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Simulating on Passengers Coordination with Distribution Service in Railway Station

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Abstract

Based on the hierarchical characteristics of passengers transfer behavior and the state-dependent queuing model, the D-M/G/C/C queuing network simulation model was put forward for simulating the coordination of subjective passenger behavior and objective distribution environment. Then, the generation method and algorithm of the model is elaborated. In case study, the simulation results are consistent with the actual states of passenger outbound process. So, it is a practical simulation tool for analyzing the dynamic situations of passengers use facilities.

Keywords: *railway passenger transport, D-M/G/C/C model, passenger transfer behavior, state-dependent queuing model, dynamic modeling*

1. Introduction

The issue of passenger distribution service in railway station has caused increasing concern of researchers, because of its key roles of comprehensive passenger transport system in a city. The distribution service capacity of stations, whether passengers could achieve transport transfer efficiently or not, was showed by the dynamic coordination between its internal distribution objective environment and passengers subjective behaviors [1-4].

Railway station has formed a complex transfer network integrated multiple transportation modes interiorly. A number of distribution facilities are situated in different floor. Passengers need to go forward according to the passenger organizational processes. For example, outbound passengers should walk to exit from the platform. Pedestrians transfer behaviors have strategic level, Tactical level and operational level [5], and each of them will be attracted by a temporary destination. Traffic system dynamic simulation methods could reproduce or predict the traffic situation and analysis the passengers transfer process in railway stations.

Models on passenger distribution can be roughly divided into two types. One is microscopic model which concerned pedestrians movement in facilities, including Social Force model [6], CA model [7, 8] Queuing Network model [9] and so on. These models advantaged the description greatly of interaction between pedestrians in a corridor or other single area, although the exports were preset. Another one is about passenger choice behavior between facilities. The utility function had been used to describe passenger choice behaviors [5]. For example, Path Selection Model [10] is a static model based on the short circuit law, and facilities choice model [11], between stair and escalator, is a dynamic model closely related to the generalized utility values. In order to gaining the virtual distribution service conditions as far as possible, during passengers transferring, a integrated framework absorbed these two types of models would be valuable.

Therefore, the subjective of this paper is to propose a simulation model on the whole process of passenger transfer, synthetically considers the dynamic collaborative relationship between passengers behavior and distribution environment. Then, the model was applied in a simulation case of passenger outbound process.

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2. Passenger activities

Based on the hierarchical characteristics of passenger traffic behavior [5], the passenger transfer behavior may be analyzed from the following three levels, in Figure 1.

In strategic layer, passengers mainly consider the time of departure and arrival and transport mode, e.g. the traffic mode choice, which has a linear characteristic. Passengers go down the stationary organizational process as the OD transport modes are confirmed. In tactical layer, passengers mainly consider the links of organization and guide services, e.g. the choice of direction, which has a segment-like feature. Passengers move forward in accordance with the various steps of the organizational process in order. In operational layer, passengers usually display their individual characteristics and selecting preferences, e.g. the facilities choice, which has a punctiform feature. When the passenger meets 2 or more kinds of facilities parallel, one must be select for using.

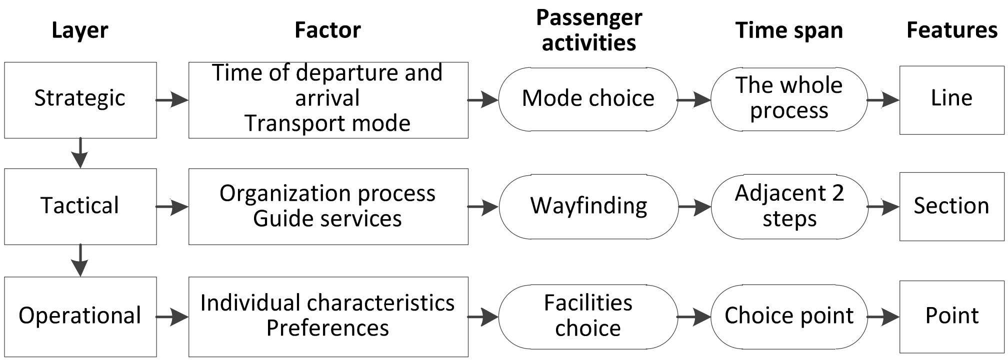

Figure 1. Routing layer division and the passengers activities

Time span of mode choice runs through the whole process of passenger transfer, way finding occurs between 2 adjacent steps of organizational process, facilities choice occurs on the decision point. For ease of understanding, the scale of the time span is showed in figure 2 to describe that mode choice covers several way findings, and way finding would cover facilities choice once or more or not.

