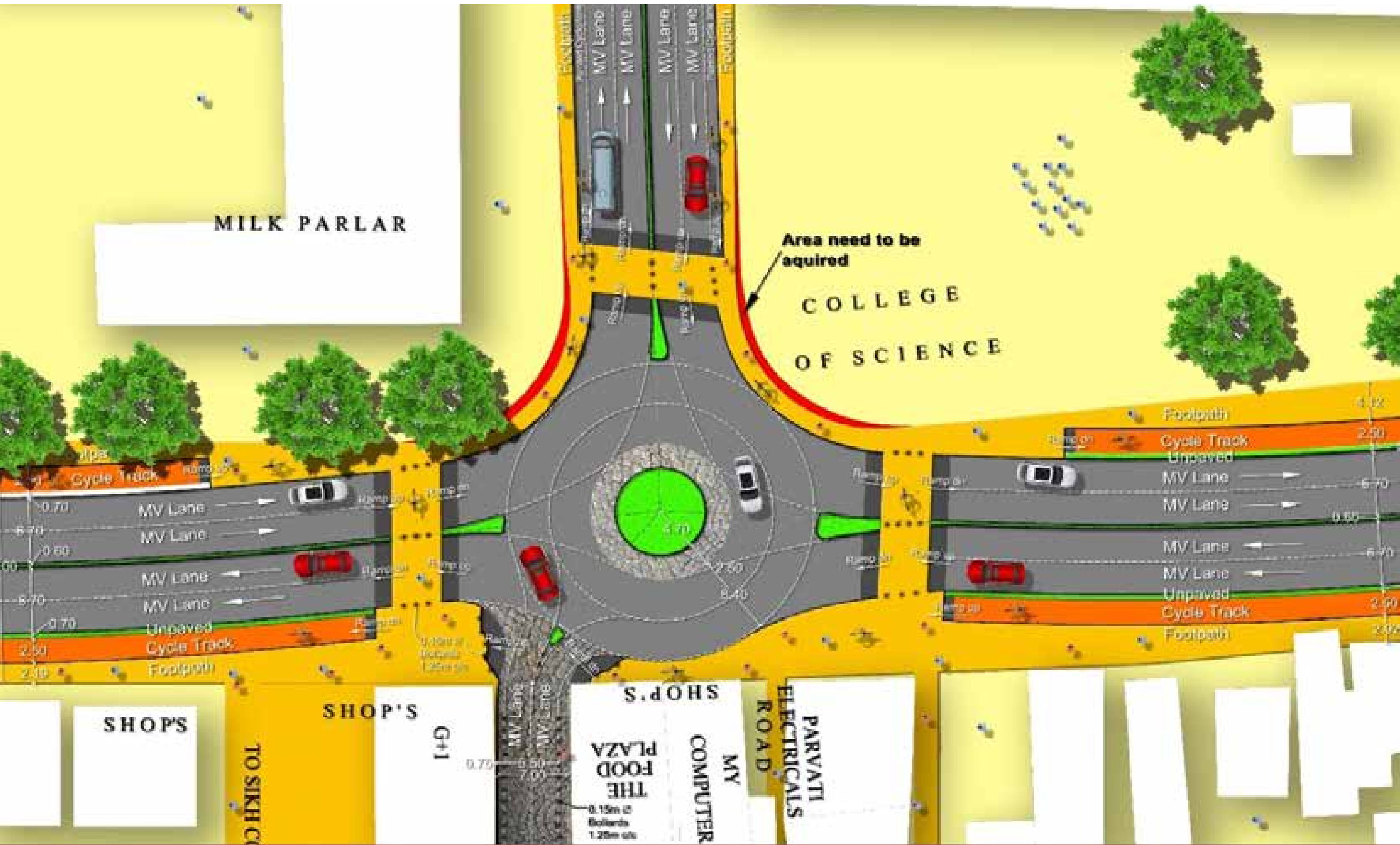
Feasibility Report for Kumharon Ka Bhatta with an Alternative Intersection Improvement: Case Study from Udaipur



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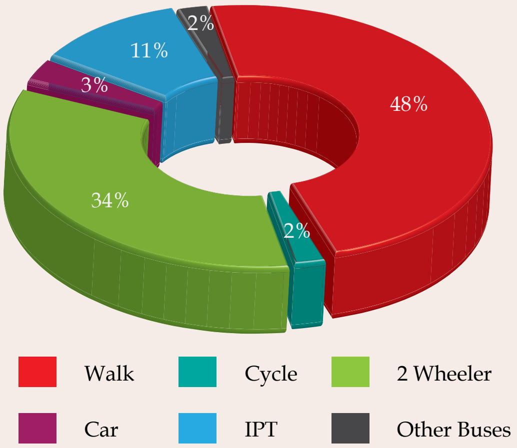
Introduction

