# The Keep-Right-Except-To-Pass Rule

## Contents

# 1 Introduction

In countries where driving automobiles on the right is the rule, multi-lane freeways often employ the keep-right-except-to-pass rule. We are expected to solve the following problems:

- Build a mathematical model to analyze the performance of the keep-right-except-to-pass rule in both light and heavy traffic case including examination of tradeoffs between traffic flow and safety. Show how this rule is effective in promoting better traffic flow.

- Analyze the role of under- or over-posted speed limits, that is, speed limits that are too low or too high.

- Suggest alternatives and analyze whether it promote greater traffic flow and safety.

- In countries where driving automobiles on the left is the norm, argue whether or not the solution can be carried over with a simple change of orientation.

- If vehicle transportation on the same roadway was fully under the control of an intelligent system with the road network or the design of all vehicles using the roadway. Show the effect of it on earlier analysis.

# 2 Problem Analysis

Keep-Right-Except-to-Pass rule is accepted in most countries. The evaluation of its performance involves two major aspects:

- Traffic flow : The number of the vehicles drive through unit length of the highway per unit time;

- Safety: Security is inversely proportional to the expected loss in security incidents .

We can examine the two major indicators of traffic flow and the safety under the rule from the perspective of the microcosmic and microscopic aspects.

From the microcosmic view , we study the single overtaking model , and then analyze the minimum and maximum allowable capacity while overtaking phenomenon occurs . By this mean ,we can establish the relation among security, the traffic flow and the speed ; In the microscopic aspect, we make a overtaking demand-probability model and multi-level fuzzy evaluation model under the rule to judge the performance of the highway in China.

About the impact on traffic flow , we can consider to establish a reasonable simulation model under the rule ,without of the rule, or under the other alternative rules ,and then we can use the computer simulation system to analysis comparatively. Computer simulation system are based on cellular automata model, As long as you can design a reasonable CA rules, computer simulation can be achieved . In addition to testing the difference between Keep-Right-Except-to-Pass rule and Keep-Light-Except-to-Pass rule, Simulation system can also verify wether the single overtaking model and the multi-lane overtaking model is the reasonable in increasing traffic and improving safety or not from the microscopic view.

In the fully intelligent traffic system ,The design of highway, smart management, and the intelligent degree of the vehicle achieves is ideal. We assume that the ideal situation exists or set this ideal situation, and than we identify the main difference to the current transportation system .The most important is and to find such different effects on the model and the optimization model , establish the ideal intelligent transportation system evaluation , simulation and prediction.

# 3 Nomenclatures

| | |
|---|---|
| $S_1$ | Distance of car 1 in its uniformly accelerated motion |
| $S_2$ | Distance of car 1 at a constant speed |
| $S_{12}$ | Distance between car 1 and car2at the initial time |
| $S_{16}$ | Distance of car 1in the whole process of overtaking |
| $S_{34}$ | Distance of car 2 in the whole process of overtaking |
| $V_1$ | The initial speed of car1 |
| sita1 | The deviation angle when the car uniformly accelerated |
| $t_0$ | Driver's reaction time |
| $V_{max}$ | The maximum speed limit |
| $S_{ij}$ | Safe distance between car $i$and car $j$ |
| $D$ | The total length of the highway |
| $n$ | The total number of the model in that lane after decomposing |
| $Q$ | The flow of the car in the lane |
| $\rho$ | The density of the car in the lane |
| $m$ | The average time headway |
| $W_i$ | weightiness |
| $C$ | Bias coefficient |

# 4 Macroscopic Evaluation

## 4.1 Probabilistic Model of Demand for Overtaking

Evident is the fact that we could not make the best of both safety and traffic flow.

**Analysis:**

Under the rule of keep-right-except-to-pass, as the increase of traffic flow, more cars can pass through the road, but could we also ensure the safety?

More cars overtaking makes the road less safer, since the potential danger increases. We might know the relationship between traffic flow and safety by analyzing the relationship of overtaking probability and traffic flow.

It is testified in some researches that demand for overtaking exists when the time headway is lower than 6 minutes. Here we assume that the demand for overtaking come into being when the time headway reach 6 minutes. If we get the distribution of time headway, we can know the probability of demand for overtaking. Further, under the same traffic flow, the safety decreases as the probability of demand for overtaking increases.

#### 4.1.1 Light Traffic Case

As the traffic volume is below 500veh/h, we study the distribution of time headway:

**(1)Negative Exponential Distribution**

The arrival of cars obeys Poisson distribution. We have:

$$P(k) = \frac{m^k}{k!} \times e^{-m}$$

(m is mean of time headway)

P(none arrives in t)=P(time headway-h is above t)=$e^{-m} = e^{-\lambda t}$.

Time headway obeys the negative exponential distribution:

$$P(h \geq t) = e^{-\lambda t} = e^{-m}$$

$$P(t) = \lambda e^{-\lambda t}$$

The mean of the distribution: $\lambda = \frac{1}{m}$

**Remark:** it is pointed out in some study that the negative exponential distribution can be applied to describe the cases where the cars arrive randomly in light traffic.

**(2)Amendment of the Distribution-Shifted Negative Exponential Distribution**

From the analysis above the distribution of time headway is negative exponential distribution. Therefore, it is easy to notice that P(t) is in negative correlation with t ,that is, the probability of less space headway is more likely. However, it is widely known that adjacent cars should keep distance to each other. Here, we assume the least space headway is $\tau$ and we are going to amend the distribution of the circumstance where $t < \tau$ .

$$P(h \geq t) = e^{-\lambda(t-\tau)} \quad (where \;\; t \geq \tau)$$

Probability density:

$$P(t) = \begin{cases} e^{-\lambda(t-\lambda)} & t \geq \lambda \\ 0 & t < \lambda \end{cases}$$

Mean of the distribution:

$$\frac{1}{\lambda} + \tau = m$$

So: $P(h \geq t) = e^{-(t-\tau)/(m-\tau)}$
(Where $m = \frac{3600}{q}$,q is traffic flow)

**(2) Overtaking Probability**

As we have mentioned, demand for overtaking exists when the time headway is lower than 6 minutes. Then we calculate and display the probability of demand for overtaking as following.

$$\begin{aligned} P_1(t < 6) &= 1 - P_1(t \geq 6) \\ &= 1 - e^{-\frac{6-\tau}{m-\tau}} \\ &= 1 - e^{-\frac{6-\tau}{(3600/q)-\tau}} \quad (t \geq \tau) \end{aligned}$$

