SEYYED MOHAMMAD SADAT HOSEINI, Ph.D. cand.
E-mail: Sadathoseini1@yahoo.com
MANOUCHEHR VAZIRI, Ph.D.
E-mail: manouchehrvaziri@yahoo.com
Sharif University of Technology
Civil Engineering Department
Tehran, Iran

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MODELLING DRIVERS' BEHAVIOUR AS A CRASH RISK REDUCTION PROCESS

ABSTRACT

The evermore widespread use of microscopic traffic simulation in the analysis of road systems has refocused attention on sub models, including car-following and lane-changing models. In this research a microscopic model is developed which combines car-following and lane-changing models and describes driver behaviour as a crash risk reduction process of drivers. This model has been simulated by a cellular automata simulator and compared with the real data. It has been shown that there is no reason to consider the model invalid for drivers' behaviour in the basic segments of freeways in Iran, during not-congested conditions. Considering that uncertainty of position of vehicles is caused by their acceleration or deceleration, a probability function is calibrated for calculating the presence probability of vehicles in their feasible cells. Multiplying the presence probability and impact of crash, crash risk of cells is calculated. As an application of the model, it has been shown that when difference between vehicles brake deceleration increases, the total crash risk increases.

KEYWORDS

lane changing, car-following, optimization, cellular automata

1. INTRODUCTION

Microscopic and macroscopic approaches can be used for traffic flow analysis. In microscopic approach, traffic behaviour is modelled based on the movement of vehicles individually, while in macroscopic approach, macroscopic traffic parameters such as density, volume and the average speed of vehicles are considered [1].

Many studies have been implemented considering movement behaviour of drivers in microscopic approach. In most of these studies, vehicles movements are defined in two models, car-following and lane-changing [2]. In these models car-following and lane-changing models are presented separately. Usually in car-following models, it is assumed that drivers tend to reach their desired speed in their current lane as they prevent any collision with their front vehicles [3]. When a driver is not able to reach its desired speed, lane-changing to the neighbouring lanes is considered [4,5]. Most of the lane-changing models are based on the assumption that drivers evaluate the current and adjacent lanes and choose the lane with higher average speed. Even in few models that consider untidiness of traffic flow and lack of drivers' observance to driving lanes, drivers' behaviour is modelled according to their position in the freeway driving lanes [6].

In this research a model has been implemented, which joins the car-following and lane-changing models as a crash risk reduction process. The proposed model is suitable for simulating the drivers' behaviour in basic freeway segments where drivers' destinations do not affect their movements.

A time-based simulation software is provided that uses cellular automata to simulate traffic behaviour. In cellular automata a basic freeway segment is divided into cells. Individual vehicles in each simulation time step occupy single cells and their movements in these cells describe the movement of the vehicles on the freeway [7,8]. Cellular automata are used for modelling pedestrian walking behaviour as a discrete choice model [9], where there are no regulations and no lane to be considered. It has been shown that drivers' behaviour in many countries can not be modelled by the traffic regulations and drivers do not consider driving lanes [10,11]. The proposed model is based on the realities of the drivers' behaviour on the freeways of such countries.

There are many studies that use image processing techniques for detecting the position of vehicles to be used for calibrating and validating the microscopic traffic models [12]. In this research, an image processing computer program has been invented for determining the position of vehicles in the images taken from the motorway. The data is used for calibrating and evaluating the proposed model.

A new concept for measuring crash risk of vehicles has been introduced, named total risk. Total risk is the sum of crash risk on the path of the considered vehicles. It has been shown that when difference between vehicles characteristics, like brake deceleration, increases, crash risk increases and vice versa.

This research has been carried out in four major phases: formulation of the proposed model, preparation of an image processing system for data collection of real positions of vehicles, preparation of micro simulation program for simulating the proposed model, evaluation, and measuring crash risk using the proposed model.

2. MODEL STRUCTURE

In this section, the structure of the proposed model is presented. The proposed model combines lane-changing and car-following models as an optimization process for increasing the speed and decreasing the crash risk. The algorithm of the proposed model is shown in Figure 1.

