Developing a Model for Analyzing Pedestrian Flow in Small Scale Airport Terminal Building

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***Abstract:** According to the common belief, pedestrian behavior is as 'complex' or 'irregular' as to predict easily. Pedestrians have individual requests, routes, preferences, and goals most of which are determined by the experiences. Moreover, those experiences influence the reaction towards certain physical environments in order to develop and choose the best behavioral preference(s). The effect of predicting and modeling pedestrian movement on architectural design has been argued and gaining importance among today's architectural environment particularly for complex buildings and conditions. Due to the rapidly changing technology and human needs, traditional pedestrian modeling methods including based modeling and micro simulation which demonstrate the pedestrian flow have been becoming insufficient. Therefore, more user-sensitive modeling methods are needed particularly to evaluate and analyze the pedestrian movement. Many models such as Markovian Model, Constructral Theory, Crowds Models have been accepted as efficient model approaches to develop pedestrian flow dynamic models. Analysis and simulation techniques of pedestrian flow characteristics comprise the base in order to develop pedestrian movement simulation. A field study related to collecting pedestrian characteristics and behavior data was conducted in Adana Airport. This building was established in 1956 and used for a limited number of flights for a long time until its privatization. Following the privatization period, both the flight and passenger numbers have considerably increased in this airport. This paper mainly concerns on the future demands of customers which will be affected by the rapidly increasing trend of passenger and flight numbers, as well as changing needs due to physical and emotional conditions of users. As a result, the increasing pedestrian traffic will raise the issue on design and construction, as well as post-occupancy evaluation of the terminal building. A crowd-density prediction was developed for the future functioning of the terminal building particularly for domestic flights. The records were mainly taken by camera, and analyzed through statistical methods in order to understand and evaluate pedestrian flows. A model which is named as 'Semi-major Axis for Pedestrian Ellipse' was developed to analyze design parameters of the existing terminal building due to the passenger movement. In specific, the research results reveal that the pedestrian flow-density relation model is a quadratic equation model for the transport axis within the airport terminal building particularly for the corridors. Parameters of a social force model were acquired all of which based on the developed model. Range of semi-major axis for pedestrian ellipse in social force model was ascertained as well.*

Keywords: Pedestrian Flow, Social Force, Airport Terminal Simulation, Adana Airport, Transportation Building

1. Introduction

Pedestrian flow is a dynamic process that points out a multi-body system which strongly influences persons' activities. The pedestrian flow dynamics is closely connected with many particular systems each of which has driven effects on human movement. It is important to know the properties of pedestrian flow. Pedestrian flow has become a remarkable topic in architecture, engineering, and even physics and mathematics [1].

Understanding pedestrian flow is very important in designing or improving public facilities. Researchers are encouraged by pedestrian flow dynamics in order to simulate evacuation behavior by using various macroscopic and microscopic modeling approaches, such as cellular automata models [2 ; 3] fluid dynamic models [4 ; 5], lattice gas models [6; 7] and social force models [8; 9] and evacuation models [18; 19;20; 21].

Pedestrian flow effects on evacuation cases which are observed as phenomena including the clogging effects at bottleneck, the faster-being-slower effect and the inefficient use of alternative exits are reproduced in social force models[8]. It is suggested that the optimal behavior in escape situations can be understood through mixture of the individualistic and herding behaviors.

In discrete modeling aspect, the floor field model has been widely used [3; 10]. The floor field is sufficient to model collective effects and self-organization encountered in pedestrian dynamics [3]. Kirchner and Schadschneider [10] stress that the evacuation time depends on the strength of the herding behavior. A method is developed by Huang and Guo [11] to calculate the static floor field which is determined by the most feasible distance to each exit.

The typical pedestrian flows have been simulated by the use of a few models: the lattice-gas model of biased-random walkers [12; 13]. Tajima et al. [14] depict that the clogging transition occurs in the unidirectional channel flow with a bottleneck if the density is higher than the threshold. Aforementioned studies are carefully reviewed and analyses were conducted in one of the mid-scale airport terminals, Adana Airport Terminal, in Turkey under the illumination of social force model. Mainly the flow speed and density of passengers are concerned in the analyzing process.