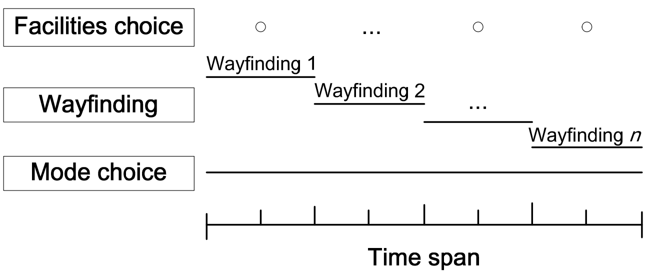

Figure 2. Time span of passenger activities

3. D-M/G/C/C model and algorithm

3.1 The state-dependent queuing model

The state-dependent queuing model is an appropriate tool for modeling pedestrian traffic networks. A linear pedestrian congestion model [12] was proposed to represent the relationship of average walking velocity of the pedestrian V_n, the number of pedestrians n and channel capacity C. Because the number of pedestrian in the channel $n=C+1$ is not achieved, and $n \geq C+1$ will lead to $V_n=0$, that is

$$V_n = \frac{A}{C}(C+1-n) \quad (1)$$

In which C is the channel capacity, and the maximum capacity of the pedestrian is less than or equal to 5 times of the channel area, C=5(L×W), L is the length of the pedestrian access, W is the width of the pedestrian access.

Cheah [13] demonstrated that the M/G/C/C state-dependent queues are stochastic equivalent, and proposed the limit probability model as follows

$$P_n = \left[\frac{[\lambda E(S)]^n}{n!\,f(n)\cdots f(2)(1)}\right]P_0, n = 1, 2, \ldots, C. \quad (2)$$

Where:

$$P_0 = 1\Big/1 + \sum_{i=1}^{C}\left[\frac{[\lambda E(S)]^i}{i!\,f(i)\cdots f(2)(1)}\right]$$

$$E(S) = L/1.5, \quad f(n) = V_n/V_1$$

In which, L is the length of the channel, V_n is the average velocity of pedestrian as the number of pedestrians is n, $E(S)$ is the time of single pedestrians to cross the channel, P_0 is the probability of no pedestrian in the passage.

3.2 D-M/G/C/C model

For the sake of marking the abilities of decision-making and environmental interaction of subjectives, in figure 3, a kind of decision node D is put forward into the queuing network model, which besides the node 1 of split structure. M/G/C/C model with decision nodes is denoted as D-M/G/C/C. In calculation, the proportions of route p_2 and p_3 are updated timely according to the environment of the system.

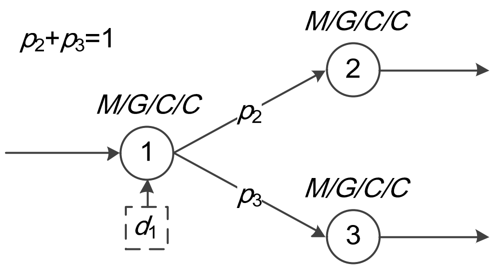

Figure 3. D-M/G/C/C Queuing model

Because of passage 2 and 3 are parallel, passengers would meet two alternatives after leaving the node 1. Two elements consiste the set D. One is the choice of direction d_1, the passenger organization process, which is static rule. The other one is facility selection d_2, the passenger facilities choice behavior, which is dynamic rule. So, they can access passage 2 or 3 selectively.

3.3 General topologies

The generalized extension method [14] is used to labelled the *D-M/G/C/C* Queuing model under arbitrary topologies. After adding a series of decision and buffer nodes, the target queuing network would be expanded into an equivalent Jackson network. The process is described as follows:

Step 1: Initialization

1.1: Input the network *G* (*N*, *A*) and parameters.

1.2: Mark all nodes as unlabelled.

Step 2: Determine the node type

2.1: Select one node *i* randomly.

