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Studies on Three Dimensional Pedestrian Motion on Railway Foot over Bridge

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Abstract

With the advancement of civilization and research skills over the years vehicular traffic has been given priority over pedestrian traffic. With the increase of population in cities, pedestrian traffic is increasing day by day. Pedestrian safety has become a matter of concern for the Traffic Engineers. Pedestrian comfort is primary importance for the Engineers who design different pedestrian facilities. Pedestrian comfort and safety can be measured for various facilities in terms of different level of service (LOS). In this study video data on pedestrian movement have been collected from different Railway foot over bridges (FOBS) in India. The level of service of those facilities has been analyzed. A cellular automata based model has been formulated to mimic the route choice behavior of the pedestrians on the foot over bridges.

Keywords: Foot over Bridges (FOBS), Level of Service (LOS), Cellular Automata Model

1. Introduction

India has observed high-level of mobility and accessibility at urban as well as intercity segments due to improvisation of socio-economic conditions in last two decades. Even though, majority of the intercity travel is made by road based modes, number of passengers traveling by railways is significant on certain highly industrialized corridors. In India, railway is the most efficient mode of the transportation carrying nearly 21 million passengers regularly through its large rail network of more than 60,000 km and has passenger growth rate of 5.3% p.a. The eastern states of India is leading industrial growth of the country through continuous rise in industrial activities along its urban corridor. Apart from daily commuters for work and business purpose, better socioeconomic conditions in the region generate significant amount of non-work travel along the corridor through railways as well as roadways. Railway stations are most important public transport buildings, which provides an access to trains, perform a variety of functions. Safety is the most crucial factor that should be ascertained by every transit provider to its commuters. Significant level of industrialization in along specific industrial regional corridors generate huge amount of commuter traffic as well as casual travel. The demand for mobility encourages the development of mass rapid transit infrastructure along such corridors. Design of vital elements like stairways and foot over bridges (FOBS) should incorporate the behavior of flow of various class of pedestrian to ensure desired level of service as well as safety in case of emergency. Pedestrians use Railway foot over bridges (FOBS) as a part of their trip making can’t be complete without using FOBs. Level of service on the FOBS can provide a sense of safety conditions. If the level of service of a FOB is good then it can be considered as safe during maximum flow of pedestrians.

2. Related research works done by various researchers

Pedestrian movement is very important for designing any pedestrian facility, considering the characteristics of pedestrians and existing facilities. Over the years, various researchers studied on pedestrian moment and found useful findings pertaining to pedestrian characteristics and behavior. Oeding (1963) conducted a study to determine the pedestrian characteristics under mixed traffic condition. Chandra (2010) studied the pedestrian flow characteristics in Indian mix traffic conditions. Older (1968) observed the walking characteristics of Britain shoppers. Fruin (1971) understand that walking speeds of females are slower than males and the speeds of pedestrian decrease with age. Most of the stations on the rail corridor witness intercity commuters as well as casual travelers. Yang (2010) observed that primary function of passenger transport station is gathering and distributing passengers, goods and train operation (including allied services e.g. parcel and post) and enhance operation efficiency. As observed from various literatures, pedestrian flow characteristics are influenced by number of attributes of pedestrian like age, gender, physical dimensions, luggage carried, group size, activity while walking, purpose etc. The relationship between fundamental flows attributes like speed, density and flow are expected to be influenced by this factors along with the arrival time of trains at the station.

Many studies on level of service of different pedestrian facilities can be found in literature. Tanaboriboon (1989) used pedestrian space and flow rate as parameters to define level of service on sidewalks in Bangkok. Asadi-Shekari (2014) made comparative analysis between existing and standard level of service in a technical university campus to evaluate the LOS conditions. Zhang (2013) conducted controlled experiments to understand pedestrian dynamics empirically and showed the different characteristics of different pedestrian streams. Some perception based survey technique is available in literature. Muraleetharan (2000) used people’s perception and conjoint analysis, level of service of different sidewalks and crosswalks were determined. Different level of service measures have been suggested in highway capacity manual (HCM) (2010), but level of service in Indian context is different. Burghardt (2013) determined that fundamental diagram of pedestrian motion on stairs given by some researchers can be found, but these are based on controlled experiments on a helical stair. Literature on level of service on FOBs is rarely available and almost nothing is found on Indian context expect one, Shah (2013) where pedestrian behavior was monitored on one Railway FOB and some fundamental diagrams were suggested but no route choice model was proposed.

