MODELLING PEDESTRIAN CHOICE BETWEEN STAIRWAY AND ESCALATOR IN ASCENDING ELEVATED PASSAGEWAY INSIDE INTERCITY RAILWAY STATION

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Abstract

Pedestrians alighting and boarding trains in intercity railway stations often use elevated passageway using stairways or escalators to access among platforms. While making route choice, they in general take shortest route in terms of travel time and distance. In making choice between vertical facilities: stairway and escalator, pedestrian's demographic characteristics, infrastructure characteristics and flow characteristics influence as the effort involved in traversing increases with individual's age, luggage, trip purpose, step rise step foot, inclination etc., The choice is found to be more sensitive to relative delays. In this study, an attempt is made to understand and replicate pedestrian perception in choice making between stairway and escalator with respect to demographic factors. Pedestrian flow characteristics are studied on six stairways from three intercity railway stations Secunderabad, Warangal, Vijayawada of South Central Railway (SCR) zone, India. Pedestrian perception of choice between stairway and escalator for an excerpt video captured on the stairways is acquired from questionnaire survey. It is observed that pedestrian's age, gender, educational qualification, marital status, employment status, inclination of stairway with horizontal, time of day and frequency of visiting intercity railway station (familiarity) significantly affect the choice between escalator and stairway. A binary logit model is developed for the choice with influencing variables. This study helps in understanding the proportion of pedestrians' shift towards a new facility. It aids as a tool in design, planning, and management to accommodate the predicted demand for an intercity railway station.

Keywords : Pedestrian, stairway, escalator, railway stations, choice behavior, binary logit model

Introduction

Pedestrians' routes in an infrastructure includes horizontal and vertical movement. They often use the shortest path or routes with shortest walking time in horizontal level. When they arrive at a point in route where to make a vertical traverse, there comes a decision making scenario in choosing among different facilities stairs, escalator and ramps. The choice of vertical walking facilities is the result of the interactions between pedestrians' rational decision-making and habitual behaviors

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under the combined effect of a variety of internal and external factors (Zhang *et al*., 2015). External factors include route network characteristics: number of routes available and redundancy among routes; facility characteristics: walking distance, walking time, congestion level. Internal factors include decision making, personal attributes: age, gender, luggage carrying; behavioral habit: selection of route, following the line, avoiding conflicts, and avoiding physical exertion; familiarity and travel purpose.

Studies across the world have been conducted to find the parameters influencing route choice behaviour of pedestrians. Zhang *et al*. (2015) found that walking distance, walking time and age were found to be influencing choice between stairway and escalator. With increase in pedestrian flow and delay, pedestrians using stairway increases giving up escalator. They are more sensitive to relative delays in descending direction than in ascending direction. Pedestrians getting off the train often use the facility (stairway/ escalator) near them. Lazi and Mustafa (2015) studied pedestrian flow proportion variation between escalator and staircase and observed that over 90% of pedestrian prefer to use escalator and Malaysian's prefer escalator to staircase in descending direction. Pedestrians using staircase during morning are higher than evening. Ji *et al.* (2013) developed logit model to replicate pedestrian choice between escalator and stairway in Shanghai transfer metro station. Walking disutility and congestion disutility together defines the pedestrian perceived disutility in making choice. Time pressure parameter defines the pressure a pedestrian is subjected to, which is more dominant during peak hour. The time pressure parameter is found to be more fluctuating because of the pedestrian hesitate between saving time and saving energy. Daamen *et al.* (2006) studied pedestrian route choice behavior in railway stations and found that pedestrians choose routes with shortest walking time. Type of facility in the route influence passenger's route choice behavior. Stairs are least valued over escalators and ramps with more preference to escalators. Zacharias and Tang (2015) studied the effect of pedestrian volume, height, and distance between stairway and escalator on pedestrian's choice between stairs and escalators in China and found that separating stairway and escalator increases stairway use effectively. Increasing height between floors reduces stairway use. Pedestrians tend to use stairway in descending direction than in ascending direction when pedestrian volume increases. Faskunger *et al.* (2003) studied pedestrian use of stairway and escalator under escalator favored condition and found that pedestrian volume count for each condition resulted that the stairway use dropped by half and the use of escalator increase by nearly one third when two escalators are operated. They concluded that the constructed environment influences the decision to use stairway. Srikukenthiran *et al.* (2014) developed mixed logit model to replicate pedestrian vertical transport choice in Toronto subway Stations. Variables stairway use factor, opposing density, escalator use factor, queue factor, stair approach, and height were considered for model development. It was observed that opposing stair flow and queuing show negative effect in stair use. Zacharias and Ling (2015) studied pedestrian use of escalator and stairway in shopping centers to understand the effect of location of facilities and observed that the distance has positive impact and height has negative impact on stair use. For a 100% increase in height reduced stair use by 50%. Increase in distance between stairway and escalator increase the variance in stairway use. Daamen *et al*. (2005) found that pedestrian route choice is independent of facility route consists of and is dependent on walking time, effort involved. Escalators and ramps are much valued to stairs as stairs involves more effort in climbing. For lower level heights, stairs are preferred and with increase in height passengers shift to escalators. Trip characteristics, boarding or alighting, does not influence passengers behavior. Passengers' behavior is independent of time of day and bad weather makes passengers to choose shortest route. Cheung and Lam (1998) observed that pedestrians are more sensitive to relative delays on descending facilities than in ascending direction. Pedestrians' use of escalator in ascending is higher than escalator in descending direction for same travel time and is due to the effort involved in traverse. The free flow walking speeds descending direction is higher than the ascending direction. Pedestrian speeds are less evenly distributed at lower flow rates as they are free to control their speeds. Li *et al*. (2016) found that height has significant effect on the pedestrian choice behavior between escalator and stairway. With the increase in interlayer height, pedestrian shift towards escalator use increases.

