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Implication of Land Use and Street Characteristic on Overhead Pedestrian Bridge Usage

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Abstract
Overhead pedestrian bridges are usually warranted at locations where there are greater chances of vehicular and pedestrian conflict but even at such locations there isn't any guarantee of the bridge usage by all pedestrians at all circumstances. The choice by pedestrians whether to use the overhead pedestrian bridge at established "appropriate" location involves a complicated process which is a product of not just individual preference but maybe of external factors such as land use and street characteristic which is of the primary focus for this study. The study was limited to observation on field for a period of six days during which the pedestrians as well as jaywalkers on the site were observed for three different time periods. In addition the land use and street characteristics were analyzed based on the on site situation during the study period. For the purpose of this study the two overhead pedestrian bridges at two different places in Kathmandu Valley was studied and analyzed in order to understand the implication of land use and street characteristic on the usage of overhead pedestrian bridge. The results show that the usage of the bridges were higher where the land use is supportive to pedestrian movement and accessibility and drops in the case of low vehicular traffic and absence of elements such as medians.

Keywords
Pedestrian, Footfall, Land use,Street Characteristic Median, Usage

1. Introduction

Overhead pedestrian bridges are vital part of the non-motorized urban mobility system serving pedestrians from different walks of life. They form a critical link to the pedestrian system by connecting areas separated by variety of barriers. These structures are provided at locations of heavy traffic volume where conflicts between motorist and pedestrians can arise and are built in response to user demand for safe crossings where they previously did not exist. This facility is one of the safety approaches to overcome accident by minimizing conflicts and separates traffic flow between pedestrians and vehicles [1].

Overhead pedestrian bridges or *"Aakase Pul"* in Nepali literally translates to sky bridges, is common around the Kathmandu. These pedestrian bridges are provided at busy traffic junctures for pedestrians to safely cross the road. However some of them are more effective than others in catering to the pedestrian demands. The main objective of the paper is to understand whether the utility rate of the overhead pedestrian bridges are influenced by land use and street characteristic as suggested in many literature.

2. Literature Review

The extraordinary growth of cars in cities has generated extremely dense urban flows and in turn road networks have been reconfigured to provide maximum vehicular capacity which has unfortunately led to erosion of public spaces and breakage in pedestrian connectivity. The layout of most cities are still characterized by street configuration to accommodate the exponential growth of vehicles and streets and squares have been transformed in their geometric layout to comply with traffic engineering [2].

The location of pedestrian overhead bridge within the overall pedestrian network can provide acute insights to its usage. These bridges are generally warranted only at locations where exceedingly heavy volume of pedestrian traffic crosses a heavy vehicular flow. Factories, large sports arenas, and school are places

where such forced conditions usually exist. A well sited bridge with comprehensive non-motorized facilities might attract higher use by offering a relatively easy access from its surrounding network whereas fragmented facilities like discontinuous sidewalks may suffer from real or perceived difficult access [3].

The link between overhead bridges with its surrounding area is influenced hugely by street connectivity. Limited cul-de-sacs and short blocks with well-connected streets can provide direct access to the bridge from surrounding areas. On the other hand a less connected street can diminish a bridge's attractiveness by increasing real or perceived out of direction travel. The presence of informal paths can be an indicator of bridge itself or its approaching paths may not be located along a desired or direct pedestrian travel routes. Pedestrian bridges should be located to serve identified desired lines as much as possible as it ensures maximum usage of the bridge while at the same time isolated locations should be avoided as much as possible (ibid).

Forms of land use that attract pedestrian uses such as schools, hospitals, public transport, commercial areas are most supportive for the establishment of pedestrian overhead bridges [4]. In addition these land uses generally attract and generate vulnerable road users such as school going children, elderly and differently-abled pedestrians. The roads and streets constitutes a part of land use and is affected directly by transportation infrastructure just as transport is by land use. Accessibility refers to mobility of all pedestrians to reach desired destinations, access goods and services and appropriate use of the built environment whereas connectivity indicated the degree the roads are connected that allows direct travel between destinations. Some literature has also shown light on the influence of the road beneath the footbridge on its usage. For example the presence of posted speed limit, median barrier, fence and distance of the facility influence the usage of the bridge. To raise the efficiency of the usage of the footbridge researchers have also suggested topography, and fencing along sides of the street or in the median for several hundred feet on either side of the grade-separated crossing[5].