Some Literatures on the route choice behavior of pedestrians can be found. Using cellular automata for modelling complex phenomena is a favourite practice among the researchers. Blue (2001) developed one of the simplest models for bi-direction pedestrian movement was explained using cellular automata and it only could mimic pedestrian movement on sidewalks. Hoogendoorn (2004) developed a route choice model of pedestrians using normative pedestrian behavior theory was proposed, but this model cannot describe pedestrian motion on elevated stairs. Wagoum (2011) used shortest path algorithm, for modelling pedestrian route choice behavior during building evacuation but behaviour on stairs was not covered. Leijonmarck (2013) modelled the panic stricken pedestrians during emergency evacuation from a building. But the definition of panic is not clear and the entire thought process of the modelling is considered to be vague and the model is not validated with any real life or experimental data.

3. Data collection and Empirical observation

Data collection is one of the important part of this work done. Data collection is done at the railway footbridge at Rourkela and Manhorpur railways station. This data collection is done with the help of high definition camera, tripod stand, measuring tape and colour adhesive tape. First the desired section of the staircase is marked with the colour adhesive tape. This marking is done in rectangular section with 3m in width and 2m in length. Then the camera is set at 3m from the start of the marked section. Then the recording of the camera is started when there is crowd of passengers that is 10 mins before arrival of the train to 10 mins after arrival of train. This process is repeated for all the staircases n foot over bride sections. Thus is how the data collection was done. A typical sketch of data collection is shown in figure 1.

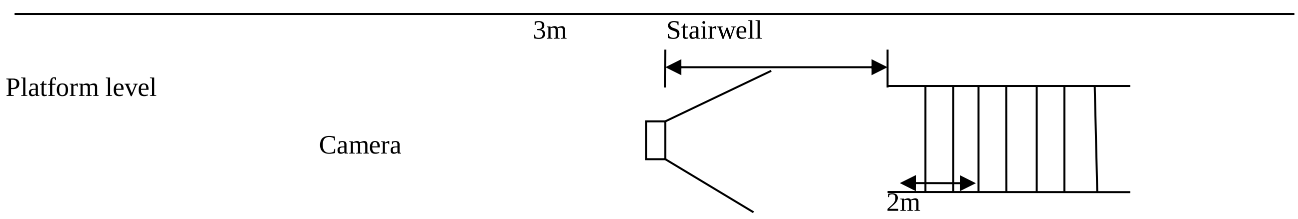

Figure 1: Typical sketch of data collection on FOBs

Speed is measured by taking two sections and recording the entry and exit time of the pedestrians. This is the space mean speed and expressed in m/s. Flow is the number of pedestrians moving out of a particular section per minute and expressed in pedestrians/min. Density is obtained at any instantaneous time by measuring the number of pedestrians occupying a squared meter space and can be expressed in pedestrians/m^2. After a huge number of data collection some fundamental diagrams are plotted using a few of them. Speed–density (u-k) fundamental diagram is shown in figure 2 and flow-speed (q-u) fundamental diagram is shown in figure 3.