As can be seen in Figure 1, drivers calculate the presence probability of their feasible cells. Then crash risk of feasible cells is calculated and the cell with lower risk is selected to go into the next time step. After choosing the cell with lower risk, the driver must adjust his speed to the maximum safe speed of the chosen cell with respect to the deceleration or acceleration of their vehicle. If the current speed of the vehicle is less than the maximum safe speed, the driver will increase the speed with respect to the acceleration rate of their vehicle. If the current speed of the vehicle is more than the maximum safe speed, the driver will decrease the speed with respect to the deceleration rate of their vehicle. The next sections describe the calculation of maximum safe speed and crash risk of cells.

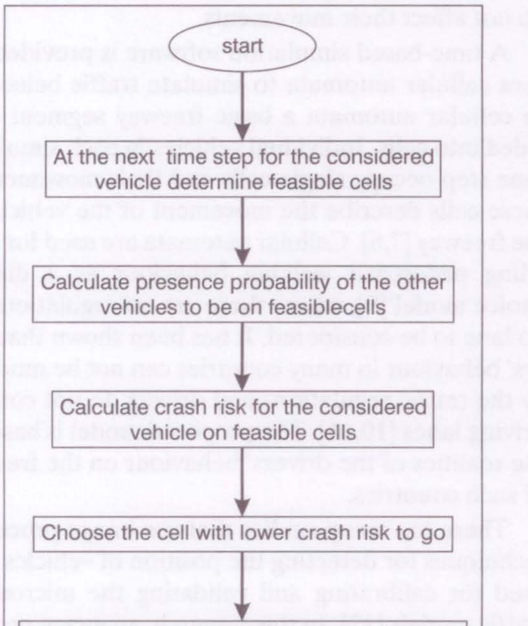

Figure 1 - Applied algorithm in the proposed model

2.1 Maximum safe speed

Maximum safe speed, V_{MSS}, of a cell is the maximum speed that a vehicle can reach on that cell avoiding collision with the front vehicle. Maximum safe speed of a cell is determined by the position and speed of its front vehicles. A function must be defined for V_{MSS} value of each cell.

Suppose vehicle 2 is following vehicle 1 and their speeds are V_2 and V_1 respectively, the distance between vehicles is d meter and L is the length of the front vehicle. It is necessary to calculate the safe distance for reducing the probability of collision between vehicles.

If the front vehicle sees an obstacle and brakes at t_0; vehicle 2 will brake after reaction time τ at $t_0+\tau$. In order to prevent the collision between the vehicles, it is important that there exists a safe distance between vehicles according to their speed and brake deceleration.

Considering the movement equation of vehicles for avoiding collision between them, equation 1 must be applied, where a_1 and a_2 are the brake deceleration of vehicle 1 and 2 respectively.

$$L+V_2\tau+\frac{V_2^2}{2a_2}=\frac{V_1^2}{2a_1}+d \tag{1}$$

Equation 2 shows the maximum safe speed of vehicle 2 for prevention of accident.

$$V_{MSS}(x,y,ID,t)=V_2=-a_2\tau+ \\ +\sqrt{a_2^2\tau^2-2a_2\left(L-d-\frac{V_1^2}{2a_1}\right)} \tag{2}$$

Where $V_{MSS}(x, y, ID, t)$ is the maximum safe speed of cell (x, y) for vehicle ID at time t. In this way, the maximum safe speed of a cell can be calculated using the distance between that cell and its front vehicle, d, speed of the front vehicle, V_1, and brake deceleration of the two vehicles, a_1 and a_2.

2.2 Crash risk

The idea of risk is complex, but conventionally its definition has been consistent, risk can be defined as a measure of the probability and impact of adverse effects [13]. Crash risk is calculated by multiplying the impact and probability of crash. In this research, crash risk of a cell for vehicle ID is the probability of collision between vehicle ID and any other vehicle in that cell multiplied by the impact of collision between them. The impact is set to 1 for all of the crashes. As there may be more than one vehicle that can cause a collision in a cell, the crash risk of vehicle ID in cell (x, y) at time t is the maximum risk created by other vehicles and can be calculated by equation 3.

$$Risk(x, y, ID, t) = Max\ \{Impact\ (x, y, ID, t).\ P(x, y, i, t)\}\ for\ all\ i \neq ID \tag{3}$$

where:

Risk (x, y, ID, t): crash risk for vehicle ID in cell *(x, y)* at time t,

Impact (x, y, ID, t): collision impact of vehicle ID in cell *(x, y)* at t which is set to 1 and,

P(x, y, i, t): presence probability of vehicle i to be in cell *(x, y)* at t.

