An analysis of effects of microcars driven in transport network

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Effects of microcars on traffic and environment in urban transport network are analyzed. Two kinds of vehicles, conventional passenger car and microcar are assumed in the traffic stream. The predicted traffic assignment data of 2020 in Nagoya urban area are used to calculate the effect of introducing microcar on traffic flow. Traffic flow and energy consumption are computed for congestion, and environmental points of view. Results from a previous study simulated by a two-lane cellular automata model are used. The relationship between average speed and needed power is fitted. The result elucidate that traffic volume will increase as more microcars are assumed to be owned, and more microcars driven on road give a positive influence to the atmosphere as they give less emission when driving.

Key Words : microcar, traffic *flow, cellular automata model, simulation*

1. INTRODUCTION

Waste of fuel, increased air pollution and carbon dioxide emissions owing to increased idling, acceleration and braking are only a part of negative effects caused by traffic jam, which cause many losses to human. Nowadays, traffic congestion is a widespread problem. Traffic during peak hours in major Australian cities, such as Melbourne, Sydney, Brisbane and Perth, is usually very congested and can cause considerable delay for motorists. In USA, according to the 2011 Urban Mobility Report (Schrank and Lomax, 2011), congestion is a significant problem in the 439 urban areas. Congestion caused urban Americans to travel 4.8 billion hours more and to purchase an extra 1.9 billion gallons of fuel for a congestion cost of $101 billion compared to $21 in 1982. Traffic congestion is increasing in major cities and delays are becoming more frequent in smaller cities and rural areas.

Microcar is the smallest automobile classification usually applied to standard small car (smaller than city cars). As microcar has some similar characters with conventional car, also has some ones with motorcycle, we can say it is a kind of vehicle between the compared two, whatever the compared aspects are size, or speed, or some other characters. As microcar has lower maximum speed and smaller size than conventional car, it will be more convenient to use microcar for daily short to medium distance trip. For these trips, individuals do not need high speed. If there is not microcar, they mostly choose motorcycle, which have lower speed but more mobility, but the latter one cannot protect people from bad weather, as the microcar can meet all three requirements mentioned before for short to medium distance trip, it is the most appropriate vehicle for such kind of trip.

As microcars have different characters with traditional cars, such as maximum speed, acceleration, and dimension, there are many differences between the have-microcars traffic flow and the have-not-microcars one. Some research about introduction of microcar to road segment has been done[1)]. Series of simulation with both conventional cars and microcars running on road were done to analysis characteristics of traffic flow with microcars. Effects of microcar brought to traffic flow were analysed. It is demonstrated that driving microcars can avoid and relieve traffic congestion. Following the analysis of road segment, the research about microcar driven on transport network is necessary. As the era of Electric Vehicle (EV) is coming, and microcar has similar characteristics with EV, such as smaller footprint, less emission, less travel cost, and so on. So this research supposes that the route choice behaivour of EV and microcar is the same. And use the predicted traffic assignment data of 2020 in Nagoya urban area to analysis introduction of microcar, where EV is considered as microcar.

The rest of this paper is organized as follows. Section 2 gives a brief introduction of microcar. Section 3 describes the cellular automata model designed in this study. The results of simulation was listed and analysed in section 4. Finally, conclusions are summarized along with a discussion about future research issues in the last section.

2. MICROCAR CHARACTERISTICS

Typical microcars usually have some of the following features:

(1)Lightweight and deliver greatly improved fuel/efficiency over conventional cars, which result in cheaper running cost;

(2)Reduced spatial footprint allowing a higher vehicle density on road;

(3)Easy to park in tight spaces;

(4)Have some load carrying capacity;

(5)Can carry at least one passenger;

(6)Afford the same weather protection as a conventional car.

