Agent-based modelling and simulation of rear-end collisions on the highway

1. Introduction

With more highways being built, a huge number of people choose travelling by car. Although the road facilities are adequate nowadays, there are still many car accidents on the highway, especially the rear-end collisions. From researches, the main factors that cause the traffic accidents are always human factors. This report is aim to find how human factors impact the rear-end collisions by using ABM model, and focus on the relationship between different human factors and the number of accidents over a certain time.

2. Literature Review

Benhamza et al. (2012) develop a multi-agent based traffic simulator by using agent-based modeling in the paper named 'AGENT-BASED MODELING FOR TRAFFIC SIMULATION'. This traffic simulator shows the traffic situation of a region by representing the objects (vehicles, drivers and traffic lights) and the represents of environment (road, lanes and intersections). The simulator describes how traffic jam happen at the crossings, and focus on avoid the traffic jam by regulating traffic flow and optimizing transportation modes. Apart from traffic jam, traffic accidents are also one of the most unwilling things drivers face on the road, especially on the highway (high speed will lead to more serious car accidents).

Vogel and Bester (2005) analyse the reasons of accidents on a highway (in South Africa which stretches 25km). The result shows that the biggest factor of traffic accidents is human factor (including negligence and dangerous overtaking). Besides, there are also environment factors (including rush hour traffic and inadequate facilities) and vehicle factors. From 1999 to 2003, most accidents are caused by negligence (65.8%). As for the factors cause negligence, it should be unconcentration and fatigue. Besides, less patience of drivers will cause a dangerous overtaking.

3. Method

The factors this report would like to analyse are drivers negligence and dangerous overtaking, the attributes of unconcentration and fatigue will cause negligence and less patience will cause dangerous overtaking. This report will use 'negligence score' as the representation of unconcentration and fatigue value and will use 'patience' to represent patience value. Therefore, the report

will be divided into two parts: a) single lane for 'negligence score' so that there is no overtaking on the road and b) four lanes in order to consider the overtaking.

3.1 Single lane

This situation do not need to consider lane changing so the patience value will not be used for this part. The number of cars is 12 (the maximum number) for this part because this analysis is to consider the heavy traffic situation. Using BehaviorSpace tool to compare the number of accidents with maximum unconcentration and fatigue values between 0 and 15. In order to get an accurate result, the model will repeat each combination 50 times and use the mean value. The result shows the relationship between score and the number of accidents. The boxplot shows that there is no outliers so the points can be shown by scatter diagram.

Figure 1 shows the scatter diagram of score and the number of accidents. From the diagram, the shape of the points are curved, so the logarithm can be used for the values of score.

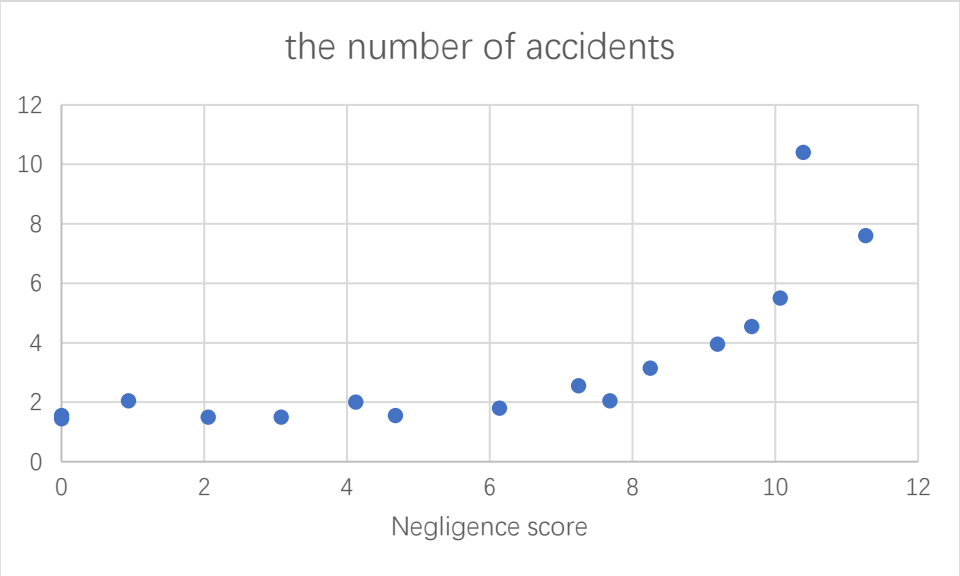

Figure 1. Scatter diagram

Figure 2 shows the simple linear regression of log-score. Fitted regression equation is y = 0.0518x - 0.063, where Y denotes the negligence score and x denotes the number of accidents. R^2 = 81.6% means that the regression explain 81.6% of the variation in the data. This percentage is really high, indicating that there is strong relationship between the number of accidents negligence score.

