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Pedestrian flow Characteristics and Level of Service Assessment for Footpaths along the section of Koshi Highway, at Biratnagar

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Abstract
Pedestrians are considered to be one of the vulnerable road users in regards to road safety. Biratnagar stands as one of Nepal's bustling cities with several ongoing road development project. Being one of the busiest city, activities of the city should be supported by adequate facilities, such as pedestrian facilities— crucial yet much neglected matters, so pedestrians can walk along the roadway. As a result, conflicts between pedestrians with motor vehicle users and accidents might occur at any time. This study was aimed at investigating the geometric conditions of pedestrian facilities, identifying the characteristics of pedestrians and the pedestrian facilities and determining the level of service for pedestrian facilities at three junctions of Koshi Highway. The study was conducted through survey of location, survey of geometric conditions, estimation of the number of pedestrians using sidewalk (data recorded every 15 minutes), measurement of pedestrian speed, and questionnaire about pedestrian's identity, destination, as well as travel time and distance. Data analysis was carried out to identify the pedestrian characteristics, pedestrian flow characteristics, and pedestrian level of service. The obtained data were then analyzed using INDO HCM 2017 in order to find out the level of service and it was found the sidewalk at those junctions has PLOS of grade "A" and further the project also included the qualitative assessment for analysis of geometric condition of pedestrian facilities.

Keywords: Pedestrian, Roadway, Level of Service, INDO HCM

1. Introduction

Transportation infrastructures encompass the facilities essential for operating diverse transportation modes such as air travel, automobiles, and ensuring smooth pedestrian flow. The advancement of transportation infrastructure mirrors a country's economic progress. Over time, Nepal has witnessed a growth in transportation infrastructure, including road networks and pedestrian amenities (Thapa, 2013). However, this surge in infrastructure has also led to a rise in road accidents or crashes.

In 2018, the World Health Organization (WHO) ranked Road Traffic crashes as the eighth most common cause of death worldwide, with half being 'Vulnerable road users'— including pedestrians, cyclists, and motorcyclists. Nepal has experienced a significant rise in road accident fatalities and injuries since the early 2000s. Additionally, the United Nations General Assembly has set an ambitious goal of reducing the global number of deaths and injuries from road traffic crashes by 50% by 2030. Consequently, prioritizing road safety engineering has become a crucial aspect preceding the development of transportation infrastructure.

Road safety engineering commonly involves altering the physical road environment or structure through established processes and techniques aimed at minimizing risks for all categories of road users (Global status report on road safety, 2023) A pedestrian typically denotes an individual, whether abled or disabled, who travels by foot, wheelchair, or with the aid of designated paths like tactile pavements. Essential pedestrian facilities such as sidewalks/footpaths, crosswalks, tactile pavements, curbs & ramps, pedestrian overhead bridges, etc., are crucial aspects for ensuring pedestrian road safety. But sadly, these pedestrian amenities are frequently overlooked in the planning of transportation infrastructure and developing projects related to pedestrian facilities has consistently posed a challenge in Nepal due to the country's inadequate infrastructure characterized by narrow streets, obstructions, insufficient transportation policies, and aggressive driving behaviors (Daniel, Nor, Rohani, Prasetijo, Aman & Ambak, 2016) (Acharya & Marsani, 2021) .

Pedestrian Level of Service (PLOS) is the qualitative measure that describe the operational characteristics of pedestrian based upon service measures like speed, comfort, convenience, interruptions and freedom to maneuver. In Nepal, there is no proper procedure to evaluate PLOS of footpath of their own. International codes of developed countries are used for evaluation of PLOS which may not be appropriate. The suitable methodologies need to be developed that can help in proper planning, design, construction and operation phase of road projects. For the determination of different level of service (LOS) categories parameters like flow rate, pedestrian space and volume by capacity ratio are calculated. Then with the help of codes like HCM 2000 and INDO HCM 2017 six different ranges of PLOS categories that are from “A” to “F” are determined (Acharya & Marsani, 2021) . A similar study was perfomed in Johor Bahru where 25 streets footpath were taken for sample and different location footpath represented diversity of footpath characteristics which were further rated poor to excellent in terms of level of comfort and safety (Daniel, Nor, Rohani, Prasetijo, Aman & Ambak, 2016). Also a research was conducted on the commercial area of Birendrangar for the assessment of pedestrian sidewalk where the researcher have followed the Indo-HCM 2017 and rated for the determination of Level of service (Bohara & Tiwari, 2022).

