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PASSENGER BOARDING/ALIGHTING MANAGEMENT IN URBAN RAIL TRANSPORTATION*

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ABSTRACT

Heavy traffic consequences in crowded cities can be extremely reduced by using mass transportation. Recent extensive studies on Tehran subway system, as a representative of crowded cities, show that ever increasing commutation demand results in rapid decline in service quality and satisfaction level, system capacity wastage, and poorer system performance. Since passenger boarding/alighting period is noticeable compared to the inter-station travel time, it seems that passenger boarding/alighting management would play a significant role in system performance improvement. Aiming at increasing satisfaction level and service success rate, while reducing travel time, different boarding/alighting strategies are proposed. Passengers behaviors are carefully simulated based on a microscopic model, through introducing an inclination function which governs a passengers movement in a two-dimensional queue. Simulation results, in terms of three aforementioned measures of performance, show that in less crowded stations, the first strategy, expectedly, outperforms the other two. However, in crowded stations (e.g. interchange stations) the third strategy outperforms the others significantly.

1 INTRODUCTION

The continuing world-wide urbanization and ever increasing number of cars have produced traffic jams. Mass transportation, and in particular urban rail transit, as the most convenient, environment friendly, having highest capacity per hour per direction, fastest transportation means [1], has received much attention amongst urban planners.

Train stations are the passenger hubs in railway systems and proper layout of the station can lead to better capacity deployment. Utilization of capacity is of particular importance for main stations in which line inter-changes, service interchanges or transfer to other modes of transportation is possible [2]. Moreover, the station layout affects passenger's movement which in turn affects system performace. Regarding passenger behavior (movement), number of simulation models have been proposed, e.g. queuing models, transition matrix models, and stochastic

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models, which are partly related to each other [3].

Cellular Automata (CA) micro simulation has emerged as an effective technique for modeling complex behaviors. CA is named after the principle of automata (entities) occupying cells according to localized neighborhood rules of occupancy. The attractiveness of using CA is that the interactions of the entities are based on intuitively understandable behavioral rules, rather than performance functions [4].

The update of the cells may occur in a synchronous or asynchronous form. CA-based models have been widely used in pedestrian movement modeling and have advantages in the simulation of crowdy condition and friction effect. Also, the CA model is capable of effectively capturing collective behaviors of pedestrains who are autonomous at a micro-level [3]. In this paper, we, too, use CA-based models for predicting passengers' behaviors regarding their movements inside wagons and on the station platform. In section 2, *PROBLEM DEFINITION*, The significance of a train's stop time period compared to the total inter-station travel time is brought up. Then our approach to improve the system performance using passenger's behavior model is discussed. In the next section, *SYSTEM'S MODEL*, system objects, and its dynamics are accurately studied. Herein, Measures of Performace (MoP) of interest are also introduced. Different boarding/alighting scenarios are discussed in section 4.The relevant Simulation setup and results, in terms of aforementioned MoPs, for different boarding/alighting scenarios are mentioned in section 5. Concluding remarks and final comparisons appear in section 6.

2 PROBLEM DEFINITION

Field information collected in Tehran metro system show that, on average, boarding/alighting period constitutes 28% of the total inter-station trip period. This shows that passenger boarding/alighting period is noticeable compared to the inter-station travel time. A shorter stop period at station permits trains to travel faster while keeping inter-train disance limit. Thus, it seems that passenger boarding/alighting management would play a significant role in overall system performance improvement. The main concern in passenger boarding/alighting management can be identified as follows:

How to manage passenger movement in such a way to experience less collisions, travel faster, and be served successfully regarding getting in/out of the wagon.

To answer this question, different scenarios of boarding/alighting are presented in which passenger movement is of critical importance. In order to compare scenarios, passenger movement is simulated by microscopic modeling of the passenger's behavior.