2.2: If node *i* was labeled, go to step 4.1.

2.3: Mark node *i* as labeled.

2.4: If the node *i* is a source node, go to step 3.2.

2.5: Check the number of input and output arc of node *i*.

- If the number of input and output arc of node *i* is equal to 1, go to step 4.1.
- If the number of output arcs of node *i* is more than or equal to 2, the number of input arc is equal to 1, go to step 3.1.
- If the number of input arcs of node *i* is more than or equal to 2, the number of output arc is equal to 1, go to step 3.2.

Step 3: Increase the buffer and decision nodes

3.1: Add the buffer nodes before each of the alternative nodes and a decision node dj besides the node *i*, go to step 4.1.

3.2: Add a buffer node hi behind node *i*, go to step 4.1.

Step 4: End

4.1: If all nodes were marked as labeled, the end. Otherwise, go to step 2.1.

3.4 Simulation algorithm

The time marching method is used to solve the simulation of D-M/G/C/C model. The occurrence of the next event, such as arrival, decision-making, leaving event and so on, according to the time marching, and the system state will be updated as well. The main program flow chart of D-M/G/C/C queuing network simulation is shown in Figure 4.

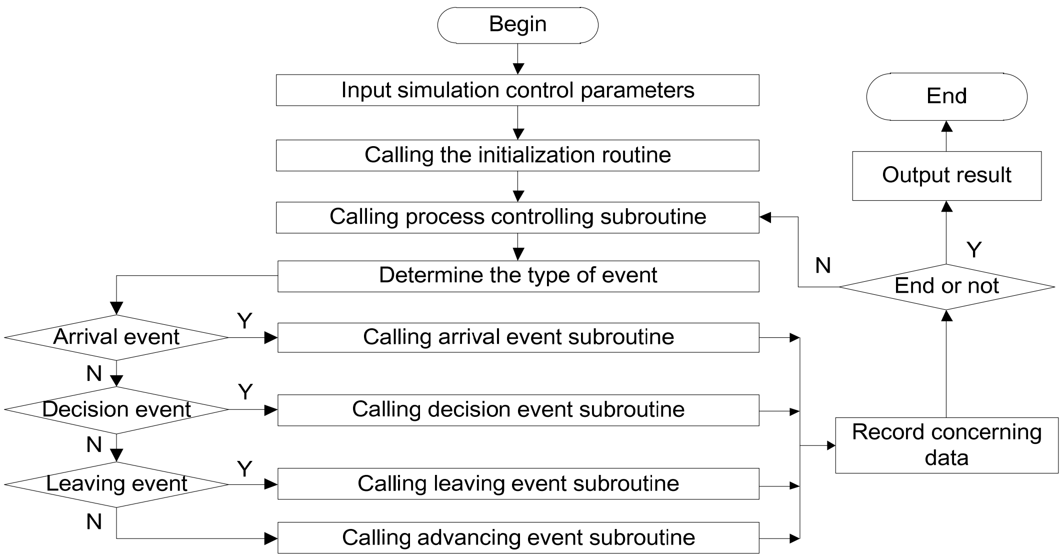

Figure 4. Flow chart of main program

4 Experiment Analysis

4.1 Example Illustration

A scenario of passenger outbound process in railway station of china is developed to analysis the dynamic load of D-M/G/C/C, as is shown in Figure 5. This virtual network is described as follows:

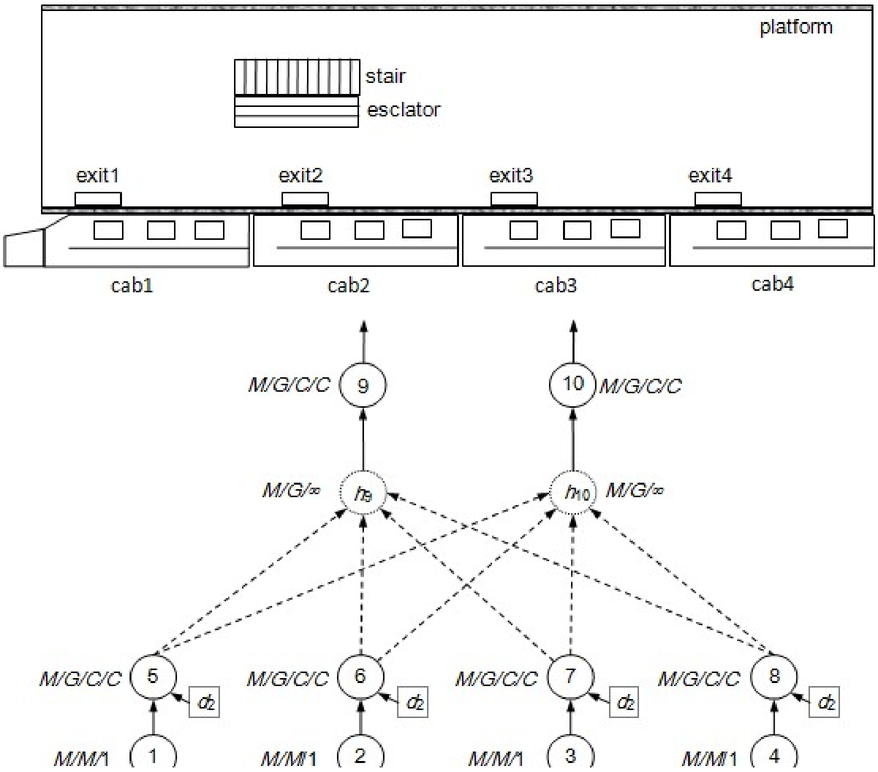

Figure 5. D-M/G/C/C simulation model on passenger outbound

The network illustrates a process of passengers from the platform aground to the check posts underground. Nodes 1 to 4 are the exits, nodes 5 to 8 represent the straight line from each exit to the escalator, nodes 9 and 10 are the escalator and stair, nodes h_9 and h_{10} are buffer nodes. Passengers appear obeys Poisson distribution λ=1.5 from four exits, which accomodates 70 people eachly. Baggage was not considered. Passengers move forward the check posts through the stair or escalator connected to the platform. About stair, length is 30m, width is 2.8m, height is 12.5m, and , speed attenuation coefficient α=0.5. About escalator, length is 30m, capacity is 1.69 person/second, speed is 1.7 m/s. The distance from car exit 1, 2, 3, 4 to the stair are 23.8m, 7.2m, 29.6m and 54.3m. The probability of facilities choice downstairs is calculated with reference [11].

4.2 Result analysis

A program used to implement the simulation. In the passengers evacuation, the dynamic load of various nodes are shown in Figure 6, the number of passengers on the platform is the sum of nodes 5-8, h_9 and h_{10}.

Proper analysis can prove the rationality of the simulation.

Firstly, the number of passengers on the platform increases linearly at the beginning, the maximum number of passengers on the platform is nearly 100 persons. After all passengers went out of the cars, the number of passengers decreased to 0.

Secondly, the volume in escalator increased linearly first, and then maintained at the maximum capacity level for 80 persons, subsequently converted to a linear decrease. Such changes is consistent with operation characteristics of escalators. When the number of passengers on the platform is 0, the number of passengers in escalators begin descreas. The last part of passengers through the escalator downstairs.

Thirdly, the volume in stair began to increase until the passengers waiting for escalator up to 30 people. The acceptable time for waiting escalator is about eighteen seconds with height differentce of 12.5m.

Otherwise, they will consider selecting the stair. Above features consistent with the actual situation of outbound process.