Another study performed in Florida shows that the researcher proposed a six-point PLOS scale that considered factors like presence of buffer between footpath and road, sidewalk width, speed and volume of traffic based on the HCM 2000 (Landis, Vattikuti, Ottenberg, McLeod & Guttenplan, 2001). A study investigated features and properties of a pedestrian flow on sidewalks in Haifa, Israel. The data was collected with a videotape recorder connected with a digital clock, to specify the walking speeds. Level of service was determined by speed and density relationship, with linear models. The results demonstrated that there was an inverse proportion between speed and density (Polus, Schofer, & Ushpiz, 1983). A conjoint technique can be used to analyze the PLOS by determining the importance of the sidewalks characteristics such as, flow rate of pedestrians, sidewalk width, existence of obstacles, crossing facilities, etc. They found that the most significant factor to determine the PLOS was the pedestrian flow rate and the sidewalk width. Speed is one of the major factor contributing to road crashes; and even is worse for pedestrian crashes (Tiwari, 2015).This research focus on finding out the level for service of pedestrian footpath and develop a strategy for providing a connected safe and accessible pedestrian network for users of all ages and abilities within Koshi highway. More-Over this study is focused on the commercial section of Koshi Highway as we see mixed of flow in this section. These study done will aid in the future development of the road at various section of Koshi Highway and will help to evaluate the condition of footpath and prioritize the footpath need to be redesigned and reconstructed.

Vulnerable road users which includes pedestrians, cyclists, and motorcyclists, face heightened risks especially in urban areas and hence it becomes utmost necessity to prioritize the safety of these vulnerable users, ensuring that their needs and safety concerns are adequately addressed during design and construction (Tiwari & Luitel, 2023).

2.0 Study Area

Koshi Highway also known as H08 is 111.46 KM long located in Province 1 which starts from Rani boarder of Biratnagar to Kimthanka boarder of Sankhushabha. The study was carried out on three junction of Koshi Highway located inside Biratnagar area. The three junction where the study was performed are:

- Bhatbhateni Section
- Bargachi
- Kanchanbari

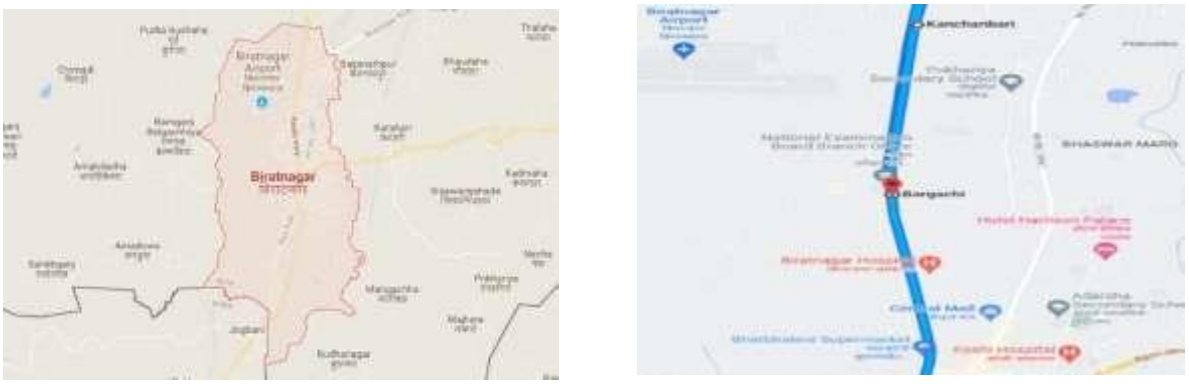

Figure 1 Study Area Showing Map of 3 junction of Koshi Highway (source: Google Map)