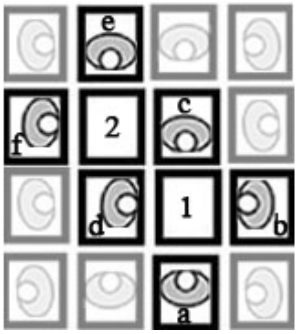

FIGURE 1. Movement mechanism

3 SYSTEM'S MODEL

A Passenger's behavior governs his movement in a two-dimensional queue. This behavior is modeled through introducing an inclination function, *I(P,S)*, which specifies how attractive a free space look to a subject passenger. This attractiveness accommodates parameters such as, number of stations to the passenger's final destination (station), passenger's distance to exit door(s), potential of a free space (higher for seats and spaces in less populated areas) that the passenger is inclined to occupy. Other parameters such as group pressure, sex, and age are not considered herein, either for complexity reasons or because they are not applicable.

3.1 System's Basic Objects

To study passenger movement, the two main data structures to be defined are *Space* and *Person* structures. The structure have features as follows:

Space:

1. (x,y) coordinates
2. Occupancy status (free/occupied)
3. Set of competitors (persons)
4. Occupant
5. Space type (seat/non-seat)
6. Space's potential coefficient (attractiveness coefficient, assigns higher coefficient values to seats, and spaces in less populated areas)

Person:

1. (x,y) coordinates
2. Direction status (going in/out of the wagon)
3. Success/unsuccess status with regards to boarding/alighting
4. Set of free surrounding spaces
5. Origin/destination of the person's trip
6. Inclination-to-occupy level corresponding to the set of free surrounding spaces

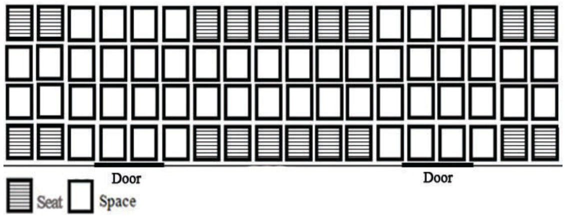

FIGURE 2. The partial layout of a wagon.

Figure 1 illustrates how the movements are performed according to *I(P,S)*. In the figure, passenger *c* can potentially compete with passengers *a*, *b*, and *d* over space *1*, and compete with passengers *d*, *e*, and *f* over space *2*. Applying the related inclination function to passenger *c* leads to passenger *c* competing for either space *1* or *2*. The same situation applies to passenger *d*. A Passenger's behavior in filling the spaces is being considered from the origin station to the destination. This is done for all stations from first to last. In order to maintain generality, population is randomly distributed inside the wagon. Also, passengers' origins/destinations are set at random. Service demand in some stations, e.g. interchange stations, are considered to be higher. The number of people boarding/alighting in stations is set based on the traveler's origin/destination matrix. The elements of this matrix are set at random accounting for the fact that interchange stations are more crowded.

As shown in Fig. 2, 72 places are available inside a wagon (partially) including 20 seats. Each door can pass two persons side-by-side. To provide a fair basis for comparing different scenarios (section 4), part of a wagon which includes two doors is considered throughout.

3.2 System's Dynamics

In this subsection, the interaction mechanism between system objects introduced in the previous section are studied. We assume a bi-directional microscopic model which accounts for side-stepping, forward and backward movements (a slightly similar approach have been adopted by [5, 6, 8]).

Regarding movement implementation, we proceed as follows :

◇ Door opens.
◇ For each (free) space, the inclination functions of all potential competitor passengers are evaluated.
◇ For each competitor passenger, all inclination functions corresponding to all surrounding free spaces are evaluated.
◇ The maximum of the inclination functions corresponding to a specific passenger determines for which space this passenger is going to compete.
◇ From the above, for all (free) spaces, the set of competitors is determined.
◇ For each member of the set, based on the previously calculated inclination values, and using a uniform random number generator, movements are determined. The movements are not enforced from member to member calculations.
◇ By investigating the movements, for each space, three outcomes might occur. The space gets occuppied, or it stays free due to a collision, or lack of movements from competitiors.
◇ The previous steps are repeated until the door is closed.
◇ The door is closed if there is no crossings for a crossing period limit.

For the sake of brevity, the details have been left out ,though, the main idea has been illustrated by the flowchart of Fig. 3.