Udaipur is a rapidly growing city with an area of 64 sq. km under its municipal limits, and a total population of 0.45 million. Currently, the average trip length in the city is 5.09 km. Modal split shows that 3% of the trips are by cars, 34% by two wheelers, 2% by bus and 11% by Intermediate Public Transport (IPT). 48% of trips are by walk and 2% by cycle (Refer Figure 1). Even though significant number of trips is by non-motorized modes in the city, the road infrastructure lacks any provision for the same. Most of the streets do not have any pedestrian or bicycle infrastructure. This forces cyclists and pedestrians to mix with motorized means of transport.



Source: UMTCL. (2015). Low-carbon Comprehensive Mobility Plan for Udaipur: UNEP and DTU

Figure 1.: Modal Split

The current report - Feasibility Report for Kumharon Ka Bhatta with an Alternative Intersection Improvement: Case of Udaipur is a part of the output reports under the project “Supporting Smart Urban Mobility and Built Environment in Indian Cities” under Grant Ref: G 15 SSEF-140 for the period of October 2015 to January 2017. The main objective and deliverables of the project were to broadly engage with state level officials in two states and have continuous on ground engagements with targeted authorities in cities on urban transport and built environment towards implementing the Smart Cities Mission. This included assessment of existing urban transport scenario in the identified cities for each state providing handholding support to city teams for smooth initiation of Smart Cities Mission

The report highlights the various aspects of assessment undertaken by the project team to verify the feasibility of the proposed flyover at Kumharon ka Bhatta. The report also includes an assessment of current carrying capacity of road stretch, future projections related to traffic demand and the most appropriate alternative design solutions to increase the carrying capacity of road stretch.

The construction of flyover was proposed on College Road leading to Sewashram at Sikh Colony Junction, Kumharon ka Bhatta, Udaipur. The flyover was proposed along east-west on the Saraswati Marg, Kumharon Ka Bhatta Road. This flyover was proposed on 25th January 2014 to resolve about 200 m long queues observed at the existing signalized intersection during peak hours. Then, the flyover proposal was approved by the Gramin Vikas and Panchayati Raj Vibhag State Minister at the Urban Improvement Trust, Udaipur, which was further approved in the Nagar Nigam Board Meeting on 4th February, 2014. A budget of Rs.13.50 Crore was approved for the same.

However, on 14th July 2014, the Principal Secretary to the Local Self Government, Rajasthan, rejected the proposal on grounds that current demand does not warrant the need of a flyover. This feasibility report evaluates the flyover proposal in terms of its planning and physical feasibility against benefits intended to be achieved and alternatives available.

Methodology

The study was conducted in four parts:

A. Issues at the junction were video recorded and an activity survey was carried out for adequate registration of the current situation of the junction and associated arms.
B. Traffic flow at junction was projected according to three different situations, considering current traffic flow recorded through sample video recorded at peak hour and possible growth trends.
C. Alternate options were considered for facilitation of smooth traffic flow of the projected volume, including the option of proposed flyover, intersection redesign and the Do-Nothing Scenario.
D. Analysis was then conducted, thereby, recommending the most suited option.