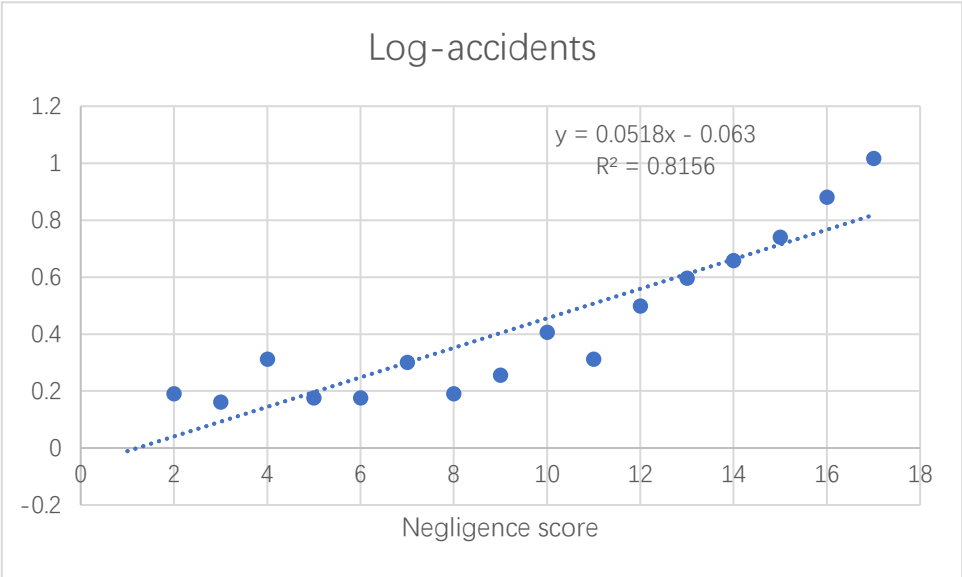

Figure 2. Linear regression

3.2 Four lanes

After setting the maximum number of cars (12 for each lanes and totally 48), the maximum unconcentration and fatigue value will be set for 5. The independent variable for this part's analysis is maximum patience value, so another independent variable 'Max-Unconcen-Fatigue' will be set as a small number 5 to avoid the impact to the final result.

By using BehaviorSpace tool, setting the maximum patience value from 10 to 100 in increments of 10, and set repetition to 50 times.

Figure 3 shows the scatter diagram of patience value and number of accidents. It is clearly shown in the diagram that there is an outlier: when patience value is 0, the number of accidents is 22.5. This point indicates that if all the drivers do not have patience, all of the drivers will change lanes immediately when there is a car ahead, which will cause a huge number of accidents. However, apart from this special point, all of the other points do not show an obvious relationship. The number of accidents are around 6 no matter what patience value is.