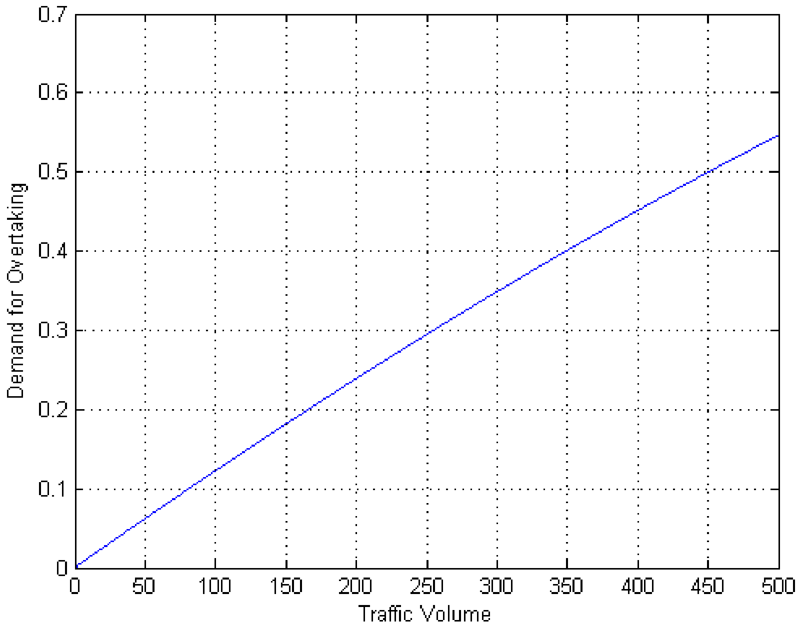
With the keep-right-except-to-pass rule, the figure above shows that the demand for overtaking increases as the traffic flow growing. Therefore, the potential danger caused by overtaking increases, that is the safety decreases as other accidental factors remain the same.

We conclude that the safety of the road decreases as the traffic flow increases. We could not make the best of both safety and traffic flow.

### 4.1.2 Heavy Traffic Case

**(1)Weibull Distribution:** We discovered that the Negative Exponential Distribution and Shifted Negative Exponential Distribution is the special case of Weibull Distribution.

Therefore, we may make use of Weibull Distribution to fit the distribution of time headway as follows.
Density: $P(t) = \frac{1}{\beta-\gamma}(\frac{t-\gamma}{\beta-\gamma})^{\alpha-1} \times e^{-\frac{t-\gamma}{\beta-\gamma}\alpha}$




Parameter Estimation:

For specific road, we can observe the time headway of cars, and get the mean and variance of the sample is m and $s^2$.

Bias Coefficient:$C_s = \frac{\sum_{i=1}^{n}(t_i-m)^3}{(n-3)s^3}$

For the specific sample, compare the $C_s$to the fitting chart of Weibull Distribution and we can have the value of $\frac{1}{\alpha}, B(\alpha), A(\alpha)$. Since $\alpha, \beta = m + S \times A(\alpha), \gamma = \beta - S \times B(\alpha)$, We can know the probability of overtaking by various traffic flow.

**(2)the Irish Distribution:** We discovered that the Negative Exponential Distribution is the special case of the Irish Distribution.

we may make use of the Irish Distribution to fit the distribution of time headway as follows:

Density:

$$P(h \geq t) = \sum_{i=0}^{l-1} (\lambda l t)^i \times \frac{e^{-\lambda/t}}{i!}$$

Parameter Estimation:

When $l = 1$,it is negative exponential distribution, fitting the light traffic case; When $l \to \infty$ it means the traffic volume is increasing. When l is big enough, it can fit the heavy traffic case.

**(4) Test of the Distribution:**

We apply $\chi^2$test both distribution. Here, we let significance $\alpha = 0.05$ .

So:

$$\chi^2_{0.05} = 15.51 > \chi^2 \quad Accept$$
$$\chi^2_{0.05} = 15.51 < \chi^2 \quad Refuse$$

We use a specific case to calculate the $\chi^2$:

$$\chi^2_{0.05}(Weibull) = 18.92$$
$$\chi^2_{0.05}(Irish) = 15.47$$

We conclude that the Irish Distribution can better fit the time headway distribution rather than Weibull Distribution.

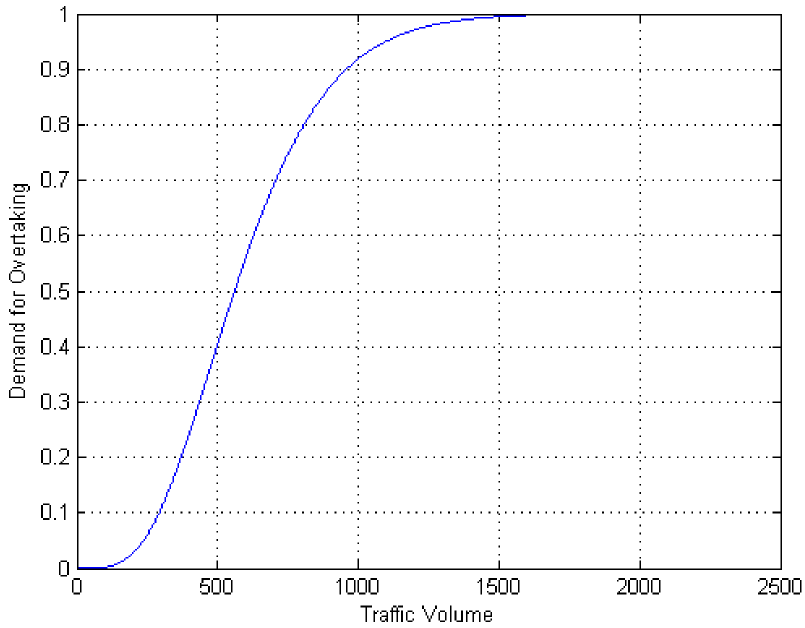
**(5)Overtaking Probability:**

As we have mentioned, demand for overtaking exists when the time headway is lower than 6 minutes. Then we calculate and display the probability of demand for overtaking as following.

$$P(h < 6) = 1 - \sum_{i=0}^{l-1} (\lambda lt)^i \times \frac{e^{-\lambda/t}}{i!}$$

With the keep-right-except-to-pass rule, the figure above shows that the demand for overtaking increases as the traffic flow growing. Therefore, the potential danger caused by overtaking increases, that is the safety decreases as other accidental factors remain the same.

We conclude that the safety of the road decreases as the traffic flow increases. We could not make the best of both safety and traffic flow.




### 4.1.3 Conclusion

The demand for overtaking increases as the traffic flow increases under the rule of keep-right-except-to-pass. That is, the safety decreases as the traffic flow increases. We can not make the best of both safety and traffic flow which are the things we expect for.

How to evaluate the keep-right-except-to-pass rule by judging both safety and traffic flow? We are expecting to make a general evaluation of the rule in next part.

## 4.2 General Evaluation Model

(–To take both safety and traffic flow into consideration)

### 4.2.1 Qualitative Analysis

To evaluate the keep-right-except-to-pass rule, we may consider qualitatively as follows:

- Light traffic case

When the traffic volume is light, when the traffic flow is increasing, the distance between cars is still long enough to keep highly safe. That is to say, the increase of traffic flow is more striking than the decrease of safety. Therefore, generally speaking, the evaluation of the rule is rising.

- Heavy traffic case

When the traffic volume is heavy, when the traffic flow is increasing, the traffic flow is difficult to be improved. Meanwhile, as the distance between cars get much closer, its more likely to cause accidents, so the safety is decreasing. That is to say, the decrease of safety is more striking than the increase of traffic flow. Therefore, generally speaking, the evaluation of the rule is reducing.