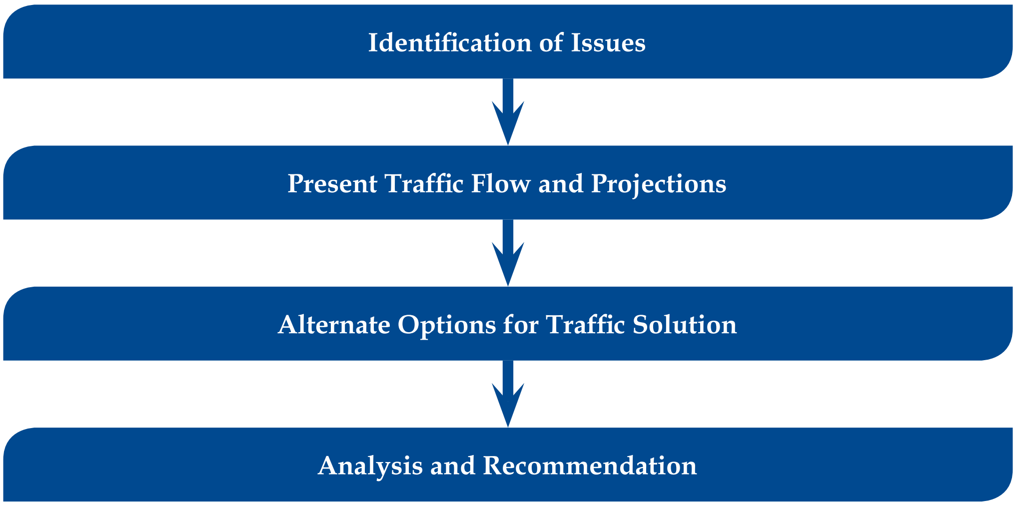


Figure 2.: Methodology

Intent of Taking the Project

The flyover at Kumharon ka Bhatta Junction is proposed on an important road, connecting major institutional area with Sewashram. The stretch is flanked by institutional land use on one side and mixed land use on the other, combining a Gurudwara, commercial and residential space.

The capacity of present carriage way is reduced by 35 - 40% along Kumharon Ka Bhatta and Sikh Colony due to presence of unpaid, perpendicular two and four-wheeler parking, electric poles, etc. Cycle tracks are almost occupied by such activities and other road infrastructures like markings, stop signs, etc. Walking is convenient in the residential wing of the stretch due to sun path and shade provided by the buildings, but the same is not present on the other side. Non-motorised transport (NMT) facilities are negligible due to constrained Right of Way (ROW).

The Gurudwara is along the College Road, amidst the Sikh colony, with mixed land use character along the entire length of the stretch. Access roads to Kumharon Ka Bhatta observe steep slope towards the neighbourhood.

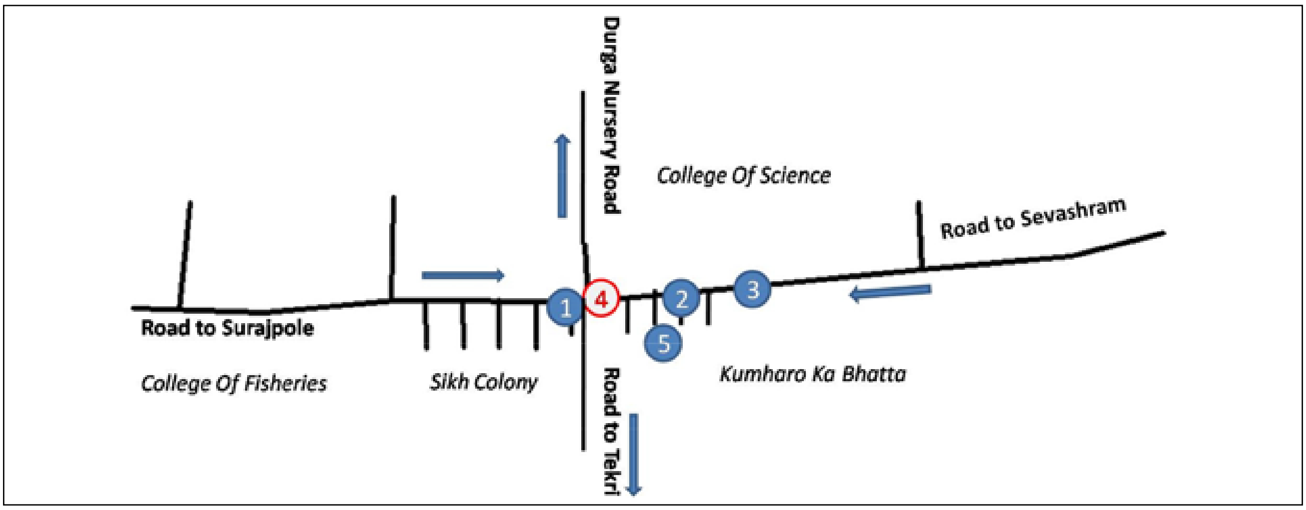


Figure 3.: Schematic Sketch of the Stretch Proposed for Construction of the Flyover

Relatively old buildings, upto G+3 floors, are located on the stretch on one side and University property is earmarked by boundary wall on the other. The area outside the institutional wall along the road is used for parallel parking near the entry gates of institutes and few other spots.

