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To Evaluate The Pedestrian Level Of Service Based On Passenger Behaviour: Charbagh Railway Station

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Abstract— *Pedestrians are the oldest and largest scale of uses for short and medium-range travel. Movements of pedestrians are not constrained by lanes or particular routes, but rather by the physical limitations that surround them, such as the presence of walkways or pedestrian ways. As a result, while designing transportation infrastructure, pedestrian demands should be taken into account. Pedestrian facilities include crosswalks, stairways, curb cuts, ramps, and transit stations. There are several places where pedestrians may share the road or its shoulders, especially in suburban and rural settings. To encourage walking and ensure the safety of pedestrians, these facilities have to be pedestrian-friendly.*

To capture data for the interchange system during peak hours for every location, a system of surveys was established, and a deployment timetable was made. The data is then further structured and analyzed based on passenger behaviour at various forms of transportation. Interchange and Level of Services are put up, which will assist in assessing the service levels on seven parameters and six levels.

This paper presents the study of the existing pedestrian situation for the Charbagh railway station located in the city of Lucknow (Uttar Pradesh), computation of the pedestrian level of service for the entire frontage of the railway station and suggests ways to improve the Pedestrian Level of Service. This research aims to improve the P.L.O.S. (Pedestrian Level of Service) of the interchange of Charbagh railway station by giving various solutions to current problems.

Keywords— Interchange, Level of Service, Passenger Behavior Parameters, PEF (Passenger Equivalent Factor).

1. INTRODUCTION

Effective public transportation is crucial because urban populations are expanding and intercity travel has grown in many big cities. Due to the restricted pedestrian space on the transportation infrastructure and the high population. The system's capacity will be demanded more as a result of the growth in passenger traffic. Particularly around the railway station's front entrance space, where there was heavy foot traffic. [1]

At Charbagh Railway Station Lucknow, daily footfall is 1.2 lakhs. It creates huge foot traffic at peak time and creates pedestrian congestion.

Age, Gender, Luggage, Speed, Density, Flow, and Space are the seven parameters. PEF (Passenger Equivalent Factor), a system created to standardize passenger behaviour, is then applied to gauge the level of service. The fundamental classification of levels is A, B, C, D, E, and F, where A and B are overdesigned, C is optimally designed, D is sub-optimally designed, and E and F are under-designed. The Interchange route will then be examined in light of these, and conclusions will be drawn. Our understanding of the existing condition of exchange and the necessity of taking action to improve its functioning will be guided by the inference.

Aside from knowing the level of service additionally, the relationship between space and time according to the Benz model is investigated. The requirement for space during peak hours and if the interchange system is using space efficiently are two of this study's most significant outputs related to space and time.[2]

1.1 Need of Study

- Only when facilities give people adequate room, which is uncommon in the Indian setting, can travel be seamless.
- Finding the variables that may affect passenger behaviour in various circumstances is necessary since it changes according to a person's temperament, dimension, etc. These characteristics are then examined to see which ones have a substantial influence on the interchange and how they affect passenger behaviour.

1.2 Objectives

- To study the attributes of passenger behaviour.
- To assess the parameters impacting the interchange.
- To assess the current structure of interchange and interconnectivity within the system.
- To evaluate the current level of services for the existing interchange.
- To develop the capacity norms for the passengers at the interchange in terms of a new level of service.

2. LITERATURE STUDY

2.1 Factors affecting pedestrian demand

The demand for pedestrian facilities is influenced by several factors of which some of the most important are:- The nature of the local community: -

- Walking is more likely to occur in a community that has a high proportion of young people. Car ownership: - The amount of walking is day by day reduced by private cars, even for a short journey.
- Local land use activities: - Walking is primarily used for short-distance trips. Consequently, the distance between local origins and destinations (e.g. homes and schools, homes and shops) is an important factor influencing the level of demand, particularly for the young and elderly.
- Quality of provision: - Then demand will tend to increase if good quality pedestrians are provided.
- Safety and security: - facilities should be provided to pedestrians so that they can feel safe and secure. This means freedom from conflict with the motor vehicle, as well as uneven surfaces and personal attacks also.

2.2 Pedestrian Problems

Accidents Circumstances - Pedestrian accidents occur in a variety of ways the most common type involves pedestrian crossing or entering the street at or between intersections. Darting is used to indicate the sudden appearance of a pedestrian from behind a vehicle Dashing refers to running pedestrians.

2.3 Special Problems

Age: - The largest group of victims in pedestrians are children under 15 years of age group, they have more chances of injury also. Intoxication and Drug effects: Alcohol and drugs impair the behaviour of pedestrians to a large extent which may be the cause of the accident. Dusk and Darkness:- During dusk and darkness motorists cannot see pedestrians.

2.4 Literature review

- Intermodality is an integral part of sustainable mobility, and its enhancement is of vital importance mainly, in highly congested transit hubs as their efficient design could lead not only to the increase in the share of commuters who use urban public transport but also to the consolidation of the overall public transport system.

