Advanced Engineering Forum *Online: 2012-07-26*
ISSN: 2234-991X, Vol. 5, pp 144-149
doi:10.4028/www.scientific.net/AEF.5.144

Research on Route Selection Model of Road Network Emergency Evacuation under Ice and Snow

Zhang Yaping[1,a], Song Chengju[1,2,b], Yang Zhichao[1,c], Zhang Wei[1,a]

[1]School of Transportation Science and Engineering, Harbin Institute of Technology, 73 Huanghe Road, Harbin 150090, China

[2]School of Automotive and Transportation Engineering, Heilongjiang Institute of Technology, 999 Hongqi Street, Harbin, 150050, China

[a]zxlt0905@163.com, [b]songchengju@sohu.com, [c]hit-yangzhichao@163.com

Keywords: Ice and Snow Condition; Emergency Evacuation; Route Selection; Network Optimization

Abstract: The route selection of road network emergency evacuation is of great practical significance for possible emergencies in future. Based on analyzing the principles of emergency path selection, the paper takes the traffic capacity, intersection density and vehicle delays in the intersection into consideration, and establishes the route selection model of road network emergency evacuation under ice and snow.

Introduction

Urban road network is one of the Infrastructures exposed to the natural conditions, the influence of adverse weather conditions or disaster weather on the urban road network is generally serious[1], northern cities in winter suffer more snow and ice, the traffic in Beijing and Shenyang have been disordered and even paused caused by snow storm. Some southern cities have also suffered the freezing rain and snow weather. In order to effectively resist the influence of snow and ice on the urban road traffic, reduce the impact on urban emergency evacuation, it is necessary to study In-depth on the route selection problem of emergency evacuation under ice and snow[2].When an emergency takes place in cities, it is necessary to evacuate and transfer persons in large scale[3], due to the sharp increasing of traffic flow and the change of traffic operating conditions in the short time, the running balance of the road network must be broken, the road network traffic in entire city will be re-allocated, therefore, it is of great significance for guiding future possible emergency to establish the route selection module based on the emergency evacuation conditions[4].

The Initial Selection of emergency evacuation route

Evacuation route would depend on the existing road network, but not the full use, therefore, for the route selection, it is necessary to conduct route initial selection for the final optimal results [5]. When the route is selected, the safety and efficiency of emergency evacuation routes should be fully considered, to conduct initial selection on candidate routes. The main selected parameters include:

Road condition. The basic condition of the road influence comfort of drivers and evacuees directly, and better conditions could ensure the safety of vehicles. In addition, from the evacuation demand and the road design, the urban roads on high level have better performance in road capacity and road stability [6], and meet the evacuation needs better avoid traffic congestion in large scale caused by the evacuation.

The emergency lane and the shoulder setting.

When emergencies happen and emergency evacuation is needed, evacuation vehicles are mostly large vehicles, and it is possible for mechanical accidents and the possibility of misuse to take place under emergency conditions. Therefore, it is necessary for vehicles to park on the emergency lane so as not to affect others emergency vehicles, otherwise it will cause the traffic congestion and slow down the progress of emergency evacuation.

The connecting roads quantity and intersection density.

"Connecting road" refers to the link road between the public roads and residential main road in the foreign definition, and the link road between the two adjacent signalized intersections in emergency evacuation, as well as other minor roads or the import and export of everyday life and commercial services. If the number of connection is too much, it is bound to affect the evacuation efficiency of vehicles on the main roads. The high density of intersections will also aggravate the vehicles intertwined exacerbate.

Traffic control methods and information level.

In the existing urban road traffic conditions, the information level will directly influence the evacuation efficiency and the enforcement of evacuation plan in the process of emergency evacuation. Intelligent transportation facilities could transmit information of all sections in road network to the control and command center, and transmit the corresponding guidance and decision-making information back to the road users, so that real-time monitoring and induction for the evacuation in site could be realized.

Regional climate conditions.