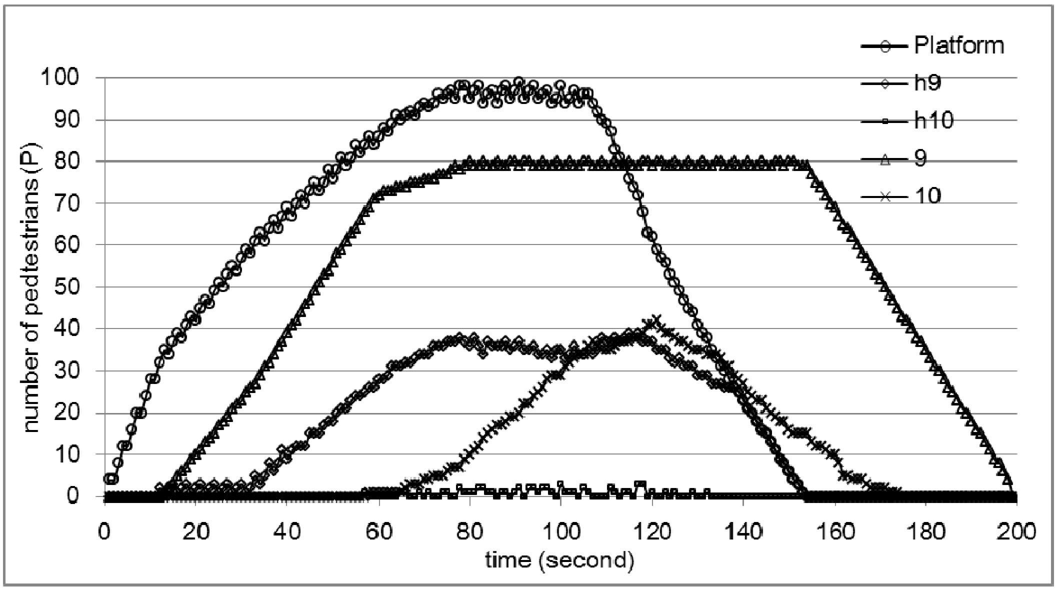

Figure 6. Simulation results

5 Conclusion

A D-M/G/C/C model was proposed to fulfill the coordination of subjective passenger behavior and objective distribution environment, which is a practical simulation tool for analyzing the dynamic situations of passengers use facilities. The detailed description of the passenger behavior makes it possible to draw more realistic simulation results. Moreover, it is exciting that the model would be further applied.

Acknowledgements

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References

[1] Dirk Helbing, Peter Molnar, Illes J Farkas, Kai Bolay. Self-organization pedestrian movement. *Environment and planning B: planning and design*. 2001; 28: 361-383.

[2] Dirk Helbing, Lubos Buzna, Anders Johansson and Torsten Werner. Self-organized Pedestrian Crowd Dynamics: Experiments, Simulations, and Design Solutions. *Transportation Science*. 2005; 39(1): 1-24.

[3] Eleonora Papadimitriou, George Yannis, John Golias. A critical assessment of pedestrian behavior models. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2009; 12(3): 242-255.

[4] Hirth J, Mehdi S, Schmitz N, Berns K. Development of a Simulated Environment for Human-Robot Interaction. *Telkomnika*. 2011; 9(3): 465-472.

[5] Hoogendoorn SP, Bovy PHL. Pedestrian route-choice and activity scheduling theory and models. *Transportation Research Part B: Methodological*. 2004; 38: 169-190.

[6] Dirk Helbing, Peter Molnar. Social force model for pedestrian dynamics. *Physical review E*. 1995; 51(5): 4282-4286.

[7] Vietor J Blue, Jeffrey L Adler. Cellular Automata Micro simulation for modeling bi-directional pedestrian walkways. *Transportation Research Part B: Methodological.* 2000; 35(3): 293-312.

[8] Li Yang, Junhui Hu, Lingjiang Kong. Two dimensional mixed traffic flow considering the transit traffic. *Telkomnika*. 2012; 10(8): 276-283.
[9] Mitchell DH, Smith MGJ. Topological network design of pedestrian networks. *Transportation Research Part B: Methodological*. 2001; 35(2): 107-135.
[10] Gipps M. A Micro-simulation Model for Pedestrian Flows. *Mathematics and Computers in Simulation*. 1985; 27(2-3): 95-105.
[11] CY Cheung, William HK Lam. Pedestrian Route Choices between Escalator and Stairway in MTR Stations. *Journal of Transportation Engineering*. 1998; 124(3): 277-285.
[12] Yuhaski SJ, Mac Gregor Smith J. Modeling circulation systems in buildings using state dependent models. *Queuing Systems*. 1989; 4(3): 19-38.
[13] Cheah J, Mac Gregor Smith J. Generalized M/G/C/C state-dependent queuing models and pedestrian traffic flows. *Queuing Systems*. 1994; 15: 365-86.
[14] Kerbache L, Mac Gregor Smith J. Asymptotic behavior of the expansion method for open finite queuing networks. *Computers & Operations Research*. 1988; 15(2): 57–69.