An accident occurs when two vehicles take place in the same cell. Therefore, the collision probability is the probability of the presence of two vehicles in the same cell. Consider vehicle i to be in the cell $(x_i(t), y_i(t))$ at t and in the cell $(x_i(t+\Delta t), y_i(t+\Delta t))$ at $t+\Delta t$. The longitudinal and lateral position of vehicle i at $t+\Delta t$ can be calculated by the equations below:

$$X(i, t+\Delta t) = X(i, t) + V_x(i, t).\ \Delta t \tag{4}$$

$$Y(i, t+\Delta t) = Y(i, t) + V_y(i, t).\ \Delta t \tag{5}$$

where:

$V_x(i, t)$: longitudinal speed of vehicle i at t,

$V_y(i, t)$: lateral speed of vehicle i at t,

Considering independency of lateral and longitudinal positions of the vehicles, the presence probability of vehicle i in the cell (X, Y) can be calculated by the equation below:

$$P(i, X, Y, t+\Delta t) = P(i, X, t+\Delta t).\ P(i, Y, t+\Delta t) \tag{6}$$

where:

$P(i, X, Y, t+\Delta t)$: probability of vehicle i to be in the cell (X, Y) at $t+\Delta t$,

$P(i, X, t+\Delta t)$: probability of vehicle i to be in the longitudinal position X at $t+\Delta t$,

$P(i, Y, t+\Delta t)$: probability of vehicle i to be in the lateral position Y at $t+\Delta t$,

Longitudinal position of vehicle i at $t+\Delta t$ is calculated by the equation:

$$X(i,t+\Delta t) = X(i,t) + V_x(i,t)\cdot \Delta t + \frac{1}{2} a_x(i,t)\cdot \Delta t^2 \tag{7}$$

where $a_x(i, t)$ is the longitudinal acceleration rate of vehicle i at t and can be calculated by the equation:

$$a_x(i,t) = \frac{V_x(i,t+\Delta t) - V_x(i,t)}{\Delta t} \tag{8}$$

For calculating the longitudinal speed, longitudinal position of vehicle i at the time t, $X(i, t)$, is determined and compared with the longitudinal position of the same vehicle at $t+\Delta t$, $X(i, t+\Delta t)$. Longitudinal speed of vehicle i is calculated by the equation:

$$V_x(i,t) = \frac{X(i,t+\Delta t) - X(i,t)}{\Delta t} \tag{9}$$

For estimating the longitudinal position of vehicles, it is important to notice that drivers can calculate speed of other vehicles in the last time steps; but they do not know the change of speed in the next time step. Considering that acceleration is the change in speed; uncertainty of longitudinal speed is caused by the acceleration of vehicles. Supposing that the acceleration is distributed as a normal distribution with the average μ_{ax} and standard deviation σ_{ax}; longitudinal position of vehicle i at $t+\Delta t$ can be estimated by the following distribution:

$$X(i,t+\Delta t) \approx Normal_x(X(i,t) + V_x(i,t)\cdot \Delta t + \frac{1}{2}\mu_{ax}\cdot \Delta t^2, \frac{1}{2}\sigma_{ax}\cdot \Delta t^2) \tag{10}$$

Considering equation 10, the presence probability of vehicle i to be in the longitudinal position X can be calculated by the following equation:

$$P(i,X,t+\Delta t) = \int_{X-\frac{l_v}{2}}^{X+\frac{l_v}{2}} Normal_x(x, x_i(t) + V_x(i,t)\Delta t + \frac{1}{2}\mu_{ax}\cdot \Delta t^2, \frac{1}{2}\sigma_{ax}\cdot \Delta t^2)\cdot dx \tag{11}$$

Position of each cell is determined by the position of the centre of that cell. Each cell has a length which is equal for all of the cells and is shown by lv, therefore lower and upper boundaries of integral are determined as X- $l_v/2$ to X+ $l_v/2$.

