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EFFECT OF PASSAGEWAY WIDTH ON PEDESTRIANS FLOW CHARACTERISTICS IN INTERCITY RAILWAY STATIONS

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Rail transportation is most economical means of the mode in comparison to road transportation. Intercity railway stations are nodal points of the rail network. With the growing demand and land use constraints, these are to be well planned, managed and designed. In intercity railways station infrastructure, passageways are confined and elevated elements for pedestrian movements to access among platforms to alight and board trains. Provision of appropriate width for passageway is of greater importance regarding comfort, convenient, evacuation, efficient, aesthetic, cost-effective, environment-friendly and well integrated with other elements of infrastructure. A proper understanding of pedestrian flow characteristics and affecting factors on passageway aids in design implications. In the present work, pedestrian flow characteristics variation on passageway and its width effect is studied. Results showed that, under normal conditions, flow rate (ped/m/min) and mean walking speed (m/min) reduces with increase in width (m). For a given flow rate, volume (ped/min) of pedestrians served on passageway increases with increase in width. Statistical tests revealed that there exists a significant difference in mean walking speed of pedestrians on passageways with different widths.

Keywords: Pedestrian, Flow Characteristics, Passageway, Width, Intercity railway station

1. Introduction

Opportunities and needs drive people to make trips to various places. Passengers make long hauling trips for various reasons via public transportation. Railways being the economical and fast means of access mode, a majority of passengers rely on rail transportation in developing countries like India. Intercity railway stations are nodal points in railway network. Passengers in intercity railway stations include heterogeneity with respect to physical, social and cultural aspects. They board and alight trains in intercity railway stations with different trip purpose, the frequency of trip making, group size, gender, age, and luggage. Intercity railway station infrastructure is to be well managed within the limited land available for the passenger's convenience, safe and easy access. In a comparison of foot over bridge (FOB) passageway with that of intercity railway station as a whole, it is the only means to access among various platforms. However, they have a choice between stairway and escalator to ascend FOB passageway.

A common passageway for passenger's bidirectional movement with differential flow ratios effects pedestrian flow characteristics. They become bottlenecks reducing free-flow speed and maximum flow (Rastogi and Chandra, 2013). Proper planning, design, and management let the best efficient use of infrastructure. Understanding pedestrian behaviour and factors affecting lets the planner in policy making and developing design standards. Analysis of pedestrian flow characteristics and model calibration forms bases for pedestrian simulation (Hongfei *et al.*, 2009). A thorough revision of literature leads to understanding pedestrian behaviour and various factors affecting them.

Pedestrian flow characteristics are to be well understood, and design standards are to be modified before the use of foreign standards (Rahman *et al.*, 2013). They vary by location, site, and region (Nazir *et al.*, 2012; Tanaboriboon *et al.*, 1986; Kawsar *et al.*, 2017; Lam *et al.*, 1995). Pedestrian studies on sidewalks, footpaths concluded that pedestrian flow characteristics are affected by culture and special events (Sukhadia *et al.*, 2016). Free flow speed on passageway is double to that of stairway (Chen and Jian, 2010). Factors affecting pedestrian flow characteristics include pedestrian characteristics: age, gender, and luggage, environmental characteristics: climate, time of the study (Laxman *et al.*, 2010), infrastructure characteristics: gradient of the facility (Al-Azzawi and Raeside, 2007). Pedestrians mean walking speed on stairways is greater than that of walkways (Liu *et al.*, 2008). Walking speed of male pedestrians is greater than female pedestrians (Rastogi *et al.*, 2010). Mean walking speed of pedestrians in