Pedestrian route choice behavior studies are conducted across the world considering various quantitative factors at various locations; transfer stations, shopping centers, and metro stations. Regression models, logit models are used to predict pedestrian choice behavior based on revealed preferences and tracking the pedestrians along the path. Studies addressing pedestrian choice between vertical facilities in intercity railway stations, particularly in developing countries like India are not addressed. Pedestrians using urban railway stations/intercity railway stations make

longer trips, comprises of trip made and trip yet to be made, subjected to various time pressures, luggage/child carrying, group size, uncertainty in knowing the platform on to which the train arrives, unfamiliar in using automated vertical facility. Thus a greater heterogeneity in pedestrian traffic exits in intercity railway stations in respect to trip characteristics, personal attributes, and familiarity to facility use. However all are subjected to use common level changing facility associated with a stairway and escalator. Research results, Shah *et al*. (2013); Jiten *et al*. (2015); Patra *et al*. (2017); Sala *et al*. (2017), showed that the pedestrian flow characteristics varies with facility type, pedestrian attributes and facility characteristics. Hence heterogeneity causes imbalanced usage of the vertical facilities resulting in capacity reduction. Pedestrian perception of choice between stairway and escalator to ascend helps in understanding the proportion of facility use under an anticipated flow rate. A research gap is identified in addressing pedestrian choice of vertical facility in intercity railway stations. In this research work an attempt is made to understand pedestrian perception in making choice between stairway and escalator under a given flow condition, facility characteristics, personal attributes, and environmental characteristics.

Study Area and Data Collection

Three intercity railway stations along railway corridor Secunderabad (S) - Warangal (W) - Vijayawada (V) of South Central Railway, India, are considered in this study. Video recording data of pedestrian movement on stairways and physical dimensions of stairways are collected. Data is collected for six stairways from Secunderabad, Warangal, and Vijayawada railway stations. Dimensional description of observed stairways is shown in Table 1**.** Width ranges between 2.0-3.6 m and inclination with horizontal range from 30°- 34°.

Figure 1 shows the snapshots of video excerpts of pedestrian flows on each stairway. From the figure it can be observed that the side friction due to waiting pedestrians sitting on the stairways is present on V_{st2} V_{st3} and S_{st} causing the reduction in usable width of stairway.