Adana Aerodrome was opened to civil and military traffic in 1937 and has been opened to the international air traffic since 1956 [15]. Adana airport has been serving 24 hours to the domestic and international passenger and cargo traffic since 1993.It has been serving as a statue of airport since 1995.

This study gives object and establishes relation between parameters of pedestrian flow models of different facilities using field pedestrian flow speed, density, and flow data collected in corridors and stairways in the Adana Airport Terminal Building in Turkey.

2. Pedestrian Flow Model in Small Scale Airport

The corridors and stairways in transport terminal are chosen as the observation entities to study the relations of pedestrian “flow (F)”, “density (D)” and "speed (S)”.

2.1 Corridors

Pedestrian flow-density relation graph in corridors is demonstrated in Figure 1.

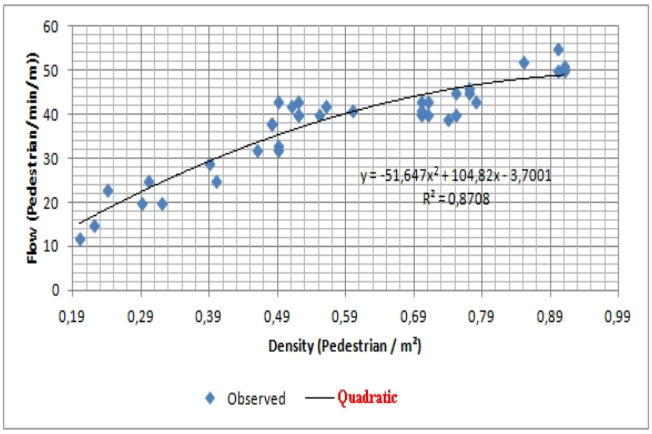


Figure 1: Flow-Density Relation (Corridors)

The relation model when the quadratic function is used gives the formula as in (1) as displayed in the Figure 1.

$$F = -51.64\, D^2 + 104.82D - 3.70 \qquad (1)$$

In a similar case, Figure 2 demonstrates the relation between flow and space.

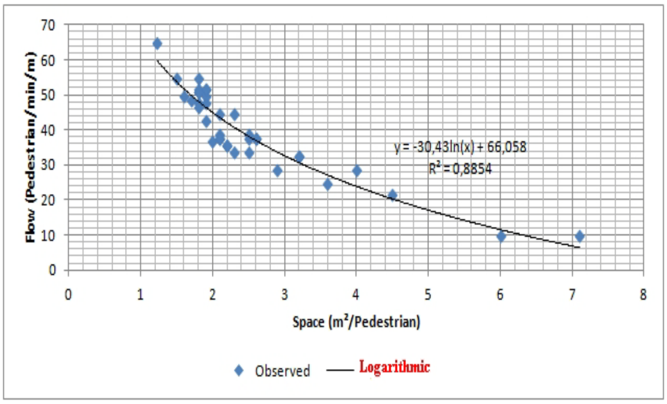


Figure 2: Flow-Space Relation (Corridors)

Formula 2 given in the below is produced from the relation model of F (flow) and SP (space) in a logarithmic function.

$$F = -30.43 \ln SP + 66.05 \qquad (2)$$

According to Equation 1, in flow-density relation model, D=0.88 ped/m², SP=1.1 m²/ped, Flow goes to maximum value of 55 ped/min/m. The minimum space that is expected for pedestrian walk is determined as 1.1 m²/ped. If SP is less than 1.1 ped/m², Flow is reduced through the reduction of SP. The minimum space which is needed for a comfortable walk by a pedestrian is defined as "the maximum dynamic space". Figure 3 shows the speed-density relation curves.