descending directions is greater than that in ascending direction on stairway (Shah *et al.*, 2013). Mean walking speed on daytime is greater than evening time (Shah *et al.*, 2013). Flow ratio on stairways varies with train schedule, and directional distribution is found to be influencing pedestrian walking speed on stairway (Jiten *et al.*, 2015a, 2015b). The flow rate and mean walking speed increases with an increase in width of stairway (Jiten *et al.*, 2016). Artificial neural network performed better in comparison to conventional speed- density- flow models for the interrelationship between pedestrian flow characteristics on walkways and carriageways (Das *et al.*, 2015). In many of these studies, pedestrian flow characteristics are studied on walkways, footpath, and stairway at various locations. Age, gender, time, train schedule, direction, flow ratio, gradient are found to be affecting pedestrian flow characteristics on stairways in metro train stations. Pedestrian flow studies on foot over bridges inside intercity railway stations are unnoticed. Pedestrians making long hauling journeys via intercity trains show up varied flow behaviour in comparison to metro trains, where they make short trips. Also, the aforesaid flow characteristics vary on the stairway to a passageway. Provision of an unscientific width of a passageway to a stairway for an anticipated flow rate of heterogeneous pedestrian traffic leads to non- uniform flow and create an accumulation of pedestrians on various infrastructure elements (stairway, escalator, and passageway) of foot over bridge. In this regard, there is a need to study the flow behaviour on level changing passageway inside intercity railway stations for a better management of existing passageways and to develop design standards for future expansion. This paper reflects the pedestrian flow behaviour on passageways in intercity railway stations, India. Also, a comparison of flow characteristics on passageways of different widths is made to understand the effect of the width of the passageway.

2. Data collection

Seven passageways from three intercity railway stations located along Secunderabad and Vijayawada corridor are falling under South Central railway zone of Indian railways is considered. Two passageways each of width 4.5m, one having a center rail to separate directional flow (to and fro) and other don't have, in Secunderabad railway station. One passageway of width 2.1m in Warangal railway station. In Vijayawada, four passageways of widths 3.5, 2.3, 2.3 and 3.4m are considered.

Secunderabad (S) railway station is the capital of Telangana State, India. It has an integrated multi-modal transport system (MMTS) facility. Warangal (W) Railway station is located in Warangal, capital of Warangal district, Telangana state, India. Vijayawada (V) railway station is located in the state of Andhra Pradesh, second biggest railway station in India. Table 1 shows the passageway dimensions in the three intercity railway stations considered for this study.

Table 1. Passageway dimensional details

Description	Secunderabad (S _{p1}) (Without Central rail)	Secunderabad (S _{p2}) (With Central rail)	Warangal (W _{p1})	Vijayawada (V _{p1})	Vijayawada (V _{p2})	Vijayawada (V _{p3})	Vijayawada (V _{p4})
Length (m)	14	14	25.7	17.8	17.8	58.1	28.4
Width (m)	4.5	4.5	2.1	3.5	2.3	2.3	3.4

Video recording technique is used for data collection. It provides permanent data; aids in a large number of data point extraction, observe and track pedestrian's movement. On each passageway, three hours of video is recorded. In the later stage, pedestrian traffic parameters flow, density and speed are determined from playback videos in Media Classic Player. Figure 1 shows the snapshots of video recording data collected on each passageway in Secunderabad, Warangal and Vijayawada railway stations.

On each passageway, directional pedestrian volume crossing a reference line is counted for each minute. Directional flow is calculated as a ratio of volume in a direction to the width of the facility per minute. With two references lines fixed of known length, time taken to cross the two reference line to the nearest millisecond is noted. His/her walking speed is determined as a ratio of distance between two reference lines to the time taken to cross. Mean walking speed is taken as the average of pedestrians walking speed in a particular minute. To determine the pedestrian density for a minute, playback video is paused, and the number of pedestrians present between two reference lines is manually counted. Density is calculated as a ratio of the pedestrian count to the area (length between references lines multiplied by the width of the facility).

1(a): S_{P1} - Secunderabad without central rail 1(b): S_{P2} - Secunderabad with central Rail 1(c): W_{P1} - Warangal 1(d): V_{P1} - Vijayawada passageway 1 1(e): V_{P2} - Vijayawada passageway 1(f): V_{P3} - Vijayawada passageway 1(g): V_{P4} - Vijayawada passageway*Figure 1. Snapshots of passageways in intercity railway stations*

3. Pedestrian flow characteristics and variation with width of passageway

Pedestrian flow characteristic plots, flow-density-space, are plotted for the extracted data points for the observed seven passageways from Secunderabad, Warangal, and Vijayawada intercity railway stations. Figure 2 shows the flow- density (2a) and flow- space (2b) plots. Second-degree polynomial trend line fits for flow- density and flow- space showed an exponential trend. Table 2 shows the fitted trend line equations with respective R^2 value and observed pedestrian flow characteristics on each passageway are tabulated in table 3.

The passageway in Secunderabad railway station has relatively lower values of pedestrian flow characteristics with the highest width among the observed passageways. As Secunderabad railway station has integrated MMTS facility operated, there are relatively considerable daily commuters. Hence pedestrian flow on passageway is observed to be affected by the side friction caused by other waiting pedestrians.