Although in Kathmandu there has been significant decline from 53.1 percentage in 1991 to 40.7 percentage in 2012 and forecasted to reduce to 38.8 percentage by 2020, walking is still the major model of travel [4]. Walking as a mode of travel is still pretty high in Kathmandu compared to other cities of Asia. However walkability studies of Asian cities has revealed that Kathmandu is among one of the least walkable cities in the region receiving one of the lowest ranking and has been categorized as 'Not Walkable', whereas Hong Kong and Metro Manila have been rated the highest. Especially the areas where commercial and public transport terminals where a large number of pedestrians are generated are found to be less walkable compared to other areas such as residential and educational mainly due to poor pedestrian infrastructure and high walking path modal conflict due to poor planning.

Nepal has also formulated its own criteria to warrant overhead pedestrian bridge which is specified in Nepal Urban Road Standard, 2070 as following; "They may be warranted where there are heavy peak pedestrian movements, such as at central business districts, factories, schools, or athletic fields, in combination with moderate to heavy vehicular traffic or where unusual risk or inconvenience to pedestrians would otherwise result" [6].

3. Study Area

The study area were two overhead pedestrian bridge of which one was located in Kathmandu Metropolitan City and another was located in Lalitpur Metropolitan City. Kathmandu is the largest city of Nepal whereas Lalitpur ranks third. The first footbridge (Bridge-1) is located near the entrance of Bhotahiti, Kathmandu in the street of Kanti path which lies on the north western corner of Ratnapark and opposite to the famous Rani-Pokhari. While the other one (Bridge-2) is located near B&B Hospital, Gwarko and lies on the recently completed Kalanki-Koteshwor ring road section.

4. Methodology

For this survey, mixed method was used as a research of this nature entails both quantitative as well as qualitative data. The land use and street characteristics were observed on site and were summarized as well as inventoried which included the number of lanes, presence of traffic island, building typology, traffic characteristics etc. For the purpose of data collection for the survey, a pedestrian count survey was carried out in January, 2019. A click counter application on the smart phone was used to

record the volume of pedestrians using the respective bridges. For each of the bridges, the volume of pedestrians using the bridge was recorded for every 15 minutes interval with each lasting an hour for three different time period; morning (9:00-10:00 am), mid-afternoon (12:00-1:00 pm) and evening (3:00-4:00 pm). Convenience ratio(R) was calculated to make comparison between the time taken to travel on the bridge and the time taken to cross the road from non-designated road level. The survey was done at random and different age groups for both genders. A stopwatch was used to calculate the pedestrian time spent on crossing on the footbridge as well as the time spent on non-designated crossing on the street level. To obtain the convenience ratio, the time taken for pedestrians to cross the road through the footbridge was divided by the time taken by pedestrians to cross through road level.

5. Data and Results

5.1 Land use near Bridge-1

The central civic space of Kathmandu lies on the periphery of Tundikhel, Kathmandu on which the overhead pedestrian bridge-1 selected for this study lies. The study area on which bridge-1 lies on a very distinctly segregated zone; on the eastern part lies the famous and historic open space like Rani-Pokhari and Tundikhel while on the western part buildings ranging from institutional, commercial and educational characteristic mushrooms right on the edge of the road. The overhead pedestrian bridge is a literal bridge between this two distinct land uses that has its own function and character. The urban characteristic of this area is compact urban forms of the over-concentrated commercial zone and densely built transport stations, large flows of both pedestrian and vehicular traffic with specialization of economic activities. Although primarily constructed for improving urban circulation, pedestrian bridges in high density areas are also utilized as a form of public space to sustain people's various urban activities and to complement city's urban function such as evidenced by the shops located on the lower half of the Bridge-1.