There are many advantages using microcar. Firstly, in some countries, microcars with a certain maximum weight are considered motorcycles and therefore car driving license is not needed (Austria, France, Germany, Spain, Italy). This assures a certain market for elder people who do not want to or who cannot pass a car driving license. Another advantage is the ease of parking. Some microcars can be parked perpendicular, where other cars park parallel, or be lifted by hand, like a motor scooter, to get into a tight spot. Thirdly, the small size improves handling by reducing the angular inertia. The Messerschmitt and Spatz have been described as much better than ordinary cars on snow and ice. Spare room on the road and ease of missing obstacles are also improved.

Table 1 Attributes of vehicles in reality

Attribute	Conventional car	Micro-car
Length(m)	4.0~5	2~3
Maximum speed(km/h)	200~260	60
Maximum speed on road(km/h)	80	60

Table 2 Set attributes in simulation

Attribute	Conventional car	Micro-car
Length(unit length, one unit length=4m)	2	1
Maximum speed on road(unit length/s)	7	5
Maximum speed on road(km/h)	100.8	72
Acceleration and deceleration(unit length/s^2)	1(4m/s^2)	1(4m/s^2)

Table 3 Set variables in simulation

Variable	Value
Boundary	Periodic
Unit time	1s
Time steps(s)	10000
Count time(s)	600
Total length(unit length)	200
Total length(m)	800

3. SIMULATION MODEL

The simulation result on road segment with microcars is used here. Relationship between average speed and power needed per km per vehicle is made into function to calculate the relative emission of traffic flow mixed conventional car and microcar.

A two-lane cellular automata model is founded before for segment analysis[1)]. In CA models, space, time and velocity is discrete. Roads are divided into unit cells locating one by one, and each cell is either occupied by a vehicle or empty.

(1) Basic parameters

There are 100 cells counting as 400-meters in length on a highway with two parallel lanes, the length of a cell is 4 meters, which is interpreted as the length of a microcar plus distance between vehicles in a jam. According to the attributes of vehicles in reality as shown in Table 1, it was assumed in the simulation as shown in Table 2 that one microcar occupies one cell, while one conventional car occupies two cells. Thus 8 meters is the headway space of a conventional car in a jam. One time step lasts 1 second, which is of the order of the reaction time of humans. In the present paper, velocity of conventional cars ranges from 0,…,v_{max}=7, as that of microcars is 0,…,v_{max}=5, corresponding a maximum speed of 72km/h for microcars and 100.8km/h for conventional cars.

In lane-changing step, vehicles may change lanes in parallel according to lane-changing rules and the system updates according to independent single-lane NaSch model(Nagel and Schreckenberg, 1992) in the speed updating step. The lane-changing rules are symmetric.

(2) Rules of lane-changing

Chowdhury et al. have assumed a symmetric rule[3)] set where vehicles change lanes if the following criteria are fulfilled:

A. $d_{t,n} < \min(v_{t,n} + 1, v_{max,n})$

B. $d_{t,n,other} > \min(v_{t,n} + 1, v_{max,n})$

C. $d_{t,n,back} > 5$

D. $rand\,() < P_{n,change}$

Where,

$d_{t,n,other}$: space headway of vehicle *n* and its front vehicle of the other lane at time *t*

$d_{t,n,back}$: space headway of vehicle *n* and its back vehicle of the other lane at time *t*

rand ():a random number between 0 and 1

$P_{n,change}$: lane-change probability of vehicle *n*

Referring to a comprehensive examination of naturalistic lane changes by Lee et al, drivers of fast vehicles are willing to change lane even when a vehicle is approaching from behind in the adjacent lane. So in this paper, the condition that the space headway of vehicle n and its back vehicle of the other lane was considered being more conformed to reality. Here if vehicle n meets the following three conditions, it can change lane.

