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Analysis of Level of Service and Quality of Service of shared Bicycle lane of Lalitpur- A case study of Kupondole to Lagankhel road section

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Abstract

As used in the all the major European countries, bicycle is the major transport vehicle used for urban mobility due to its environmental, social and economic benefits. The cycle lane of the Lalitpur was made as the shared cycle lane which prioritizes the cycle users first and then it can be shared by other vehicles as well. But this concept faced various criticisms as it is not considered safe, especially in the route of Lalitpur which accommodates large number of other traffic volume. In this case the performance measure of the shared cycle lane is necessary. This study uses Level of Service (LoS) and Quality of service (QoS) approach to evaluate the performance of the shared cycle lane. Empirical formula developed by Nayak [1] was used to calculate the LoS by collecting the necessary traffic volume data and other parameters and QoS analysis was done by collecting the perceptional data. The LoS of Kumaripati and Lagankhel was found to be worst in comparison with the fairly similar LoS of other study areas. And by using the QoS approach, the variables such as road safety, network connectivity, traffic pollution, pavement surface, sign post, road marking, conflict due to parked cars and conflict due to bus stop were found to be the most significant ones in influencing the quality of service

1. Introduction

Transportation modalities such as private automobiles have grown in popularity as wealthy countries' living standards and economies have improved. Although a developing country, Nepal has experienced rapidly growing urbanization, especially Kathmandu valley. It is Nepal's first metropolitan region to encounter the tremendous challenges of rapid urbanization [2]. Rapid urbanization and greater economic activity in cities have resulted in a significant increase in car ownership and use in Nepal's metropolitan areas. Traffic congestion, air and noise pollution, and traffic accidents and injuries are all negatively impacted by existing motorization practices. Also, private automobiles are inefficient mode of transportation for short urban mobility as it occupies more space in roads and produces huge greenhouse gas emission. This makes the private automobiles one of the major causes of air pollution and climate change [3]. However, most European countries have prioritized cycling as a mode of urban transportation due to its environmental, social, and economic benefits [4]. Bicycles may blend in with traffic flow while taking up less space than other vehicles due to their small size and low cost. This has led to the notion that commuting by bicycle is the most environmentally friendly mode of transportation in cities [5].

In the context of Nepal, capital city Kathmandu has been swallowed up in the vicious spiral of motorized vehicle-centric growth, resulting in rampant road widening and continuous congestion [6]. However, Lalitpur is one of the few districts to have begun incorporating bicycle lanes into existing highways. In an endeavor to create a more ecologically friendly metropolis, the Lalitpur Metropolitan launched a 4.7-kilometer bike lane from Kupondole to Mangal bazar in November 2019 [7] . The bicycle lane was built using the shared lane idea, which means that the right of way of the bicycle lane

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is shared with other automobiles, but bikers are given higher priority. Many others, however, have criticized this implementation as unscientific [8] and impractical. In such case, it becomes necessary to evaluate the LoS and QoS of the bicycle lane to understand whether actual accomplishment of the objectives have been achieved for which it was introduced in the first place.

Popular method of performance evaluation is calculating the LoS and compatibility index based on traffic volume, pavement condition, posted limit, heavy vehicle, etc. [9]. In addition to that, it has been argued that the perception and experience of the bicyclists play vital role in design as well as performance evaluation of the bicycle lane by QoS [10]. Therefore, combining these two evaluation approaches can yield a highly effective outcome from distinct kind of analysis. If the present bicycle lane in Lalitpur district is evaluated using these approaches, it can be incredibly valuable in determining the current service scenario as well as a roadmap for future bicycle lane expansion in other districts.

Almost every assessment of the Kathmandu valley's traffic transportation network concludes with a recommendation to encourage a cycle-friendly transportation network as cycling contributes to the creation of safer, livelier, greener, and healthier cities, which is particularly true in compact cities like Lalitpur. But the actual number of commuters using the newly constructed bicycle lane is underwhelming [6].

The criticism regarding the cycle lane that it is not practical and effective has been ever present since the cycle lane of the Kathmandu, from Tinkune to Baneshwor Section [8]. The cycle lane of the Lalitpur has faced complains in terms of the safety, behavior of the vehicle drivers, parking of the vehicle, etc. In the presence of such criticism and questions, it becomes necessary to evaluate the performance of the current infrastructure to address those criticism and to improve the service quality of the infrastructure.