From play back videos, pedestrian volume crossing a reference line is counted for each and determined as flow (ped/m/min). Playback video is paused at three random points in a minute, and the number of pedestrians in known trap area are counted. Average density (ped/m^2) is calculated for each minute. Travel time to cross trap length is obtained from the difference of entry time and exit time for a pedestrian and his/her attributes- age,

Table 1. Dimensional Description of Observed Stairway Infrastructure

Description	S_{st}	W_{st}	V_{st1}	V_{st2}	V_{st3}	V_{st4}
Width of stairway (m)	3.5	2.4	3.6	2.0	2.0	3.5
Step foot (m)	0.4	0.35	0.3	0.3	0.3	0.3
Step riser (m)	0.22	0.15	0.15	0.15	0.15	0.15
Number of steps	41	33	41	41	41	41
Length of intermediate landing (m)	1.76	1.45	1.50	-NP-	1.40	2.5
Inclination	32^o	34^o	30^0	30^0	30^0	34^0

(a) Secunderabad Stairway - S_{st}

(b) Warangal Stairway - W_{st}

(c) Vijayawada Stairway - V_{st1}

(d) Vijayawada Stairway - V_{st2}

(e) Vijayawada Stairway - V_{st3}

(f) Vijayawada Stairway - V_{st4}

Figure 1. Snapshots of stairways from the excerpts

gender, and luggage are noted from visual interpretation. Pedestrian is classified as a kid (2-15 years), young (15-30 years), middle-aged (30-60 years) and old-aged (>60years). From the travel time to cross reference length, speed (m/min) is calculated. Average walking speed for every minute is calculated as the average of all observed walking speeds of pedestrians for that minute. Thus the flow characteristics flow, average density and average walking speed for each minute are determined. Pedestrian flow characteristics maximum flow, optimal density and mean walking speed are determined from the relationships flow-density. The optimal density is determined from polynomial trend equation fitted for the flow-density data points obtained for each minute of the survey period. The maximum flow, optimal density and mean walking speed observed on the stairways are tabulated in Table 2.

To understand the perception of pedestrians in making a choice between stairway and escalator, six videos each of a minute duration are cropped from the collected video recording data of pedestrian flows on the selected stairways from the three intercity railway stations. Flow characteristics on each stairway for one minute video are tabulated in Table 3. Level of Service (LOS) of the stairway is determined from the Transit Capacity and Quality of Service Manual (TCQSM, 2003).

A questionnaire survey form is prepared to collect respondent's stated preference in choosing between stairway and escalator when subjected to the condition in the excerpt. Table 4 shows the variable description for the questionnaire survey adopted. Respondent's characteristics included age, gender, educational qualification, employment status, marital status, and frequency of visiting railway station. Stairway characteristics: width, inclination with horizontal, step rise, and step foot are described for the corresponding video. A respondent is shown the video excerpt of each stairway and provided with the flow characteristics of it. After watching the video, respondent's choice between stairway/ escalator is collected.

Table 2. Pedestrian flow characteristics on observed stairways

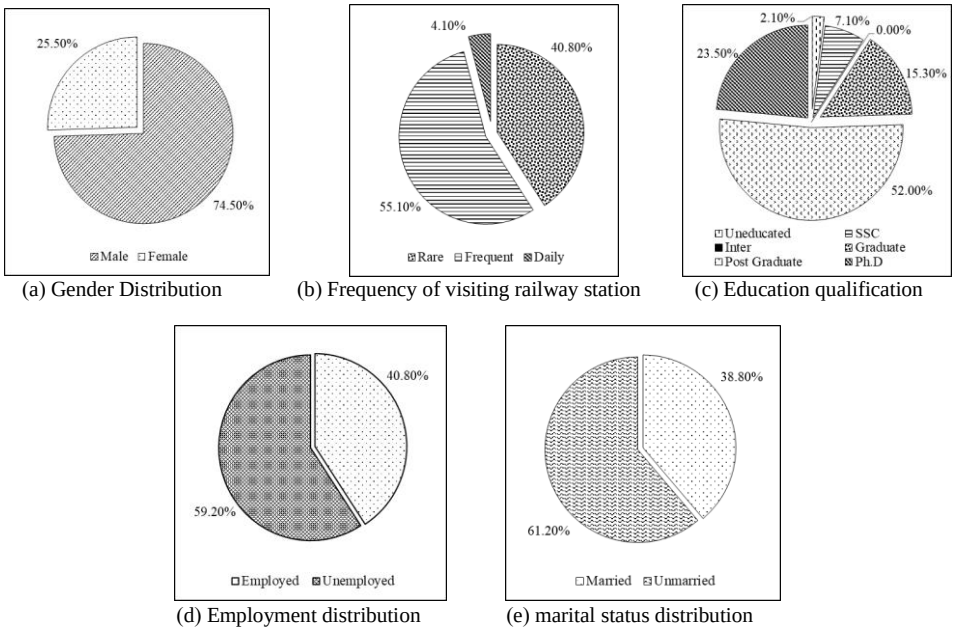
Description	S_{st}	W_{st}	V_{st1}	V_{st2}	V_{st3}	V_{st4}
Maximum Flow (ped/m/min)	40	40	28	14	25	28
Optimal density (ped/m^2)	2.60	2.29	1.55	0.72	1.37	2.55
Mean Walking Speed (m/min)	42.16	43.70	35.84	36.00	34.25	40.33