The road leading to the Tekri serves as a major bottleneck for smooth traffic flow. Through traffic is avoided from Tekri to Durga Nursery Road through movable diverters (used in the entire city) and traffic is diverted to College Road. During peak hours, long queues are observed on College Road, creating travel speed delays. The junction is managed by Traffic Police and channelized mildly by a very small landscaped roundabout.

Figure 4.: Gurudwara: Landmarks at the Junction

Figure 5.: Institutional dead wall on one side of road

Study Area Delineation

1. Footpaths and cycle tracks: 1.5 m wide tracks in front of institutional buildings, which are otherwise encroached and bisected by varying pavement construction by shop keepers
2. Bus lanes: Absence of dedicated bus lane
3. Formal provisions for parking: Unpaid or street parking along the stretch
4. Median width: 1 m

5. Turning radii: 12 m (Durga Nursery Road)
6. Vehicular accesses in and around the junction
7. Right of Way (ROW) widths

a. Surajpole road: 25 m
b. Durga Nursery Road: 18 m
c. Road to Tekri: 7.5 m
d. Sevashram Road: 25 m

Figure 6.: Location of the Flyover Proposed at Kumharon ka Bhatta Junction

It is observed that the current traffic numbers can be accommodated in one to two motor vehicle lanes per direction. This is significantly less than the current available capacity. However, even when the demand is theoretically less than capacity, considerable congestion levels and long traffic queues are reported during peak hours. This implies that the reason for traffic congestion at this junction is not under-capacity, but other inefficiencies which need to be investigated.

Two inefficiencies were thus observed. These are:

- Friction and capacity constraint caused by mixing of slow traffic (including pedestrians and cyclists) with motor vehicles on the carriageway; as well friction caused by considerable number of parked motor vehicles at or near the intersection.
- Possible sub-optimum signal phase plan, and the reliance on manual signal operations during peak hour.

It is known that manual management of traffic leads to long signal phases and an overall cycle which far exceeds the optimum 180 seconds[1]. This is a primary reason for emergence of long vehicular queues even in low demand intersections. However, it is likely that trigger for shifting to manual operations by traffic police is reduced throughout in peak hours, caused by friction by slow modes and parked vehicles. Thus both these inefficiencies need to be tackled by the selected alternative for junction improvement.

Description of Process

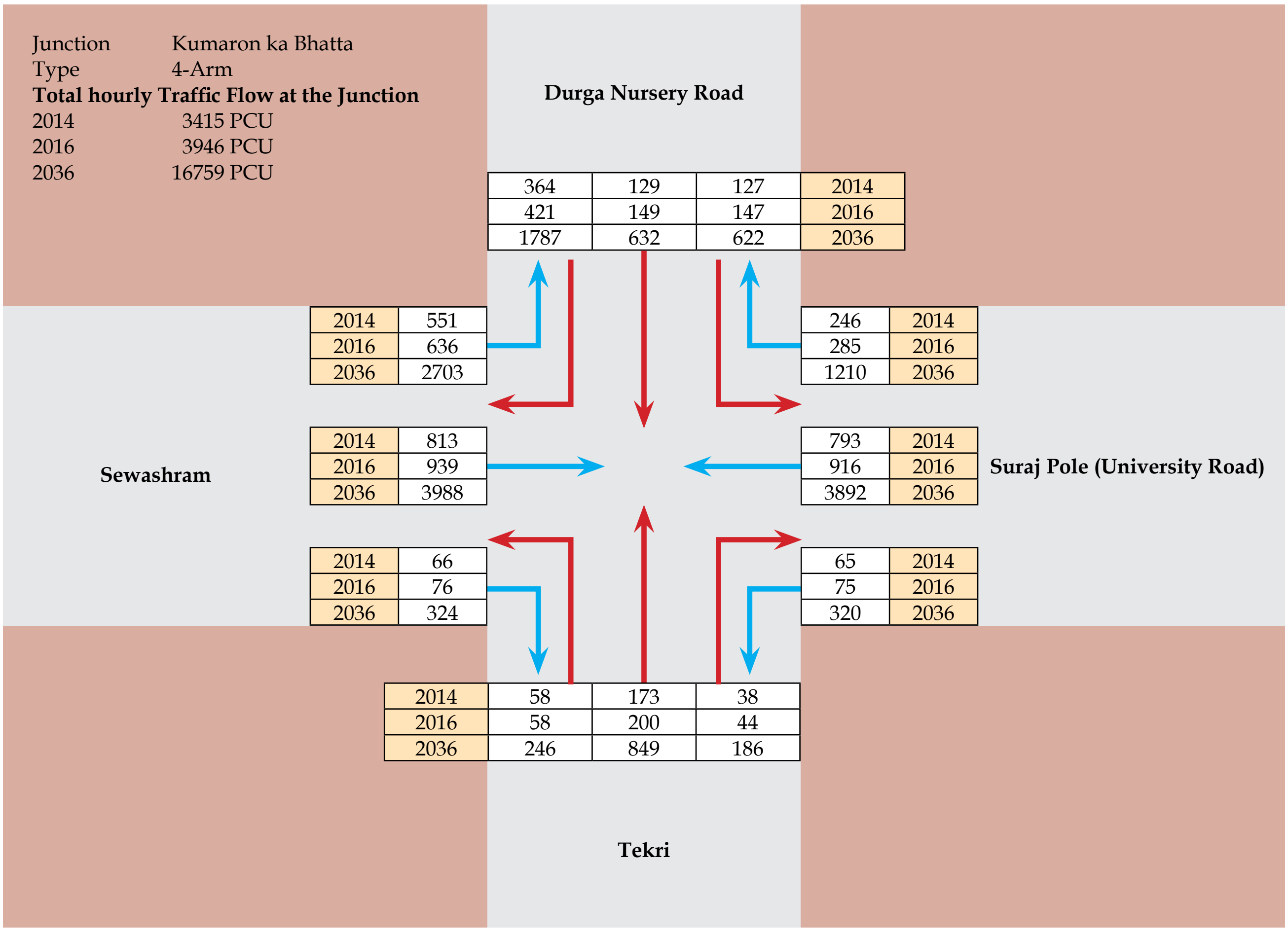
At present, the total average hourly traffic at intersection is about 3,415 Passenger Car Unit (PCU). The straight going traffic is 1,908 PCU per hour out of which about 1,610 PCU is on Suraj Pole, Sewashram