4 DIFFERENT BOARDING/ALIGHTING SCENARIOS

Passenger boarding/alighting management in urban rail transportation can be considered either from a macroscopic point of view or from a microscopic one. In the former case, strategies are adopted according to relative location of wagon doors and station components (exit corridors, stairs, scalators and etc). In the latter, which is our approach, scenarios are adopted in connection with detailed modeling of passengers' movements. In general, different strategies try to somehow regulate and separate in-flow and out-flow of passengers.

In this article, three different scenarios have been proposed which are compared against the de facto scenario, as a benchmark, where boarding and alighting are performed concurrently and through the same door. To be harsh on comparisons, the de facto scenario has been modelled so that boarding passengers make a free corridor for alighting passengers, waiting for sometime (no alighting activity), and thereafter try to board. This shows its best case performance and is sometimes far from real life (Fig. 4-a).

- **Boarding/Alighting Space Division (BASD):** The entrance to and exit out of wagons are isolated through a seperator. This helps to somehow seperate the in-flow and out-flow of passengers Fig. 4-c. In this scenario, a barrier at the exit path prevents boarding passengers from entering. On the other hand, boarding passengers queueing to enter, do not let the alighting passengers to exit from the entry path. Not using a barrier on the entry path facilitates exit from both paths in case there are no boarding passengers waiting. A 3D view of this scenario is depited in Fig. 5.
  As can be clearly seen in this figure, regardless of the MoPs derived for different scenarios, more accessibility for children, disables and elderly is provided in BASD.

- **Boarding/Alighting Dedicated Doors (BADD):** The in-flow and out-flow of passengers are directed through different doors of the wagon. Fig. 4-b.

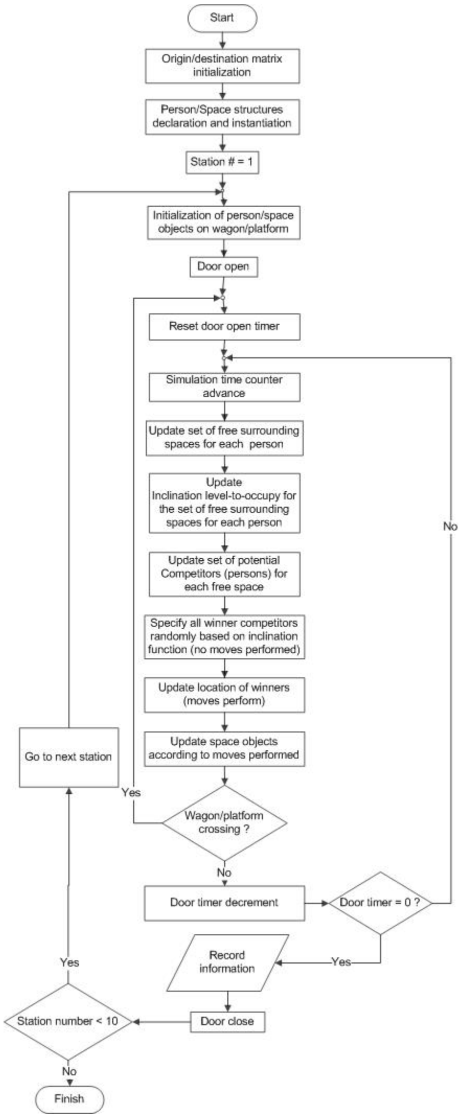

FIGURE 3. System's dynamic flowchart.

- **Boarding/Alighting Time Division (BATD):** In-flow and out-flow of passengers are scheduled in different times. This is done by first letting out-going passengers to exit through a chamber closed to in-coming passengers. Then the chamber opens to in-flow passengers Fig. 4-d. Due to space requirements and conventional platforms' limited width, the third scenario (BATD) proves impractical. Thus, we are not considering this scenario in our performance evaluation procedure herein. However, in future works, where we intend to study how different platform layouts might affect system perfomance, BATD will be evaluated.

