

PEDESTRIAN FLOW MODELLING IN PUBLIC TRANSPORT TERMINALS: A CASE STUDY OF DELHI METRO

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INDIAN INSTITUTE OF TECHNOLOGY DELHI
SEPTEMBER 2020**

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by

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Submitted

in fulfilment of requirement for the degree of Doctor Of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI
SEPTEMBER 2020

CERTIFICATE

This is to certify that the thesis entitled “*Pedestrian flow modelling in public transport terminals: A case study of Delhi metro*” being submitted by Ms.Lakshmi Devi Vanumu to the Indian Institute of Technology, Delhi, India, for the award of the degree of **DOCTOR OF PHILOSOPHY**, is a record of original bona-fide research work carried out by her. Ms.Lakshmi Devi Vanumu has worked under our guidance and supervision. To the best of my knowledge, the thesis has reached the requisite standard. The material contained in this thesis has not been submitted, in part or in full to any other University or Institute for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

First of all, I would like to express my sincere gratitude to my supervisor, Prof. K. Ramachandra Rao for his continuous support, motivation and guidance throughout my thesis work. I owe my deepest gratitude to my Co-supervisor Prof. Geetam Tiwari for her insightful comments and suggestions. Their guidance is invaluable in successful completion of my doctoral research. I am fortunate to work and learn from them.

I appreciate the feedback offered by all student research committee members namely Prof. K.S.Rao, Prof. Shashi Mathur and Prof. Nimesh Bolia for their valuable suggestions during the course of my research.

I am deeply indebted to Dr. Hari Krishna Gaddam, my beloved husband and co-scholar who has been extraordinarily tolerant and supportive during my Ph.D. work. This Ph.D. would not have been possible without his support and care. A special thanks to my family for their love and affection.

I also wish to thank all my Ph.D. Scholars specially Mohit Kumar Singh and Amit Sharma, Post Graduate colleagues, undergraduate students Sugam Bansal, Khushi Ram, Hemant Jain at Traffic and Transportation Laboratory of Transportation Engineering Section for their help in data collection and extraction process.

I would like to acknowledge the help of Mr. Kaushik Pahari, Mr. Siya Ram, Mr. Malli Ram, Mr. Ashok, staff of Transportation Engineering Section and Mr. Mahesh Gaur, Mr. Hari, Staff of TRIPP.

I am extremely grateful to Mr. D.K. Sinha, CGM/S&T, Delhi Metro Rail Corporation and Mr. Mukund Sinha, Joint Secretary & Officer on Special Duty (Urban Transport) at Ministry of Housing & Urban Affairs, Government of India for permission to use the data related to Delhi Metro Rail Corporation.

Finally, I am thankful to library staff and administrative staff of IIT Delhi for their cooperation.



Lakshmi Devi Vanumu

ABSTRACT

The geometry and orientation of pedestrian facilities has a significant influence on the movements of pedestrians and impacts its environment. Understanding the pedestrian movements are crucial to estimate the capacity of the system accurately, specifically in the transportation terminals such as railway stations, bus terminals, airports and so forth, where large crowd gathers and transfers. To have a safe and comfortable movement in normal conditions and also a quick evacuation in emergency conditions, the pedestrian movement patterns should be analysed and modelled properly. Once the behaviour of pedestrians is established in terms of speed, flow and density with respect to the environment, even for the massive systems, the pedestrian flow characteristics can be modelled by applying extremely efficient simulations. The main modelling element in the pedestrian flow models is the fundamental relationship amongst the speed, flow and density. A review of the fundamental diagrams of pedestrian flow characteristics developed for various flow types and geometric elements using various approaches such as field, experimental and simulation were discussed. The design values of flow parameters and walking speeds of pedestrians at various facilities in the literature were presented. Based on the thorough review of literature, it is identified that limited research has been carried out in India for understanding pedestrian dynamics in the context of development of the fundamental diagrams. In this regard, present study is aimed to develop fundamental diagrams of pedestrian flow characteristics for different infrastructural elements in public transport terminals in Indian scenario. Pedestrian data has been collected in Delhi metro railway stations on various infrastructural elements such as corridors, stairways and escalators. The pedestrian characteristics on corridors and stairways for different flow conditions such as unidirectional, bidirectional were studied. To extract the relevant data, a semi-automatic video image processing MATLAB® based tool is developed. Video data