Figure 2. Flow Rate- Density- Space Plots of Observed Pedestrian Traffic on Passageways

Table 2. Flow - Density- Space- Speed trend line equations with respective R^2

Station	Description	R^2
Flow - Density		
S_{p1}	$y = -0.4814x^2 + 19.735x$	0.8445
S_{p2}	$y = -0.3921x^2 + 15.761x$	0.8651
W_{p1}	$y = -15.774x^2 + 52.957x$	0.9102
V_{p1}	$y = 36.082x^2 + 0.6544x$	0.6665
V_{p2}	$y = 29.83x^2 + 12.912x$	0.5691
V_{p3}	$y = -0.2332x^2 + 26.241x$	0.2708
V_{p4}	$y = 29.832x^2 + 5.8908x$	0.7720
Flow - Space		
S_{p1}	$y = 18.779x^{-0.988}$	0.8729
S_{p2}	$y = 15.689x^{-1.113}$	0.8410
W_{p1}	$y = 33.639x^{-0.788}$	0.7804
V_{p1}	$y = 26.94x^{-1.664}$	0.7305
V_{p2}	$y = 28.469x^{-1.274}$	0.7364
V_{p3}	$y = 26.976x^{-1.136}$	0.4104
V_{p4}	$y = 19.141x^{-1.259}$	0.7440

The passageway in Warangal (W_{p1}) of width $2.1m$ showed higher flow rate (48 ped/m/min) of all the passageways. Warangal has two foot over bridges for pedestrian access, one located in the middle of platform nearer to the entry/exit of the station and other at one end of the platform. Pedestrians tend to use infrastructure nearer to entry/exit in higher proportion in comparison to the facility at other location. This lead to the higher use of the passageway nearer to entry/exit in more number in comparison to the other passageways at other locations.

Four passageways are considered in Vijayawada railway station. It has four passageways connecting platforms and two entry/exit location. Moreover distributed ticketing services at various places lead to the distribution of pedestrian flow on foot over bridges. Hence relatively lower flow rates are observed in this case. It is evident that the flow rate on V_{p2} (33 ped/m/min) and V_{p3} (35 ped/m/min) are the almost equal width ($2.3 m$). While on V_{p1} and V_{p4} , flow rates (23 ped/m/min) and (21 ped/m/min) respectively, are nearly equal for almost equal widths. Hence for a given station, flow rate varies with width of passageway. Secunderabad has almost an equal maximum flow rate for the passage with and without central rail for directional flow separation.

3(a): Maximum Flow rate- Width

3(b): Mean Speed- Width

3(c): Volume- Width

Figure 3. Maximum Flow Rate, Mean Walking Speed and Volume of Pedestrian's Variation with Width of Passageways

Variation of flow with the width of passageway S_{p1} , S_{p2} , V_{p1} , V_{p2} , V_{p3} and V_{p4} , figure 3(a), shows that the maximum flow rate (ped/m/min) reduces with increase in width and stabilizes at greater width. It is asserted to the distribution of pedestrians with width. It can be concluded that with the increase in width, flow rate decreases and attains equilibrium at widths ranging $3.5m$ to $4.5m$. Pedestrians mean walking speed variation with the width of the passageway, figure 3(b), reflects a reduction in mean pedestrian walking speed with an increase in width and tends to stabilize at greater width. Comparing the flow and speed variation with width acknowledge that, at lower widths pedestrians are packed such that they have no choice of choosing their desired speed with their attributes like age, gender, luggage and tends to follow the lead pedestrian. Also at lower widths, pedestrians tend to get out of the congested confined area and hence walk with a higher walking speed than on passageways with higher widths. Critical density increases with increase in width of the passageway and stabilized at higher width.

From the table 3 and figure 3(c), Comparison of width with the volume of pedestrians it serves at the observed maximum flow rate, it signifies that the pedestrian volume increases with increases in the width of the passageway. Considering the passageway flow rates on S_{p1} , S_{p2} , V_{p1} and V_{p4} which are in close range, it can be stated that for a given flow rate, volume (ped/min) of pedestrians served on passageway increases with increase in width.

To understand the variation of flow characteristics on passageways with width within a station, V_{p1} , V_{p2} , V_{p3} , and V_{p4} at Vijayawada station are considered. For a given station characteristics and anticipated pedestrian demand, flow rate reduces with an increase in width.