The land use around this bridge is a cumulative of various different types. This bridge lies on the historical heart of Kathmandu with Tundikhel to the south, Rani Pokhari to the north, Bhotahiti to the west and Ratnapark to the east. Bhotahiti is the entrance to the old town and has high residential density along with heavy commercial activities. It is well known for commodities ranging from daily grocery to special spices from ages ago whereas it has also seen a boom in low price retail items such as clothes and bags in recent years. The area is also known for Ratna Park on its east as a major transportation hub with large number of micro buses that connects the place with different corners of the city. The biggest change in land use currently is the temporary relocation of Purano Bus park to Khulamanch since May 2016 to enable the construction of the proposed 12-storey Kathmandu View Tower. This has generated a lot of pedestrian movement in the area which was not conceived before. Since the earthquake of 2015, the reconstruction effort has gained a lot of momentum. A number of buildings have been proposed in the area replacing the old and new buildings such as surgical block of Bir Hospital are being constructed which which means that more vehicular as well as pedestrian traffic is be likely to be generated in the near future .

Figure 1: Stairway connecting to Bhotahiti, Bridge-1

5.2 Street layout and Streetscape near Bridge-1

The widening of road carried on the expense of pedestrian was evidenced by the shrinkage of pedestrian sidewalk in width from 36'-0" in 1995 to approximately 10'-0" currently in 2019 near the bridge. This has inevitably led to creation of bottlenecks at various intersections as well as the segregation of pedestrians and automobiles ultimately leading to streets being non friendly to pedestrians. There was no observed consistency in design in terms of width, height, and continuity of footpaths. A

number of footpaths have meter width forcing the pedestrians to use the main roads. Other amenities such as lamp post and greenery occupy the footpaths and existing guard rails are in poor state. This segregated layout and one-directional flow of traffic was aimed mainly at reducing traffic congestion rather than pedestrian ease. Since the traffic flow is one directional, there are no medians provided on the road. While there were railings on the side of the footpath leading to the Bridge-1, it was only present on the northern side and the southern side was left open. It was noticed that in absence of such railings, pedestrians especially coming from the western side did not hesitate to cross on road level in spite of presence of the Bridge-1 in close proximity.

High density buildings that span several floors is characteristic of the case area which has generated a lot of traffic however the quality of pedestrian facilities have not been improved. The pedestrian bridges in the case area are situated almost on the second floor level of the city but connects to none on that level. As a three-dimensional city, the case area on the western side has very few remaining areas for sprawl spaces for urban development. This lack of space has caused dense, high rise building of commercial and institutional nature resulting in intense urbanization. The streets that were reconfigured facilitated vehicular movement rather than as an urban space. However the establishment of buildings such as Bir Hospital, Military Hospital, Trauma Center around the case area has added, though lacking in homogeneity as in Malla period, has demonstrated a new style of architecture to the streetscape.

Table 1: Characteristic of road beneath Bridge-1

Type	Width (m)	Traffic	Lanes
Arterial	15	One-way	4

5.3 Land use near Bridge-2

The overhead pedestrian Bridge-2 lies in proximity to residential settlements on both sides. Along both front sides of the road there are a handful of institutional buildings such as colleges and hospitals whereas the remaining are mainly mixed used building that have commercial usage on ground floor such as shops, eateries and residences on the upper floors. Some of the notable buildings near the bridges are B&B Hospital, Kathmandu College of Management, B and B Medical Institute (nursing College). The remaining majority in the area are residential building. The overhead bridge is placed between two land-use of similar nature. The pedestrian bridge is almost 300m away from the busy intersection of Gwarko Chowk on the north and approximately 800m away from another busy intersection of Satdobato on the south side. 2 bus bays are located on either side of the road approximately 100m away to the north side. The legs of the stairway are aligned opposite to the bus bays, the hospital and the nursing college which adds extra distance to walk before reaching the foot of the bridge. There is no continuous path that connects the pedestrian bridge to the neighboring residences and one has to cross the service road that is not equipped with any road crossing facilities.

Figure 2: Discontinuous pathway to surrounding residence, Bridge-2

Much of the land use change around the site of Bridge-2 has been due to the road expansion drive that started from 2011. The rationale behind road expansion in ring road was to provide a solution to the rising traffic congestion problem in the valley. Such policy of road expansion was an example how conventional policy makers and planners see the urban mobility issue and the solutions through the perspective of car-centric mobility. More than 1000 trees along the Kalanki-Koteshwor section on which this overhead pedestrian bridge lies were chopped down in a few days to expand the road into eight lanes during the project time period which resulted in reduction of green spaces.