A. $d_{t,n} < \min(v_{t,n} + 1, v_{max,n})$

Table 4 Attributes of vehicles in reality

Attributes	Range	Step
Rates of microcar	0%~100%	5%
Vehicle quantity	20~200	20
Brake probability	0.2~0.2	0

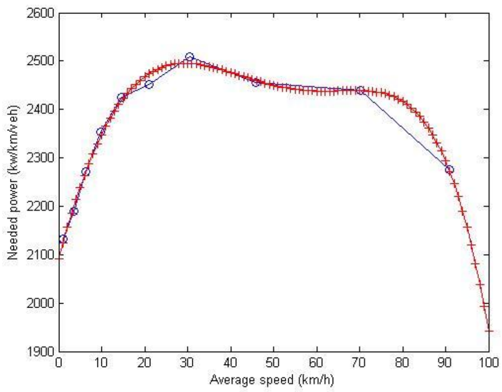

Fig.1 Simulated and Fitted Average speed-Needed power curves under microcar rates being 10% (blue one for simulated result and red one for fitted)

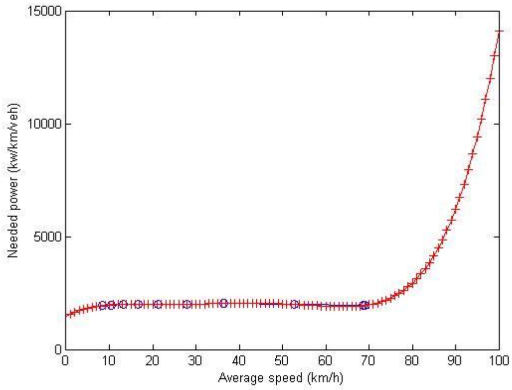

Fig.2 Simulated and Fitted Average speed-Needed power curves under microcar rates being 80% (blue one for simulated result and red one for fitted)

B. $d_{t,n,other} > \min(v_{t,n} + 1, v_{max,n})$

C. $d_{t,n,back} > \min(v_{t,n,back} + 1, v_{max,n,back})$

D. $rand\,() < P_{n,change}$

Where,

$v_{t,n,back}$: speed of the back vehicle in the other lane of vehicle *n* at time *t*

$v_{max,n,back}$: maximum speed of the back vehicle in the other lane of vehicle *n* at time *t*

(3) Rules of speed updating

We have the following setting of speed updating (9) rules, which are proposed by Nagel and Schreckenberg. The situation is updated in parallel for all vehicles:

$v_n = \min(v_{t-1,n}+1, d_{t,n} - 1, v_{max,n})$

$v_{t,n} = \max(0, v_n)$, with probability p_{brake}

$v_{t,n} = v_n$, with probability $1 - p_{brake}$

$x_{t+1,n} = x_{t,n}+v_{t,n}$

where,

t: current time step

$v_{t,n}$: velocity of vehicle n at time t

$x_{t,n}$: position of vehicle n at time t

$v_{max,n}$: maximum speed of vehicle n

$d_{t,n}$: space headway of vehicle n and its front vehicle at time t

p_{brake}: brake probability

4. SIMULATION AND RESULT

(1) Input and output

The input data of the simulation are the number of vehicles on the road ranging from 20 to 200 with step 20 with different rates of microcars (mentioned as r in following expression) whose range is from 0% to 100% with step 5% as shown in Table 4. Simulations in which brake probability (mentioned as p in following expression) equals 0.2 and lane changing probability equals 0.8 are done. As the simulation includes stochastic elements, each simulation was ran ten times to calculate the average values of the results to avoid randomness to some extent.

The output results are as follows:

average speed of all vehicles in the last counted 600 time steps;

needed power per vehicle per km.

(2) Simulation result

As predicted traffic assignment data of 2020 in Nagoya urban area have forecasted traffic speed and volume of every link. The speed is used to compute relative emission of all travelled vehicles of that link according to the relationship, which were got from road segment simulation. The function (Fig.1 and Fig.2, for example) between average speed and needed power is fitted with the two output of simulation.