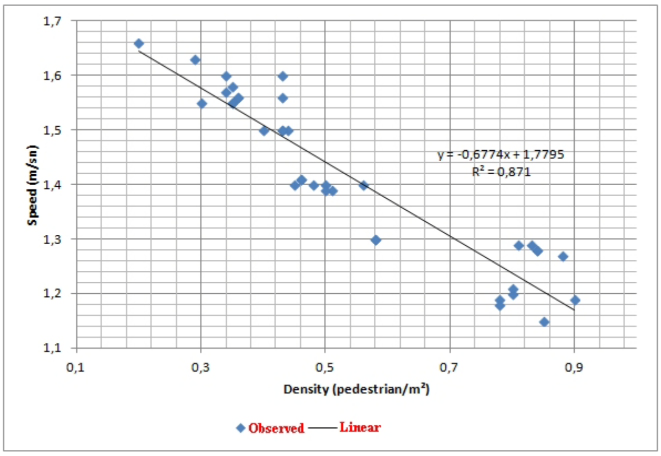


Figure 3: Speed-density relation for pedestrian (Corridors)

Relation model between pedestrian flow speed (V) and density (D) is given in the Equation 3.

$$V = -0.6774D + 1.77 \qquad (3)$$

2.2 Stairways

With a similar way which applies same rules for stairways (in terms of up&down movement), flow-density and flow-space relation curves are attained as shown in Figure 4.

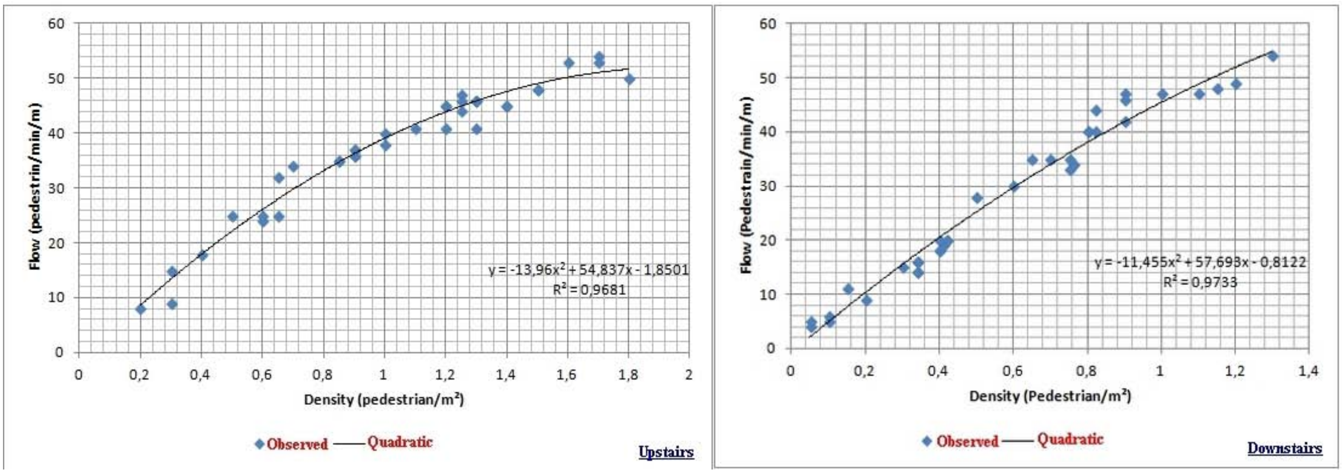


Figure 4: Flow-density relation for pedestrian (Stairways)

Figure 5 shows the speed-density relation curve obtained from the field data.