(covering peak and non-peak hours) was extracted on each element considering different pedestrian attributes such as gender, age and luggage. A new methodology has been proposed for calculating pedestrian density on escalators which helps in estimating the capacity of the escalator accurately. The average capacity (6552 Pedestrians/h) and maximum capacity (10530 Pedestrians/h) values obtained from this study are higher compared to the practical capacity value (5850 Pedestrians/h) provided by National Building Code of India 2016 for an escalator with speed of 0.65 m/s. Further, it is observed that the density on escalators is maximum when the proportion of male pedestrians, pedestrians with no luggage or medium luggage, younger and elder pedestrians is high. Finally, it is suggested that the capacity estimation procedure can be applied to any escalator irrespective of whether the pedestrians are standing or walking, as the method depends on pedestrian flow. The design values of pedestrian flow characteristics for stairs, corridors for Indian conditions are provided and compared with the existing guidelines and studies. It is observed that the maximum density and density at maximum specific flow values for stairs proposed by Indo HCM (2017) are higher compared to the design values proposed in this study. Pedestrian speeds on stairs in unidirectional and bidirectional movements are varying significantly. Further, it is found that the speeds in bidirectional movements are higher compared to unidirectional movements. Hence changing the directional movement of pedestrians on a facility from unidirectional to bidirectional or vice versa would have an impact on pedestrian flow characteristics. Finally, it is anticipated that the results of this study provides insights into fundamental diagrams of pedestrian flow characteristics and walking behaviour of pedestrians. This would help in the design of different infrastructural elements of the pedestrian facilities effectively.

सार

पैदल यात्री सुविधाओं की ज्यामिति और अभिविन्यास का पैदल यात्रियों के आंदोलनों पर महत्वपूर्ण प्रभाव पड़ता है और इसके पर्यावरण पर प्रभाव पड़ता है। पैदल चाल को समझना प्रणाली की क्षमता का सही अनुमान लगाने के लिए महत्वपूर्ण है, विशेष रूप से रेलवे स्टेशनों, बस टर्मिनलों, हवाई अड्डों और इतने पर परिवहन टर्मिनलों में, जहां बड़ी भीड़ इकट्ठा होती है और स्थानांतरित होती है। सामान्य परिस्थितियों में एक सुरक्षित और आरामदायक आंदोलन और आपातकालीन परिस्थितियों में त्वरित निकासी के लिए, पैदल यात्री आंदोलन पैटर्न का विश्लेषण और ठीक से मॉडलिंग की जानी चाहिए। एक बार पैदल चलने वालों का व्यवहार पर्यावरण के संबंध में गति, प्रवाह और घनत्व के संदर्भ में स्थापित हो जाता है, यहां तक कि बड़े पैमाने पर प्रणालियों के लिए, पैदल यात्री प्रवाह विशेषताओं को बेहद कुशल सिमुलेशन लागू करके तैयार किया जा सकता है। पैदल प्रवाह मॉडल में मुख्य मॉडलिंग तत्व गति, प्रवाह और घनत्व के बीच मूलभूत संबंध है। क्षेत्र, प्रायोगिक और सिमुलेशन जैसे विभिन्न दृष्टिकोणों का उपयोग करके विभिन्न प्रवाह प्रकारों और ज्यामितीय तत्वों के लिए विकसित पैदल यात्री प्रवाह विशेषताओं के मौलिक आरेखों की समीक्षा की गई। साहित्य में विभिन्न सुविधाओं पर पैदल चलने वालों के डिजाइन मान और पैदल चलने की गति को प्रस्तुत किया गया। साहित्य की गहन समीक्षा के आधार पर, यह पहचाना जाता है कि मौलिक आरेखों के विकास के संदर्भ में पैदल चलने वालों की गतिशीलता को समझने के लिए भारत में सीमित शोध किए गए हैं। इस संबंध में, वर्तमान अध्ययन का उद्देश्य भारतीय परिदृश्य में सार्वजनिक परिवहन टर्मिनलों में विभिन्न अवसंरचनात्मक तत्वों के लिए पैदल यात्री प्रवाह विशेषताओं के मौलिक आरेखों को विकसित करना है। दिल्ली के मेट्रो रेलवे स्टेशनों पर विभिन्न बुनियादी ढांचे जैसे कि गलियारों, सीढ़ी और एस्केलेटर पर पैदल चलने वालों का डेटा एकत्र किया गया है। विभिन्न प्रवाह स्थितियों जैसे कि यूनिडायरेक्शनल, बिडायरेक्शनल के लिए गलियारों और सीढ़ी पर पैदल चलने वालों की विशेषताओं का अध्ययन किया गया था। प्रासंगिक डेटा निकालने के लिए, अर्ध-स्वचालित वीडियो इमेज प्रोसेसिंग