3.0 Research Framework and methodology

The research was carried out at various time frame and interval based on the need of data and area. The study was conducted through various surveys of location, survey of geometric condition and study of pedestrian characteristics. The framework of research is shown in flowchart:

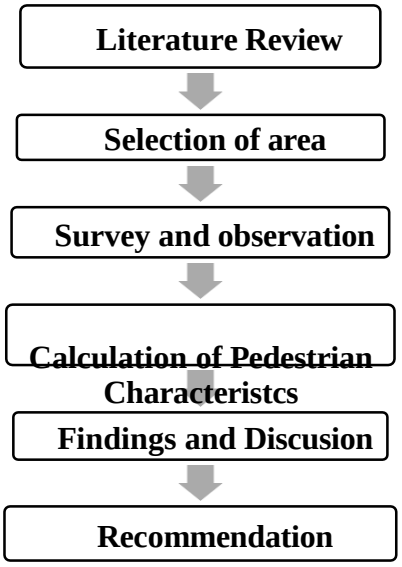

Figure 2 Research Framework

3.1 Study Location Identification

Pedestrian risk zone are identified based on road accident related data that was collected from the traffic office and the local police station. The data provided by traffic office was not enough to identify the location as all data of accident were not provided by traffic office due to confidential issues and the location were identified with verbal discussion with traffic inspector, head of Morang Traffic office Department. The location identified were Bargachi Chowk, Bhatbhateni and Kanchanbari Chowk.

3.2 Survey and Data Collection

Survey was carried out to get various data of the pedestrian facilities and road geometric design by direct observation and measurement. The survey included estimation of the number of pedestrians using sidewalk (data were recorded every 15 minutes for two hours in three interval part of the day), measurement of pedestrian speed, and identification of pedestrians, as well as travel time and distance (Sangeeth & Lokre, 2019). Also the survey included the qualitative assessment by direct observation of 37 different location recording the data related to physical characteristics of pedestrian facilities (footpath width, obstruction etc.) and user characteristics (crossing facilities, encroachment etc). Further to obtain the characteristics of pedestrian facilities the footpath area of 3 junction was thoroughly surveyed and were assessed based on the parameter and ranking of INDO HCM 2017.

3.3 Data analysis

The data collected was further analyzed based on the INDO HCM 2017, HCM 2000 and Nepal Road Standard 2070.According to High capacity manual 2000 and the INDO HCM 2017 the pedestrian current of flow are calculated using: (INDO HCM, 2017) (HCM, 2000)

$$Q = \frac{\mathrm{n}}{\mathrm{T} * \mathrm{W}}$$

Where,

Q = Pedestrian flow (person/meter/minute)

n = Pedestrian time passes through observation area (people)

T = Observation time (minutes)

W = Effective width of sidewalk/footpath (meter)

Pedestrian speed is calculated using the formula from Mannering and Kilareski (Mannering, Washburn & Kilareski, 2008)

$$V = \frac{\mathrm{L}}{\mathrm{t}}$$

Where,

V = Pedestrian Speed (meter/minute)

L = length of Observation

t = Pedestrian time passes through the observation area (minute)

The relationship between density, speed and flow for pedestrian are presented as: (INDO HCM, 2017)

Q = V x K Where,

Q = flow (ped/min/m)

V = speed (m/min)

K = density (ped/m^2)

According to INDO HCM 2017 the estimation of capacity of footpath considers effective width of the facility as well. The effective width is the portion of footpath that a pedestrian can use effectively. So the code includes the hidden things coverage as shy distance and gives the following table data to be considered:

Table 1: Estimated Shy Distance as per INDO HCM 2017

S.N	Obstacle	Shy Distance (m)
1.	Bench	0.3-0.5
2.	Kerb (in case of divided carriageway)	0.1-0.2
3.	Kerb (in case of bidirectional)	0.2-0.4
4.	Wall	0.4-0.6
5.	Guardrails	0.4-0.6
6.	Hawkers	0.3-0.5
7.	Light poles	0.8-1.1
8.	Traffic Sign	0.6-0.8
9.	Traffic Signal Poles and Boxes	0.9-1.2

Indo HCM (2017) defined PLOS based upon fundamental flow parameters like space, speed and flow rate for footpath of five different land uses (Commercial, Institutional, Terminal, Recreational, Residential). Six LOS are also defined starting from LOS A to F for each land use in Indian context (Mohanty, 2013). PLOS ranges from LOS A to F based upon flow rate (p/min/m) for footpaths at different land use are showed:

Table 2: PLOS categories in Indo HCM 2017

LOS	Commercial	Institutional	Terminal
A	<=13	<=13	<=15
B	13-19	13-19	15-26
C	19-30	19-27	26-32
D	30-47	27-36	32-68
E	41-69	36-42	<= 68-78
F	Variable	Variable	Variable

Six steps is included by INDO HCM 2017 to identify PLOS of footpath. At first, footpath should be identified considering surrounding land use, secondly width and effective width of the available footpath should be measured. Further, pedestrian flow (ped/min) should be observed from the selected location and peak flow data should be converted into flow rate (ped/min/m) to estimate maximum or peak flow rate. Finally, using the peak flow rate value, PLOS can be identified for any Footpaths.

4.0 Results and Discussion

4.1 Effective width of three junction

Chapter 9 of INDO HCM 2017 was used for calculation of the effective width of footpath deducting the shy distance. The effective width calculation as illustrated on table shows the footpath at kanchanbari section has the maximum width of 2.15m compared to the other two section which have effective width of 1.35 m and 1.15 m respectively.

Table 3: Effective Width of Footpath

LOCATION	Footpath Width	Shy Distance	Effective width.
Bargachi	2.75 m	1.4 m	1.35 m
Bhatbhateni	2.35 m	1.2 m	1.15 m
Kanchanbari	3.15	1 m	2.15 m

4.2 Observed Flow Data, Peak Pedestrian Flow and Gender wise Flow Data

Pedestrian flow data was recorded in all three junction of Koshi Highway using the digital camera on three working days (Sunday, Monday and Friday) at three interval of time in morning, afternoon and evening. The pedestrian using the footpath was recorded as shown in table 4 and after the volume count at every 15 minutes the peak pedestrian flow data was calculated and shown in table 5.

Table 4: Overall observed flow data

			Pedestrian				Cycle			
No.	Location	Time	Sunday	Monday	Friday	Average	Sunday	Monday	Friday	Average
1	Bargachi	9:00-11:00	320	356	346	**341**	560	506	528	**531**
		1:00-3:00	316	326	298	**313**	274	332	286	**297**
		4:00-600	416	392	458	**422**	350	402	424	**392**
2	Bhatbhateni	9:00-10:00	488	556	518	**521**	750	566	582	**633**
		1:30-2:30	522	548	526	**532**	392	402	416	**403**
		4:30-5:30	626	582	688	**632**	512	466	608	**529**
3	Kanchanbari	9:00-10:00	386	372	382	**380**	322	376	328	**342**
		1:30-2:30	364	408	374	**382**	396	352	344	**364**
		4:30-5:30	448	506	502	**485**	550	486	492	**509**

Table 5: Peak Pedestrian flow data

Location	Sunday	Volume	Monday	Volume	Friday	Volume	Average
Bargachi	5:15-5:30	64	5:15-5:30	61	5:00-5:15	67	**64**
Bhatbhateni	5:00-5:15	89	5:00-5:15	94	5:00-5:15	104	**96**
Kanchanbari	4:45-5:00	72	5:15-5:30	79	5:15-5:30	74	**75**