In the existed study on emergency routes selection, the premise is normal weather conditions. It is needed to take the extreme climatic conditions into consideration for establishing and selection emergency evacuation routes. According to the weather conditions, it will determine the number of evacuation routes, the performance of evacuation vehicle, and the equipment of vehicle ancillary facilities and so on.

Emergency Evacuation Network Optimization

After the initial selection of evacuation routes, the selected evacuation routes are generally irregular, and the actual evacuation capability needs to be verified. The capacity of evacuation networks is calculated as follows:

$$C_p = C \times N \times f_w \times f_S \times f_B \times f_D \times f_V \times f_P \tag{1}$$

Where, C_{p} is possible capacity (pcu/l/h), N is the lanes number of One-way road, f_W is the capacity correction factor by Lane width and lateral clear width, f_S is the capacity correction factor by snow and ice conditions, f_B is the capacity correction factor by bus, f_D is the capacity correction factor by driver conditions in Emergency situation, f_V is the capacity correction factor by Fault vehicle, f_P is the capacity correction factor by interference of pedestrian and bicycle .

On the existing urban roads, buses occupy a certain proportion. When the bus is in and out of temporary stops, it will inevitably lead to the reduction of road capacity. The urban road network capacity will be reduced in different snow conditions, and with snow at a different level, the reduce extent of capacity is different.

Emergency evacuation route selection model

The basic selected steps of emergencies route in the snow and ice conditions is: firstly, determine urban roads which meet certain basic conditions as an evacuation road objects by initial selection, and then in accordance with the evacuation route selection model, evacuate from the shortest time and vehicle flow reasonable allocation point of view, and take the traffic capacity, intersection density and vehicle delays in the intersection into consideration to determine a reasonable evacuation route.

The influence of different evacuation routes on evacuation time.

In the actual evacuation, the evacuation route is divided into series route, parallel route or mixing route, and the series route is divided into series route with same lanes or not. Evacuation route is the series route of single-path: in order to analyze and calculate conveniently, the paper refers to the concept of evacuation time in unit road length, known as the "equivalent evacuation time”. The formula is as follows:

$$t_{0,ij} = t_{0,ij}^{0}[1+\alpha_{ij}(\frac{q}{c_{ij}^{n}})^{\beta_{ij}}] \tag{2}$$

$$t_{0,ij}^{0} = \frac{l_d}{v_{f,ij}} \tag{3}$$

Where, $t_{0,ij}$ is travel time per unit length of i kinds of road in j kinds of weather conditions, l_d is length of sections , $V_{f,ij}$ is free speed of i kinds of road in j kinds of weather conditions, q is traffic of sections ; C^{n}_{ij} is capacity under the condition, $\alpha_{ij,}$ β_{ij} is lock coefficient of the road and snow conditions respectively, it is shown as follows in Fig.1.

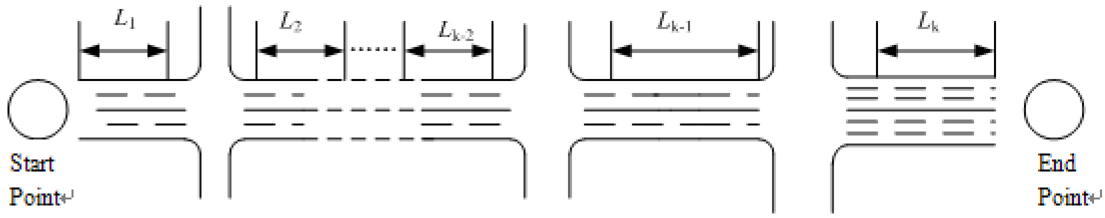

Fig. 1. Schematic diagram of series evacuation route travel time (excluding the intersection)

Therefore, when the evacuation route is connected by multi-path with different lanes, the total travel time for the evacuation section is that:

$$T = \sum_{k=1}^{k} L_k t_{0,ij} \tag{4}$$

Where, T is total evacuation time of series route, L_k is the length of k-th route, $t_{k,ij}$ is unit travel time of k-th route in corresponding climate condition and road types.