Bicycle lanes have a different QoS than motorist lanes. Unlike how motorists view infrastructure service from inside their car, the cyclist's perception of service quality is not just based on speed or journey duration. The use of guidelines related to minimum criteria for dimensions (geometry) and materials, as well as best practice recommendations, is referred to as a supply-oriented strategy [10]. However, the viewpoint of bicyclist is rarely included in these documents. As cyclists are more vulnerable to the surroundings, more than a supply-oriented strategy should be used in analyzing and constructing cycle-related infrastructure. As a result, in addition to a supply-oriented strategy, cyclists' actual perceptions of various variables such as safety, environmental interaction, traffic pollution, and so on must be assessed.

In order to evaluate the existing bicycle lane in Lalitpur city, a combination of empirical and perception of the users' satisfaction approaches would be required in the current context.

2. Research objectives

The general objective of this study is to evaluate the LOS and QoS of the current shared bicycle lane of Lalitpur (Kupondole to Lagankhel).

3. Material and methods

For bicycle LoS, the empirical methodology created and validated in numerous states of India [1] was used to determine the performance of the bicycle lane because the traffic conditions in Nepal are more similar to India than in the United States. The required relationship is shown in Equation 1 below:

$$BLOS = 0.478 \ln\left(\frac{\mathrm{Vol}_{15}}{\mathrm{Ln}}\right) + 0.193 S_{Pt}(1 + 10.38 HV)^2 + 2.95\left(\frac{1}{PR_5}\right)^2 - 0.074(\mathrm{We})^2 + 1.729 \quad (1)$$

Where, $BLOS$ is the Bicycle Level of Service, Vol_{15} is the volume of directional traffic in 15 minutes, Ln is the total number of through lanes, S_{Pt} is the posted speed limit, HV is the percentage of heavy vehicles, We is the average effective width of the outside through lane, and PR_5 is FHWA's 5-point pavement surface condition rating (5 = best) [9].

For qualitative approach, questionnaire survey was utilized to construct a prediction model for estimating quality of service based on bicyclists' perceptions of several criteria as listed in the Table 1. The overall rating of quality of service of respective locations was also be obtained from questionnaire. The questionnaire uses a 1 to 5 Likert rating ('1' being very poor, '2' being poor, '3' being fair, '4' being good and '5' being excellent) [11].

The study area is in Lalitpur Metropolitan, is shown in the Figure 1. The data (physical as well as questionnaire) was collected on five locations of the bicycle lane of the study area starting from Kupondole to Lagankhel viz. Kupondole, Pulchowk, Jawalakhel, Kumaripati, and Lagankhel whose route length is about 4.7 km.

Since the data of exact current population of the bicycle rider is not known, an experimental questionnaire of sample size of 250 respondents was used, 50 responses for each location [12]. Volume of directional motorized vehicle in the peak 15 minutes time period (Vol_{15})

Table 1: List of variables proposed for analysis with perceptional survey

S.N.	Variables	Perception of Infrastructure Service (Rate 1 to 5)
1	Width of cycle lane	Is the width of the existing bicycle lane enough?
2	Road safety	Feel safe regarding the accident?
3	Personal safety	Feel safe regarding crime?
4	Comfort while sharing bicycle lane with cars	Do you feel comfortable sharing the bicycle lane with cars?
5	Motivation due to presence of cyclists	Do the presence of other cyclists motivate you to ride the bicycle?
6	Cycle lane network	Is there a well-connected cycle lane network?
7	Pleasure	Is it pleasant to ride a bicycle in this infrastructure?
8	Behavior from other vehicle drivers towards the bicyclists	How's the behavior from other vehicle drivers towards the bicyclists?
9	Traffic Pollution	Do traffic pollution (air and noise) bother while cycling?
10	Pavement surface	How's the pavement surface quality along the bicycle lane?
11	Sign posts	Are there enough sign posts for the bicycle path?
12	Road Marking	Are there enough road markings for the bicycle path?
13	Conflict with parked cars	Do the parked vehicles bother you?
14	Conflict in bus stop	Does the bus stop bother you?
15	Conflict with pedestrians	Do the pedestrians bother you?