5.4 Street layout and Streetscape near Bridge-2

Kathmandu Ring Road Improvement Project was executed with Chinese assistance to widen the two-lane road to eight lanes which commenced on June, 2013 after which the overhead pedestrian Bridge-2 was conceived. Road is currently eight

lane-two way and where walking and crossing the road has become all the more dangerous after the Koteshwor-Kalanki section of the Ring Road was expanded into an eight-lane expressway. Four lanes out of the total eight have been separated for expressway in the middle of the road whereas remaining four lanes-two lanes on each side of the road have been designated as service lanes. On the main expressway, vehicles can run at far greater speed and without medians dividing the four lane expressway makes it more prone to fatal road accidents. Kathmandu has traditionally been a city of pedestrians and cyclists but the growing number of automobiles have displaced the pedestrians and cyclists in the road hierarchy. Even during the original contract signed between the DoR and the Shanghai Construction Group Co Ltd the project had mentioned encompassing design of cycle lane and sidewalks on both sides of the road but today it can be seen the road doesn't include such facilities.

Table 2: Characteristic of road beneath Bridge-2

Type	Width (m)	Traffic	Lanes
Expressway	31	Two-way	8

5.5 Pedestrian count survey

It can be seen from the following Table 3 representing the pedestrian count, Bridge-1 had the highest pedestrian count for any given time of the day almost exceeding the other Bridge-2 by a margin of two hundred.

Table 3: 15-minute Pedestrian count survey

Period	Time	Bridge-1	Bridge-2
Morning	9:00-9:15	285	30
	9:15-9:30	283	20
	9:30-9:45	287	49
	9:45-10:00	292	45
Afternoon	12:00-12:15	329	45
	12:15-12:30	403	32
	12:30-12:45	405	51
	12:45-1:00	409	43
Evening	3:00-3:15	405	40
	3:15-3:30	409	43
	3:30-3:45	420	38
	3:45-4:00	426	32
	Total	4353	468

It was also observed that the highest pedestrian number or peak was observed on Bridge-1 (426) during the evening period. The lowest total pedestrian count was for Bridge-2 for the all the three time period. In addition, Bridge-2 also accounted for the lowest flow which was observed at morning period (20). Overall there is quite sharp fluctuations in the pedestrian flow on both the bridges were seen throughout the observation period.

5.6 Convenience Ratio

Despite the many benefits there are many pedestrians who for various reason do not use the pedestrian overhead bridge. Even in this study area there were plenty of pedestrian who chose to cross the road through non-designated areas rather than the footbridge. During the course of observation on the site there were frequent sights of pedestrian dashing to cross the road from non-designated road level. It was noticed that people tend to cross the road through some non-designated spaces frequently than others. For this study there were two such areas that were frequently being used for jaywalking and were chosen as they were also in close proximity to the respective bridges. The crossing time was also calculated for different people from these spots.

Table 4: Time taken to cross through Bridge-1

S.N.	Gender	Age (approx)	Time (min-sec)
1	Male	55-60yrs.	1:22:04
2	Female	25-30yrs.	1:17:10
3	Male	25-30yrs.	1:06:26
4	Male	25-30yrs.	1:07:19
5	Female	45-50yrs.	1:14:54
		Total time	6:07:53
		Avg. Time	1:13:35

Table 5: Time taken to cross from Jaywalking spot-1

S.N.	Gender	Age (approx)	Time (min-sec)
1	Female	25-30yrs.	0:14:25
2	Male	35-40yrs.	0:38:52
3	Male	15-20yrs.	0:17:30
4	Female	45-50yrs.	0:37:02
5	Male	45-50yrs.	0:25:07
		Total time	2:12:56
		Avg. Time	0:26:35
		Convn. Ratio-1	**2.8**

Table 6: Time taken to cross through Bridge-2

S.N.	Gender	Age (approx)	Time (min-sec)
1	Female	15-20yrs.	1:56:49
2	Male	25-30yrs.	1:55:04
3	Male	35-40yrs.	1:45:00
4	Female	55-60yrs.	2:03:43
5	Female	35-40yrs.	2:17:44
		Total time	9:57:50
		Avg. Time	1:59:34

Table 7: Time taken to cross from Jaywalking spot-2

S.N.	Gender	Age (approx)	Time (min-sec)
1	Female	35-40yrs.	0:30:00
2	Male	25-40yrs.	0:25:03
3	Female	45-50yrs.	0:32:02
4	Female	15-20yrs.	0:16:30
5	Male	25-30yrs.	0:25:07
		Total time	2:08:42
		Avg. Time	0:25:44
		Convn. Ratio-2	**4.7**