- In interchange, there are multiple public transport systems merging. Each interchange between two has passengers of different characters and parameters.

2.5 PEDESTRIAN LEVEL OF SERVICE (PLOS)

Table 1 Pedestrian Level of Service

LEVEL OF SERVICE A	Equivalent to an average area occupancy of 35 sq ft per person or greater. Pedestrian Space > 60 ft^2/p, Flow Rate = 5 p/min/ft, pedestrians move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.
LEVEL OF SERVICE B	Equivalent to an average area occupancy in the range of 25 to 35 sq ft per person. Pedestrian Space > 40-60 ft^2/p, Flow Rate > 5-7 p/min/ft, there is sufficient area for pedestrians to select walking speeds freely to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians and to respond to their presence when electing a walking path.
LEVEL OF SERVICE C	Equivalent to an average area occupancy of 15 to 25 sq ft per person. Pedestrian Space > 24-40 ft^2/p, Flow Rate > 7-10 p/min/ft, space is sufficient for normal walking speeds, and for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, and speeds and flow rates are somewhat lower.

LEVEL OF SERVICE D	Equivalent to an average area occupancy of 10 to 15 sq ft per person. Pedestrian Space > 15-24 ft²/p, Flow Rate > 10-15 p/min/ft, freedom to select individual walking speed and to bypass other pedestrians is restricted. Crossing or reverse-flow movements face a high probability of conflict, requiring frequent changes in speed and position. The LOS provides reasonably fluid flow, but friction and interaction between pedestrians are likely
LEVEL OF SERVICE E	Equivalent to an average area occupancy of 10 sq ft per person Pedestrian Space > 8-15 ft²/p, Flow Rate > 15-23 p/min/ft, virtually all pedestrians restrict their normal walking speed, frequently adjusting their gait. At the lower range, forward movement is possible only by shuffling. Space is not sufficient for passing slower pedestrians. Cross- or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with stoppages and interruptions to flow.
LEVEL OF SERVICE F	Equivalent to an average area occupancy of 05 sq ft per person or less. Pedestrian Space = 8 ft²/p, Flow Rate varies p/min/ft, all walking speeds are severely restricted, and forward progress is made only by shuffling. There is frequent unavoidable contact with other pedestrians. Cross-and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams.

Pedestrian LOS for sidewalks and sideways is calculated using the pedestrian unit flow rate. In addition to LOS grades A to F, space (ft²/p)[2]

Table 2 PLOS for an interchange formed

PLOS for an interchange formed				
PLOS	**Average Space (Sq.mtr / PEF)**	**Related Measure**		
		Flow Rate (PEF / Min)	**Average Speed (m /Min)**	**Density (PEF / Sq.m)**
A	14.40 - 12.68	14.40 - 12.68	14.40 - 12.68	14.40 - 12.68
B	12.68 - 9.26	12.68 - 9.26	12.68 - 9.26	12.68 - 9.26
C	9.26 - 6.94	9.26 - 6.94	9.26 - 6.94	9.26 - 6.94
D	6.94 - 4.17	6.94 - 4.17	6.94 - 4.17	6.94 - 4.17
E	4.17 - 1.88	4.17 - 1.88	4.17 - 1.88	4.17 - 1.88
F	1.88 - 0.15	1.88 - 0.15	1.88 - 0.15	1.88 - 0.15

2.6 Passenger Equivalent Factor (PEF) Profile

Passenger equivalent factor (PEF) has been formulated to define different attributes of passengers in one unit. Chandra's method has been used to formulate PEF. Chandra's formula states that {(An/Ap)*(Vp/Vn)}, where An is the area of the passenger with no luggage, Ap is the area of the passenger with attributed luggage, Vp is the speed of the passenger with attributed luggage and Vn is the Speed of passenger with no luggage. PEF has been formulated for different categories of a passenger with attributed luggage with differing speeds based on their age, gender and groups.

Speed-based PEFs have been formulated for this study. For evaluating the passenger profile passengers have been categorized and the area of influence is taken through an anthropometry study. Twelve categories have been formulated depending on their luggage.

Table 3 PEF for different passenger categories

PEF for different passenger categories				
PEF (Passenger Equivalent Factor)				
Types of Passengers	**Age & Gender**	**Area (sqm)**	**Average Speed (m/ min)**	**PEF**
Without Luggage	5-14 YRS	0.22	40	**0.6**
	Male (15-59yr)	0.47	52	**1.0**
	Female (15-59yr)	0.39	49	**0.9**
	>60 YRS	0.47	45	**1.2**
With polybag/lunch bag	Male (15-59yr)	0.56	41.6	**1.5**
	Female (15-59yr)	0.47	39.2	**1.3**
With bag pack	5-14 YRS	0.24	32.87	**0.8**
	Male (15-59yr)	0.65	38.1	**1.9**
	Female (15-59yr)	0.52	37.64	**1.5**
With Duffle Bag	Male (15-59yr)	0.65	34.36	**2.1**
	Female (15-59yr)	0.55	32.28	**1.9**
	>60 YRS	0.65	28.7	**2.5**
With 2 Duffle Bag	Male (15-59yr)	0.75	26.6	**3.1**
	Female (15-59yr)	0.64	24.47	**2.9**
With Duffle &Bag pack	Male (15-59yr)	0.90	29.6	**3.3**
	Female (15-59yr)	0.77	26.32	**3.2**
With Trolley Bag	Male (15-59yr)	1.96	28.56	**7.6**
	Female (15-59yr)	1.52	26.3	**6.4**
With Trolley &Bag pack	Male (15-59yr)	2.14	27.46	**8.6**
	Female (15-59yr)	1.61	25.12	**7.1**
	Male (15-59yr)	2.41	26.6	**10.0**