Evacuation route is the parallel multi-path: In parallel route, the simplest case is two parallel roads; it is shown as follows in Fig.2:

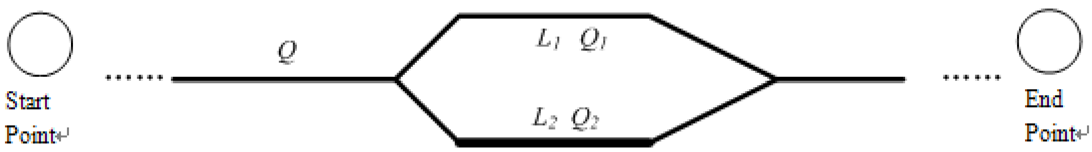

Fig.2. Schematic diagram of Parallel evacuation route Travel time

It can be seen from the above figure:

$$\begin{cases} Q=Q_1+Q_2 \\ T(L_1)=T(L_2) \end{cases} \tag{5}$$

The solution of this equation could be obtained by equation 5 and 3, in order to obtain the travel time of two evacuation slip. Similarly, when the evacuation route is multiple parallel routes, the calculation method is similar:

$$\begin{cases} Q=Q_1+Q_2+......+Q_n \\ T(L_1)=T(L_2)=T(L_3)...=T(L_n) \end{cases} \quad (6)$$

When the candidate routes are the combination of several parallel roads, evacuation the route with the gross shortest vehicle traveling time is optimal.When the drawn route is the combination of series and parallel ones, which is shown as equation 7:

$$T=\sum_{k=1}^{k} L_k t_{0,ij} + \sum_{n=1}^{m} T(L_n) \quad (7)$$

Where, m is the number of parallel routes, $T(L_n)$ is the road blocking function value of n-th parallel sections, the remaining parameters are the same meaning as above.

If the evacuation route is the combination of series and parallels, it needs to calculate the evacuation time of the connections. Respectively, the total evacuation travel time of entire routes could be obtained by the sum of the the evacuation time of sub-sections. The optimal route is the route with shortest evacuation time.

The influence of evacuation intersection on the evacuation time: under different weather conditions, the main reason for the vehicles delay in signal intersection is the vehicles interleaving of the different direction. According to the above analysis and existing reference, it is known that N junctions in an evacuation path, its total delay is:

$$D=\sum_{k=1}^{n} d_k \quad (8)$$

$$d_k=\frac{a_j C_k (1-\lambda_k)^2}{1-Y} + b_j x_k^2 [(x_k-1)+\sqrt{(x_k-1)^2+\frac{16x_k}{Q_k}}] \quad (9)$$

Where, d_k is average delays per vehicle of k-th intersection, C_k is the cycle length of k-th intersection (S), X_k is the imported Road saturation of k-th intersection = qC/sG, λ_k is G/C, Q_K is capacity (pcu/hr), y is $\lambda_k X$.

In the reference [7], the ITS setting is considered as an impact factor on emergency evacuation of urban road network. According to the ITS setting of the evacuation routes, the impact factor is divided into three levels and take use of direct correction factor to standardize the emergency evacuation route selection model. This study considers the impact factor that ITS setting impact on emergency evacuation as 1 during the process of model standardizing, and that is no impact on emergency evacuation selection.

Selection Model of emergency evacuation route.

The emergency evacuation route selection process in the paper is divided into sections and intersection. The sections part should establish travel time impedance function in different snow and road grade conditions; while in the intersection, vehicles delays model in different snow conditions should be established. Through the combination and calculation of these two parts, the optimal evacuation route selection model based on a single OD points could be drawn. The formula is as follows:

$$T=\min(T_j)=\min[T_{Tj}+T_{Dj}], i=1,2,...n \quad (10)$$

Where, T_j is the evacuation time of the j-th route, T_{Tj} is the evacuation time of the j-th route in the consideration of capacity, T_{Dj} is the total intersection delays of the j-th evacuation route.