Table 3. Pedestrians flow characteristics on passageway

Description	S_{p1}	S_{p2}	W_{p1}	V_{p1}	V_{p2}	V_{p3}	V_{p4}
Width (m)	4.5	4.5	2.1	3.5	2.3	2.3	3.4
Max Flow rate (ped/m/min)	24	23	48	23	33	35	21
Volume (ped/min) at Max flow rate (rounded off to nearest whole number)	108	104	101	81	76	81	72

Description	Sp ₁	Sp ₂	Wp ₁	Vp ₁	Vp ₂	Vp ₃	Vp ₄
Critical density (ped/m ²)	1.25	1.4	1.4	0.72	0.56	0.76	0.69
Space available (m ² /ped)	0.8	0.72	0.62	1.54	2.02	1.60	1.60
Mean Speed (m/min)	35.25	28.19	66.53	56.90	73.04	67.67	68.92
Free flow speed (m/min)	39.00	31.80	75.00	58.80	85.20	71.40	70.20
Critical speed (m/min)	21.00	15.60	36.00	30.00	33.60	34.20	39.60

4. Effect of passageway width on pedestrian walking speed

A statistical t-test is conducted in Statistical Package for the Social Sciences (SPSS) software at 95% confidence level. Null and alternate hypotheses respectively are assumed to be as

$$H_0; \mu_{\text{Passageway1}} = \mu_{\text{Passageway2}},$$

$$H_1; \mu_{\text{Passageway1}} \neq \mu_{\text{Passageway2}},$$

where μ is the pedestrians mean walking speed on passageway here. Levene's test for equality of variances is considered for the acceptance and rejection of assumed equal variance with significance value, $\alpha = 0.05$. The calculated p-value is compared with α . If $p \leq \alpha$, the null hypothesis is rejected thereby resulting in that there exists a significant difference in pedestrians walking speed on passageways of different widths (Using SPSS for t Tests, 2017).

Table 4 shows the t-test results for the various combinations of pedestrian walking speed on observed passageways. Keen look into the results, it can be drawn that there exists a significant difference in pedestrian walking speed on passageways with different widths.

Considering passageways with and without central rail (Sp₁ and Sp₂ respectively) for directional flow separation, for equal width 4.5m, there existed a significant difference in pedestrian walking speed. Pedestrian flow in intercity railway stations is of such a kind that the flow in the direction of a platform to which train arrives will have greater flow before the arrival and the flow in other direction increases after the arrival of the train on to the platform. Pedestrians have the feasibility to use the entire width of a passageway in the absence of central railing. While in case of the passageway with central railing, because of the confinement of flow to the respective side of the central rail, pedestrian density increased thereby leading to the reduction in mean walking speed. Hence there existed a significant difference in pedestrian walking speed on passageway with and without a central rail for equal width.

Table 4. Statistical test results of width effect on pedestrian mean walking speed

Stairway Combination	n1	n2	μ_1	μ_2	f	sig	t	sig	Significance
Sp ₁ - Sp ₂	180	180	35.25	28.19	5.606	0.018	13.166	0.000	S
Sp ₁ - Wp ₁	180	170	35.25	66.53	68.377	0.000	-26.649	0.000	S
Sp ₁ - Vp ₁	180	177	35.25	56.90	23.664	0.000	-28.633	0.000	S
Sp ₁ - Vp ₂	180	158	35.25	73.04	35.162	0.000	-44.496	0.000	S
Sp ₁ - Vp ₃	180	145	35.25	67.67	22.428	0.000	-40.830	0.000	S
Sp ₁ - Vp ₄	180	154	35.26	68.92	37.331	0.000	-38.225	0.000	S
Sp ₂ - Wp ₁	180	170	28.19	66.53	96.575	0.000	-33.758	0.000	S
Sp ₂ - Vp ₁	180	177	28.19	56.90	57.041	0.000	-41.276	0.000	S
Sp ₂ - Vp ₂	180	158	28.19	73.04	72.878	0.000	-56.359	0.000	S
Sp ₂ - Vp ₃	180	145	28.19	67.67	58.445	0.000	-53.600	0.000	S
Sp ₂ - Vp ₄	180	154	28.19	68.92	74.35	0.000	-49.108	0.000	S
Wp ₁ - Vp ₁	180	177	66.53	56.90	24.931	0.000	7.674	0.000	S
Wp ₁ - Vp ₂	180	158	66.53	73.04	14.353	0.000	-4.955	0.000	S
Wp ₁ - Vp ₃	170	145	66.53	67.67	22.364	0.000	-0.891	0.373	NS
Wp ₁ - Vp ₄	170	154	66.53	68.92	12.041	0.001	-1.789	0.075	NS
Vp ₁ - Vp ₂	177	158	56.90	73.04	1.747	0.187	-16.946	0.000	S