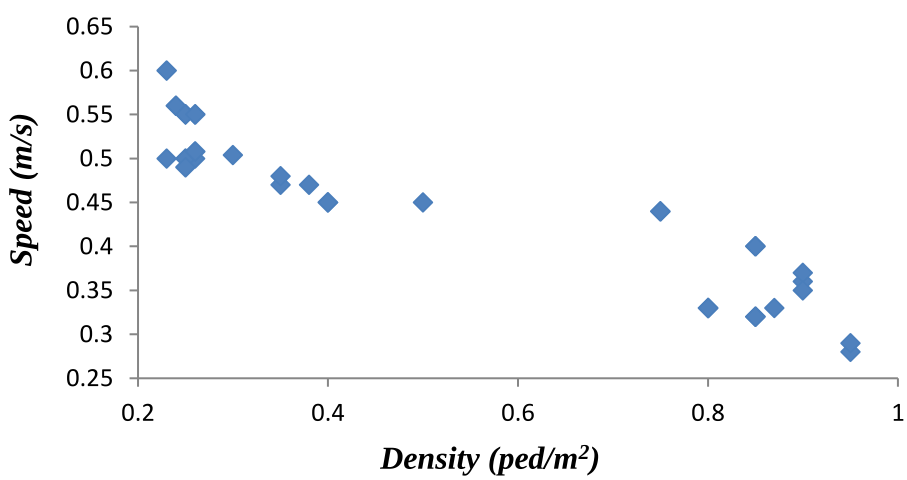

Figure 2: Speed-density fundamental diagram

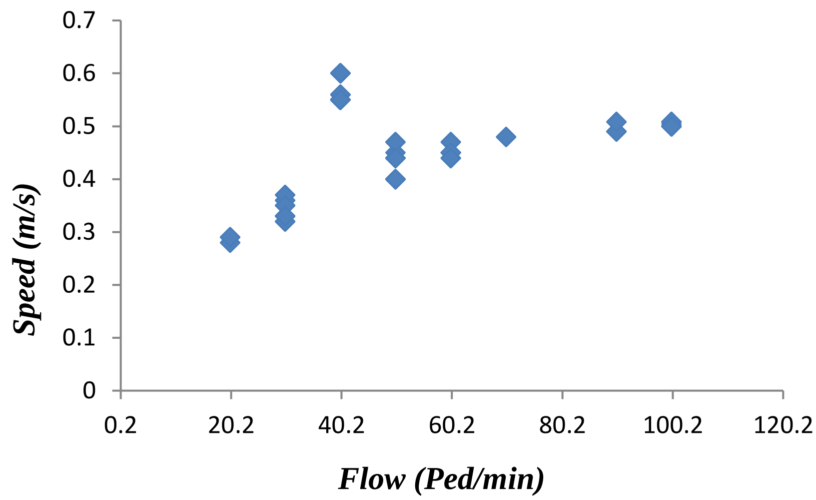

Figure 3: Flow-speed fundamental diagram

These diagrams are obtained after careful decoding of speed-flow-density data from the video recordings. The average values of the observations are tabulated in table 1. Average flow rate (Pedestrians/min) and average pedestrian spaces (m^2/pedestrian) are tabulated here. Volume by capacity ratio and average speed is also calculated.

Table 1: Average pedestrian parameters on FOBs

Flow Rate (pedestrian/s)	Space (m^2/pedestrian)	Speed (m/s)	V/C
5	1.8	0.50	0.06

Based on the above observation, the level of service of the two FOBs can be conferred to 'A' that is those FOBs have good serviceability conditions.

4. Proposed model

Some update rules are considered as the algorithm of the proposed model. These rules are simple cellular automata rules which the system (bidirectional pedestrian stream) follows. Pedestrians maneuver their moves on the foot over bridges (FOBs) while they make a co-ordination with other pedestrians i.e. each one makes a move after sensing the possible movements of other pedestrians at his/ her neighborhood at every time step. The model proposed in this study is a rule based on cellular automata model. There are various user–defined space and time related parameters and inputs used in this model; namely, cell size, time step, desired speed, distance of interaction, speed choice and direction choice. The whole domain is divided into small cells of rectangular sizes (0.4×0.4 m). In this model Moore's neighborhood is followed. The possible movement of each pedestrian and its neighborhood is shown in figure 4.