### 4.2.2 Quantitative Evaluation

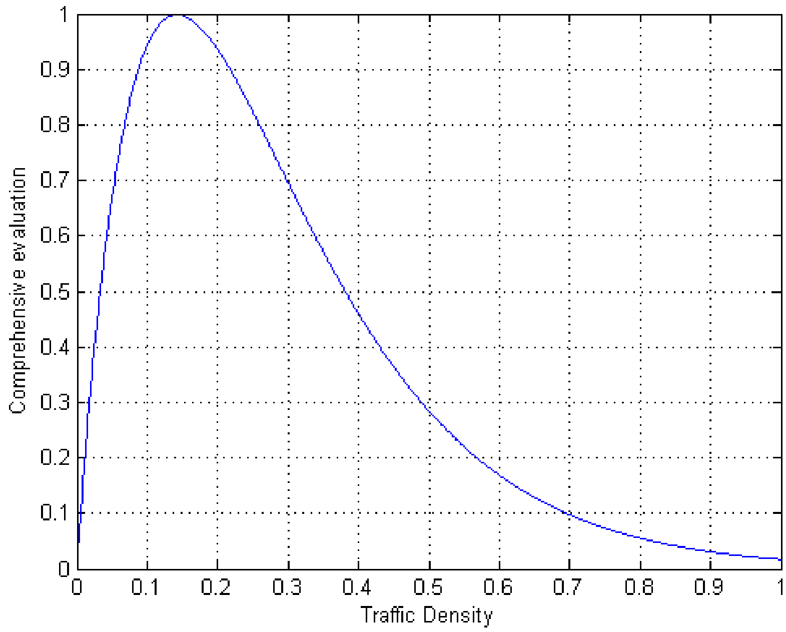
- Light traffic case:

$$\begin{aligned} P_1(t<6) &= 1 - P_1(t \geq 6) \\ &= 1 - e^{-\frac{6-\tau}{m-\tau}} \\ &= 1 - e^{-\frac{6-\tau}{(3600/q)-\tau}} \quad (t \geq \tau) \end{aligned}$$

- Heavy traffic case:

$$\begin{aligned} P_1(t<6) &= 1 - P_1(t \geq 6) \\ &= 1 - \sum_{i=0}^{l-1} (\frac{6l}{m})^i \times \frac{e^{-6l/m}}{i!} \\ &= 1 - \sum_{i=0}^{l-1} (\frac{ql}{600})^i \times \frac{e^{-ql/600}}{i!} \end{aligned}$$

(q: traffic flow;$\mu$:the probability of accident when overtaking)
Evaluation of safety:$e^{-s}$ (where $s = p \times \mu \times q$)




(since the safety decreases as the probability of danger increases)
General evaluation:

$$L = m \times k \times e^{-s}$$

(where m is the constant coefficient letting the value of L is between 0 and 1)

#### 4.2.3 Graphic Analysis

We use MATLAB to draw the general evaluation by various traffic volume as follows:

#### 4.2.4 Conclusion

The same with our qualitative analysis, the evaluation of the keep-right-except-to-pass rule is rising by the increase of traffic volume in light traffic case, since the increase of traffic flow is more striking than the decrease of safety; and the evaluation is reducing by the increase of traffic volume in heavy traffic case, since the decrease of safety is more striking than the increase of traffic flow.

# 5 Microscopic evaluation model

## 5.1 Single Overtaking Model

Single overtaking model is a mathematical model of analyzing physical processes in which overtaking is occurring. The phenomenon of once over more than one vehicles and cross overtaking can be decomposed into a linear combination of multiple single overtaking models. It is very effective for simplifying the physical process. We can define that the maximum/minimum capacity of this stretch of road is the number of single overtaking models in the highway. Through the analysis of the single overtaking model, We can get the relationship between the maximum/minimum capacity and the speed limit. As we all know, clearly, the maximum capacity and the minimum capacity represent the safety and the flow.Therefore, when using the keep-right-except-to-pass rule, we can analyze the change of security and flow under the condition of excessive speed.

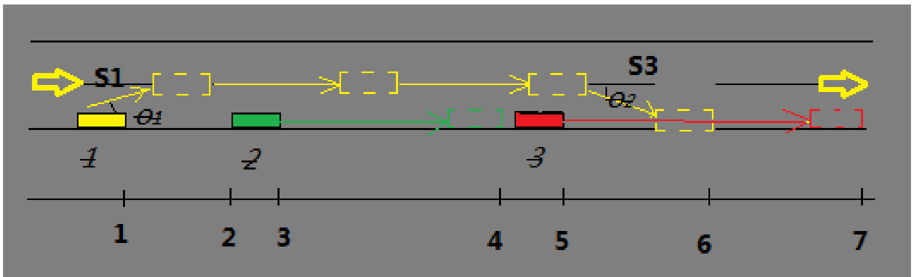
### 5.1.1 Assume of the Model

- Keeping the original speed of 2,3 unchanged in the process of overtaking .
- Maintaining the angular of the car unchanged in the process of changing lanes.
- The road is flat and uncurved.
- 1,2,3 car will not be broken unexpectedly in the process of overtaking .
- Length of all vehicles on the road are the same.

### 5.1.2 The Single Overtaking Model

(1) Schematic of the Single Overtaking Model

(2) Description of the Physical Processes



Single overtaking model

Initially, the 1,2,3 cars is driving at the constant speed of V1, V2, V3.Assuming in the process of driving car 1 wants to overtake car 2, according to the principle of The Keep-Right-Except-To-Pass Rule, the overtaking process can be described as follows:

- Chang lanes when car 1 is uniformly accelerated;
- Keep a constant speed and pass car 2;
- Maintain the uniformly accelerated state and return to the lane;
- Car 2 and car 3 drive with the original speed in the original lane.

$$V_i \times t - \alpha_1 \times (t - t_0)^2/2 = S_{ij} + V_j \times t - \alpha_2 \times t^2/2$$

$\alpha_1$ and$\alpha_2$ stand for the acceleration of car 1 and car 2 when they are decelerating, t0 is the reaction time of the driver; t is equal to the total time from the initial time to the time when i, j is nearest; $V_i$and $V_j$ represents the initial speed of car i and car j.