Table 3. Pedestrian flow characteristics in one minute video cropped for the questionnaire survey on observed stairways

Description	S_{st}	W_{st}	V_{st1}	V_{st2}	V_{st3}	V_{st4}
Flow (ped/m/min)	20	16	21	16	22	18
Density (ped/m^2)	0.70	0.55	1.00	0.67	1.67	1.11
Space available (m^2/ped)	1.41	1.81	1.00	1.50	0.60	0.90
Mean Speed (m/min)	42.79	39.79	44.91	31.70	23.03	27.12
LOS (TCQSM, 2003)	B	B	B	B	B	B

Table 4. Variables description for questionnaire survey

Characteristic	Variable	Description
Dependent Variable	Pedestrian perceived choice between stairway and escalator	Stairway Escalator
Pedestrian Characteristics	Age	>30 else
	Gender	Male Female
	Education	Under graduate Graduate and higher
	Employment Status	Unemployed Employee/ employer/ self-employed/ Business
	Marital Status	Unmarried Married
	Frequency of using intercity railway station	Frequent Daily
Stairway characteristics	Width	In meters (m)
	Step rise	In meters(m)
	Step foot	In meters(m)
	Inclination	In degrees (°)
Flow characteristics	Flow	In ped/m/min
	Density	In ped/m^2
	Mean walking speed	In m/min
	Space	In m^2/ped



(a) Gender Distribution (b) Frequency of visiting railway station (c) Education qualification

(d) Employment distribution (e) marital status distribution

Figure 2. Distribution of pedestrians according to (a) Gender (b) Frequency of visiting railway station (c) Educational qualification (d) Employment and (e) marital status

A total 564 responses are collected. An overview of respondent's characteristic distribution is shown in Figure 2. The frequency of visiting railway station gives the respondents association with familiarity in using various facilities. Familiarity distribution in present study included 40.80% rare visitors and 55.10% frequent visitors. Employed respondents contributed to 59.20%. The percentage choosing stairway is 36.70, 32.70, 22.40, 29.60, 21.40, and 55.10 on S_{st}, W_{st}, V_{st1}, V_{st2}, V_{st3} and V_{st4} respectively. In comparison of S_{st} and V_{st4}, for similar width, percentage of respondents choosing stairway increased with the absence of side friction. In comparison of percentage of respondents choosing stairways on all stairway with respect to width, preference of using stairway is lower on stairway with lower widths.

Binary Logit Model Development

A pedestrian perception to choose between stairway and escalator is a binary event where the probability of choosing lies between 0 and 1.

$$y_i = \begin{cases} 0, & if\ i^{th}\ respondent\ choose\ stairway \\ 1, & else \end{cases}$$

Factors affecting pedestrian's choice set are considered, and influencing factors are identified from statistical significance test for model development. Coefficients of influencing variables are estimated using the maximum likelihood function, and utility functions are defined. Probability of choosing stairway or escalator is given by Equations 1 and 2.

