffic; micro-car; microscopic simulation; environmental burden; traffic network; VISSIM

1 Introduction

In recent years, there comes a transformational change in the automobile [1]. Many arising issues threatened the traditional car's supremacy, such as peak oil concerns, rising fuel prices, congestion, parking limitations, legislations verdict to reduce carbon emissions and other factors related to climate change. As a result, the micro-car concept is once again at the forefront of catering to the new challenges facing private automobiles. Mainstream original equipment manufacturers (OEMs) of automobiles around the globe have provided market momentum – with over 30 micro-car models introduced at the 2010 Paris Motor Show and 2011 Geneva Motor Show. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism presented guidelines in June, 2012 assuming that micro-cars would eventually play a daily role in transportation. The merits of micro-car were analyzed according to Japan's own situation, with the conclusion that experiments with micro-cars in various situations should be planned.

The definition of a micro-car has varied considerably in different countries. As defined in this research, a micro-car is less than three meters in length, lightweight, usually a two seater, and with two doors. This is smaller than the current Japanese "K" car designation and is much smaller than the definition of a small car in the USA.

Micro-cars generally have lower maximum speeds than conventional cars, so route choice behavior differs from vehicles with a normal maximum speed. Also, their lower speed may influence the behavior of other vehicle drivers, which without doubt will affect the traffic network as a whole. With the rising popularity of micro-cars, there is a need to explore their effects on traffic flow, traffic safety, the environment, etc.. The objective of this research is to analyze the influence of micro-cars on road network, from an environmental point of view, or in other words their marginal effect on traffic. Other aspects of their effect investigated in this research are network travel time, travel delay time and average speed.

There are two possible methods of implementing such an investigation. One is to carry out experiments, by placing a

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specific percentage of micro-cars into a real traffic situation, then measuring the desired data for analysis. Another is to simulate the situation. Simulation is an alternative that can be useful for complex and prospective hypotheses. In this research, it would be impossible to carry out experiments because the percentage of micro-cars on the roads cannot be controlled in the real world, while the desired data would be difficult to obtain. Thus the simulation path is chosen here.

VISSIM is a simulation package based on the microscopic level, using a psycho-physical car-following model to provide realistic driving behavior. The complex model that it implements offers many parameters that can be calibrated using measurement data from driving experiments. For this reason, VISSIM is chosen as the simulation tool in this research.

The rest of this paper is organized as follows. Section 2 reviews past discussions of micro-cars and researches using VISSIM to develop a simulation model or to perform simulations aimed at various traffic and transportation analyses. Section 3 outlines the process of development, validation and calibration of the base model for the simulations in the next step. Section 4 describes the basis for setting assumptions in this research and presents three different sets of assumptions based on diverse micro-car desired speeds. Section 5 analyzes the simulated total positive power output for total travel demand in the chosen small network (as described in Section 3) for various assumptions and micro-car proportions in the traffic. Section 6 is a discussion of the network performance evaluation results and an analysis of the effect of micro-cars at different micro-car percentages and desired speeds. Section 7 presents the conclusions of this research and looks at future prospects.

2 Literature review

Micro-cars are smaller and lighter than conventional cars. These physical characteristics are obvious ones that immediately lead to concerns about changes that the introduction of micro-cars will cause: will their smaller size and lower mass influence traffic on many aspects including: microscopic traffic flow, macroscopic flow, safety, etc. There have been investigations that discussed the relationship between car size/mass and traffic safety. Evans [2] examined the relationship between accidents per unit distance of travel and car mass using police accident reports for North Carolina. The accident involvement rate was found to increase with car mass when cars were driven by drivers of similar age. Sparrow and Whitford [3] gave a short history of small vehicle regulations in the U.S., analyzed the worldwide markets for such vehicles, and closed with a discussion on mini/micro car safety issues in urban traffic and on highways. Their conclusion was that mini/micro cars should not be dismissed as posing too great of a safety risk due solely to their size. This led to a series of discussions about the relationship between car size and safety. One of the above two researches is an analysis on historical statistic accident data, and another is a comprehensive policy analysis based on historical data. The effects of introducing micro-cars into the traffic flow from a congestion perspective have also been studied in previous research [4]. It was proved that micro-cars will relieve traffic congestion to some extent, and that a higher density of vehicles is possible due to the smaller size of the micro-car. Mu and Yamamoto [5] also calculated the energy consumption of traffic on both a highway segment and an arterial segment with a single traffic light at its midpoint for different ratios of micro-cars. From the results, the environmental effects of micro-cars were analyzed. Those two studies are a prediction of micro-cars' effect on assumed road segments, not traffic network. So, this research focuses on micro-cars' influence on a small downtown network by use of a simulator.

The simulation package VISSIM has been used for many traffic and transportation related research projects. Some of them are multi-class vehicle related, but until now, there is rarely research applying VISSIM to simulate mixed traffic with micro-cars. Since the aimed traffic studied in this research is a multi-class, there are similar setting options for such traffic type in VISSIM. So, researches on multi-class simulation with VISSIM are reviewed. Matsuhashi *et al*. [6] assess the situation of traffic composed by motorcycles, cars, buses, and bikes in Ho Chi Min, Vietnam, using image processing techniques and VISSIM. It was found that the high ratio of motorcycles in the network results in interference with other vehicles, therefore reducing the average speed of the traffic stream drastically. Furthermore, VISSIM has been used to derive the benefits of increasing the share of trips made by public transport. Velmurgan *et al*. [7] studied free speed profiles and plotted speed-flow equations for different vehicle types for varying types of multi-lane highways using VISSIM and subsequently estimated roadway capacity for four-lane, six-lane and eight-lane roads under heterogeneous traffic conditions with a reasonable degree of authenticity. Bains *et al*.[8] used VISSIM to model traffic flow on Indian expressways by evaluating the Passenger Car Equivalent (PCE) of different vehicle categories at different volume levels on flat terrain.

There are many researches that applies VISSIM to simulate assumed traffic situations for policy analysis, impact evaluation, etc. For instance, Zhang *et al*. [9] conducted a study using VISSIM to evaluate a proposed feedback-based tolling algorithm to dynamically optimize High Occupancy Toll (HOT) lane operations and performance.

There are also researches related to the validation of VISSIM. Fellendorf and Vortisch [10] presented the possibilities of validating the microscopic traffic flow simulation model in VISSIM, both on a microscopic and macroscopic level in homogeneous flows. Park and