(3) Mathematical Description of the above Process

a. Uniform acceleration

$$S_1 = V_1 \times t_1 + a_1 \times t_1^2/2$$
$$V_{11} = V_1 + a_1 \times t_1$$

b. Constant speed process

$$V_{11} * t_2 = S_2$$

c. Uniform deceleration

$$V_{11} = V_{111} + a_2 \times t_3$$
$$S_3 = V_{11} \times t_3 - a_2 \times t_3^2/2$$

d. Distances of car 2 and car 3 in the whole process of overtaking

$$S_{34} = V_2 \times t$$
$$S_{57} = V_3 \times t$$
$$t = t_1 + t_2 + t_3$$

e.Conditions of speed limit

$$V_{11} \leq V_{max}$$

$$V_{min} < V_1, V_2, V_3 < V_{max}$$

f.Conditions of no security risks overtaking
Before overtaking:

$$S - 12 \geq S_{(12)}$$

After overtaking

$$S_{46} - L = S_l$$

$$S_{67} - L = S_m$$

Hence,If you want to overtake safely ,you must try to ensure that it can not have another vehicle in the security distance. This condition is satisfied:

$$d = S_{46} + S_{67} - L = S_{47} - L$$

(4) Expand

Passing more than a one car one time , Just over the top of a car can be,

The required safety distance is a linear superposition of the safety distance of the single overtaking models. Cross overtaking, can be seen as a combination of Passing more than a one car one time and the single overtaking model.
(5) Application

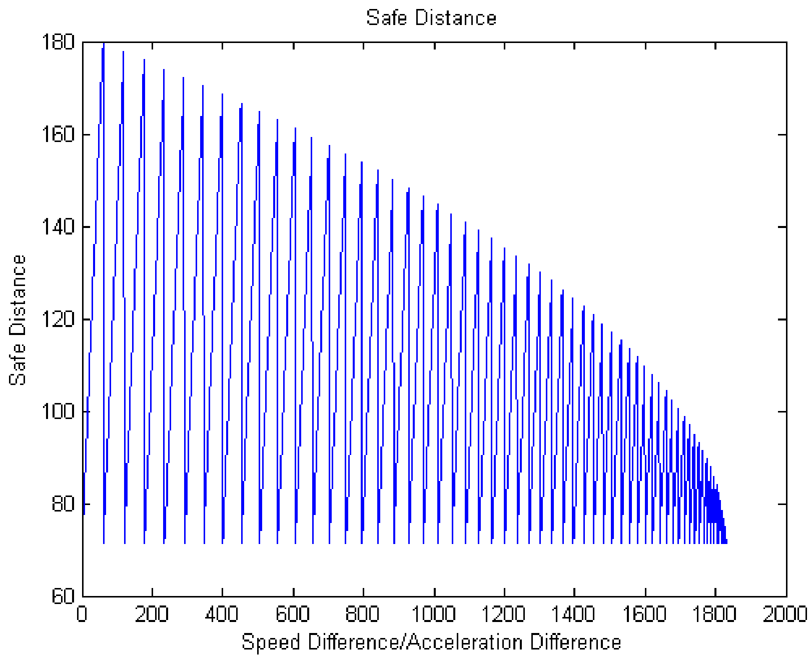
In consideration of a total length of lane is D ,We decompose the complex process of overtaking into combinations of n simple overtaking model s, Set the safety distance for the i-th is on behalf of di,so when the road is filled by Overtaking model ,the sum of d1 , d2 , d3 ,. . ., dn is equal to D; For Further discussion ,we assume that the maximum speed is Vmax and the minimum is Vmin; Appropriately ,safety distance is Smax and Smin. Therefore, we can calculate the number of overtaking models during a period in this section of the lane. The maximum and the minimum capacity can be represented by D / Smax and D / Smin.

### 5.1.3 Conclusion

(1) In the same flow and probability of overtaking occurring , the greater the speed, the less the model can accommodate overtaking models, therefore, the lower the security;Contrarily, the lower the speed, the more the model can accommodate overtaking models, therefore, the higher the security;
(2) When the road is light, the car density, if the maximum speed limit is too low, the traffic will be little,the safety will be high. Hence, emergency brake, emergency situations such as road collapses has a little effect on traffic safety.
(3) When the road is heavy, the car density, if the minimum speed limit is too high, the traffic will be heavy, the safety will be low. Hence, emergency brake, emergency situations such as road collapses has a great impact on traffic safety.

## 5.2 Model Testing

According to the actual situation of China's high-speed road we assume as follows: Car 1 's speed is 60 120Km / h, car 2 's speed is 60 120Km / h; the maximum speed limit is 120Km / h and the minimum is 60Km / h.




Length of The highway is 100Km; Drivers reaction time t0 is equal to 1.5s. Assuming that the acceleration of car 1 and car 2 is a1, a2 when braking is needed. Their ranges are 0 to 10m /s2; In addition,the average length of the car can be represented by L = 5m.

(1) Relation between speed difference and safety distance.

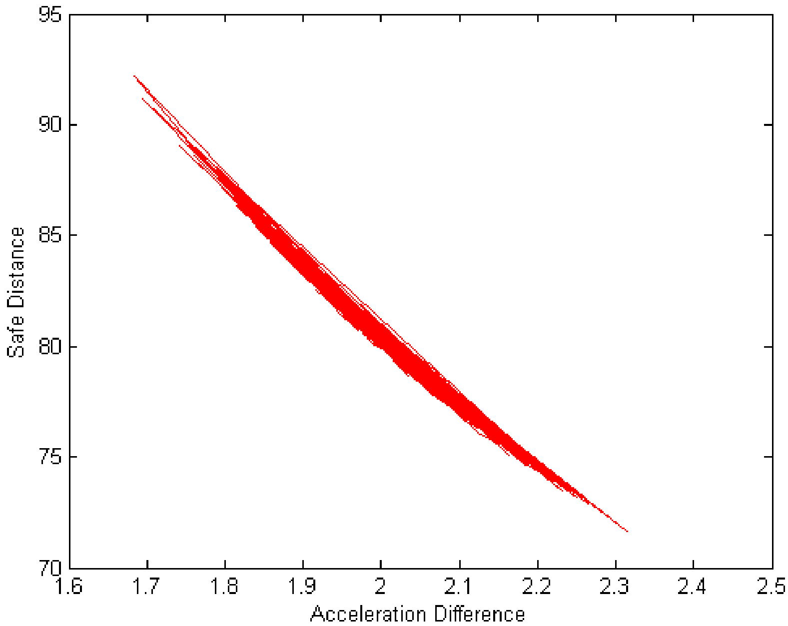
Using Matlab we can draw the curve in the figure.

We assume that the acceleration is constant,The curve represents the relations between the speed difference and the safe distance. The horizontal axis stands for the speed difference, and the ordinate axis represents the safety distance requirements.

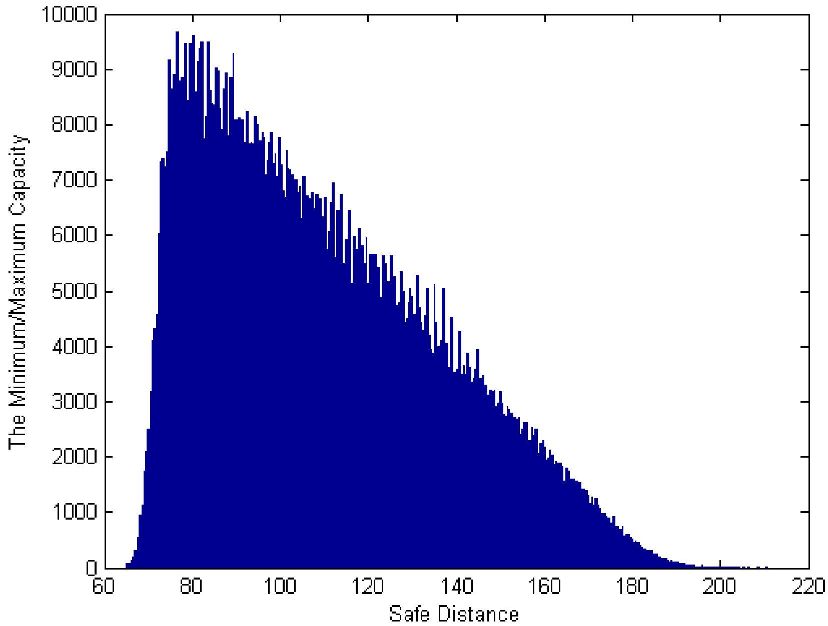
(2) Relation between Acceleration difference and safety distance We assume that the speed is constant,The curve represents the relations between the acceleration difference and the safe distance. The horizontal axis stands for the acceleration difference, and the ordinate axis represents the safety distance requirements.