$$\Pr(P_{st} = 0) = P_{st} = \frac{e^{V_{st}}}{e^{V_{st}} + e^{V_{esc}}} \quad (1)$$

$$\Pr(P_{esc} = 1) = P_{esc} = \frac{e^{V_{esc}}}{e^{V_{st}} + e^{V_{esc}}} = 1 - P_{st} \quad (2)$$

The maximum likelihood is given by the product of the probabilities and Log transformation is given by Equation 3.

$$\ln L = \sum_i P_{st} \ln(P_{st}) + (1 - P_{st}) \ln(1 - P_{st}) \quad (3)$$

where P_{st} and P_{esc} are probabilities of choosing stairway and escalator respectively

V_{st} and V_{esc} are vectors of the influencing variables as described in Table 4. Measured characteristics influencing the choice between stairway and escalator and are given by the following Equation 4,

$$V_{in} = \sum_{t=1}^{n} a_{it} x_{int} \quad (4)$$

where x_{int} is the t^{th} characteristics variable of selecting mode i for an individual n and a_{it} is the coefficient of t^{th} variable for mode i (stairway/ escalator)

It is to be noted that escalator provision inside intercity railway stations is given only in ascending

direction. Hence pedestrian's choice prediction model to choose between stairway and escalator is developed for ascending direction only. Data collected from the questionnaire survey is exported to Statistical Package for Social Science (SPSS) software with predicting variables, pedestrian characteristics: age, gender, education, employment, marital status, frequency of visiting railway station, trip characteristics: morning time, evening time, infrastructure characteristics: width, inclination and flow characteristics: flow, density, speed, side friction on stairway due to waiting/sitting pedestrians. The categorical variables- presence of side friction due to waiting pedestrians on stairways, female pedestrians, education qualification being post graduate and higher, unemployed, married, evening time usage, daily visitor to intercity railway station and age greater than 30 years are assigned 0 and others assigned 1. The dependent variable is the pedestrian perceived choice between stairway and escalator with binary values 0 and 1 respectively. Frequency distribution of perceived choices showed 32.6% choose stairway and 67.4% choose escalator to ascend. Classification cutoff is set to default value 0.5. Of the 564 responses, 70% are used for model generation and the 30% unselected are used for validation.

Forward stepwise method is selected. It starts with model that does not include any variable. In the next step, variable with highest score statistic and whose significance value less than 0.05 is added to the model. The steps continue until all significant variables are added to the model thus leaving the insignificant variable with significance value greater than 0.05. Thus a sequence of models are developed and the variables with p-value less than 0.05 are included. The final model includes age, gender, educational qualification, employment status, marital status, frequency of visiting intercity railway station (familiarity), stairway inclination, and time of day. A Binary logit model is developed to predict the respondent's perception of choice between stairway and escalator. When the coefficient of a variable is positive, it defines that the probability of choosing escalator increases. And conversely if the coefficient is negative, the probability of individual's choice towards escalator decreases. The coefficient of a variable defines the change in logit of the probability associated for a unit change in significant variable when the other significant variables are held constant.

From Table 5, it is observed that the pedestrian characteristics has greater influence in choice making between stairway and escalator. It is evident that respondent's with characteristics of younger age, male, under graduate, unemployed, married, rare visitors tend to use escalator to that of stairway. They tend to use escalator in morning time more than that of evening as they are much active and board escalator with much ease. The maximum likelihood of a pedestrian choosing escalator in ascending directing inside an intercity railway station is given by the following equation 5**.**

$$\ln\left(\frac{P_{esc}}{1-P_{esc}}\right) = -4.851 + 1.039 * A + 1.012 * G + 1.510 * Q - 0.773 * E - 1.845 * M + 1.650 * F - 0.276 * I + 0.578 * T \quad (5)$$

The Hosmer-Lemeshow statistics for the test of model fit showed chi-square of 3.772 and significance value of 0.877 (>0.05) indicating a good fit adequately fits the data. Classification of choice generated from the model developed showed correct prediction of 72.4% from the 402 responses. Unselected 162 samples are used for validation and the validation results showed correct predictions of 64.8 %. Figure 3 shows the change in deviation of predictions verses predicted probabilities. The curve extending from the lower left to the upper right corresponds to responses in which choice stairway with value 0. Curve extending from lower right to upper left corresponds to the responses with escalator as choice with value 1. It shows that the respondents' choice of stairway are poorly predicted in comparison to escalator choosing respondents. This may be due to the dynamics in