MATLAB® आधारित टूल विकसित किया गया है। लिंग, आयु और सामान जैसे विभिन्न पैदल यात्री विशेषताओं पर विचार करते हुए प्रत्येक तत्व पर वीडियो डेटा (शिखर और गैर-शिखर घंटों को कवर) निकाला गया था। एस्केलेटर पर पैदल यात्री घनत्व की गणना के लिए एक नई पद्धति का प्रस्ताव किया गया है जो एस्केलेटर की क्षमता का सही आकलन करने में मदद करता है। इस अध्ययन से प्राप्त औसत क्षमता (6552 पैदल यात्री / एच) और अधिकतम क्षमता (10530 पैदल यात्री / घंटे) व्यावहारिक क्षमता मूल्य (5850 पैदल यात्री / घंटा) की तुलना में अधिक हैं, जो कि गति के साथ एस्केलेटर के लिए नेशनल बिल्डिंग कोड ऑफ़ इंडिया 2016 द्वारा प्रदान किया गया है। 0.65 मीटर / से। इसके अलावा, यह देखा गया है कि एस्केलेटर पर घनत्व अधिकतम होता है जब पुरुष पैदल चलने वालों का अनुपात, बिना सामान या मध्यम सामान वाले पैदल यात्री, छोटे और बड़े पैदल यात्रियों का अनुपात अधिक होता है। अंत में, यह सुझाव दिया गया है कि क्षमता आकलन प्रक्रिया को किसी भी एस्केलेटर पर लागू किया जा सकता है, भले ही पैदल यात्री खड़े हों या पैदल चलें, क्योंकि विधि पैदल प्रवाह पर निर्भर करती है। मौजूदा दिशा-निर्देशों और अध्ययनों के साथ सीढ़ियों के लिए पैदल यात्री प्रवाह विशेषताओं, भारतीय परिस्थितियों के लिए गलियारों के डिजाइन मूल्य प्रदान किए जाते हैं और उनकी तुलना की जाती है। यह देखा गया है कि इंडो एचसीएम (2017) द्वारा प्रस्तावित सीढ़ियों के लिए अधिकतम विशिष्ट प्रवाह मूल्यों पर अधिकतम घनत्व और घनत्व इस अध्ययन में प्रस्तावित डिजाइन मूल्यों की तुलना में अधिक है। यूनिडायरेक्शनल और बिडायरेक्शनल मूवमेंट में सीढ़ियों पर पैदल चलने वालों की गति काफी भिन्न होती है। इसके अलावा, यह पाया गया है कि अप्रत्यक्ष आंदोलनों की तुलना में द्विदिश आंदोलनों में गति अधिक है। इसलिए पैदल यात्रियों के दिशात्मक आंदोलन को यूनिडायरेक्शनल से बिडायरेक्शनल या इसके विपरीत में बदलने से पैदल यात्री प्रवाह विशेषताओं पर प्रभाव पड़ेगा। अंत में, यह अनुमान लगाया जाता है कि इस अध्ययन के परिणाम पैदल यात्री प्रवाह की विशेषताओं और पैदल चलने वालों के व्यवहार के बुनियादी आरेखों में अंतर्दृष्टि प्रदान करते हैं। इससे पैदल यात्री सुविधाओं के विभिन्न बुनियादी ढाँचों के प्रभावी ढंग से डिजाइन में मदद मिलेगी।