The images show:

In V1¿ V2 and a2¿ a1 ,The relationship between speed difference and safe distance ,acceleration difference and safety distance :



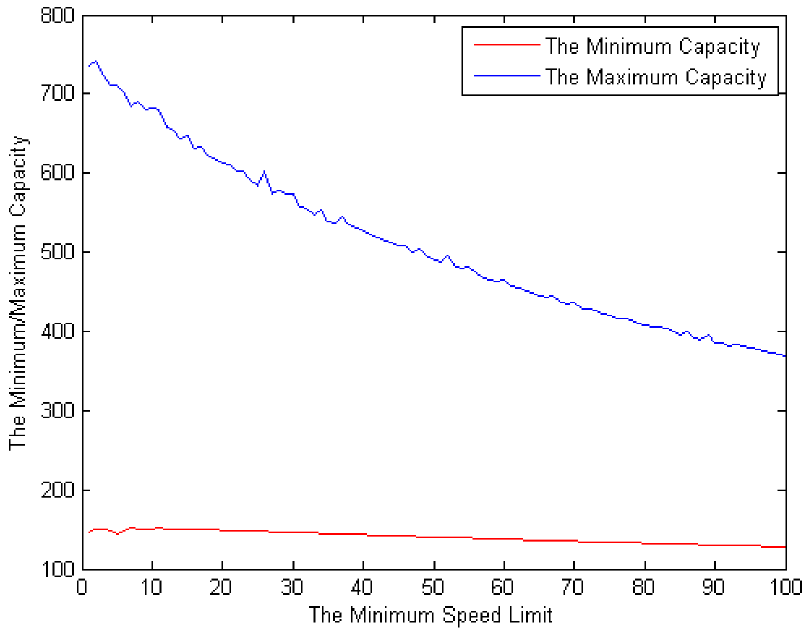

a.In an constant acceleration difference, the speed difference is only related; The greater the difference in speed, the greater the safe distance requires;
b.In an constant acceleration difference,the acceleration difference is only related;, The greater the difference in acceleration, the smaller the safe distance requires;
(3) Safe Distance Distribution
Safe distance distribution as follows:
From the image, we can conclude that:
a.To ensure that the vehicle can drive without any security risks in the lane.Distance between the car should be more than 323m.
b.In any case, distance between the two car should not be less than 72m, or there will be a traffic accident.
c.If the distance is maintained at 72m 323m, you should choose a reasonable speed and a high performance vehicle to guarantee no accidents.
d.This figure can also reflect Indirectly that in the highway, if you want to get more accurately determine the actual distance should be kept in with a range of 72m 323m , You should try to balance the other factors such as speed, automobile braking performance.




According to the calculated results: $S_{max} = 323m, S_{min} = 72m$
Therefore, the largest number of simultaneous single overtaking models the road can accommodate can be calculated :$100000/(72 \times 2 + 5) = 679$
the least number of simultaneous single overtaking models the road can accommodate can be calculated :$100000/(323 \times 2 + 5) = 679$
(4)Relationship between the maximum speed limit and capacity of the highway.
The minimum speed is too high: Top speed is too low.

Conclusion:

The lower the maximum speed limit, the more single overtaking models the lane can accommodate and the greater the change in traffic flow.However,you can find that the maximum capacity has a little change, it indicates that change in safety performance is little . In summary, Considering the safety and the traffic flow, the maximum speed is not too high, it is desirable in 120-140Km / h; the minimum speed can not be too high, at 40 60Km / h comparison is better.


The Minimum Capacity
The Maximum Capacity
The Minimum/Maximum Capacity
The Minimum Speed Limit
800
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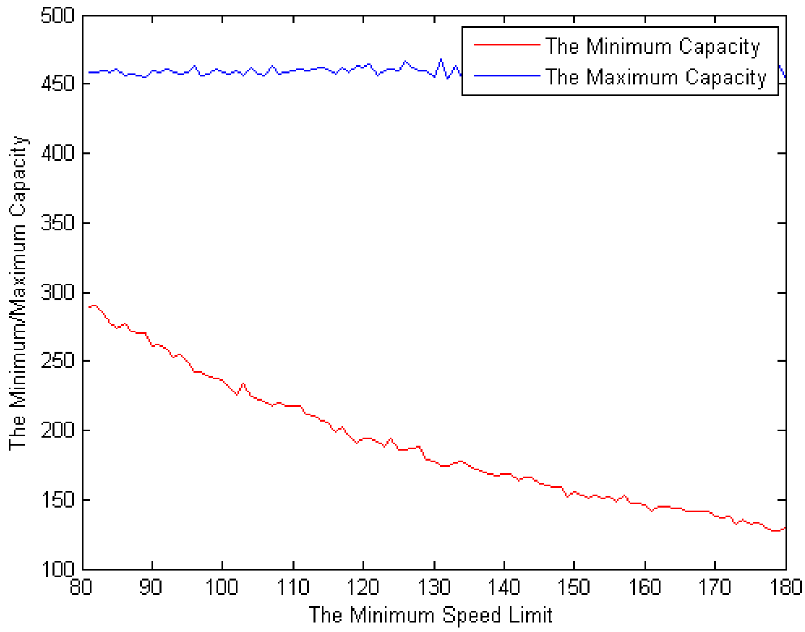
The Minimum Capacity
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### 5.3 Summary and Evaluation

Single overtaking model in The Keep-Right-Except-To-Pass Rule is created directly from the physical process of overtaking. It is a microscopic analysis model.However,Though establishing this model we can study the relationship between speed limit and safety performance.The results of this study is also a reflection of the macroscopic phenomena.

This analysis model is very simple and can reflect the physical phenomenon itself,explain a variety of phenomena, indirectly reflect macroeconomic analysis;However, the accuracy of this model is not very high.