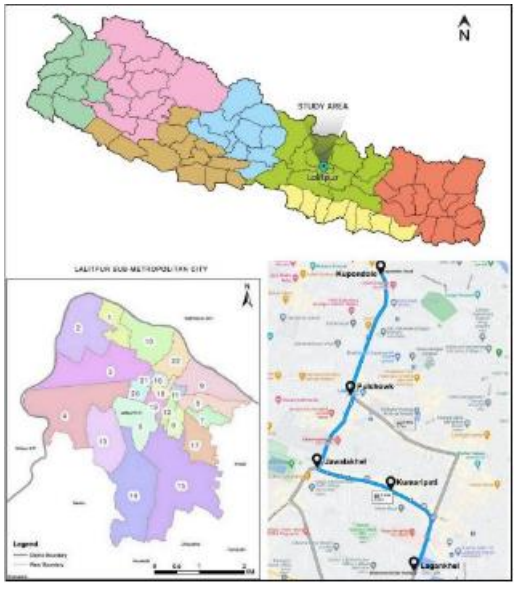

Figure 1: Study Area

was measured by using videography recording of the study area during peak hour time i.e., 9am-11am and 4pm-6pm [13] during week days for all the concerned locations. Percentage of heavy vehicle (HV) was determined by the same videography recording as per HCM [14]. For evaluating the pavement surface condition rating as per FHWA, detailed observation of the study area was done. Total width of the outside lane (and shoulder) pavement (W_t), width of paving between the outside lane stripe and the edge of pavement (W_l) and width of pavement striped for on-street parking (W_{ps}) was measured on study area for five different locations [1].

The questionnaire was delivered to cyclists with the support of Nepal Cycle Society, for experimental sample size as mentioned above. Bicyclists' perceptions of the overall QoS of overall bicycle lane infrastructure, as well as the variables listed in Table 1, was measured using a Likert scale via questionnaire. A survey of bicyclists from the site was obtained.

4. Results and discussion

The vehicle types and their equivalency factors are in accordance with the Nepal Road Standard [15]. The 15-minute traffic volume count is calculated by multiplying actual vehicle count by its equivalency factor. Percentage of Heavy vehicles is calculated with reference to the Highway Capacity Manual. The pavement condition was visually inspected and rated as per U.S. Department of Transportation. Highway Performance Monitoring System-Field Manual. Measurement of the width of cycle lane, outermost lane width and the parking width was done at site during the early morning period when the flow of the vehicle was minimum.

The videography data collected was also used to count the traffic volume of cyclist and it is summarized as shown in Table 2. It shows that the larger number of cyclists were found in the Kupondole area and the least number of cyclists was found in Lagankhel area.

Table 2: Cyclist's volume count during the peak hour

Location	Morning Peak Hour	Evening Peak Hour
Kupondole	409	303
Pulchowk	188	156
Jawalakhel	241	170
Kumaripati	223	234
Lagankhel	162	170

Table 3: Summary of the LOS of five study area

Location	Direction of Traffic	Morning		Evening	
		9:00-10:00	10:00-11:00	16:00-17:00	17:00-18:00
Kupondole	Forward	B	B	B	B
	Backward	B	B	B	B
Pulchowk	Forward	B	B	B	B
	Backward	B	B	B	B
Jawlakhel	Forward	C	C	C	C
	Backward	C	C	B	C
Kumaripati	Forward	D	E	E	E
	Backward	C	C	C	C
Lagankhel	Forward	D	D	E	E
	Backward	C	C	C	C

Equation 1 developed by Nayak [1] was used to calculate the LoS of the shared bicycle lane of the study areas. The results of bicycle level of service is shown in Table 3.

Site investigation and visual inspection of the study area helped understanding the ongoing situation of the cycle lane. It was understood that the left cycle lane of Kumaripati and Lagankhel were converted into the parking area at side of the road. Due to this reason, the effective width of the existing outermost left decreased. This was the reason for poor level of service in Kumaripati and Lagankhel in the forward direction. Comparing the forward and backward of Kumaripati and Lagankhel, backward direction has clear cycle lane. So, this caused the improvement in level of service. This decrease and increase in level of service due to absence and presence of the cycle lane and presence of the parking area is simple to explain as there is difficulty for the cyclists travelling in the forward direction due to lack of cycle lane.

Due to heavy traffic during the peak hour, the posted speed limit was always less than 32.18 kmph. So, the factor of the speed is neglected in the formula in the LoS calculation. The LoS of the cycle lane of the bicycle lane in the area of Kumaripati and Lagankhel can be improved by properly managing the parking area and painting the cycle lane marking in the road as there is no current bicycle lane marking in that area. The lane width of the area of Jawalakhel and Pulchowk is not made for two through lane for a single direction. There is issue of congestion of the vehicle and safety for the cyclists. Unprotected cycle lane increases the risk for the cycle users in such kind of places.