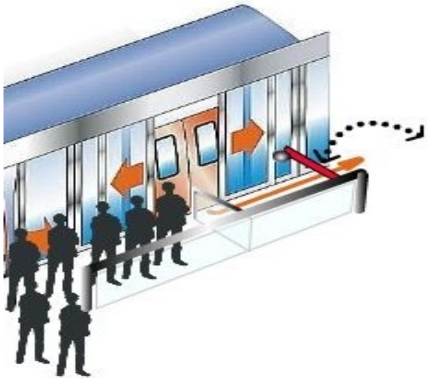

FIGURE 5. The 3-D view of the exit/entry separator per door scenario.

The practical simulated boarding/alighting strategies are: using the same door (status quo) as it is shown in Fig. 4-a, using an exit/entry separator per door (Fig. 4-c), using different doors (some doors are used for boarding and the others for alighting). All strategies are evaluated in equal simulated real conditions for comparison purposes. For more clarity the Fig. 5 also presents the same strategy showed in Fig. 4-c drawn in a graphical environment.

5 SIMULATION RESULTS & PERFORMANCE EVALUATION

Increasing customer satisfaction and service success rate, while reducing travel time are the most common goals in public transportation systems. We have quantified these factors by the following MoPs, though they are not necessarily uncorrelated :

Train's stop time period at the paltform
This period represents the simulation time step between wagon's door open and close.
Service Success Rate
Service success rate is the percentage of the passengers succeeded in getting in or out according to the origing/destination.
Satisfaction Level
Satisfaction Level depends on many subjective factors. However, we choose to equate the satisfaction level with how comfortabley passengers move around. Thus, the number of collisions one experiences from his/her origin to destination is adopted as a representetive of satisfaction level.

System dynamics of the three aformentioned new scenarios together with the de facto one have been simulated using MATLAB. The simulated scenarios have been run many times to produce reliable results.

The simulation setup is as follows:

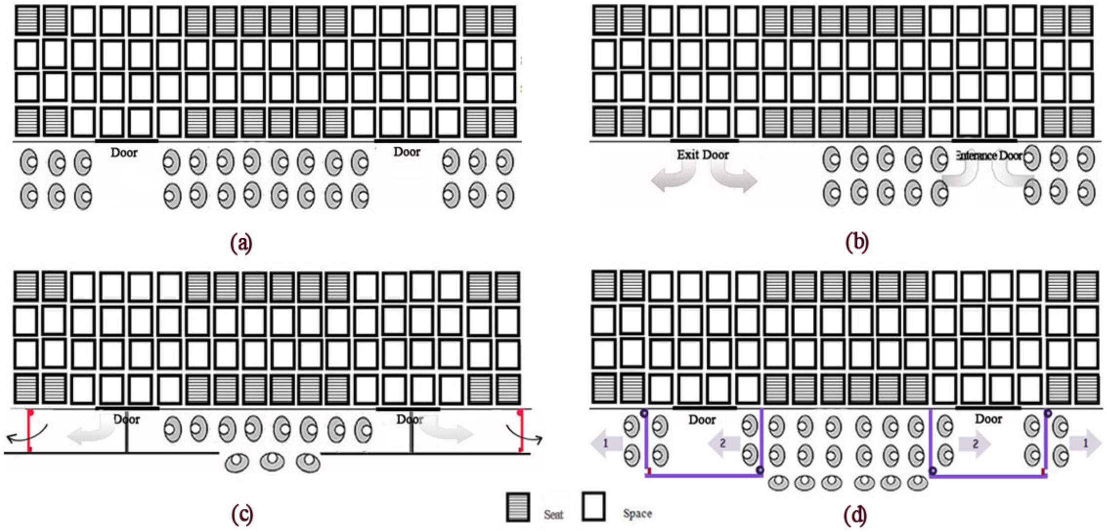

FIGURE 4. (a) De facto scenario, (b) Boarding/Alighting Dedicated Doors (BADD), (c) Boarding/Alighting Space Division (BASD), (d) Boarding/Alighting Time Division (BATD).