## 6 Amendment of the Keep-Right-Except-to-Pass Rule

### 6.1 New Rule

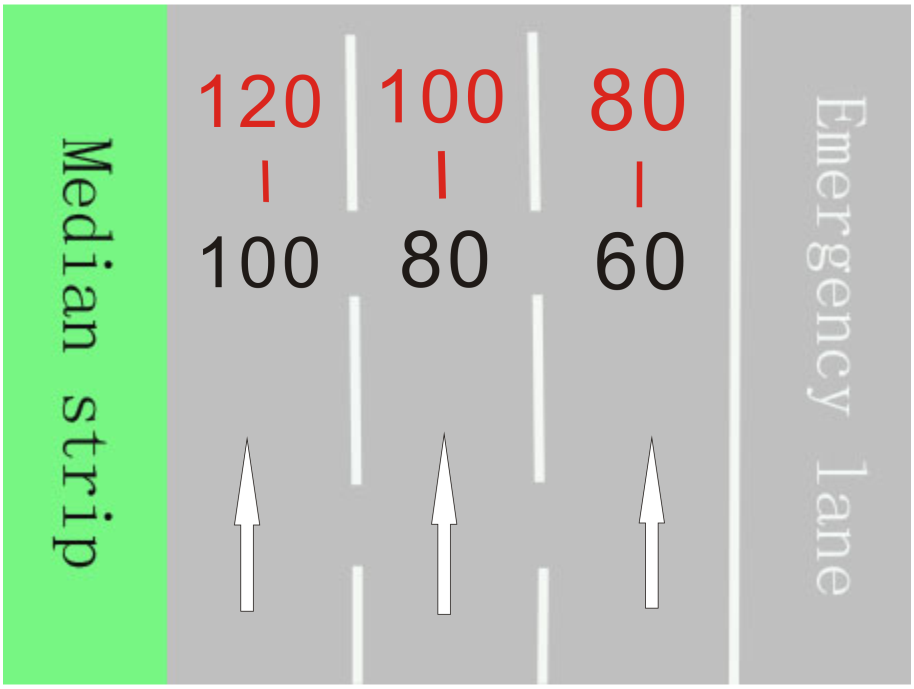
- The speed limits of the road decrease from left to right.
- All the roads are traffic lane. Cars at various speeds should drive on specific road.
- Cars on the left-most road cant overtake; if the cars on other roads want to overtake, they should move to the left, pass, and return.

### 6.2 Probabilistic Model of Demand for Overtaking under new rules

- Light traffic case

The probability of demand for overtaking under the keep-right-except-to-pass rule:

$$\begin{aligned} P_1(t < 6) &= 1 - P_1(t \geq 6) \\ &= 1 - e^{-(6-\tau)/(m-\tau)} \quad (t \geq \tau) \end{aligned}$$




The probability of demand for overtaking under the new rule:

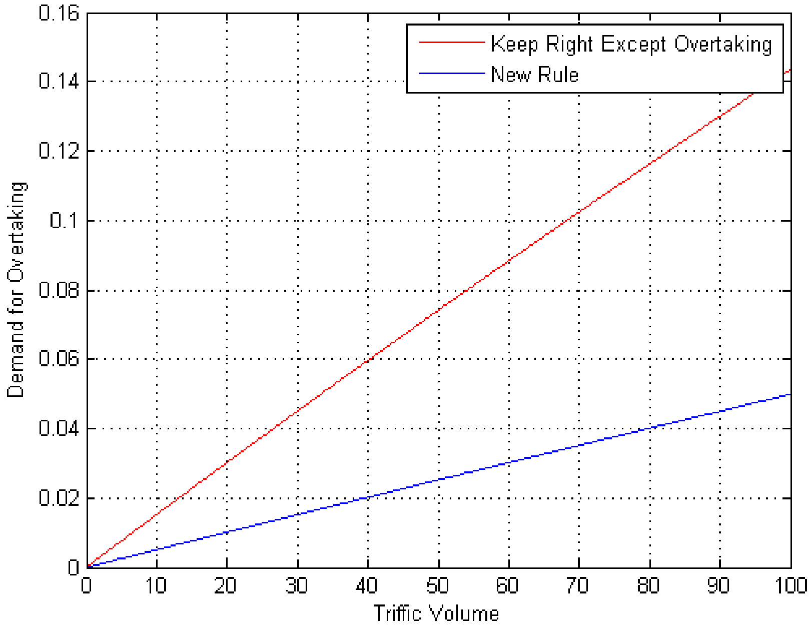
$$\begin{aligned} P_2(t < 6) &= 1 - P_2(t \geq 6) \\ &= 1 - e^{-(6-\tau)/(3m-\tau)} \quad (t \geq \tau) \end{aligned}$$

As some researches point out, we let $\tau = 1.5$.

- Heavy traffic case

The probability of demand for overtaking under the keep-right-except-to-pass rule:

$$\begin{aligned} P_1(t < 6) &= 1 - P_1(t \geq 6) \\ &= 1 - \sum_{i=0}^{l-1} (\frac{6l}{m})^i \times \frac{e^{-6l/m}}{i!} \\ &= 1 - \sum_{i=0}^{l-1} (\frac{ql}{600})^i \times \frac{e^{-ql/600}}{i!} \end{aligned}$$




The probability of demand for overtaking under the new rule:

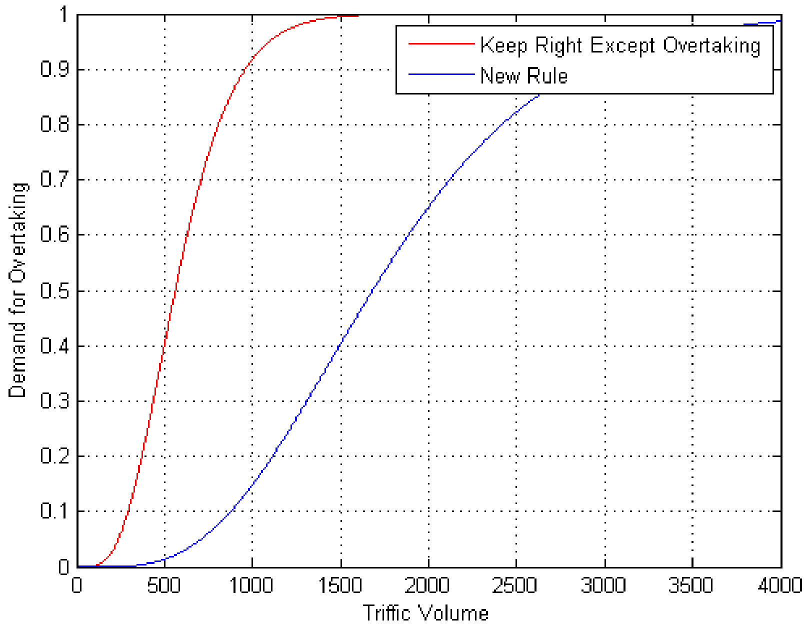
$$
\begin{aligned}
P_2(t<6) &= 1-P_2(t\geq 6)\\
&= 1-\sum_{i=0}^{l-1}(\frac{2l}{m})^i \times \frac{e^{-2l/m}}{i!}\\
&= 1-\sum_{i=0}^{l-1}(\frac{ql}{1800})^i \times \frac{e^{-ql/1800}}{i!}
\end{aligned}
$$

Here, we let l=5 and calculate. As some researches point out, we let$\tau = 1.5$We have:

## 6.3 Comparison and Conclusion

- In Light Traffic Case

As the traffic volume increasing, the probability of demand for overtaking




is rising under both two rules. However, evident is the fact that under the new rule we suggested, the probability of demand for overtaking is quite less than the keep-right-except-to-pass rule. That is to say, the accident caused by overtaking is less.