In the same way, as it was mentioned about the longitudinal position; lateral position can be calculated by the following equation:

$$Y(i,t+\Delta t) = Y(i,t) + V_y(i,t)\cdot \Delta t + \frac{1}{2} a_y(i,t)\cdot \Delta t^2 \tag{12}$$

where $a_y(i, t)$ is the longitudinal acceleration of vehicle i at t and can be calculated by the following equation:

$$a_y(i,t) = \frac{V_y(i,t+\Delta t) - V_y(i,t)}{\Delta t} \tag{13}$$

For calculating the lateral speed, lateral position of vehicle i at time t, $Y(i, t)$, is determined and compared with the lateral position of the same vehicle at $t+\Delta t$, $Y(i, t+\Delta t)$. Lateral speed of vehicle i is calculated by the following equation:

$$V_y(i,t) = \frac{Y(i,t+\Delta t) - Y(i,t)}{\Delta t} \tag{14}$$

For estimating the lateral position of vehicles, it is important to notice that drivers distinguish lateral position of other vehicles in the last time steps; but they do not know the change of lateral position in the next time step. Considering that lateral acceleration is the change in lateral speed; uncertainty of lateral speed is caused by the lateral acceleration of vehicles. Supposing that acceleration is distributed as a normal distribution with the mean μ_{ay} and standard deviation σ_{ay}; lateral position of vehicle i at $t+\Delta t$ can be estimated by the following distribution:

$$Y(i,t+\Delta t) \approx Normal_y(Y(i,t)+V_y(i,t)\cdot\Delta t + \frac{1}{2}\mu_{ay}\cdot\Delta t^2, \frac{1}{2}\sigma_{ay}\cdot\Delta t^2) \quad (15)$$

Considering the equation, the presence probability of vehicle i to be in the lateral position X can be calculated by the following equation:

$$P(i,Y,t+\Delta t) = \int_{Y-\frac{W_v}{2}}^{Y+\frac{W_v}{2}} Normal_y(y, y_i(t) + V_y(i,t)\cdot\Delta t + \frac{1}{2}\mu_{ay}\cdot\Delta t^2, \frac{1}{2}\sigma_{ay}\cdot\Delta t^2)\cdot dy \quad (16)$$

The positions of cells are determined by the position of their centre. The widths of all of the cells are equal and shown by Wv, therefore lower and upper boundaries of integral are determined as Y- $W_v/2$ to Y+ $W_v/2$.

2.3 Vehicle acceleration and deceleration

When a vehicle chooses a cell in which to move in the next time step, it must adjust its speed to the maximum safe speed in that cell. This cannot be done immediately and must be done according to the vehicle acceleration or deceleration.

If the current speed of vehicle ID be less than the maximum safe speed, it can increase its speed with respect to its acceleration. In this way the speed of the vehicle in the next time step can be determined using equation 17.

$$V(ID,t+\Delta t) = V(ID,t) + a(ID)\cdot\Delta t \quad (17)$$

where:

$V(ID, t+\Delta t)$: speed of vehicle ID in the next time step,

$V(ID, t)$: speed of vehicle ID in the current time step,

Δt: duration of the time step,

$a(ID)$: acceleration rate of vehicle ID.

If the current speed of vehicle ID be more than the maximum safe speed, it must decrease its speed with respect to its deceleration rate. In this way the speed of the vehicle in the next time step can be determined using equation 18.

$$V(ID,t+\Delta t) = V(ID,t) - b(ID)\cdot\Delta t \quad (18)$$

where:

$b(ID)$: brake deceleration of vehicle ID.

3. DATA COLLECTION

Two sites, each one covering a basic segment of about 100 metres of Tehran-Karaj freeway, were used for videotaped observation. This freeway connects Tehran to a nearby city, Karaj. In the selected segments of the freeway, there are four moving lanes in each direction and each lane is 3.65 metres wide. The camera was installed on a bridge over the freeway and a good view of freeway was available.

The duration of observation was about 30 minutes in each site. The position, time, and kind of the vehicles passing the segments during the observation in every frame of the film are identified and stored in a table using an image processing system [10]. In the image processing program, the considered freeway has been divided into windows which are used for detecting the vehicles on the freeway. The size of these windows is determined as if they can produce a complete view of the considered freeway with enough resolution and accuracy. Windows are arranged in horizontal rows. Each row contains 12 windows. Considering the nonlinear projection of 3D images to 2D images, vertical distances between rows of windows are determined by a nonlinear equation [10]. Figure 2 shows the windows on a sample image of Tehran-Karaj freeway.