4.3 Average Flow, Speed and Space Calculation

The calculation of average flow value was carried out by analyzing the two hour video data of three interval period (morning, afternoon and evening) and finding the peak hour and extracting the peak 15 min peak volume and further a sample of 10 person (5 male and 5 female) was observed at 5 m interval distance in order to calculate the pedestrian speed at all three location using video graphic survey. And pedestrian space was calculated using speed and flow rate data.

Table 6: Average Flow Calculations

LOCATION	Effective width of footpath (m)	15min peak volume	Average Flow value (Ped/min/m)
Bargachi	1.35	64	3.16
Bhatbhateni	1.15	96	5.57
Kanchanbari	2.15	75	2.33

As per INDO HCM 2017 table 9A.6 PLOS for footpath considering commercial land uses, the flow value of above observed data are <=13 ped/min/m which indicates the LOS “A”.

Table 7: Average Speed in Different Location

S.N	LOCATION	AVERAGE SPEED (m/min)
1.	Bargachi	65.5
2.	Bhatbhateni	64.4
3.	Kanchanbari	67.2

As per INDO HCM 2017 table 9A.6 PLOS for footpath considering commercial land uses, the pedestrian speed value of above observed data are >61.5 m/min which indicates the LOS “A”.

Table 8: Average Space in Different Footpath Location

SN	LOCATION	AVERAGE SPEED (m/min)	FLOW	DENSITY	SPACE
1	Bargachi	65.5	3.16	0.05	20.73
2	Bhatbhateni	64.4	5.57	0.09	11.56
3	Kanchanbari	67.2	2.33	0.03	28.84

As per INDO HCM 2017 table 9A.6 PLOS for footpath considering commercial land uses, the pedestrian space value of above observed data are >4.87m^2/ped which indicates the LOS “A”.

4.4 Pedestrian Preference and Rating

Furthermore, a questionnaire survey was carried out in order to record the pedestrian preference and rating of the footpath. A total of 150 (50 in each junction area) people participated in the survey. The table 9 shows the percent of pedestrian who prefer the use of footpath and same pedestrian are further questioned for the rating of the footpath which is further illustrated on Table 10.

Table 9: Pedestrian Preference for use of Footpath

LOCATION	Pedestrian preference for use of footpath	Pedestrian preference for no use of footpath
Bargachi	64%	36%
Bhatbhateni	62%	38%
Kanchanbari	58%	42%

Table 10: Rating of Footpath on the survey at three location

Parameters	Bargachi	Bhatbhateni	Kanchanbari
Footpath Surface	4.2	3.3	3.6
Footpath Width	4.3	3.7	4.4
Obstructions	2.2	2.4	2.4
Potential for Vehicular Conflict	2.7	2.6	2.4
Longitudinal Continuity	4.3	3.9	3.6
Encroachment	3.6	3.4	3.4
Availability of Crossing Facilities	1.8	1.4	1.7
Security	3.7	3.9	3.7
Comfort	2.2	1.8	2.5
Walking Environment	3.9	3.3	3.8

5.0 Conclusion and Recommendation

The research performed at three junction of Koshi Highway concluded that the highest pedestrian speed is at Kanchanbari section with **67.2 m/min** along with flow rate of **2.33 ped/min/m** whereas at Bargachi section pedestrian speed was found to be **65.5 m/min** and flow rate was 3**.16 ped/min/m**. Similarly at bhatbhateni section pedestrian speed was found to be **64.4 m/min** along with the flow rate of **5.57 ped/min/m**. The result was then compared to the criteria of INDO HCM 2017 which showed the PLOS at all three junction are of **"A"** grade and has adequate space for the movement of pedestrian. Furthermore, the questionnaire survey data also concluded that near about half of the pedestrian does not prefer using the footpath which has created a large need of awareness campaign for educating the pedestrian for safe use of footpath. Also the survey data has showed the pedestrian rating on various ten criteria which shows the pedestrian are not able to use the footpath efficiently. Strong policies topic regarding pedestrian safety from the national and local level should be a hot topic in order to change the present scenario.