5. PREDICTED RESULT IN NETWORK

In this study, the EV in predicted traffic assign-

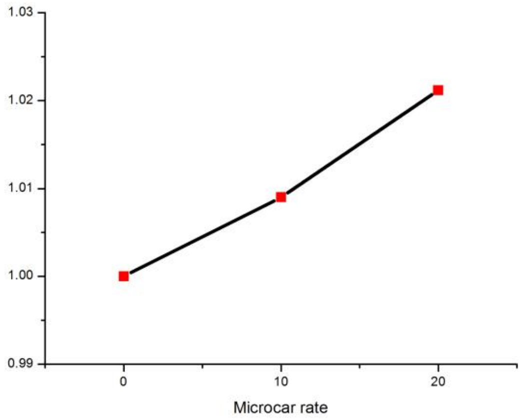

Fig.3 Volume rates in different microcar rate

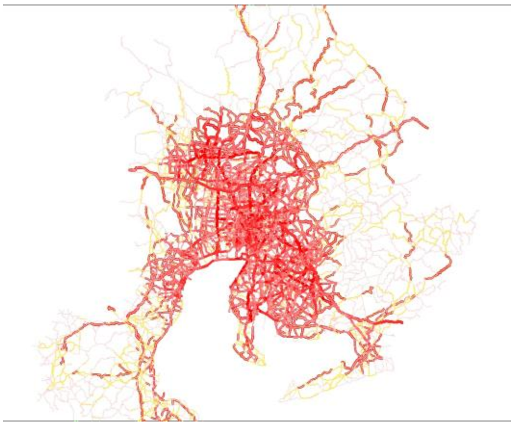

Fig.4 Volume in network when microcar rate equals 0%

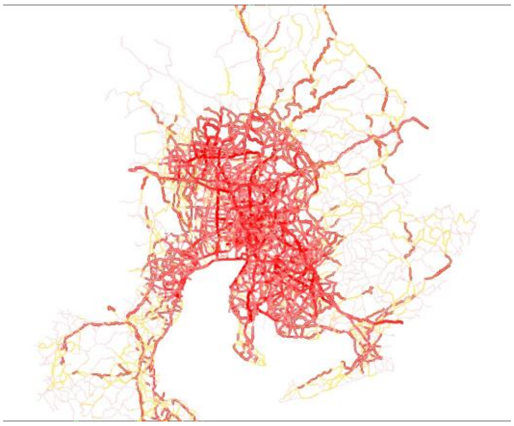

Fig.5 Volume in network when microcar rate equals 10%

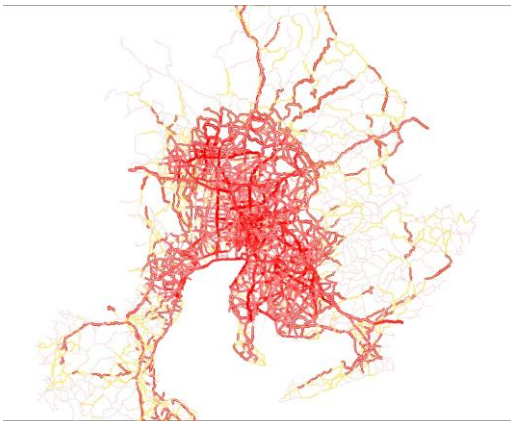

Fig.6 Volume in network when microcar rate equals 20%

ment data of 2020 in Nagoya urban area is considered as microcar, hence, microcar traffic volume in network equal that of EV, and microcar is assigned into links instead of EV. The needed power travelling in each link is calculated for emission analysis.

(1) Congestion analysis

Fig.3 shows that when there are more microcars in network, the total traffic volume will increase a little. Fig.4, Fig.5, and Fig.6 shows the volume in network when total microcar rate is 0%, 10%, and 20%.

(2) Environmental analysis

Fig.6 demonstrates that relative vehicle emission will obviously decrease after introduction of microcar, even the network volume has increased as microcar rate increases. That's because the microcar have lighter weight and lower maximum speed. Fig7, Fig.8, and Fig.9 reveal the relative emission in Nagoya urban area when total microcar rate is 0%, 10%, and 20%.

6. CONCLUSION

Microcar is more and more popular for its small size and better mobility especially in high population density areas. Research on influence from microcars to the traffic is necessary nowadays.