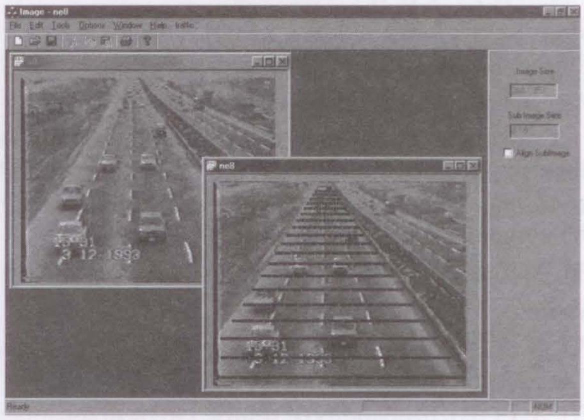

Figure 2 - Windows on a sample image of Tehran-Karaj freeway

Windows positions are determined as if all of the distances between rows of the windows show a specified distances on the freeway. So each window can be matched to a specified space on the street. Each window is processed for detecting whether there is a vehicle in it or not. Vehicles positions in each frame are saved in a table in the form of (ID, X, Y, K, t) where:

ID: identity number of vehicles,

X, Y: longitudinal and lateral position,

K: vehicle type according to its size (for truck or bus K=1, for private car K=0)

t: time of observation.

Using the table of vehicles positions, microscopic traffic characteristics of the vehicles can be determined. For example, the speed of a vehicle ID at time t could be calculated using the position and time of that vehicle by equation 9. Macroscopic parameters like average speed may be calculated by averaging the speed of vehicles.

4. MODEL CALIBRATION

For calibrating the maximum safe speed, V_{MSS}, in equation 2, it is assumed that for all the vehicles deceleration rate is 5 m/s^2 and reaction time is 2 sec [14]. In this way, equation 2 can be calibrated as follows:

$$V_{MSS}(ID,X,Y,t) = -10 + \sqrt{50 + 10d + V_i^2} \qquad (19)$$

Using the above equation, maximum safe speed of cells can be calculated according to its distance to the nearest ahead vehicle, d, and speed of the nearest ahead vehicle, V_i.

For calibrating the presence probability of vehicle i in longitudinal position X, $a_x(i, t)$ is calculated for different vehicles, i, at different times t. In this way, a sample of a_x is prepared and the frequency of different values of a_x in the sample is calculated. It is shown that frequency of a_x can be fitted as a normal distribution with average $\mu_{ax}=0$ and standard deviation $\sigma_{ax}=82$. Considering $l_v=5$ equation is calibrated as equation 20.

$$P(i,X,t+\Delta t) = \int_{X-2.5}^{X+2.5} Normal_x(x, x_i(t) + V_x(i,t)\cdot\Delta t +, 41\cdot\Delta t^2)\cdot dx \qquad (20)$$

For calibrating the presence probability of vehicle i in lateral position Y, $a_y(i, t)$ is calculated for different vehicles, i, at different times t. In this way, a sample of a_y is chosen and the frequency of different values of a_y in the sample is calculated. It is shown that frequency of a_y can be fitted as a normal distribution with average $\mu_{ay}=0$ and standard deviation $\sigma_{ay}=3$. Considering $W_v=2$ equation is calibrated as equation 21.

$$P(i,Y,t+\Delta t) = \int_{Y-1}^{Y+1} Normal_y(y, y_i(t) + V_y(i,t)\cdot\Delta t +, 1.5\cdot\Delta t^2)\cdot dy \qquad (21)$$

Although acceleration and deceleration rate varies for different kinds of vehicles; vehicle acceleration is set to 1.2 m/s^2 and deceleration is set to 5 m/s^2 [14] in equations 17 and 18.

5. PREPARED MICROSCOPIC TRAFFIC SIMULATION SOFTWARE

A time-based simulation software is prepared for simulating the movement behaviour of vehicles using the proposed model [10].

In the prepared simulation software the freeway is divided into some cells, each cell almost equal to the length of a private car 5 metres long and 2 metres wide. In each time step, each vehicle occupies a cell and the movement of vehicles is described by their movements in the cells. The vehicles are created in the time and location that they have been seen for the first time in real data. Only the first position of a vehicle in simulation program is the same as in the real data and the positions in the subsequent time steps are calculated using the proposed model.

Figure 3 shows a moment of the simulation software as it is executing the simulation. Figure 3 shows the existence of vehicles in cells specified with the change of cells colour and ID number of vehicles in the cells.