For QoS, total of 273 survey data were collected from the questionnaire survey, with the minimum of 50 data from each study area. Along with the Likert scale rating on overall satisfaction of the users, their demographic data such as gender, age, and purpose of use of bicycle and increase or decrease in preference of use of bicycle lane after the introduction of shared bicycle lane were also collected. Among the 273 participants, 218 (79.9%) were male and 55 (20.1%) were female, 1.8% of the participants teenager, 64.1% were from the age group of 20-35 years, 32.2% were from 35-50 years age and 1.8 % were above 50 years. Among the participants surveyed, 27.8% used bicycle for commuting, 33% used for recreation, 11.4% for work, 18.3% for exercise and 9.5% used bicycle for some other purpose. The survey for the increase in preference to use cycle more after introduction of the cycle lane shows that 73.3% of the participants preferred the use of bicycle after the introduction of the cycle lane but, 26.7% didn't prefer. Table 4 shows the descriptive analysis of the overall perception on QoS of the cycle lane of the users and the perception of the QoS of the variables.

Table 4: Descriptive analysis of the variables of the perception survey

Variables	Statistic	Value	Std. Error
Perception on Quality of Service	Mean	2.71	0.059
	Median	3	–
	Variance	0.92	–
	Std. Deviation	0.959	–
Width	Mean	3.03	0.052
	Median	3	–
	Variance	0.721	–
	Std. Deviation	0.849	–
Road Safety	Mean	2.07	0.049
	Median	2	–
	Variance	0.65	–
	Std. Deviation	0.806	–
Personal Safety	Mean	2.7	0.062
	Median	3	–
	Variance	1.014	–
	Std. Deviation	1.007	–
Comfort while sharing bicycle lane with cars	Mean	1.93	0.055
	Median	2	–
	Variance	0.807	–
	Std. Deviation	0.899	–
Motivation due to presence of cyclists	Mean	3.4	0.057
	Median	3	–
	Variance	0.873	–
	Std. Deviation	0.934	–
Cycle lane network connectivity	Mean	2.94	0.062
	Median	3	–
	Variance	1.033	–
	Std. Deviation	1.016	–
Pleasure	Mean	2.91	0.066
	Median	3	–
	Variance	1.172	–
	Std. Deviation	1.083	–
Behavior from other vehicle drivers	Mean	1.63	0.047
	Median	1	–

Table 4: Descriptive analysis of the variables of the perception survey

Variables	Statistic	Value	Std. Error
	Variance	0.062	–
	Std. Deviation	0.776	–
Traffic Pollution	Mean	1.9	0.047
	Median	2	–
	Variance	0.583	–
	Std. Deviation	0.764	–
Pavement Surface Quality	Mean	3.02	0.056
	Median	3	–
	Variance	0.83	–
	Std. Deviation	0.911	–
Sign Post	Mean	2.79	0.053
	Median	3	–
	Variance	0.753	–
	Std. Deviation	0.868	–
Road Marking	Mean	2.55	0.062
	Median	3	–
	Variance	1.037	–
	Std. Deviation	1.019	–
Conflict with Parked Cars	Mean	1.87	0.06
	Median	2	–
	Variance	0.949	–
	Std. Deviation	0.974	–
Conflict in Bus Stop	Mean	1.94	0.061
	Median	2	–
	Variance	0.981	–
	Std. Deviation	0.991	–
Conflict with Pedestrian	Mean	3.12	0.073
	Median	3	–
	Variance	1.434	–
	Std. Deviation	1.197	–
Congestion in Cycle Lane due to Other Bicyclists	Mean	3.75	0.058
	Median	4	–
	Variance	0.909	–
	Std. Deviation	0.953	–

Overall QoS of the shared bicycle lane regarding the satisfaction of the users was determined to be 2.71. The highest average quality of service was found to be of the variable "Motivation due to presence of cyclists" and the lowest average quality of service was found to be of the variable "Behavior from other vehicles".

5. Conclusion

This study was aimed to find the bicycle level of service and overall quality of service of shared bicycle lane of Kupondole to Lagankhel road section in Lalitpur district. From the results and discussion, it can be concluded that:

1. BLOS is highest with 'B' for Kupondole to Jawlakhel in both directions, whereas BLOS from Jawlakhel to Lagankhel ranges from 'C' to 'E'.
2. The overall quality of service from qualitative analysis of cyclists has been determined to be 2.71, showing a moderate level of satisfaction. The highest factor is "Motivation due to presence of cyclists," while the lowest average quality of service was found to be the variable "Behavior from other vehicles."

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