1. Four types and in total nine stations are considered. Start station (all in-flow), end station (all out-flow), six regular stations, and one inter-change station (high demand).
2. In setting origin/destination matrix, the service demand of regular stations has been considered to be half of the inter-change station. In each repetition, origin/destination matrix has been randomly set.
3. For each on board passenger, failure to alight sets his/her new destination to the next station.
4. All MoPs are evaluated against Initial Occupancy Level (IOL) which shows the percentage of the wagon's capacity, initially occupied at the start station. The IOLs considered are 20%, 40%, 50%, 70%, and 80% which may represent demands at different times of the day.
5. Crossing time period is set at 5 simualtion time steps.
6. For the de facto scenario, boarding passengers wait for 3 simulation time steps of no crossing activity, before taking movement actions.
7. Results from stations 1 (start station) and 9 (end station) have been excluded from MoPs calculations, since they have just in-flow and just out-flow passengers respectively and BASD and BADD scenarios are not actually implemented therein.

The simulation results are illustrated in Fig. 6. On all charts, vertical lines are used to specify 95% confidence intervals.
Average train's stop time at the paltform (the top chart) results show that BASD outperforms the other two for all IOLs. This outperformance grows with increasing IOL reaching up to 15%. For up to IOL of about 60%, the de facto scenario is better than BADD. After this point, BADD shows little improvment over the de facto scenario.

The second chart (the middle one), illustrates the average number of collisions a person experiences during his/her travel time, and can be a representative of passenger satisfaction level. Compared the other two, the BASD scenario shows higher satisfaction levels all over different IOLs. However, the level of improvement fluctuates going from low to high IOLs. Except for IOL of around 50% where the other two scenarios perform almost the same, the de facto scenario is slightly better than BADD.

Similar to the top chart, the average boarding/alighting failure rate (the bottom chart) demonstrates superiority of the BASD for all IOLs, which grows towards higher IOLs. The other two scenarios, change superiority position back and forth from low to high IOLs. Though, the difference is not that noticeable.

As can be seen from the results, for very low IOL of 20%, all scenarios perform the same. This is consistent with our expectation since the level of inter-passenger contention is very low.

It is worth mentioning that, regarding the de facto scenario, the best behavior of the boarding passengers was assumed. Violating this assumtion will considerably downgrade this scenario. The latter leads to even better outperformance of BASD. Also, the superiority of the de facto scenario over BADD becomes questionable.