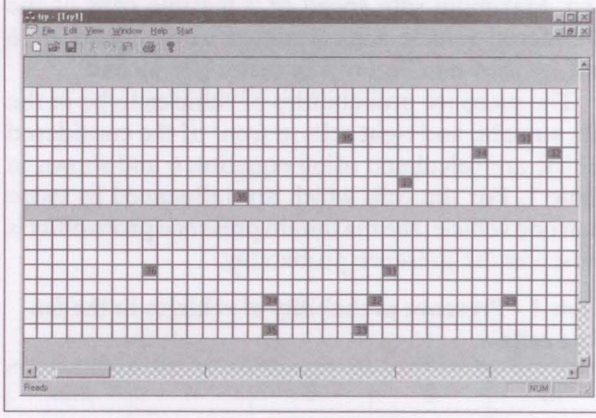

Figure 3 - Simulation and real position of vehicles

In the upper part of the Figure the vehicles on the freeway are simulated and in the lower part of the Figure the vehicles on the freeway are positioned as they have been observed in the real world using the collected data. In this way, the real world and the simulation model can be compared and verified visually.

6. AN EXAMPLE OF DRIVERS' BEHAVIOUR

Figure 4 shows an example of moving vehicles in a segment of freeway in which vehicles are moving from right to left. The considered vehicle has been shown in the black cell by number 1; other vehicles are shown in gray cells. Each cell is a 5 by 2-metre rectangle on the freeway surface. The considered section is a 4-lane freeway, each lane about 4 metres wide. In this way the width of the freeway is separated into 8 cells.

In this example, the speed limit is 120 km/h. The speed of vehicles 3 and 4 is 108km/h and the speed of vehicles 1 and 2 is 72km/h. Assuming the time step to be 0.2 second, vehicles 3 and 4 will move about 6 metres and vehicles 1 and 2 will move about 4 metres in the next time step. The cells of the freeway are 5

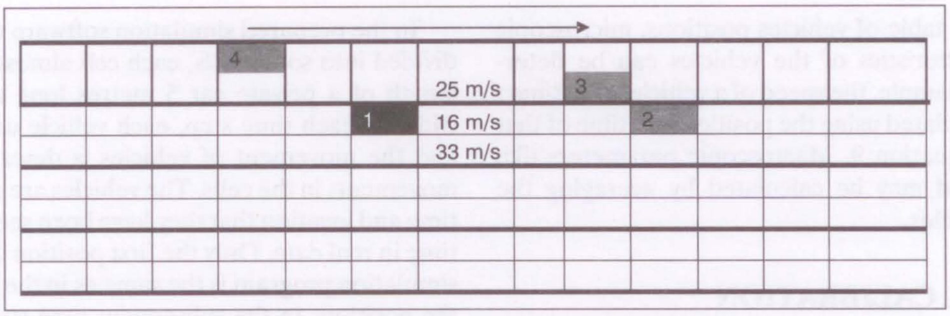

Figure 4 - Maximum safe speed of feasible cells

metres long so in the simulation all of the vehicles move one cell forward, but 1 metre will be added to the distance travelled by vehicles 3 and 4 in the next time step and 1 metre will be differentiated from the distance travelled by vehicles 1 and 2 in the next time step. Maximum safe speed of 3 feasible cells of the considered vehicle are calculated using equation 26 and are shown in Figure 4 in metre per second.

The presence probabilities of vehicles to be in the left, straight, and right cells in front of the considered vehicle are calculated using equation 6 and shown in Table 1. For the cells which are influenced by more than one vehicle, the maximum presence probability is chosen as the presence probability.

Table 1 - Presence probability of vehicles in the feasible cells

ID	2	3	4	max
Left	1.96E-25	8.35E-17	1.77E-06	1.77E-06
Straight	3.72E-24	4.41E-18	1.06E-11	1.06E-11
Right	1.96E-25	2.65E-23	0.00E+00	2.65E-23

Multiplying the impact and presence probability, the risk value of feasible cells has been calculated and shown in Figure 5.

Vehicle 1 considers crash risk of its feasible cells and chooses the cell with the lower risk. As can be seen, the cell in the right of the vehicle has the lower risk and will be chosen in the next time step.

Maximum safe speed of the chosen cell is 33m/s or 120km/h, considering that the speed of vehicle 1 is 72km/h or 20m/s, vehicle 1 increases its speed. Assuming acceleration rate to be $1.2m/s^2$ and time step to be 0.2 second, vehicle 1 will decrease its speed about (0.2*1.2=) 0.24m/s in the next time step. In this way, vehicle 1 will move to the cell in front of it and will decrease its speed to 19.76m/s or 71.14km/h in the next time step.