With Trolley &Duffle Bag	Female (15-59yr)	1.83	23.31	**8.6**
With Trolley & Bag pack& Duffle Bag	Male (15-59yr)	2.41	22.4	**11.8**
	Female (15-59yr)	1.83	20.14	**10.0**
With Infant (0-4 Yr)		0.51	34.36	**1.6**
With Physically Disabled Person		**2.72**	**17.24**	**17.4**

3. METHODOLOGY

Mainly data collection is done by a primary method such as manual dimension and video graphic technique. All pedestrian counts were done by the author via video graphic in 15 mins. Overall pedestrians are divided into seven parameters Age, Gender, Luggage, Speed, Density, Flow, and Space with different types of luggage.

The Methodology Adopted for the study will be as follows:

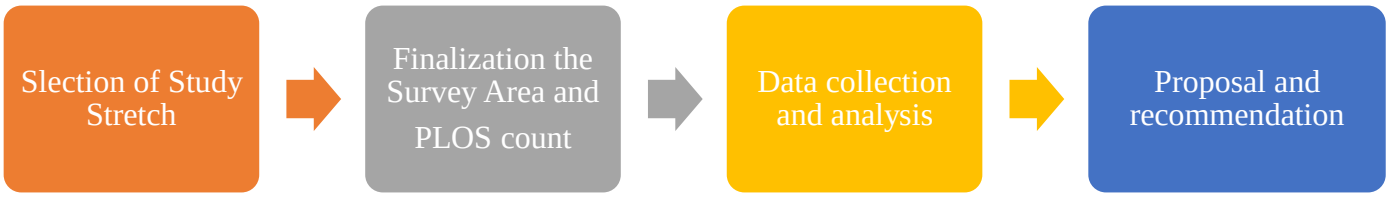


Figure 1 Methodology

To observe the passenger flow parameters, video-graphic survey data is the most appropriate one, therefore recorded footage data of multiple stairways leading to the entry and exit area connected to the station gate and Footage was collected from Metro station and Charbagh railway stations premises in mid-January 2022. The survey was conducted from 7:00 Am to 7:00 Pm. Divided the time into a pick and non-pick time based on the frequency of train passing and holding at Charbagh railway station.

3.1 Survey Type

A survey design to have been formulated is divided into five sections:

3.1.1 Passenger Survey:

The primary components of passenger surveys are commuter origin and destination, passenger volume count (a survey of footfall), and passenger journey time. These studies were carried out at the interchange zone to analyse passenger behaviour in light of various factors.

3.1.2 For commuter's OD data

At 6 location locations of the Charbagh railway station interchange and 7 location points, 383 samples were gathered. During the data collection, a key question was how long it took them to get from one interchange to the next. An OD survey has been carried out to comprehend the user flow pattern, speed, and space profile (evaluated utilising different categories).

3.1.3 Passenger volume count (footfall) surveys

All of the primary entries and exits in the interchange zone have been surveyed. 15-minute volume counts have been surveyed at chosen six locations. It counts the number of passengers entering the terminal. The interchange's entry and exit sites, as well as intersection spots where people converge to travel to separate terminals or in different directions, were designated as survey locations.

3.1.4 Passenger travel time survey

To determine the typical passenger speed for different categories, surveys have been done. By identifying the passenger routes in the interchange and categorizing them into several groups, speeds have been informed, and time has been recorded.

3.1.5 Reconnaissance Survey

The reconnaissance survey is a thorough examination of a large region that could be utilized as a road or an airport. Its goal is to find the more promising routes or places while eliminating the impractical or unworkable ones. Aerial photos and existing maps could be very useful. All potential routes and locations must be covered by the reconnaissance survey. The reconnaissance survey report should include a summary of all the data gathered, a description of each route or location, an assessment of its economic viability, and, if available, pertinent maps and aerial photos. It is carried out to comprehend the physical characteristics of roadways, infrastructure, and impediments.

4.0 DATA COLLECTION

4.1 Site profile

Charbagh railway station is known as the transport hub of Lucknow city. It has two major railway stations Lucknow Charbagh NR Railway Station (LKO), Lucknow Junction (LJN).1 metro station, and a bus station. And, Parking area (two-wheelers three wheelers four wheelers

4.2 Charbagh interchange

Charbagh interchange is well connected with Badshah Nagar railway station, metro station, Awadh bus station Qaiser bagh bus stand, and Airport.