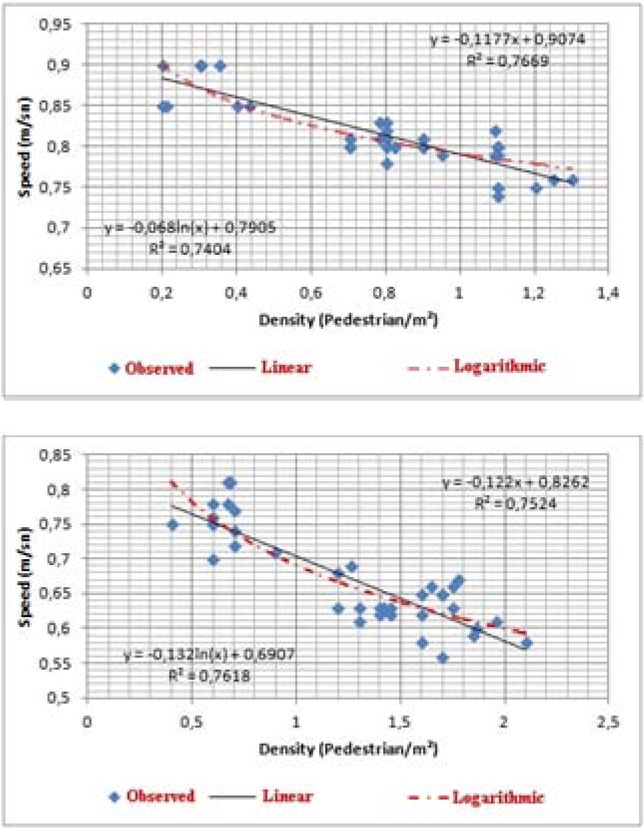
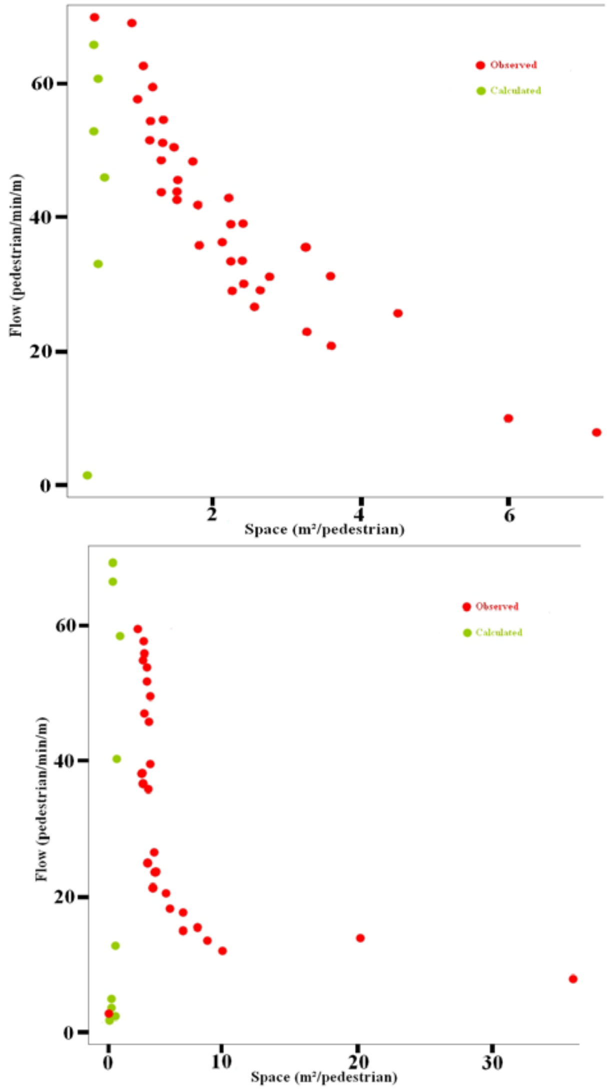


Figure 5: Speed-density relation for pedestrian (Downstairways & Upstairways)



In the flow-density, model can use logarithm function upstairs and linear function downstairs. The flow-space relation is modified in flow-space scatter diagram for corridors and stairways (up&down) as shown in Figure 6 by the help of maximum dynamic space

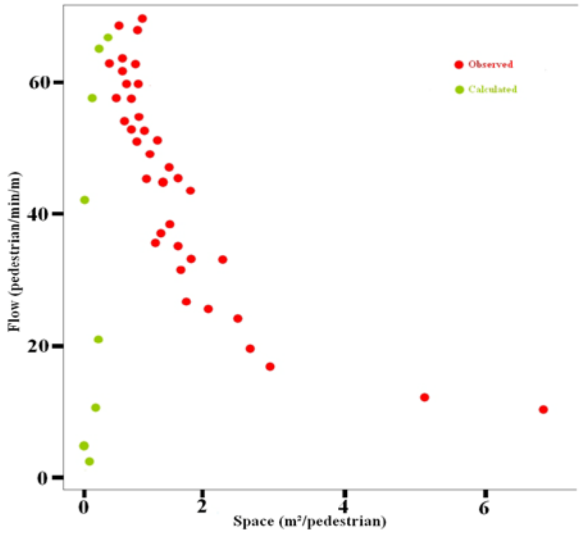


Figure 6: Modified flow-space scatter diagram for pedestrian (Corridors-Downstairs-Upstairs)