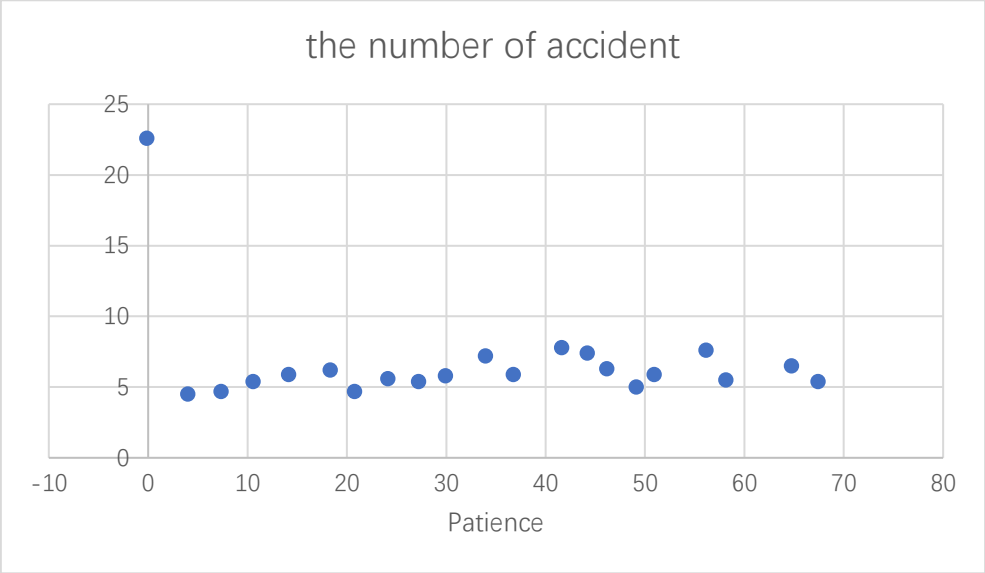

Figure 3. Scatter diagram

Therefore, drivers' patience do not impact the number of accidents in most of the situations, however, when a driver's patience equal to zero, there will be a significant influence to the number of accidents.

4. Conclusion

By using the results from the ABM model, the linear regression analysis showed that there was a strong relationship between negligence score and the number of accidents, indicating that unconcentration and fatigue of drivers strongly impact the driving safety. Besides, there is no strong relationship between patience and the number of accidents. However, when a driver do not have any patience, the possibility of an accident will increase significantly. The patience considered in this report is the initial value of drivers, but the patience value will change over time. For instance, a driver's patience will decrease when there is traffic jam, and also may lead to accidents when it decrease to zero. Therefore, all of the unconcentration, fatigue and patience values will lead to traffic accidents, and the first two attributes impact most.

Word Count: 936

Reference list:

Benhamza, K., Ellagoune, S., Seridi, H., & Akdag, H. (2012). AGENT-BASED MODELING FOR TRAFFIC SIMULATION. *Courrier du Savoir,* 11, pp.51-56

Vogel, L. & Bester, C. J. (2005). A Relationship Between Accident Types and Causes. *Southern African Transport Conference,* 7 (11-13), pp.233-241

Appendix: ODD description

What human factors cause a rear-end collision on the highway?

- Description of ABM using the ODD protocol

1. Purpose

The purpose of this Agent-Based Modelling (ABM) is to simulate the rear-end collisions on a highway (pedestrians and crossings will not be considered in this model), and focus on the reasons of individuals and the interaction between individuals. This model aims to give suggestions for drivers driving on highways.

2. Entities, state variables, and scales

The model consists of two types of entities: agents and road facilities.

As it shown in Table 1, the agents are characterized by fatigue value, unconcentration value, speed, top speed, patience value and sight. Individual behaviors include move forward, choose new lane when there is a car ahead and no car on the nearby lanes, move to target lane and collision.

Parameter	Explanation	Value or Range
Unconcentration value	The higher value they had, the less attention they paid to.	0 - 10
Fatigue value	Higher fatigue value will lead to a higher probability of accident.	0 - 10
Speed (km/h)	Speeding may lead to accidents.	60 - 120
Top speed	The maximum speed drivers wish to drive at.	60 - 120
Sight (m)	How far the drivers can check ahead	2000
Patience value	Drivers will change lanes when they lost patience	0 - 100

Table 1. Parameters of agents

The road facilities are characterized by the number of lanes. Less number of lanes will cause traffic congestion, which may lead to rear-end accidents.

Some of the values of agent characteristics are randomly, such as speed and top speed. The sight value is constant and users can change patience value as they wish. Besides, users can set the maximum values of unconcentration, fatigue and vehicle fault, and the model will randomly give a value of the attribute between 0 and he maximum value.

The model scale is 120*8, each unit of gird represents a 100m*100m area in real world. Therefore, the total length of the road that model represents is 12km in real world. Each tick represents 3 seconds. The speed of the cars is 60 - 120km/h, so each agent will go along the road about 120 – 240 ticks. Simulation runs for 2 hours (2400 ticks).

3. Process overview and scheduling

The model starting with a group of vehicles on a highway and including following actions executed each time step:

Check vehicles number: The number of vehicles on the highway should be constant in each step, when some broken vehicles leave the road, we will add same number on the road.

Check vehicles in accidents: The broken car will be cleaned every 5 minutes.

Move forward: Vehicles will speed up if there is no car ahead and will slow down if there is a car ahead.

Choose a new lane: Vehicles will choose a new lane if there is a car ahead and no car on the nearby lane.

Move to target lane: If there are cars ahead the vehicle, and the driver have no patience, then change the lane.

Rear-end collision happen: When the distance between two vehicles is zero, collision happen. After the collision, the vehicle will not move anymore, which may influence the vehicles behind.