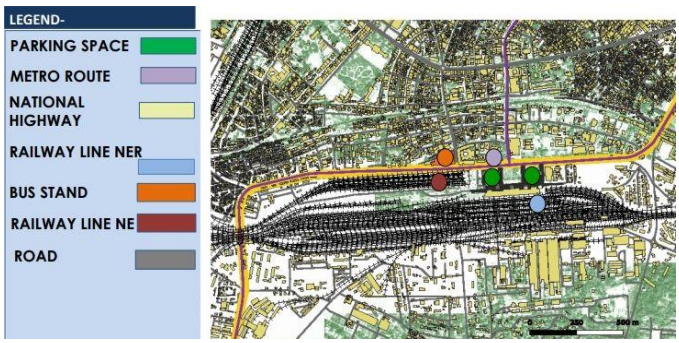
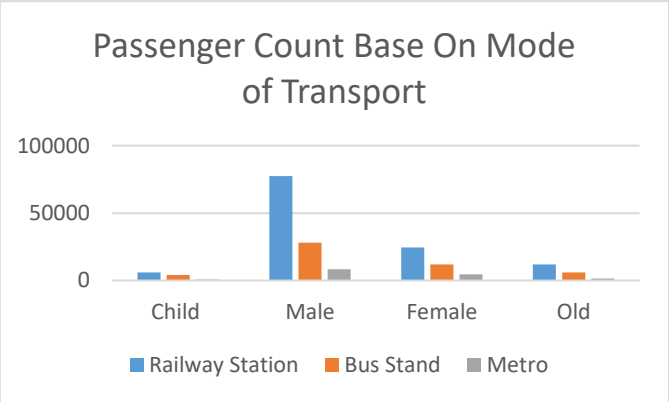


Figure 2 GIS Map of Lucknow Railway Station

Table 4 Charbagh Mode of Transport

	Charbagh		
	Railway Station	**Bus Stand**	**Metro**
Daily capacity	372	100	105
Avg Daily Passenger	120000	50000	15000
Mode of Public Transport	Auto, Cab, Bus, Rent Bike	Auto, Cab, Bus, Rent Bike	Auto, Cab, Bus, Rent Bike



Graph 1 Passenger Count Base on Mode of Transport

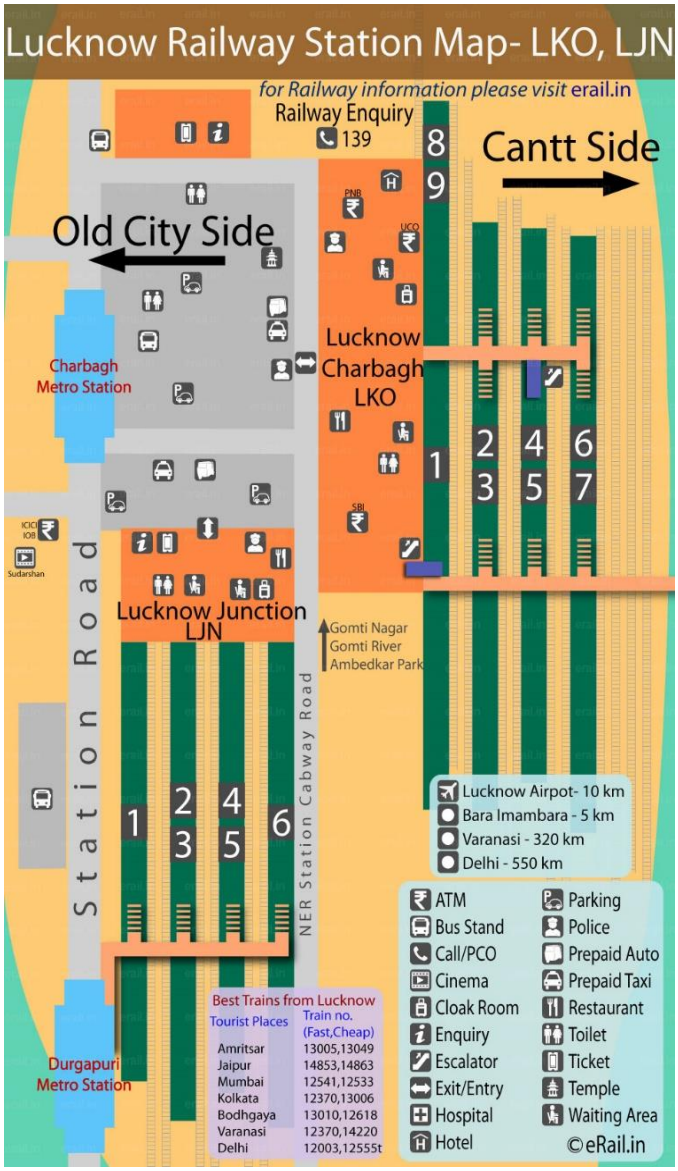


Figure 3 Lucknow Railway Station Map
Source:- erai (erail. in)

INFERENCES

The table shows the no. Of passenger footfall on daily basis on Charbagh Railway station, bus stand and metro station and the mode of public transport by this we can calculate the flow rate and speed of passenger.