3. Model

All the function models have passed the F-test (Confidence interval = 95%) through the SPSS. In literature, pedestrian simulation model covers two categories;

Discrete Models: pedestrian behavior by grid-based movement model that combines with a series of movement rules like constrained conditions. For instance, Cellular Automata (CA) model is given as the best example for this type of models. However, the model is not able to describe the differences of anthropomorphic measurement related to human body, and speed of different pedestrians during the simulation process [22]. The model fails due to the capacity of grids. Any type of steps related to any pedestrian need to be the integral multiples of the side length of a grid.

Continuous Model: Pedestrian flow dynamics describe pedestrian movement behavior by establishing continuous function pertain to pedestrian behavior characteristics. This model uses automated multi particle framework which assumes the individuals as the parts of a group who are able to think and response to the surroundings. According to Chen [16] social force model is widely used in pedestrian simulation due to its explaining capacity of the essence of pedestrian moving behavior.

Adding to all, there are two parameters in social force model: pedestrian size and its desired speed.

The social force model is not restricted by grid; on the contrary pedestrian size is relatively flexible. It can be fixed or stochastic. In pedestrian flow relation curves analysis, a 0.2 m^2 ellipse is taken into account. The relation between parameters of pedestrian flow curves and models show that when flow increases to the maximum, the space value shows the pedestrian minimum dynamic space, and when the flow reduces to 0, the space value shows the pedestrian minimum static space. On account of the regional differences of pedestrian characteristics and body sizes, the research results in this study are only compared with the existing ones indicated in literature.

There are three methods to describe pedestrians in 2D simulation: round, ellipse, and rectangle. Although SF model usually uses ellipse or rectangle, ellipse is in fact more suitable to reflect pedestrians' real modality.

On the basis of human dimension table of Turkish adults used in calculation, the ratio of chest thickness to shoulder width for Turkish adults is accepted as 0.69 [17]; that is the elliptical semi-minor axis y and equals to the semi-major axis y which is multiplied by 0.6 Using the formula of elliptical acreage to transform the extent of occupied space into the extent of elliptical semi-major axis b, which is within the range of (0.47, 0.59) m.

The desired speed in SF model is usually fixed. In fact, it is affected by many factors because it is a kind of psychological desire. Even if the external condition is identical, the desired speed of pedestrian will still be different from each other.

4. Conclusion

In this study, pedestrian flow speed depends on the average value of 30% samples among all pedestrians. Therefore, the speed values on curves represent the speed of pedestrian flow which is considered as a whole. Because of the crowd effect, individuals in pedestrian flow will hope their speeds can catch up with the whole pedestrian flow, thus desired speed can be considered as the average speed of pedestrian flow.

Simultaneously, another important factor is time pressure, which is determined as;

P (i) = t (i)/t (max), where p(i) denotes the time pressure of pedestrian i, t(i) denotes the estimate travel time, pedestrian i thinks that it will take him t(i) to reach his destination, and t(max) is the maximum usable time, with the restriction of trip aim and other factors, pedestrian should arrive at the destination within t(max).

When value p(i) rises, the desired speed of pedestrian will rise, too. When the value of p(i) is more than 1, the desired speed of pedestrian i will increase to a maximum value.

The primary target of such simulation is to accurately describe pedestrian flow characteristics in the real world. Relation between pedestrian flow parameter models of different facilities in the airport terminal building are established in this study, and then the parameters in social force pedestrian simulation model are calibrated. Pedestrian flow-density relation curves are fitted and models are established for corridors, upstairs, and downstairs. Pedestrian size and speed values of SF Model are determined. In the process of calibrating desired speed, time pressure is considered as an innovative factor.

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