7. VALIDATION OF THE PROPOSED MODEL

As it was mentioned in the data collection section, the duration of observation was about half an hour in each of the two sites, collected data of the first site is used for calibrating the model and the second site is used for validating the model. Model validation is done both at the microscopic and macroscopic level. At the macroscopic level, the average speed and the number of lane changes in the simulation and in the real world are compared and at microscopic level, longitudinal and lateral positions of vehicles are compared.

The duration of observation in the second site is divided into 6 intervals each one about 5 minutes. The simulation program is executed for each of the intervals individually. The vehicles are created in the simulation program, in the time and position that they have been seen for the first time in the real world.

There are different methods for validating the microscopic models of traffic, [15]. In this research, paired observation test is used for validating the proposed. Test statistics of the paired observation test is calculated by the following equation:

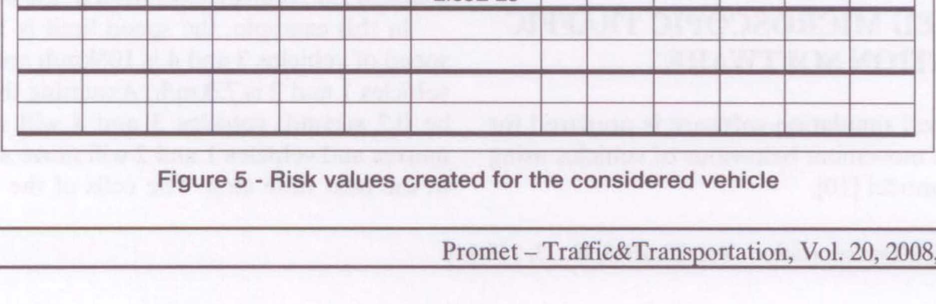

Figure 5 - Risk values created for the considered vehicle

$$t_{po} = \frac{\bar{d}}{S_d/\sqrt{n}} \qquad (22)$$

where:

t_{po}: test statistics,

$\bar{d}$: average of difference between real and simulation pairs,

S_d: standard deviation of difference between real and simulation pairs,

n: number of pairs.

If $|t_{po}| > t_{\alpha/2,\ n-1}$, validation of the model is rejected at $\alpha\%$ level of confidence; otherwise, there are no reasons to consider the model invalid [16].

7.1 Macroscopic validation

The average speed and number of lane changes in the real world and in the simulation program are calculated for each of the 6 intervals. Then, the difference of the average speed and the number of lane changes between real and simulation is calculated.

The mean and standard deviation of difference of average speed between real and simulation is -16.7 and 19.7 respectively. In this way, t_{po} can be calculated as

$$t_{po} = \frac{-16.7}{19.7/\sqrt{6}} = -2.07.$$

Considering $|t_{po}| = 2.07 < t_{\alpha/2,5} = 2.57$ there are no reasons to consider the model invalid at the level of confidence 95% for simulating the average speed. In the same way, the average and standard deviation of difference in the number of lane changes between real and simulation is -0.6 and 3.1 respectively. In this way, t_{po} can be calculated as

$$t_{po} = \frac{-0.6}{3.1/\sqrt{6}} = -1.15.$$

Considering $|t_{po}| = 1.15 < t_{\alpha/2,5} = 2.57$ there are no reasons to consider the model invalid at the level of confidence 95% for simulating the number of lane changes of vehicles.

7.2 Microscopic validation

Using the gathered data of longitudinal position of vehicles in one of the 5-minute intervals for 69 vehicles positions and comparing them with the simulation data, t_{po} is calculated for longitudinal position as

$$t_{po} = \frac{0.132}{0.486/\sqrt{69}} = -2.25.$$

Considering $|t_{po}| = 2.25 < t_{\alpha/2,68} = 2.7$ there are no reasons to consider the model invalid at the level of confidence 95% for simulating the longitudinal position.

In the same way, using the gathered data of lateral position of vehicles in one of the 5-minute intervals and comparing them with the simulation data, t_{po} is calculated for lateral position as

$$t_{po} = \frac{-0.044}{0.61/\sqrt{69}} = -0.597.$$

Considering $|t_{po}| = 0.597 < t_{\alpha/2,68} = 2.7$ there are no reasons to consider the model invalid at the level of confidence 95% for simulating the lateral position.