6.0 Acknowledgment:

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References

Global status report on road safety. (2023, June 27). https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/global-status-report-on-road-safety-2023

Daniel, B. D., Nor, S. N. M., Rohani, M., Prasetijo, J., Aman, M. Y., & Ambak, K. (2016b). Pedestrian Footpath Level of Service (FOOT-LOS) model for Johor Bahru. MATEC Web of Conferences, 47, 03006. https://doi.org/10.1051/matecconf/20164703006

Acharya, A., & Marsani, A. (2021). Evaluation of Pedestrian LOS for Footpath by Cluster Analysis and Questionnaire Survey: A case Study of Kathmandu.

Bohara, A., & Tiwari, H. (2022). Assessment of Pedestrians' Infrastructures and Facilities at Birendranagar Muncipality: A Case of Mangalgadi to Birendrachowk. In International Conference on Engineering & Technology (Vol. 2022).

Kumar, G., Acharya, A., & Tiwari, H. (2022). Public perception study on road crossing facilities and determination of waiting time.

Landis, B. W., Vattikuti, V. R., Ottenberg, R. M., McLeod, D. S., & Guttenplan, M. (2001). Modeling the roadside walking environment: pedestrian level of service. Transportation research record, 1773(1), 82-88.

Muraleetharan, T., Adachi, T., Uchida, K. E., Hagiwara, T., & Kagaya, S. (2004). A study on Evaluation of pedestrian level of service along sidewalks and at crosswalks using conjoint analysis. Infrastructure Planning Review, 21, 727-735.

Polus, A., Schofer, J. L., & Ushpiz, A. (1983). Pedestrian flow and level of service. Journal of transportation engineering, 109(1), 46-56.

Tiwari, H., & Luitel, S. Re-orienting towards Safer Roads Infrastructure in Nepal. Journal of Recent Activities in Infrastructure Science, 8(3), 14-27.

Mannering, F.L., Washburn, S.S. and Kilareski, W.P. (2008) Principles of Highway Engineering and Traffic Analysis. 4 Edition, Wiley.

Mohanty, S. (2013). Estimation of Pedestrian Level of Service for Indian Roads. National Institute of Technology Rourkela-769008.

Tiwari, H. (2015). Dependency of Road Accidents with Volume and Speed (A Case Study of Major Black Spot Location within Kathmandu Valley). In Proceedings of IOE Graduate Conference (pp. 339-343).

Indo HCM. (2017). Indian Highway Capacity Manual. Council of scientific & industrial research (CSIR). India.
HCM. (2000). Highway capacity manual. Washington, DC, 2(1).

Hung, W. T., Manandhar, A., & Ranasinghege, S. A. (2010, June). A walkability survey in Hong Kong. In Conference paper delivered at The 12th International Conference on Mobility and transport for Elderly and Disabled Persons (TRANSED), held in Hong Kong on (pp. 2-4).

Sangeeth, K., & Lokre, A. (2019). Factors influencing pedestrian speed in level of service (LOS) of pedestrian facilities. Transportation research interdisciplinary perspectives, 3, 100066.

Sisiopiku, V. P., Byrd, J., & Chittoor, A. (2007). Application of level-of-service methods for evaluation of operations at pedestrian facilities. Transportation Research Record, 2002(1), 117-124.

Thapa, A. J. (2013). Status paper on road safety in Nepal. DDG, Department of Roads. Kathmandu, Nepal, 22.

Marisamynathan, S., & Lakshmi, S. (2018). Method to determine pedestrian level of service for sidewalks in Indian context. Transportation Letters, 10(5), 294-301