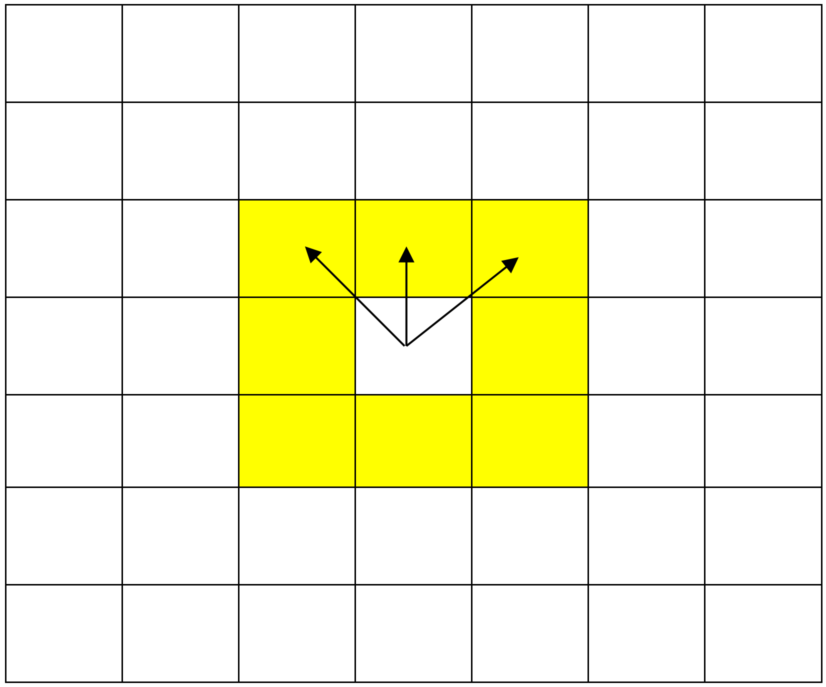

Figure 4: Moore neighbourhood and possible movement directions

These are:

i. A target cell is assigned to one pedestrian with higher level of confidence (better perception-reaction capabilities).
ii. Cross directional movements are possible while overtaking a slow pedestrian.
iii. Pedestrians can choose their speed and possible direction according to the vacancy of the cells towards the target direction.
iv. Pedestrians can choose one step or two steps per second according to the vacancies.
v. Pedestrians prioritize two steps forward motion towards the destination cell, then comes one step movement which is least preferred.
vi. Pedestrian movement at each time step is randomized i.e. at each time step all pedestrians (ascending and descending on stairs) intelligently changes their speed and direction in the flow space (on the FOB) and moves out of the flow space.

This model can illustrate pedestrian behaviour in different densities. It exactly mimics the behaviour (speed and direction change) of the pedestrians on the foot over bridges (FOBs). However, panic could not be modelled as it is a vague parameter.

5. Validation of model

About 1000 runs are performed (for different ascending and descending pedestrian densities). Outputs of the model are speed of individual pedestrians, density of the crowd and flow rate. Simulation of pedestrian motion is important for minimizing casualties in case of overcrowding of pedestrians with very less coordination among them. For the proposed model, simulations are performed after the code is developed in C++ language. Figure 5 shows the simulated and real life average speed of pedestrians in different crowd levels. The simulated results are compared with the real life data collected on the FOBs. It is found from the observations that the simulated results and real life data matches quite well.

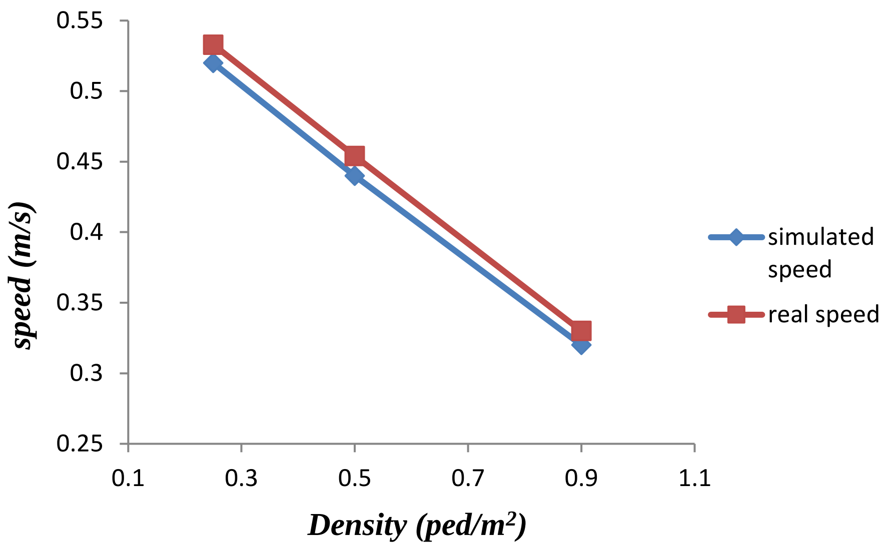

Figure 5: simulated and observed average speed at different densities

6. Conclusion

Huge number of data collection is done for Indian pedestrians on railway foot over bridges (FOBs). In this paper studies are done on pedestrian behaviour in different densities in terms of the outcomes of their behaviour (speed, flow and density). A simple bidirectional route-choice model is developed using cellular automata as a modelling tool. More studies can be conducted in future using agent based modelling. Level of service of those foot over bridges (FOBs) is evaluated using the data.

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