Table 5 Peak Hour Time

TERMINAL	PEAK HOUR TIME
METRO STATION	6:30 TO 7:30 PM
NER RAILWAY STATION	6:00 TO 7:00 PM
NR RAILWAY STATION	6:00 TO 7:00 PM
BUS STAND	6:30 T0 7:30 PM

Table 6 Visitation data from the primary survey

TERMINAL	15 MIN COUNT	PEAK HOUR	METRO	BUS	RAILWAY	AUTO	TOTAL
METRO STATION	294	1176	-	158	72	64	294
RAILWAY STATION	570	2280	149	131	-	290	570
BUS	160	2640	232	-	148	280	660
AUTO	427	1708	182	98	147	-	427

INFERENCES

As per the survey the Pedestrian Volume count (PVC) of 15 min is given and with the 15 min count, the calculation of 1 hour is estimated.

5.0 DATA ANALYSIS

5.1 User characteristics of Charbagh in different parameters

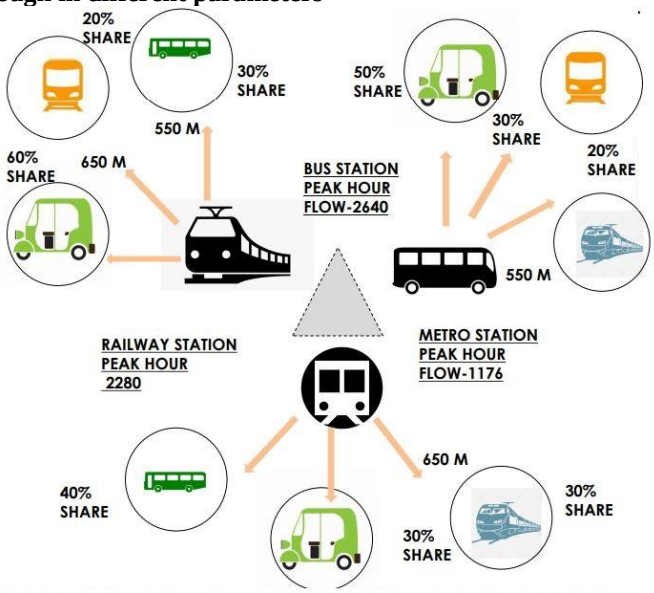
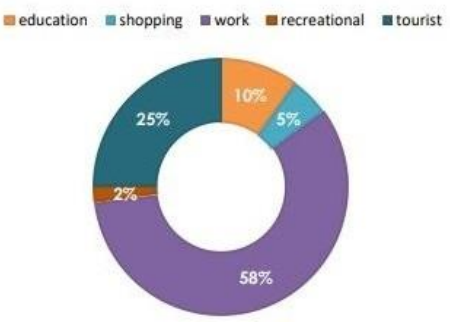


Figure 4 Charbagh railway station percentage modal share of passenger

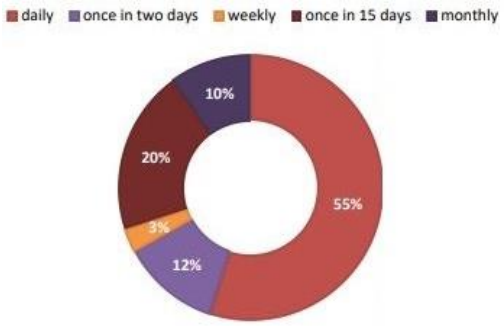
5.1.1 USER CHARACTERISTIC

Due to the presence of higher train passengers the pie chart is divided into 4 categories that are age group, passenger group, number of luggage and gender.

Primary survey data is collected from peak hour period OD survey and pedestrian volume count of different survey locations to formulate PEF considering speed (m/min) and area (sqm) of passengers with a different attribute. Effective width has been recorded from the reconnaissance survey. Chandra's formula is used to find PEF.