Stairway Combination	n1	n2	$\mu 1$	$\mu 2$	f	sig	t	sig	Significance
V _{P1} - V _{P3}	177	145	56.90	67.67	0.009	0.926	-11.808	0.000	S
V _{P1} - V _{P4}	177	154	56.90	68.92	2.666	0.103	-12.307	0.000	S
V _{P2} - V _{P3}	158	145	73.04	67.67	1.884	0.171	5.399	0.000	S
V _{P2} - V _{P4}	158	154	73.04	68.92	0.106	0.745	3.891	0.000	S
V _{P3} - V _{P4}	145	154	67.67	68.92	2.782	0.096	-1.222	0.223	NS

n - Number of samples, μ - Mean, f - f Test Value, t - t Test Value, sig - Significance Value, S - Significant, NS - Not Significant.

5. Conclusions

Planning and management of infrastructure in an intercity railway stations with resource constraints is of great challenge. Analysis of pedestrian flow characteristics on respective elements of infrastructure is the primary key to plan and designing new facility and maintenance of existing facility. A passageway is one such element which is a confined area and grade separated with the platform for pedestrian access to alight and board trains on various platforms. Width is a primary variable which affects the pedestrian flow characteristics. Understanding the effect of width on pedestrian walking speed at normal conditions helps in attaining at the appropriate width required for an anticipated pedestrian demand in an intercity railway station.

In the present research, seven passageways of varying infrastructure characteristics are considered to understand the effect of width on pedestrian flow characteristics under normal conditions. From the results, it can be concluded that the flow rate and mean walking speed reduces with increase in width and attains stability at greater widths. Critical density reduces with increase in width of a passageway and attains equilibrium at higher width. For a given flow rate, volume (ped/min) of pedestrians served on passageway increases with increase in width. For a given station characteristics, flow rate reduces with an increase in width of the passageway. A statistical t-test is conducted in SPSS to study the effect of passageway width on pedestrians mean walking speed. There existed a significant difference in mean walking speed of pedestrians on passageways for different widths. It can be concluded that width significantly affects pedestrian flow characteristics on passageway of a foot over bridge in an intercity railway station. At lower widths, pedestrians feel congested, inconvenience and tend to exit the confined section. Pedestrians follow the flow speed and do not have a choice to choose desired speed. At greater widths, pedestrians have greater space available and walk with the desired speed with respect to self-characteristic age, gender, and luggage. It can be concluded that at lower widths, pedestrian flow characteristics are predominant while at higher widths pedestrian attributes are dominant in one's walking speed.

This study has some limitations. Pedestrian attributes- age, gender, luggage, trip purpose are not considered in this present research work. Further location of passageway is also to be studied to understand the pedestrian flow distribution proportions and flow characteristics variation on various foot over bridges with in a station. In spite of these limitations, present research has identified the variation in pedestrian flow characteristics with width of the passageway in an intercity railway station. This study results can be used as an input to simulation and understand the pedestrian breakdown and capacity of passageway with width.

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References

1. Rastogi, R., and Chandra, S. (2013) Pedestrian flow characteristics for different pedestrian facilities and situations. *European Transport*, 53, paper 6.