TABLE OF CONTENTS

CERTIFICATE.....	i
ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	iii
1. INTRODUCTION	5
1.1 GENERAL	5
1.1.1 Fundamental diagrams of pedestrian flow characteristics.....	6
1.1.2 Walking speeds of pedestrians at various facilities	7
1.2 NEED FOR THE STUDY	8
1.3 AIM OF THE STUDY	9
1.4 OBJECTIVES	9
1.5 SCOPE	10
1.6 THESIS ORGANIZATION	10
2 REVIEW OF LITERATURE	12
2.1 GENERAL	12
2.2 FUNDAMENTAL DIAGRAMS OF PEDESTRIAN FLOW CHARACTERISTICS	
14	
2.3 FUNDAMENTAL DIAGRAMS OF VARIOUS FLOW TYPES.....	16
2.4 FUNDAMENTAL DIAGRAMS FOR VARIOUS INFRASTRUCTURAL	
ELEMENTS.....	18
2.4.1 Corridors	20
2.4.2 Bottlenecks and T-Junctions.....	20
2.4.3 Stairs	21
2.4.4 Escalators.....	25
2.5 WALKING SPEEDS ON VARIOUS FACILITIES	28
2.6 DISCUSSION	40
3 METHODOOGY	42
4 DATA COLLECTION AND EXTRACTION	44

4.1	STUDY AREA SELECTION	44
4.2	DATA COLLECTION	47
4.3	DATA EXTRACTION AND ANALYSIS	49
4.4	MODEL DEVELOPMENT	50
4.4.1	Selection of Simulation Software and model parameters	50
5	ESTIMATION OF CAPACITY OF ESCALATORS	53
5.1	BACKGROUND.....	53
5.2	Pedestrian density estimation procedure	53
5.2.1	Density estimation procedure	55
5.3	Findings.....	58
5.4	Summary	60
6	ANALYSIS OF PEDESTRIAN FLOW CHARACTERISTICS ON STAIRS AND CORRIDORS	62
6.1	Background	62
6.2	STAIRS	62
6.2.1	Fundamental Diagrams	63
6.2.2	Walking Speeds	70
6.2.3	Summary - Stairs	106
6.3	CORRIDORS	110
6.3.1	Fundamental Diagrams	110
6.3.2	Walking Speeds	113
6.3.3	Summary - Corridors	124
7	CONCLUSIONS.....	127
7.1	CONCLUSIONS.....	127
7.2	CONTRIBUTIONS.....	129
7.3	LIMITATIONS AND FUTURE SCOPE	130
7.3.1	Limitations.....	130

7.3.2 Future Scope	131
REFERENCES.....	133
APPENDIX – A.....	142
APPENDIX – B.....	158
PUBLICATIONS.....	170
BIODATA OF THE AUTHOR.....	172