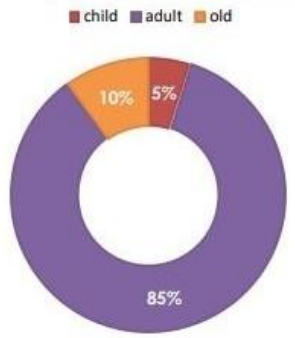


Graph 2 Trip purpose

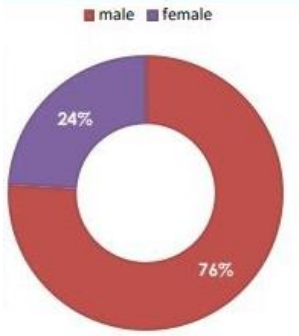


Graph 3 Travel Frequency

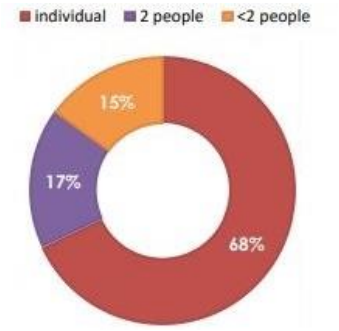
- Above graph 2 show work purpose consists of the highest share of 58%, followed by 17% of transit trips, while there is only 2% of shopping trips.
- Above graph 3 show it is observed trip frequency consists of the highest share of daily travelers 55%, followed by 20% of monthly travelers and 12% of weekly travelers.



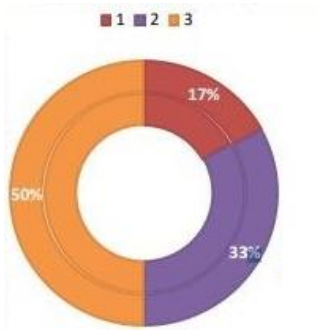
Graph 4 Age group



Graph 5 Gender



Graph 6 Passenger Group



Graph 7 Number of Luggage

1. This pie chart shows the graph 4 age group of passengers for the interchange. Where 1 adult is travelling more than old and children.
2. This pie chart shows the graph 5 gender travelling for the interchange. And shows that the male gender is higher than the female.
3. This pie chart shows the graph 6 passenger group travelling to the interchange. Where the individual ratio is re than the other.
4. This pie chart shows the graph 7 number of luggage with the passenger for the interchange. Where 1 piece of luggage is more than the other.

6.0 DATA ANALYSIS

6.1 Primary data analysis

Table 7 Primary data analysis

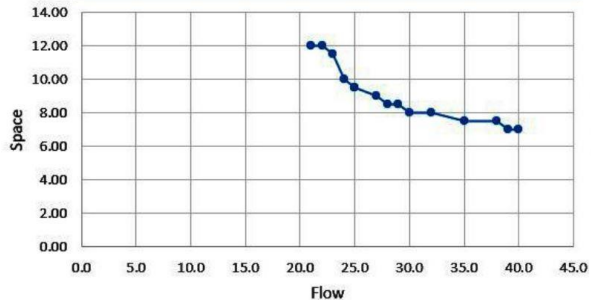
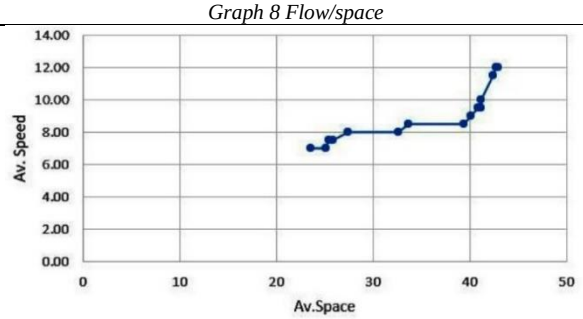
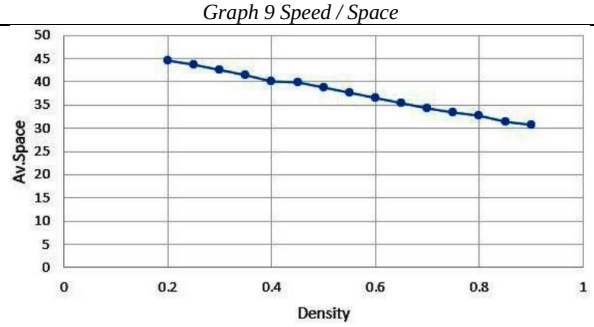
Time (min)			14 Min					
Luggage	Gender	Age (Yrs)	Count	PEF Value	Total	Speed	Av. Weighted	Av. Speed
without Luggage	Child	5-14 yr	8	0.6	4.8	0.48	0.29	34.452
	Male	15-59	36	1	36	0.68		
	Female	15-59	8	0.9	7.2	0.627		
	Old	60+	5	1.2	6	0.59		
with polybag/ Lunchbag	Male	15-59	4	1.5	6	0.493		
	Female	15-59	8	1.3	10.4	0.466		
with Bagpack	Child	5-14 yr	14	0.8	11.2	0		
	Male	15-59	50	1.9	95	0.452		
	Female	15-59	12	1.5	18	0.445		
with duffle Bag	Male	15-59	15	2.1	31.5	0.426		
	Female	15-59	5	1.9	9.5	0.392		
	Old	60+	2	2.5	5	0.378		
with 2 duffle Bag	Male	15-59	10	3.1	31	0		
	Female	15-59	2	2.9	5.8	0		
with duffle Bag + Bagpack	Male	15-59	15	3.3	49.5	0.382		
	Female	15-59	5	3.2	16	0		
with Trolley bag	Male	15-59	25	7.6	190	0.359		
	Female	15-59	4	6.4	25.6	0.339		
	Male	15-59	10	8.6	86	0		

with Trolley bag + Bagpack	Female	15-59	3	7.1	21.3	0.329		
with Trolley + Duffle Bag	Male	15-59	9	10	90	0		
	Female	15-59	4	8.6	34.4	0.305		
with Trolley + Bagpack + Duffle Bag	Male	15-59	8	11.8	94.4	0.295		
	Female	15-59	2	10	20	0		
Passenger with	Infant	(0-4 Yr)	1	1.6	1.6	0		
	Physically	Handi-capped	1	17.4	17.4	0.14		
Total Passengers			266					
Total PEF			118.8					
Total PEF Value			923.6					