- In Heavy Traffic Case

The same with the case when the traffic is light: As the traffic volume increasing, the probability of demand for overtaking is rising under both two rules. However, evident is the fact that under the new rule we suggested, the probability of demand for overtaking is quite less than the keep-right-except-to-pass rule. That is to say, the accident caused by overtaking is less.

- Conclusion

Therefore, with the same traffic flow, the new rule is safer than the keep-right-except-to-pass rule. General speaking, the new one is really greater than the old one.

# 7 Computer Simulation

## 7.1 Cellular Automata Model

Cellular automata model is a microscopic traffic flow model ,proposed in the late 1980s and developed rapidly in the 1990s.Because of its simplicity and ease of computer operations, particularly easy to implement parallel computing, It is used in the field of traffic simulation more and more widely.

### 7.1.1 The basic rule of the vehicle states updated

- Acceleration rules

Under the circumstance that the security needs are met ,the driver always tend to driving faster as far as possible. Acceleration rule describes a driving phenomenon: every vehicle has acceleration wishes under conditions permitted.

- Speed adjustment rules

Under the influence of the acceleration rules,the speed of the vehicle is increasing gradually. Obviously, this state can not be maintained , unless overtaking phenomenon is Occurring. Under circumstances of no overtaking, Speed constraint rules describes the behavior during driving the vehicle slow down its speed when it is affected by the vehicle in its front. If the distance between the preceding vehicle and the host vehicle is large, then it will continue to accelerating. If not,the vehicle will take driving safety program ,just as keep the speed in a level —Collision does not occur.

- Position change rules

Vehicles location updated renders the entire simulation system dynamics.

## 7.2 trapezoid overtaking model

On the basis of the basic model, we establish a trapezoid overtaking model; This model divide the road into multiple triangles. Cellular is defined as the apex of the triangle.

#### 7.2.1 The basic assumption

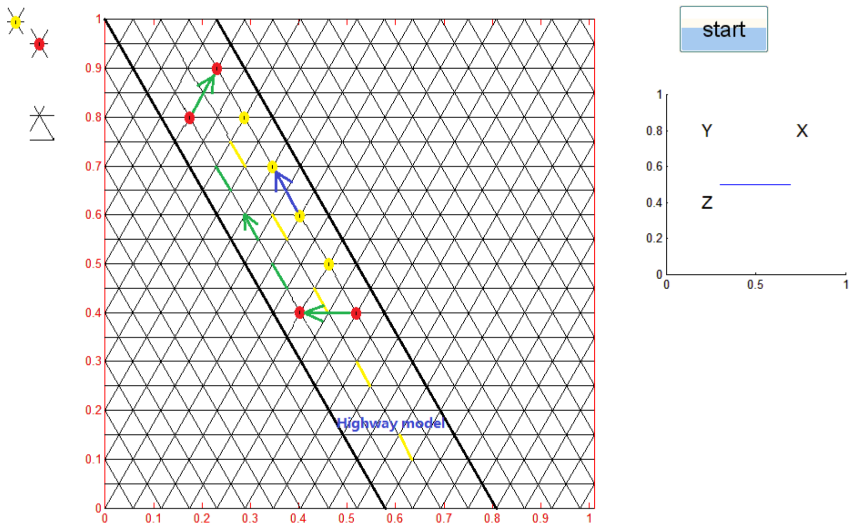
The initial condition is that the red and yellow vehicles travel normally in the same road . Overtaking follows **The Keep-Right-Except-To-Pass Rule**.The acceleration time is not counted and the vehicle keeps the speed unchanged in the process. Considering safety, after overtaking is complete, the speed is equal to the original speed minus one (vehicle random slow). Consider safety, after overtaking is completed, the original speed minus one (vehicle random slow). The initial coordinate of the red car is recorded as L1, the speed is recorded as V1; The initial coordinate of the yellow car is recorded as L2, The speed is recorded as V2; Both of the speeds should be selected in the range of Vmax Vmin.

#### 7.2.2 The CA rules

- After the start of overtaking ,the red vehicle moves two cells on the left in the next moment, Then, increases its speed to V11.
- After changing the lane,The red vehicle should move to the location where the yellow cars coordinate plus 4 in the next moment.
- In another next moment. The red vehicle returns to the original track and update the speed to original speed minus one.

### 7.3 The simulation parameters of trapezoidal overtaking model–based on the cellular automata model

(1) States of each cell contain the location information from 0-1.
(2) Length of one step is set to 0.05. It is equal to triangle side.
(3) States of each cell contain the speed information from 1-10.
(4) 0.05 seconds is set a time step unit.
(5) The probability of vehicle arriving meets to Poisson distribution .In this problem 1500pcu / h is converted into a Poisson stream parameters,It stands that the expectation is 4.17pcu.
(6) In non-overtaking model ,the speeds variation during the acceleration and deceleration is set to 1.




## 7.4 The algorithm design process of Cellular Automata

(1) Initialize the cellular environment, set the appropriate parameters, produce 343*343 location matrix and 343*343 velocity matrix, where the length of the maximum analog.1000s is the maximum length of time simulation.
(2) produce vehicles subjected to Poisson distribution at the intersection.
(3) run by CA rules in the overtaking model ,if it satisfies the conditions .
(4) Regard k as the length of the unit step ,if the overtaking condition is not met
(5) Each process of iteration follows the description of the state updated rules on the above.we update and save the updated data in parallel .

## 7.5 Schematic of the trapezoidal overtaking model when simulating.

To express the model intuitively,We modify the image generated by program directly using the graphics software (for example, adding the arrows and signs in the form of zebra).Then ,the basic models schematic is shown:

### 7.6 Conclusion

In the simulation process, we first consider the keystone-overtaking model based on cellular automata to make a verification wether the single overtaking model established under the Keep-Right-Except-to-Pass is reasonable or not. Experimental results show that: the simulation results remained the same with with the single overtaking model s conclusion, the two models can support the correctness each other . In the problem 3, we should consider keeping the left is normal in some country.so we must change some parameters to make our model flexible enough adapt more situations.According to the results of the simulation.You just need to change the direction of overtaking on the right, and you can get the same symmetry model and simulation results.