6. Discussion

There are huge disparity between the number of footfalls received on bridge-1 and bridge-2. It can be seen from the pedestrian count survey that Bridge-1 received approximately 9 times the number of pedestrian number at any given time period which indicates the link between the surrounding land use of the overhead bridge and the usage of the bridge. While Bridge-1 is situated in a highly commercial zone with a number of shops, eateries as well as schools, hospitals and transportation facilities which is conducive to attracting large number of pedestrians and vehicles, Bridge-2 is situated on a quieter land use area that is mostly composed of residential buildings. It can be seen that the overhead pedestrian bridge usage corresponds to the character of use on the surrounding land use by pedestrians. For Bridge-1, the highest count of pedestrian occurs during the evening period. This can be attributed to the high number of pedestrian travelling from work to home or those that have come to the area for a quick shopping spree as it lies on the way to Asan, an old market. This increment in pedestrian number can also be attributed to those who are heading towards the Ratna-park area to get to the bus stop. On the other hand, lowest pedestrian flow occurs during the morning period. While there is quite significant number of students in their uniform and office goers walking on the bridges, morning period is quite slow period especially since many shops on usually do not open early in the morning. It can be observed that even the traffic flow in the area is quite low compared to the evening period. The mid-afternoon period for all three period is quite erratic period where there is quite large fluctuations on the pedestrian flow. It could be seen that there were usually solitary shoppers such as housewives as well those who were there for recreational purpose for example groups of men who were heading towards Tundikhel area to soak up some sun usually accounted for the wide fluctuations.

(a) Morning period **(b)** Evening period

Figure 3: Pedestrian Flow on Bridge-1

Contrasting, for Bridge-2 there was more flow of pedestrians during the mid-afternoon period although not on the scale of Bridge-1 as there were pedestrians utilizing the bridge usually from neighbouring areas. Since the area around Bridge-2 is largely homogeneous in character and does not have areas for pedestrian generation or attraction there is low footfalls all through the day.

The lack of traffic infrastructure such as median on roads shows that pedestrian will take advantage of the stops in traffic flow and be influenced to cross the road on level rather than the provided overhead pedestrian bridge. For Bridge-2, on observing those pedestrians who were jaywalking, generally it was seen the pedestrians tend to rush towards the road when the traffic flow was relatively low despite the fact that vehicle at high speed tends to pass the stretch often. The fencing that are placed on the walkway next to the bridge do not deter the jaywalkers as they can easily jump or climb through it as it is only 0.9m in height. In addition, the sidewalk that are placed between the nodes is used as a place of refuge or rest from coming vehicles while crossing on road level. It can be concluded that it is not only the presence of medians but also the type and height of the medians

that deter such crossing behavior. On both sites there was absence of clear signage informing the pedestrians of route leading to the pedestrian bridge. It was also seen that there was a clear incongruity in design of the walkways leading up to the bridges as they varied in width and texture without continuity.

It can be clearly seen that the convenience ratio far exceeds the recommended 1.5 ratio which indicates that time could be an important factor in encouraging some pedestrian to cross through grade level and lead to non-usage of the pedestrian bridges. The time taken to cross through the road level is affected by various factors of which road geometrics as well as the traffic condition is also considerable. For both the cases, the convenience ratio has exceeded the recommended ratio which is not a good indicator. It can be seen the easier it is to cross the road through the road level even if undesignated, the greater the convenience ratio value. The higher the convenience ratio the lower the usage of the pedestrian bridge is evidenced by the convenience ratio of Bridge-2 being almost twice that of Bridge-1 as it has a lower footfall.

7. Conclusion

While the land use of the surrounding area of an overhead pedestrian bridge as well as street characteristic may not be the only factors that is influential to the bridge usage, it is nonetheless an important indicator. It is seen that usage of such overhead pedestrian bridges are supported by integrated land use and street design. The study has shown location of overhead pedestrian bridges on areas where pedestrian generation and connection between land uses is strong, lively street characteristic along with supportive traffic condition there is higher usage whereas the absence of elements that discourage jaywalking such as continuous medians of required height, signage, can discourage usage.

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