List of Figures

Figure 1.1 Fundamental diagrams of pedestrian flow characteristics from Literature (Daamen, Hoogendoorn and Bovy, 2005).....	7
Figure 1.2 Pedestrian walking speeds from various studies	8
Figure 2.1 Fundamental diagrams of uni and bidirectional pedestrian flow from various studies (a) Density–speed and (b) Density–specific flow (Zhang and Seyfried (2013)).....	17
Figure 2.2 Fundamental diagrams for pedestrian movement in planar facilities.....	19
Figure 2.3 Line diagrams of Geometric elements (a) Corridor (b) Bottleneck (c) T – Junction (d) Stair case (e) Escalator	19
Figure 2.4 Fundamental diagrams of stairs given by different planning guidelines.....	22
Figure 2.5 Measurements of the fundamental diagram for stairs obtained from various field and experimental studies. Full range of observation points has been shown in the small diagram enclosed (Burghardt, Seyfried and Klingsch (2013))	23
Figure 3.1 Research methodology	43
Figure 4.1 Delhi metro rail map (Metro stations ND is marked as 1, CC as 2, KK as 3, CS as 4, RC as 5) (Source: www.delhimetrorail.com)	46
Figure 4.2 Snapshots of data collection sites (a) Escalator in Chandini chowk (b) Corridor in New Delhi (c) & (d) Stairs in New Delhi metro stations.....	47
Figure 4.3 Schematic representation of element section details	49
Figure 5.1 Pedestrian density estimation procedure on escalators	54
Figure 5.2 Pedestrian flows observed on different Escalators	59
Figure 6.1 Specific flow – Density relationship for unidirectional movement on (a) Ascending stairs (b) Descending stairs	63
Figure 6.2 Comparison of observed data of stairs with the proposed FD's in literature (a) Ascending (b) Descending	65
Figure 6.3 Comparison of simulated data of stairs with the proposed FD's in literature (a) Ascending (b) Descending	66
Figure 6.4 Specific flow – Density diagrams for stairs (a) observed data (b) comparison of observed and simulated data	69
Figure 6.5 Performing simulations on Stairs	70
Figure 6.6 (a) Individual value plot (b) Speed distributions plot for ascending and descending speeds	72
Figure 6.7 Probability distribution for speeds in ascending stairs	74

Figure 6.8 Probability distribution for speeds in descending stairs	75
Figure 6.9 (a) Box Plot (b) Individual value plot for male and female pedestrian speeds in ascending stairs	76
Figure 6.10 Pedestrian speed distributions for male and female on ascending stairs.....	77
Figure 6.11 (a) BoxPlot (b) Individual value plot (c) Interval plot for 95% Confidence Interval for the mean (d) Games – Howell Simultaneous 95% CIs – Difference of Means plot for various categories of ages on ascending stairs	79
Figure 6.12 (a) Pedestrian speed distributions for different age categories (b) Cumulative percentile speed distributions for different age groups on ascending stairs	80
Figure 6.13(a) BoxPlot (b) Individual value plot (c) Interval plot for 95% Confidence Interval for the mean (d) Games – Howell Simultaneous 95% CIs – Difference of Means plot for various categories of luggages	83
Figure 6.14 (a) Pedestrian speed distributions (b) Cumulative percentile speed distributions for different age categories	84
Figure 6.15 (a) Box Plot (b) Individual value plot (c) Cumulative percentile speed distributions with respect to directional movement in ascending stairs	86
Figure 6.16 (a) Box Plot (b) Individual value plot (c) Cumulative percentile speed distributions with respect to directional movement on descending stairs.....	88
Figure 6.17 (a) Box Plot (d) Cumulative percentile speed distributions male and female pedestrians with respect to directional movement on ascending stairs.....	89
Figure 6.18 (a) Box Plot (d) Cumulative percentile speed distributions for different categories of ages with respect to directional movement in ascending stairs	92
Figure 6.19 (a) Box Plot (d) Cumulative percentile speed distributions for different categories of luggage with respect to directional movement on ascending stairs	95
Figure 6.20 (a) Box Plot (d) Cumulative percentile speed distributions for male and female with respect to directional movement in descending stairs	99
Figure 6.21 (a) Box Plot (b) Cumulative percentile speed distributions for different categories of ages with respect to directional movement in descending stairs	102
Figure 6.22 (a) Box Plot (b) Cumulative percentile speed distributions for different categories of ages with respect to directional movement in descending stairs	106
Figure 6.23 Specific flow – Density diagram for the observed data on cooridor.....	110
Figure 6.24 Providing the speed distributions of various categories of pedestrians to simulate the pedesrian flows on corridor.....	111
Figure 6.25 Simulation runs in VISWALK on corridor	112