## 8 Traffic Revolution

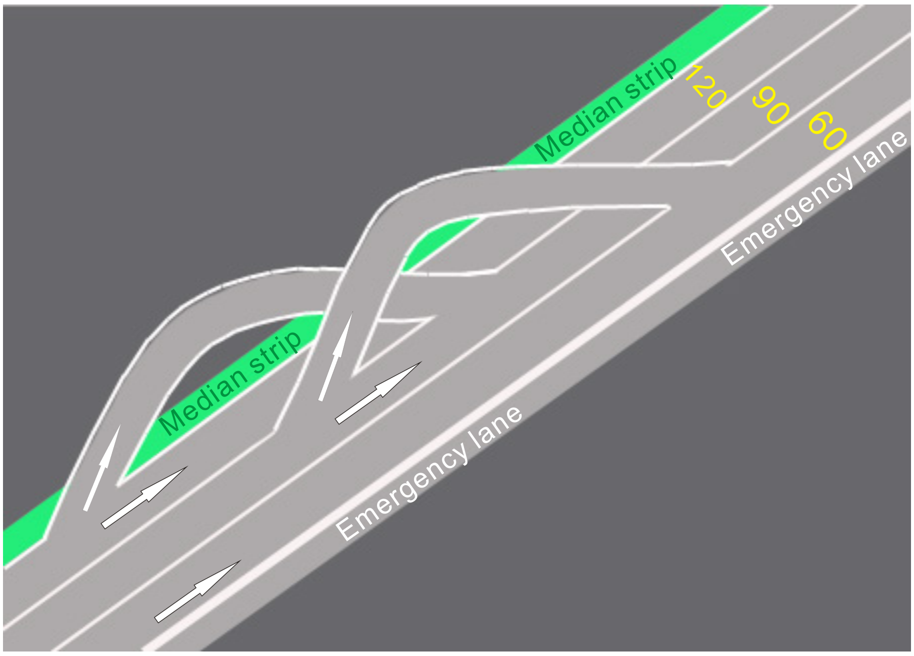
### 8.1 Analysis

Under the intelligent system, we amend the former evaluation model with concerning human satisfactory. That is to say, we consider the traffic flow, safety as well as the drivers satisfactory. Here we regard the drivers action such as overtaking and acceleration as their seeking for time. Therefore, our intelligent system is based on the drivers different expectation for the time they would like to spend from one specific place to another, including the freeways intelligent design, the intelligent administration and the cars intelligent design. We avoid overtaking and acceleration which is unsafe action in our intelligent system, and we dont have the keep-right-except-to-pass rule but a better, safer and more efficient way for traffic. Wed like to display how it works for you as follows:

**(1)Freeways Intelligent Design**

The intelligent freeway is displayed as follows:

Where the fixed speed from right-most to left-most are 60Km/h, 90Km/h, 120Km/h. Overtaking is abandon on the road, and cars share the same road should drive at the fixed speed. Only in the lane-changing area can cars change to other lane, to satisfy different requirements. For example, the cars




can choose 5 ways to accomplish the trip. He may drive at 90km/h in the first stage and drive at 60km/h in the second stage, or he can drive at 120km/h in the first stage and drive at 90km/h in the second stage. He makes his choice according to how much time he would like to spend from the starting point to the terminus. What he needs to do is choose the expected time at the starting point and according to the choice he made he may change to another road in the lane-changing area. However, he can never overtaking or accelerating and he should drive at the fixed speed except the lane-changing area. In addition, the location of the lane-changing and the speeds can be various according to different requirements. How does the system work in the lane-changing area? The intelligent administration plays an important role.

**(2)Intelligent Administration**

Intelligent administration means the data of all vehicles are shared by all drivers and we have a central system performing as the administrator in the system. The central system will receive the time when the drivers arrive at the freeway, and the chosen expected time the drivers would like to spend, and then she knows how will the driver plan to go and calculate the time when the drivers would arrive at the lane-changing area and decide who will go first. The central system will inform the cars to go. (3)Intelligent vehicles: The intelligent vehicles can share their driving information with other cars and get touch with the central system. The cars should complete the trip safely spending the fixed expected time set by the drivers. The cars should obey the central system, especially in an emergency situation.

**If we were the driver:**we want to go from place A to place B, under the current traffic rule, we may overtake or accelerate in specific cases. Why we take these actions? It is because that we want to save time. Actually different drivers expect to spend various times to accomplish the trip. However these actions increase traffic danger. If overtaking and acceleration is abandon, we cant make the best use of the road and dissatisfy the drivers. **We simply describe it like this:** To every driver, the time they would like to spend from place A to place B may be different. When they enter the freeway they could choose the time which decides which road to go in different stage. The central system know the plan of every car and coordinate the traffic.

## 8.2 Example

We assume that the road is 10Km long and the lane-changing area is set at he middle of the road(for right-driving countries). We set the speed for the three road from left to right at 120km/h,90km/h,60km/h.

The intelligent traffic system can satisfy three kinds of various time-demand as follows:

$$t_1 = (\frac{5}{120} + \frac{5}{120}) \times 60 + t_0 = 5.5min$$
$$t_1 = (\frac{5}{120} + \frac{5}{90}) \times 60 + t_0 = 6.33min$$
$$t_1 = (\frac{5}{90} + \frac{5}{90}) \times 60 + t_0 = 7.16min$$
$$t_1 = (\frac{5}{90} + \frac{5}{60}) \times 60 + t_0 = 8.83min$$
$$t_1 = (\frac{5}{60} + \frac{5}{60}) \times 60 + t_0 = 10.50min$$

The drivers who want to go from A to B could select the choices above ( ) stating how much time they would like to spend from place A to place B.

.For instance, there is a driver named Tom who would like to spend approximately 9 minutes to go from place A to place B. Tom should choose when he are arriving place A. Since the traffic system is intelligent and all cars can get in touch with the central system, the central system would know when Tom could arrive at the lane-changing area. Tom choose , so he should use the middle road in the first stage. Actually, all the cars using the middle road in the first stage are at the same speed, so they would not overtaking or accelerate. Therefore, the probability of accident keep low level and the safety keep high level. After 3.33 minutes of driving, at 90Km/h, Tom finally arrives at the lane-changing area and the central system has already known that since Tom made his choice when he are in place A. The central system know all the choices made by the drivers in place A including Tom, so she would arrange in the second stage who will be in the front and who go later. Then the central system gives the arrangement to the drivers since the cars are all intelligent. Tom get the message, and changes his way to the right-most. In the second stage, Tom will speed at 60Km/h, and so does other cars who share the same road with him. At last, Tom arrives at place B safely and satisfactorily.

# 9 Conclusion

Keep-Right-Except-To-Pass rule is accepted by most countries.However, not all, including ourselves know why .we try to build different models in different aspects to evaluate the performance of the rule.

Keep-Right-Except-To-Pass rule is accepted by most countries.However, not all, including ourselves know why .we try to build different models in different aspects to evaluate the performance of the rule.

As to be microcosmic, single overtaking model is based on its physical process. the Minimum/Maximum Road Capacity defined can reflect the safety and traffic volume.This model is very flexible.It is easy to verify by building the cellular automaton to simulate.

We try to create a new overtaking rule. Taking highways with three lanes for instance, the limitation of the speed should increase from the right to the left lanes. Overtaking is prohibited on the lane with highest speed. As for cars on other two lanes, if they want to pass another vehicle, they should move to the adjacent left lane. Running under this rule,The traffic flow is better.

We design a great efficient road network of no overtaking in the intelligent transport system In addition, it is highlighted that in our design the drivers' satisfaction is taken into consideration to make it a humanization system.

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