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Pedestrian traffic management of boarding and alighting in metro stations

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A R T I C L E I N F O

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A B S T R A C T

The objective of this work is to determine, by means of simulation and experiments, the effect of pedestrian traffic management in the boarding and alighting time of passengers at metro stations. Studies were made by means of a pedestrian traffic microsimulator (LEGION Studio) and experiments at the Human Dynamic Laboratory (HDL) of Universidad de los Andes in Santiago de Chile, to obtain criteria for the pedestrian traffic management on the platform and doors of metro cars. The methodology consists of building a boarding/alighting hall of a metro car and the relevant portion of the platform in front of the hall. The simulation scenarios included the location of the vertical handrail in the hall of the car, delimitation of a keep out zone in front of the doors and the use of differentiated doors for boarding and alighting. The results of the simulation and laboratory experiments are expressed in Pedestrian Level of Service (LOS), Passenger Service Time (PST), passenger density on the vehicle and platform, and passenger dissatisfaction. Both, the simulation results and laboratory experiments allow us to give some recommendations for the pedestrian traffic management in metro systems.

1. Introduction

In this work we define pedestrian traffic management as the rational administration of the movement of people to generate adequate behavior in public spaces to improve the use of pedestrian infrastructure.

To measure how efficient is the pedestrian traffic management in public transport systems, the Passenger Service Time (PST) can be used. The PST – also called dwell time (t_d) – is the time that a public transport vehicle remains stopped transferring passengers (TRB, 2000). It depends on the number of boarding and alighting passengers and how quickly they do it. The speed of passengers is determined by the number and width of doors, number and height of steps, internal layout of vehicles, the density of passengers inside the vehicle, the fare collection method, among other variables.

In rail systems dwell time depends in principle on the train control strategy rather than the number of boarding and alighting passengers, because at low demands trains stop a fixed time at each station. However, as the passenger demand increases, the dwell time becomes more dependent on boarding and alighting operations and "station dwell times are the major component of headways at short frequencies" (TRB, 2003: 5–19).

The main application of PST models is the prediction of effects of hypothetical or future situations, so that measures can be taken to adjustment to the infrastructure design or operation of the system. Thus, if the PST is added to the acceleration t_a and braking time t_f then the occupancy time t_o at the station is obtained. Given t_o we can calculate the capacity or maximum

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number of vehicles that can serve a station as (Fernandez and Planzer, 2002) $Q_E = \alpha N/t_o$, where N is the number of loading positions and α is the availability of those loading positions – i.e., the proportion of the time that a loading position is available. The station capacity allows the calculation of congestion in terms of delays at the station and queueing upstream the station.

The aim of this paper is to determine, by means of simulation and experiments, the effect of pedestrian traffic management in the boarding and alighting time at metro stations. In particular, this work focuses on the study of low-cost measures that have not been applied in metro stations. As a case study we use the Metro de Santiago, but the results can be expanded to other metro and LRT systems.

This paper is made of six chapters, including this one. In Chapter 2 a summary of the literature review on the topic is presented. Next, in Chapter 3 the methodology followed for this work is explained. Chapter 4 shows the simulation results of the studied scenarios. Chapter 5 presents the experimental results obtained at the Human Dynamics Laboratory of Universidad de los Andes. Finally, in Chapter 6 some conclusions and recommendations are delivered.

2. Literature review

The literature on dwell time models is profuse, mainly with respect to the bus system. It is not our objective to make a thorough review of all models. Just to mention a few contributions, Levinson (1983) was one of the first in studying in detail the dwell time. However, the European experience started with the work of Pretty and Russel (1988) by proposing the following dwell time model for buses:

$$T = C + \max\left\{\sum_{i=1}^{m} a_i;\ \sum_{j=1}^{n} b_j\right\} \tag{1}$$

where T is the stopped time measured since the wheels are stooped until they start to move again; a_i and b_j are the time that each passenger takes for alighting and boarding, respectively; n and m are respectively the number of alighting and boarding passengers; and C is the dead time for opening and closing doors.

Following this line of thought, York (1993) updates previous studies of Cundill and Watts (1973), where different values for the boarding time were observed as a result of the payment method. York proposed a specific function for the dwell time in buses of one and two doors.

In the case of the American literature the Highway Capacity Manual (HCM) (TRB, 2000) and the Transit Capacity and Level of Service Manual (TRB, 2003) elaborate the well-known dwell time model:

$$t_d = t_{oc} + t_a P_a + t_b P_b \tag{2}$$

The coefficients in Eq. (2) are as follows: t_{oc} is the time for opening and closing doors, and t_a and t_b are the average time it takes each passenger alighting and boarding, respectively. These are parameters to be obtained for each transport system, vehicle type, and method of operation. The explanatory variables, P_a and P_b, are respectively to the number of passengers alighting and boarding though the busiest door at the 15 min peak period.

Similarly, Puong (2000) proposed a dwell time model based on observation data. The study showed that the dwell time is a linear function of passenger alighting and boarding volumes, and a nonlinear function of the overcrowded level inside the vehicle. Heinz (2003) also measured the boarding and alighting times for different type of trains based on observation data and Wiggenraad (2001) studied other factors in Dutch stations such as passenger distribution on the platform, station type, vehicle characteristics and period of day.

In the Southern Hemisphere some authors found that the PST depends on the existence of a formal platform at the station; the degree of congestion of the platform; the occupancy of the aisle of vehicles; and the capacity of the entry hall before the fare collection point (Fernandez et al., 1995; Gibson et al., 1997; Fernandez et al., 2008). A formal platform is a well-defined area of the sidewalk, separated of the pedestrian traffic. On the other hand, an informal platform is a portion of the sidewalk shared with pedestrians. The resulting model is shown in the following equation, where the correspondence with parameters t_{oc}, t_a and t_b of the HCM model is indicated.

$$PST = \underbrace{(\beta_0 + \beta_0'\delta_1)}_{t_{oc}} + \max_{j=door}\left\{\underbrace{(\beta_1 + \beta_1'\delta_1 + \beta_1''\delta_2)}_{t_b}P_{Bj} + \underbrace{\left(\beta_2 e^{-\beta_2' P_{Aj}} + \beta_2''\delta_3\right)}_{t_a}P_{Aj}\right\} \tag{3}$$

In the above model, P_{Bj} and P_{Aj} are the number of boarding and alighting passengers through door j, respectively; β_k^i are parameters so that β_0^i are dead times, β_1^i are boarding times per passengers, β_2^i are alighting times per passenger, and β_2' is the parameter of the exponential function. Variables δ_k are dummy so that $\delta_1 = 1$ if the platform is congested; $\delta_2 = 1$ if more than four passengers board the bus, which was the number that can be stored before the fare collection point; and $\delta_3 = 1$ if the aisle of is full; otherwise $\delta_k = 0$, $\forall k$. Parameters of this PST model calibrated in Santiago de Chile are shown in Table 1.

As a way of illustration of the prediction of the above model in formal platforms, if this is congested the model predicts a dead time of 2.34 s, and the boarding time will be 3.39 s/pass, 13% higher than the case when there is no congestion on the platform. In addition, if 5 passengers board the bus, the boarding time will increase to 3.83 s/pass, 14% higher than the case