Figure 6.26 Comparison of Flow – Density diagram for observed and simulated data of corridor.....	112
Figure 6.27 Probability distribution curves for pedestrian speeds on ascending corridor.....	114
Figure 6.28 Probability distribution for pedestrian speeds on descending corridor	115
Figure 6.29 (a) Individual value plot (b) Box plot for speeds in ascending and descending corridor.....	116
Figure 6.30 (a) Individual value plot (b) Speed distributions (c) Cumulative probability curves for male and female pedestrian speeds on corridor	118
Figure 6.31 (a) Individual value plot (b) Interval plot for 95% Confidence Interval for the mean (c) Games – Howell Simultaneous 95% CIs – Difference of Means plot for valious categories of ages.....	120
Figure 6.32 (a) Pedestrian speed distributions (b) Cumulative percentile speed distributions for different categories of ages on ascending corridor.....	121
Figure 6.33(a) Individual value plot (b) Interval plot for 95% Confidence Interval for the mean (c) Games – Howell Simultaneous 95% CIs – Difference of Means plot for various categories of luggage's	123
Figure 6.34(a) Individual pedestrian speed distributions (b) Cumulative percentile speed distributions of different age categories on ascending corridor.....	124

List of Tables

Table 2.1 Comparison of capacity values for escalators given by different manufacturing companies and guidelines	27
Table 2.2 Review of Fundamental Diagrams of pedestrian flow characteristics for different infrastructural elements.....	32
Table 4.1 Technical details of escalators	45
Table 4.2 Categorization of pedestrian characteristics	48
Table 4.3 Calibrated VISWALK model parameters.....	52
Table 5.1 Proportion of pedestrians, estimated flows and densities at Chandinichowk metro station during peak minute.....	57
Table 5.2 Results of pedestrian density and capacity values on different escalators	58
Table 5.3 Proportion of pedestrians on escalators during total observation time and peak minute	60
Table 6.1 Comparison of design specific flow and density values for stairs with existing guidelines	67
Table 6.2 Descriptive statistics of pedestrian walking speeds in unidirectional movement on ascending and descending stairs	71
Table 6.3 Two-Sample T-Test between the speeds of pedestrians in ascending and descending stairs	72
Table 6.4 Pedestrian speed distributions for ascending stairs.....	73
Table 6.5 Pedestrian speed distributions for descending stairs.....	74
Table 6.6 Descriptive Statistics of speeds of male and female pedestrians for ascending stairs	76
Table 6.7 Two-Sample T-Test between Male and Female pedestrian speeds for ascending stairs	76
Table 6.8 Descriptive Statistics for different categories of ages for ascending stairs	78
Table 6.9 Games-Howell Pairwise Comparisons for different age groups of pedestrians for ascending stairs	78
Table 6.10 Descriptive Statistics for different Luggage categories for ascending stairs.....	81
Table 6.11 Games-Howell Pairwise Comparisons for different Luggage categories for ascending stairs	81
Table 6.12 Descriptive Statistics for pedestrian speeds in Unidirectional and Bidirectional movements on ascending stairs.....	84