In summary, the optimal evacuation route selection model based on single OD points in different snow conditions can be obtained. Assuming that in an OD points, there are n routes, each route with m sections and l signalized intersections. The optimal evacuation routes selection model in different weather conditions is calculated as follows:

$$T = \min(T_i) = \min[\sum_{k=1}^{m} L_k t_{0,ij} + \sum_{k=1}^{l} d_k], i = 1,2,...n \tag{11}$$

$$t_{0,ij} = \frac{l_d}{v_{f,ij}}[1 + \alpha_{ij}(\frac{q}{c_{ij}^n})^{\beta_{ij}}] \tag{12}$$

$$d_k = \frac{a_j C_k (1-\lambda_k)^2}{1-Y} + b_j x_k^2[(x_k - 1) + \sqrt{(x_k-1)^2 + \frac{16x_k}{Q_k}}] \tag{13}$$

Where, m is the number of evacuation routes, n is the number of candidate routes, l_d is the length of single section, $V_{f,ij}$ is the free speed of i kinds of road in j kinds of weather conditions, q is the volume of section, α_{ij}、β_{ij} is the travel time parameters in section in the corresponding road and snow conditions, $c^n{}_{ij}$ is the section capacity i kinds of road in j kinds of weather conditions; a_j,b_j is the parameters in different snow and ice condition, Q_k is capacity (pcu/hr), Ck is the cycle length of k-th intersection (S), y is $\lambda_k X_k$, X_k is the imported Road saturation of k-th intersection =qC/sG; λ_k is G/C.

For emergency evacuation, the evacuation purposes is to transfer evacuate personnel to a safe region quickly[8]. In general, the selected routes are many or more. The sort of evacuation routes by the evacuation route selection model could not effectively determine to meet the evacuation requirements or not, and the number of vehicles needed to allocate on road is not sure. So according to the characteristics of emergency evacuation, based on traffic emergency evacuation traffic allocation, multiple routes could be obtained by the emergency evacuation route selection model. It determines the number of emergency evacuation route selection and the flow on each route for minimizing the total evacuation time.

Conclusion

This paper determines the steps of the emergency evacuation route selection by analyzing the emergency evacuation route selection principle. Through the initial selection of the emergency evacuation route, it analyzes the influence of different evacuation routes on the evacuation time, and network optimization. Ultimately it establishes the emergency evacuation route selection model.

Acknowledgements

This research is funded by Heilongjiang Province Natural Science Foundation of China（Grant No. E200940）

Reference

[1] Lam, Hu Shao, Agachai. 'Modeling impacts of adverse weather conditions on a road network with uncertainties in demand and supply'. Transportation Research Part B 2008, 42: 890–910.

[2] National Climatologic Data Center. 2002. United States Snow Climatology. National Climatologic Data Center, NOAA, United States Department of Commerce, http://lwf.ncdc.noaa.gov/oa/climate/monitoring/snowclim/mainpage.html.

[3] Yang H, Zhang X. The multi-class network toll design problem with social and spatial equity constraints .Journal of Transportation Engineering, 2007,128, 128 :420-428.

[4] Perry, A.H., and Symons, L.J. Highway Metrology, University of Wales, Swansea, Wales, United Kingdom, 1991.

[5] National Climatologic Data Center. 2008. United States Snow Climatology. National Climatologic Data Center, NOAA, United States Department of Commerce.

[6] Khattak A J, Knapp K K, Giese K L and Smithson L D. Safety implications of snowstorms on interstate highways. Presented at the Annual Meeting of the Transportation Research Board, January, Washington, D. C., 2000.

[7] Traffic research center, Beijing University of Technology. Olympic transportation planning [R]. Beijing university of technology.2004.(In Chinese)

[8] Benjamin F Zhan. Three Fastest Shortest Path Algorithms on Real Road Networks: Data Structures and Procedures .Journal of Geographic Information and Decision Analysis, 1998,11, 1(1) :69-82.