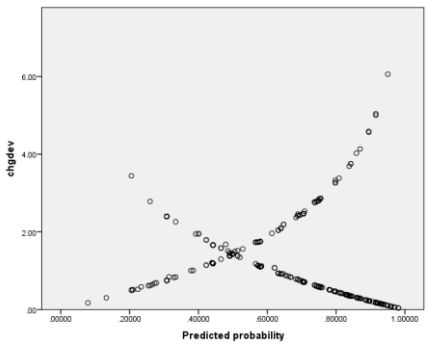


Figure 3. Predicted probability variation with change in deviation

Table 5. Pedestrian perceived choice model result between stairway and escalator

Variable	Coefficient	Sig.
Age (A)	1.039	0.013
Gender (G)	1.012	0.001
Educational Qualification (Q)	1.510	0.000
Employment (E)	-0.773	0.003
Marital status (M)	-1.845	0.000
Frequency of visiting (F)	1.650	0.014
Inclination (I)	-0.276	0.000
Time (T)	0.578	0.020
Constant	-7.503	0.292

*Sig: p value

decision making which is instantaneous prevailing to the flow conditions at the real conditions. Various other factors may affect the individual's choice of using stairway which includes luggage carrying, queue, waiting pedestrians, time pressure which are not considered for the present study. Cox & Snell R square and Nagelkerke R square are 0.170 and 0.238 respectively.

Discussion

Younger pedestrians being aggressive and active in comparison to middle aged and elders, mounts the escalator with ease. Female pedestrians feel difficult in ascending escalator with their personal attributes. Hence they are less likely to use escalator than male pedestrians. Employed pedestrians and pedestrians with education qualification graduate and higher are less likely to use escalator due to the time pressure and hence may likely use stairway to exit faster. Pedestrians of rare trip makers and married opted to use escalator. This may be because rare trip makers and married pedestrians in intercity railway stations carry considerable luggage and hence may tend to use escalator. Also the escalator use in morning time is more than the evening time and this may due to the pedestrians being active and mounts the escalator with much ease.

Conclusions

In this research work, an attempt is made to replicate pedestrian perception in making choice between vertical facilities stairway and escalator, to ascend foot over bridge inside an intercity railway station. Increase in demand, heterogeneity in pedestrian trip purpose, age, gender, luggage, and familiarity in the usage of various facilities significantly effects the pedestrian behavior. Thus pedestrian characteristics, stairway characteristics and flow characteristics effects individuals choice making in selecting vertical infrastructure to ascend foot over bridge.

The developed Binary logit model helps in understanding the pedestrian choice between stairway and escalator. Individual's age, gender, educational qualification, employment status, marital status, frequency of visiting intercity railway station (familiarity), time (morning/evening), inclination of stairway with horizontal are found to be statistically significant and influence the choice making between stairway and escalator. From the results, it can be concluded that pedestrian and infrastructure characteristics have significant effect on the pedestrian perception in making choice between stairway and escalator. Infrastructure planning, design, and management play a major role in pedestrian accessibility, disperse efficiency and evacuation of the railway station. Pedestrian usage of stairways can be increased with proper provisions of signage boards and control of friction due to waiting pedestrians on stairways. The pedestrian safety can be increased by providing edge strips for each step, lighting facility. Adequate railing facility on edges of staircase helps for proper support to aged pedestrians. Provision of central rail for higher width stairways helps in regulated directional flow and also aids as hand support. Awareness programs on health benefits of walking aids in significant usage of stairways. Educating programs on using of escalators increases the easiness and safety of pedestrians.

This study has some limitations, pedestrian perceived choice is addressed as stated preference. It does not include in situ choice made by an individual. Hence trip purpose, luggage carrying and environmental characteristic aspects are to be studied to conclude the pedestrian's choice between stairway and escalator. In spite of these limitations, results of the study help in assessing the relative proportion of shift to escalator use from existing facility and aids in decision making at the planning level, designing and managing facilities more efficiently. It also helps in evaluating the existing facilities concerning various pedestrian, infrastructure, and flow characteristics.

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