INFERENCES

As per the analysis, the PLOS of Charbagh railway station lies in D that is the speed is calculated as 34.45 which can be observed as per standard the average speed of 34.45 lies in **level "D".**

6.2 Pedestrian Flow Models

Flow/space	 *Graph 8 Flow/space*	**INFERENCES** It has been observed from the flow vs. space relationship graph that as the flow increases space per person decreases.
Speed / Space	 *Graph 9 Speed / Space*	**INFERENCES** In the space vs. speed relationship graph it has been observed that with the increase in average speed per person, average space also increases.
Density / Speed	 *Graph 10 Density / Speed*	**INFERENCES** As observed from the density vs. speed relationship graph that with the increase in average speed per person, density also decreases.

7.0 PROPOSAL

7.1 Convert the path to a one-way

Currently, traffic moves in two directions in the driveway of Charbagh Railway Station. That intersection conflict's root cause is the passengers must deal with inconvenience due to the conflicting of vehicles nearby, which causes congestion in the driveway. The competing issue will be resolved after the driveway is made one-way, which will save the passenger time and improve service.

7.2 Separating the entrance from the exit

It would improve vehicular circulation and reduce congestion while segregating the entry and departure points. While giving a pathway along the driveway for convenient drop-off and pickup, as well as enough room for pedestrians.

7.3 To give an auto/taxi stand a separate location.

Giving the auto/taxi stand and parking there will result in less encroachment on the driveway. With a one-stop facility for enquiry, booking, pickup and drop-off, compline, and other features, a taxi/auto stand system would offer a quick, comfortable, and safe journey.

7.4 Parking on multi-levels and street vendors

Currently, there are obstacles for passengers due to the encroachment of unlawful parking on driveways. And cut back on service quality.

The station and the vicinity of the station were both served by multi-level parking. Cost savings, safety, and a decrease in parking congestion are some main benefits of multi-level parking.

7.5 Street vendors

Creating a separate area for kiosks and street sellers will ease driveway congestion. The ground floor of the multi-level parking is set aside for local vendors and kiosks that have the necessary equipment.

It creates a tidy and clean atmosphere on the driveway. It assists in controlling the spread of trash and pollution, which raises the danger of bacteria and germs.

7.6 To build the pedestrian walkways

Providing a walkway beside the driveway makes it simple for passengers to get out of their cars.

It is enhancing both the pedestrians' quantitative and qualitative services. Additionally, it offers security to all age groups.

Legend

Charbagh station (NR)
Charbagh station (NR)

Bus Stand
Metro station

Figure 5 current scenario of Charbagh railway station

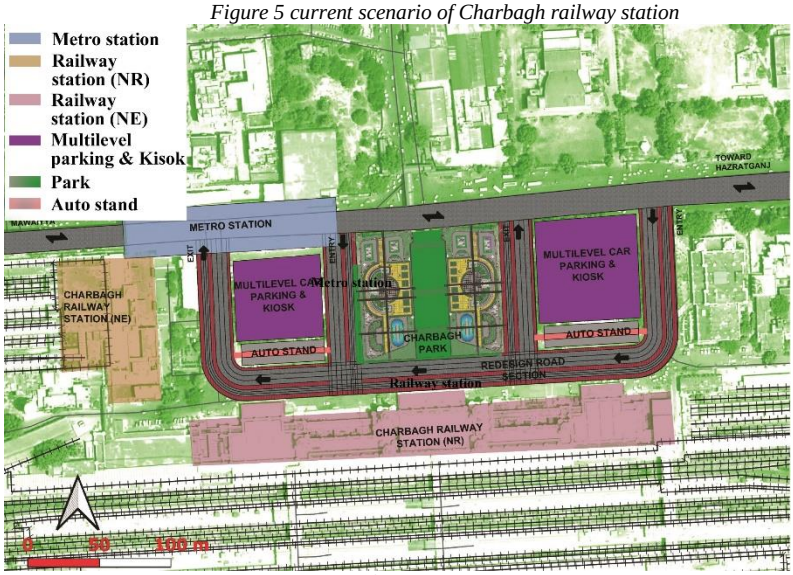


Figure 6 Proposal of Charbagh railway station

INFERENCES

On the map above the Charbagh railway station, the driveway's unidirectional traffic flow is depicted. On both sides of the campus, there are multi-level parking lots and Kiosks; this area is currently used for open, pay-to-park vehicles. Adjusting the multi-level parking so it faces the Charbagh station is suggested for the auto/taxi stand. For the convenience and safety of station visitors and pedestrians, the location of the auto/taxi stand was chosen.