8. EFFECT OF VEHICLE CHARACTERISTICS ON CRASH RISK

The collision between vehicles is a rare event and in the collected sample data, there is no collision to be observed. However, a driver's behaviour is not based on the real collisions of that driver, but it is based on the risk of collision considered by that driver. In this research, micro simulation is used for studying the effect of differences between vehicle characteristics on the total risk of collision.

Total risk is the sum of risk of all of the cells which are occupied by the considered vehicles during the simulation and can be calculated using equation 23.

$$TotalRisk = \sum_{ID=1}^{N} \sum_{t=1}^{T} Risk(x, y, ID, t) \qquad (23)$$

where:

N: number of considered vehicles,

T: number of time steps during the simulation.

In this research, total risk is used as a parameter for measuring crash risk in the considered segment of freeway. In the previous sections, it is assumed that different vehicles have the same brake deceleration and the model has been calibrated based on this assumption. In this section differences between vehicle characteristics and their effect on the total risk of collision is studied.

In equation 19 it is assumed that $a_1 = a_2 = 5$ m/s^2; here brake deceleration is assumed to be different for different vehicles and distributed as a normal distribution function as shown in equation 24 .

$$b(ID) = normal(\mu_b, \sigma_b) \qquad (24)$$

where:

b(ID): brake deceleration of vehicle ID,

μ_b : average of brake deceleration of vehicles,

σ_b : standard deviation of brake deceleration of vehicles.

Considering $\mu_b = 5$ m/s^2, total risk is calculated in 10 runs of simulation for different values of σ_b . For different values of σ_b simulation is executed for ten times and total risk is calculated using the prepared simulation software. In Figure 6, total risk average in 10 runs for different values of σ_b has been shown.

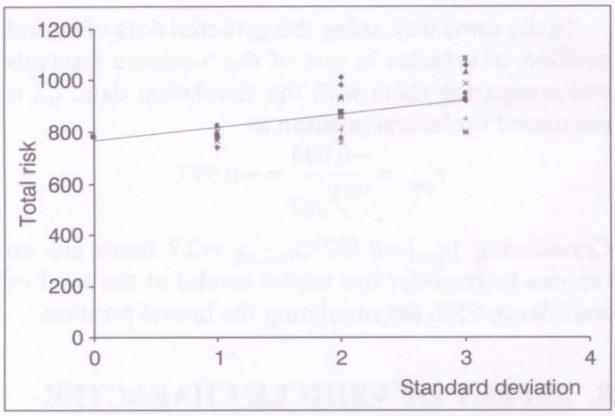

Figure 6 - Relation between total risk and standard deviation of brake deceleration

As can be seen in Figure 6, total risk average increases when the standard deviation of brake deceleration increases. It means, when difference between vehicle brake deceleration increases, more crashes are expected.

9. CONCLUSION

A cellular model is proposed for simulating the driving behaviour on freeways of Iran. The freeway has been divided into cells. Every time step, the drivers check their feasible cells and choose the cell with lower risk. This model which is based on the crash risk reduction process of drivers is micro simulated and it is shown that the proposed model is valid for describing the driving behaviour on freeway basic segments.

In this research a new concept for measuring crash risk is introduced. Considering that uncertainty of vehicles positions is caused by their acceleration and deceleration in different times, a probability distribution function is calibrated for calculating the presence probability of vehicles on feasible cells of freeway. Multiplying the presence probability and impact of crash, crash risk of cells is calculated.

Maximum safe speed of vehicles is calculated using the laws of motion. For calibrating the maximum safe speed, the reaction time and the vehicle acceleration rate are selected from the previous studies [14].

Using the proposed model, total risk is introduced as a parameter for measuring the risk of collision and it has been shown that when difference between vehicles characteristics, such as brake deceleration, increases, the crash risk increases and vice versa. Therefore, it can be advisable to a country to use vehicles with similar characteristics to decrease the rate of accidents.

This study deals with basic freeway segments where drivers' different destinations for exiting or entering the freeway or continuing the straight way do not affect their movement behaviour. For the future studies the destination factor could be added to the risk reduction process. In this way, the proposed model could be used not only in the basic freeway segment, but also in the other parts of the road networks.

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