Table 6.13 Two-Sample T-Test between pedestrian speeds in Unidirectional and Bidirectional movements on ascending stairs.....	85
Table 6.14 Descriptive Statistics for pedestrian speeds in Unidirectional and Bidirectional movement in descending stairs	87
Table 6.15 Two-Sample T-Test between pedestrian speeds in Unidirectional and Birdirectional descending stairs	87
Table 6.16 Descriptive Statistics for Male and Female pedestrian speeds with respect to directional movement on ascending stairs	89
Table 6.17 Two-sample T test for Male pedestrian speeds between Unidirectional and Bidirectional movements in ascending stairs.....	90
Table 6.18 Two-sample T-test for Female pedestrian speeds between Unidirectional and Bidirectional movements on ascending stairs	90
Table 6.19 Descriptive Statistics for pedestrian speeds of different categories of ages with respect to directional movement on ascending stairs.....	91
Table 6.20 Two-sample T test for Children speeds between Unidirectional and Bidirectional movement in ascending stairs	92
Table 6.21 Two-sample T test for Younger pedestrian speeds between Unidirectional and Bidirectional movement in ascending stairs	92
Table 6.22 Two-sample T test for Elder pedestrian speeds between Unidirectional and Bidirectional movement in ascending stairs	93
Table 6.23 Two-sample T test for Older pedestrian speeds between Unidirectional and Bidirectional movement in ascending stairs	93
Table 6.24 Descriptive Statistics for pedestrians speeds of different luggage categories with respect to directional movement in ascending stairs.....	94
Table 6.25 Two-sample T test for speeds of pedestrians with no Luggage between Unidirectional and Bidirectional movement on ascending stairs	95
Table 6.26 Two-sample T test for speeds of pedestrians with Medium Luggagebetween Unidirectional and Bidirectional movement on ascending stairs	95
Table 6.27 Two-sample T test for speeds of pedestrians with Heavy Luggage between Unidirectional and Bidirectional movement on ascending stairs	96
Table 6.28 Two-sample T test for speeds of pedestrians With Children between Unidirectional and Bidirectional movement on ascending stairs	96
Table 6.29 Descriptive Statistics for Male and Female pedestrian speeds with respect to directional movement on descending stairs	97

Table 6.30 Two-sample T test for Male pedestrian speeds between Unidirectional and Bidirectional movements in descending stairs.....	98
Table 6.31 Two-sample T test for Female pedestrian speeds between Unidirectional and Bidirectional movements in descending stairs.....	98
Table 6.32 Descriptive Statistics for pedestrian speeds of different categories of ages with respect to directional movement in descending stairs.....	100
Table 6.33 Two-sample T test for Children speeds between Unidirectional and Bidirectional movement in descending stairs	101
Table 6.34 Two-sample T test for Younger pedestrian speeds between Unidirectional and Bidirectional movement in descending stairs	101
Table 6.35 Two-sample T test for Elder pedestrian speeds between Unidirectional and Bidirectional movement in descending stairs	101
Table 6.36 Two-sample T test for Older pedestrian speeds between Unidirectional and Bidirectional movement in descending stairs	102
Table 6.37 Descriptive Statistics for for pedestrians speeds of different luggage categories with respect to directional movement in descending stairs	103
Table 6.38 Two-sample T test for speeds of pedestrians with no Luggage between Unidirectional and Bidirectional movement in descending stairs	104
Table 6.39 Two-sample T test for speeds of pedestrians with medium Luggage between Unidirectional and Bidirectional movement in descending stairs	104
Table 6.40 Two-sample T test for speeds of pedestrians with Heavy Luggage between Unidirectional and Bidirectional movement in descending stairs	104
Table 6.41 Two-sample T test for speeds of pedestrians With Children between Unidirectional and Bidirectional movement in descending stairs	105
Table 6.42 Descriptive Statistics for pedestrian speeds on ascending corridor.....	113
Table 6.43 Pedestrian speed distributions on ascending corridor.....	113
Table 6.44 Descriptive Statistics for pedestrian speeds on descending corridor.....	114
Table 6.45 Pedestrian speed distributions on descending corridor.....	115
Table 6.46 Two-Sample T-Test between speeds in ascending and descending corridor	116
Table 6.47 Descriptive Statistics of speeds of male and female pedestrians on ascending corridor.....	117
Table 6.48 Two-Sample T-Test between male and female pedestrian speeds on ascending corridor.....	117
Table 6.49 Descriptive Statistics for different categories of ages on ascending corridor.....	118

Table 6.50 Games-Howell Pairwise comparisons for different categories of ages on ascending corridor.....	119
Table 6.51 Descriptive Statistics for for different luggage categories on ascending corridors	122
Table 6.52 Games-Howell Pairwise Comparisons for different luggage categories on ascending corridor.....	122