Output: The broken cars will ‘die’ every 5 minutes, and we will count this number as accident number.

Figure 1 shows the flow chart for one step.

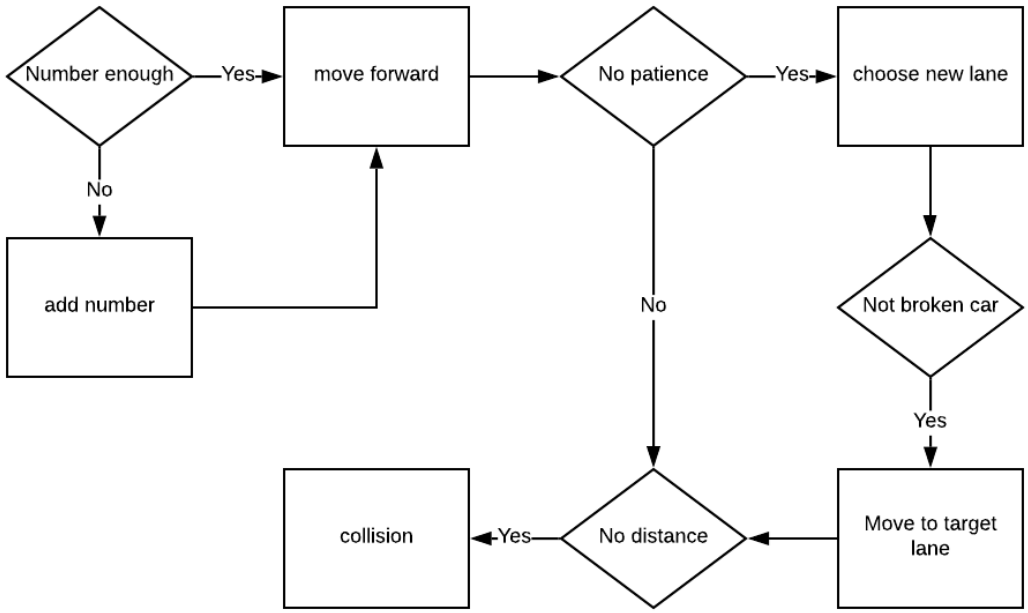

Figure 1. Flow chart

4. Design concepts

4.1. Emergence

The model's primary output is the number of vehicles in accidents in 2 hours, which emerges from the accident conditions. The accident conditions are determined by (a) values of agents, (b) values of road facilities and (c) effect of accident vehicles on the road.

4.2. Interaction

Direct interaction occurs when an accident happen, the accident will affect the behavior of the vehicles behind and may cause a pileup. When an accident happen, the vehicles behind need to slow down and change lane so that they can pass by the accident place and keep going. If the speed of the vehicles behind is too fast, it will lead to pileup. Besides, agents also interact by each other on the highway such as change lanes when the vehicle ahead goes slow.

4.3 Stochasticity

Stochasticity is used in assigning agent characteristics. Each agent have different values of fatigue value, unconcentration value, speed, top speed, patience value and sight during the simulation. Some of these characteristics are set randomly but under a specific range. These ranges are set by using investigation so that the result of the simulation can close to reality and make

sense.

4.4. Observation

The number of vehicles in accident in each step will be output as a plot. Users can watch the plot directly to see how many accident happen under different situation.

5. Initialization

At the model initialization, users can set the number of vehicles, the number of lanes, maximum value of unconcentration and fatigue and the maximum value of patience. Then system will randomly give the characteristics of agents.

6. Input data

The model does not use input data to represent time-varying processes.

7. Submodels

a) Evaluate the values of agents. The characteristics of agent need to be evaluated under some reports so that the simulation can show the reality. Besides, agents need to be assigned to a reasonable random value. The model will set a value range of three characteristics: Unconcentration value and Fatigue value, and users can choose the maximum value of the characteristics. Then the model will randomly set a value of each characteristics from 0 to its maximum.

b) Evaluate the influence of different value of vehicles number and road facilities. The length of the road is 12km, we want maximum number of vehicles on each lane is 6, so that the average distance will be 200 meters, which is conform to the reality. Besides, users can change the number of road lanes from 1 to 4, each road has a maximum number of 12 cars owing to the 100 meters distance between each car.

c) Evaluate the influence of characteristics. The model use the negligence score to measure the three characteristics: Unconcentration value and Fatigue value. The higher score will decrease the reaction distance when brake, which will cause an accident.