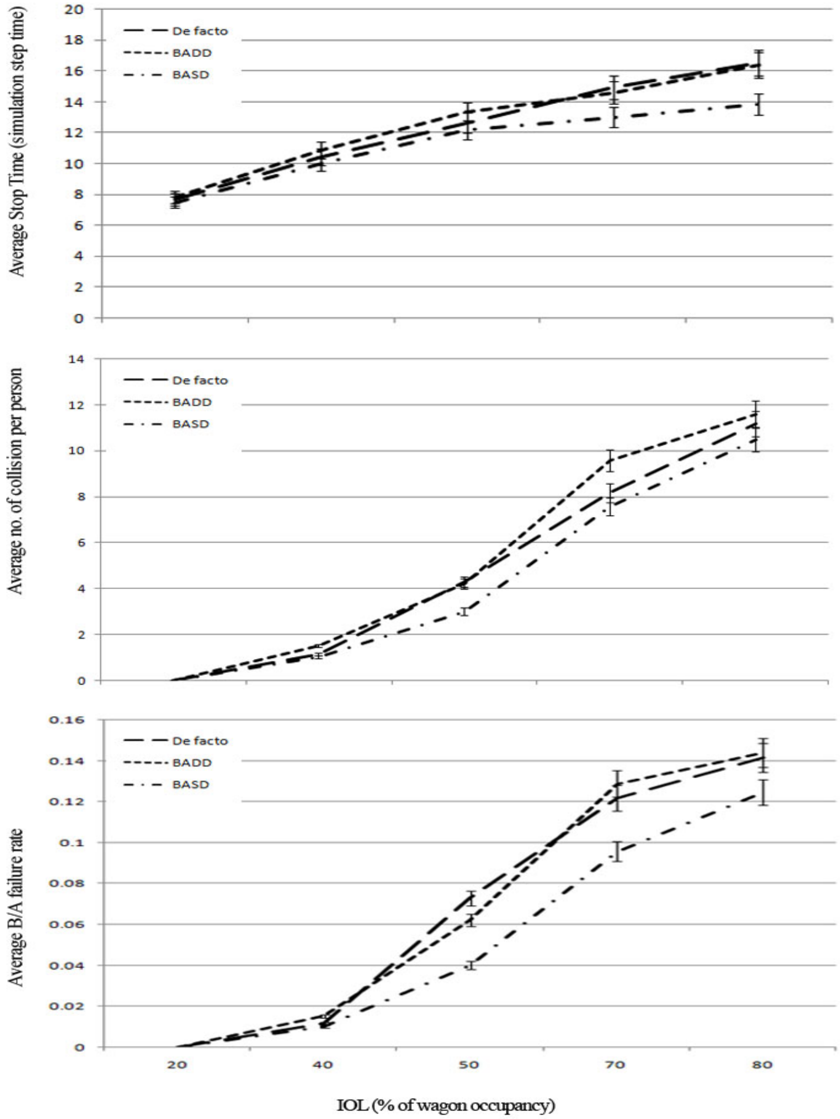

FIGURE 6. The charts show *the average stop time per station*, *the no. of experienced collisions per person*, and *the average failure rate of the system* against *initial occupancy level* from top to bottom respectively.

6 CONCLUSION

Since passenger boarding/alighting period is noticeable compared to the inter-station travel time, it seems that passenger boarding/alighting management would play a significant role in system performance improvement. To reduce inter-passenger contention, three different boarding/alighting scenarios, which try to regulate and separate in-flow and out-flow of passengers, are proposed. From practicality point of veiw, two of these three scenarios are compared with the de facto scenario of boarding/alighting. To do the comaprision, passenger movement is simulated using microscopic modeling of the passenger's behavior. The basic components of our model are *space* and *person* objects, and an *inclination function* which governs a passengers movement (interaction between person and space objects) in a two-dimensional queue. Simulation results are collected for three MoPs of interest which are *Train's stop time period at the paltform*, *Service Success Rate*, and *Satisfaction Level*. The results show definite outperformance of BASD scenario where in-flow and out-flow of passengers are seprated using the barrier at each door. This outperformance appears on all MoPs and grows with increasing IOLs. As expected, all scenarios perform almost the same for low IOLs.

REFERENCES

[1] M. Breithaupt, ”Latest Developments in BRT from Around the world”, World Urban Transport Leader Summit, Germany, 2010.

[2] C.W. Tsang and T.K. Ho, ”Passenger Flow and Station Facilities Modeling for Metro Station Layout Design”, 4th International Conference on Traffic and Transportation Studies, Dalian, China, 2004.

[3] Zhang Qi, Han Baoming, and Li Dewei, ”Modeling and Simulation of Passenger Alighting and Boarding Movement in Beijing Metro Stations”, Transportation Research Part C, Vol. 16, pp. 635-649, 2008.

[4] Jodie Y. S. LEE, William H. K. LAM, and Mei Lam TAM, ”Calibration of Pedestrain Simulation Model For Signalized Crosswalk in Hong Kong”, Proceedings of the Eastern Asia Society for Transportation Studies, pp. 1337-1351, 2005.

[5] W.K. Chow and Candy M.Y. Ng, ”Waiting Time in Emergency Evacuation of Crowded Public Transport Terminals”, Safety Science, Vol. 16, pp. 844-857, 2008, .

[6] Victor J. Blue and Jeffrey L. Adler, ”Cellular automata Microsimulation for Modeling bi-directional Pedestrain Walkways”, Transportation Research Part B, Vol. 16, pp. 293-312, 2008.

[7] L. D. Tavares, D. A. G. Vieira, R. R. Saldanha, and W. M. Caminhas, ”Simulating Car Accident with Cellular Automata Traffic Flow Model in Automata”, Department Electrical Engineering Universidade Federal de Minas Gerais, Brazil, 2009.

[8] Victor J. Blue and Jeffrey L. Adler, ”Modeling Four Directional Pedestrain Movement”, Transportation Research Board, pp. 00-1546, 2000.