2. Hongfei, J., Lili, Y., and Ming, T. (2009) Pedestrian flow characteristics analysis and model parameter calibration in comprehensive transport terminal. *Journal of Transportation Systems Engineering and Information Technology*, 9(5), 117-123. DOI:10.1016/S1570-6672(08)60082-3.
3. Rahman, K., Ghani, N. A., Kamil, A. A., and Mustafa, A. (2013) Weighted regression method for the study of pedestrian flow characteristics in Dhaka, Bangladesh. *Modern Applied Science*, 7(4), 17. DOI:10.5539/mas.v7n4p17.
4. Nazir, M. I., Adhikary, S. K., Hossain, Q. S., and Ali, S. A. (2012) Pedestrian flow characteristics in Khulna metropolitan city, Bangladesh. *Journal of Engineering Science*, 3(1), 25-31.
5. Tanaboriboon, Y., Hwa, S., and Chor, C. (1986) Pedestrian Characteristics Study in Singapore. *Journal of Transportation Engineering*, 112(3), 229-235. DOI:10.1061/(asce)0733-947x(1986)112:3(229).
6. Kawsar, L., Ghani, N., Kamil, A., and Mustafa, A. (2017) An Improved Speed-Density Relationship Model for Pedestrian Flow. *American Journal of Applied Sciences*, 14(1), 184-203. DOI:10.3844/ajassp.2017.184.203.
7. Lam, W. H., Morrall, J. F., and Ho, H. (1995) Pedestrian flow characteristics in Hong Kong. *Transportation Research Record*, 1487, 56-62.
8. Sukhadia, H., Dave, S., Shah, J., and Rathva, D. (2016) The Effect of Events on Pedestrian Behavior and its Comparison with Normal Walking Behaviour in CBD Area in Indian Context. *Transportation Research Procedia*, 17, 653-663. DOI:10.1016/j.trpro.2016.11.120.
9. Chen, X., Ye, J., and Jian, N. (2010) Relationships and Characteristics of Pedestrian Traffic Flow in Confined Passageways. *Transportation Research Record: Journal of the Transportation Research Board*, 2198(1), 32-40. DOI:10.3141/2198-05.
10. Laxman, K., Rastogi, R., and Chandra, S. (2010) Pedestrian Flow Characteristics in Mixed Traffic Conditions. *Journal of Urban Planning and Development*, 136(1), 23-33. DOI:10.1061/(asce)0733-9488(2010)136:1(23)
11. Al-Azzawi, M., and Raeside, R. (2007) Modelling Pedestrian Walking Speeds on Sidewalks. *Journal of Urban Planning and Development*, 133(3), 211-219. DOI:10.1061/(asce)0733-9488(2007)133:3(211)
12. Liu, W., Zhou, H., and He, Q. (2008) Modelling pedestrians flow on stairways in Shanghai metro transfer station. In: *2008 International Conference on Intelligent Computation Technology and Automation*. IEEE, 263-267.
13. Rastogi, R., Thaniarasu, I., and Chandra, S. (2010) Design Implications of Walking Speed for Pedestrian Facilities. *Journal of Transportation Engineering*, 137(10), 687-696. DOI:10.1061/(asce)te.1943-5436.0000251.
14. Shah, J., Joshi, G., and Parida, P. (2013) Walking Speed of Pedestrian on Stairways at Intercity Railway Station in India. In: *Proceedings of the Eastern Asia Society for Transportation Studies*, 9.
15. Shah, J., Joshi, G., and Parida, P. (2013) Behavioral Characteristics of Pedestrian Flow on Stairway at Railway Station. *Procedia – Social and Behavioral Sciences*, 104, 688-697. DOI:10.1016/j.sbspro.2013.11.163.
16. Jiten, S., Gaurang, J., Purnima, P., and Shriniwas, A. (2015a) Analysis of Commuter Flow Behaviour on Stairways at Metropolitan Transit Station in Mumbai, India. *International Journal for Traffic and Transport Engineering*, 5(4). DOI:10.7708/ijtte.2015.5(4).09.
17. Jiten, S., Gaurang, J., Purnima, P., and Shriniwas, A. (2015b) Impact of Train Schedule on Pedestrian Movement on Stairway at Suburban Rail Transit Station in Mumbai, India. *Advances in Civil Engineering*, 2015, 1-9. DOI:10.1155/2015/297807.
18. Jiten, S., Gaurang, J., Purnima, P., and Arkatkar, S. (2016) Effect of stairway width on pedestrian flow characteristics at railway stations. *Transportation Letters*, 8(2), 98-112. DOI:10.1179/1942787515y.0000000012.
19. Das, P., Parida, M., and Katiyar, V. (2015) Analysis of interrelationship between pedestrian flow parameters using artificial neural network. *Journal of Modern Transportation*, 23(4), 298-309. DOI:10.1007/s40534-015-0088-9.
20. Using SPSS for t Tests. <https://academic.udayton.edu/gregelvers/psy216/spss/ttests.htm>. Accessed 10 November 2017.