There is a park provided between the two multilevel parking lots. It makes a green, open space in the city's busiest sector.

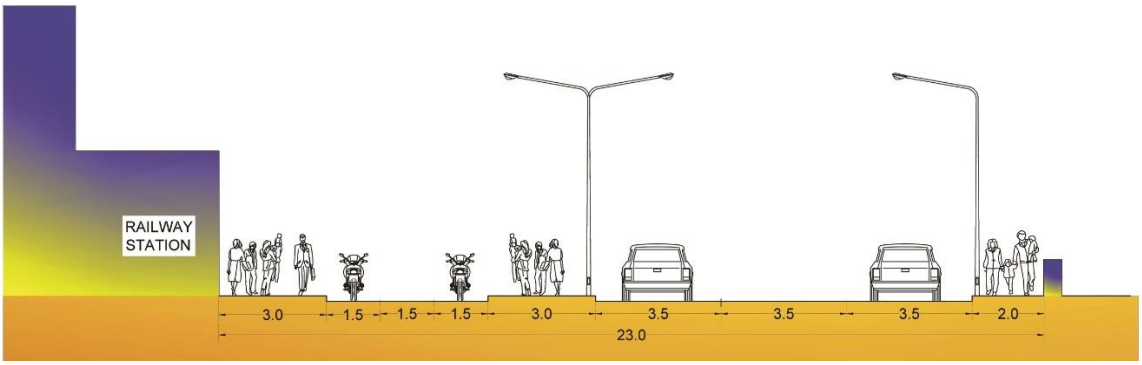


Figure 7 Proposed driveway section

INFERENCES

On the above map redesign of the driveway stretch for Charbagh station to improve traffic flow and reduce congestion.
For the convenience and safety of station visitors, a three-lane driveway is built with a sidewalk along each side for two-wheelers and four-wheelers.

7.7 Walkable radius from Charbagh Station

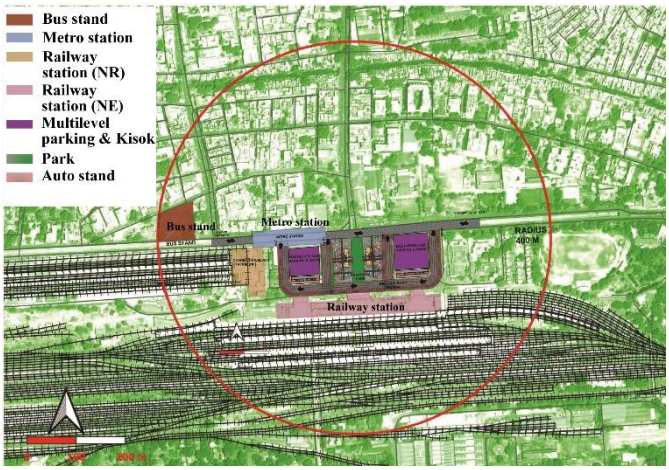


Figure 8 Walkable radius at Charbagh multilevel parking

INFERENCES

The surrounding locations from Charbagh Railway Station are shown on the map above. 400 metres away from the railroad station is a bus stop.
The typical walkability range is depicted by a circle with a 400-metre radius. The immediate effects of multilevel parking in the neighbourhood, which aids individuals in parking their vehicles, and the local road encroachment.

7.8 Some design suggestions for a curb ramp.

- Where the vertical elevation is 150 mm or less, curb ramps are offered.
- It must have a non-slip surface and must prevent water from gathering close to the ramp's beginning and terminus.
- It should be situated or shielded so that parked cars won't block it, and it shouldn't protrude into the road surface.
- There should be no obstructions, such as traffic lights or signposts.
- A curb ramp's gradient shouldn't be greater than 1:10.

8.0 CONCLUSION

According to research, management issues are the main cause of congestion. The 1.2 lakh daily visitors to Charbagh result in significant concessions during peak hours.
By isolating the entry from the exit, establishing an auto/taxi stand in a different place with street vendors, and offering parking on multiple levels. These measures will lessen the conflict point at the driveway. These are some management suggestions that enhance pedestrian safety and flow while reducing driveway encroachment. By constructing a walkway next to the driveway.

The present study concludes the following points,

- This analysis shows the average walking speed for all groups of individuals, including pedestrians.
- The differences in a pedestrian's walking speed patterns at crosswalks are influenced by the types of control used there, their gender, and their age.
- Passengers' average walking pace was found to be 34.45 metres per minute.
- The data revealed that age and gender have a considerable impact on how quickly pedestrians move through crosswalks, but that the type of traffic control at a crosswalk has little impact.
- Researching the crossing speed for group walkers and those with disabilities is highly advised.

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