This study use the microscopic simulation result to analysis the effects of microcar in network point of view. Different rates of total microcar are assumed, and traffic volume and the relative emission in every link are got for congestion and environmental analysis. The result illustrates that if more residents have microcars, there will be more volume in traffic network, and the increased rate is very small. If there are more microcars on road network, the vehicle emission will decrease obviously. In conclusion, it is better to drive microcars to reduce vehicle emission.

This paper is a try to analysis the effects which the microcars bring to traffic network. The data of EV are used instead of microcar. So it's not so exact, even though there are many similar characteristics between the two. Furthermore, traffic assignment of microcar mixed with conventional car will be researched for more exact analysis.

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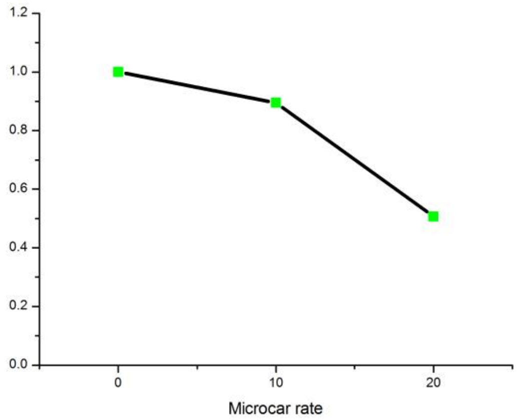

Fig.7 Needed power rate in different microcar rate

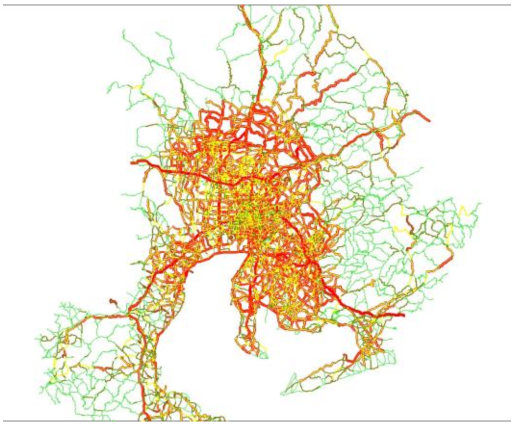

Fig.8 Needed power in network when microcar rate equals 0%

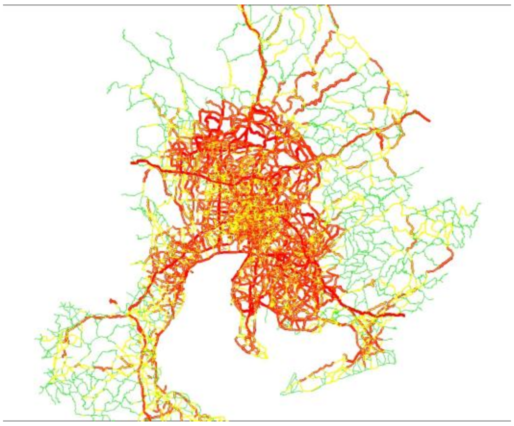

Fig.9 Needed power in network when microcar rate equals 10%

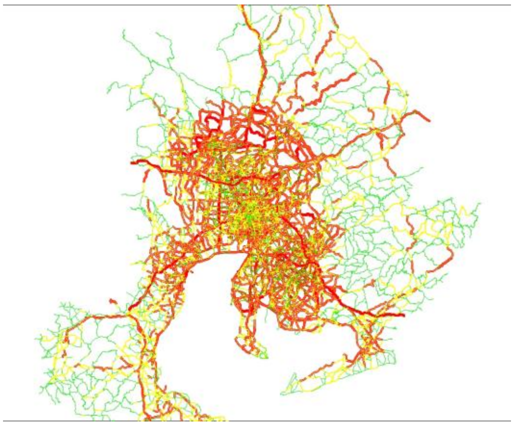

Fig.10 Needed power in network when microcar rate equals 20%

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