1. In manual operations, operators have a natural tendency to reduce the number of inputs/actions, and thus- each manual input or a signal to move the traffic lasts much longer leading in longer signal phases and thousand eventual long signal cycle.

Road. These numbers are based on traffic survey conducted in 2014. This traffic data does not include details of modal split in the traffic, nor does it include details of non-motorized traffic including cyclists and pedestrians. The flyover proposal also includes traffic projections for two horizon years – 2016 and 2036. Projected traffic in 2016 and 2036 will be 3,946 PCU and 16,759 PCU respectively. However, it is not clear which trip and traffic growth rates and modal splits have been assumed for estimating horizon year traffic demand.

A video-based pilot traffic survey was conducted on 7th April 2016 and the same provided the details of mode and direction wise traffic demand in 2016. As per this survey the average peak hour total traffic demand in PCU at Kumharon Ka Bhatta junction is 3,400 PCU (refer Table 1). This is significantly higher than that projected for 2016 (in 2014)[2]. These traffic projections can be deviated to a small extent from real traffic situation due to a quick small time sample survey conducted by the team. Thus, for evaluating alternate proposals for this intersection, it is desirable that a revised projection for horizon year be generated.

Restriction of city growth in a specific manner results in less effective solutions, as projection and planning have their own ambiguities, which require a range of flexible solutions. Hence, to prepare a realistic scenario, two alternate methods for projecting traffic in business as usual (BAU) scenario at this intersection are used, apart from one method of projection in a 'smart city scenario'. These have been explained below.



Source: Udaipur Municipal Corporation (UMC), Udaipur

Figure 7.: Traffic Flow at Kumharon Ka Bhatta Junction

2. In report prepared by UMC, 2016 & 2036 projections were made based on 2014, hence 2 close by years have been mentioned.

BAU Scenario - Method 1

Annual household income and population for Udaipur is projected for 2036. These projected numbers are compared to cities with similar population and income 'today'. Udaipur is assumed to attain the current modal share of the compared or reference city in the horizon year, i.e. 2036. The mode share and total mode wise trip distribution (in the city) is projected for each year in the future (till horizon year, i.e. 2036) using horizon year mode share, total mode wise trips and growth trend. This data is used to estimate the growth in PCU volume of Kumharon Ka Bhatta junction using the current PCU demand today.

The population of Udaipur in 2011 was 451,100. This is expected to increase to 810,000 in 2036[3]. Similarly, the current average annual house hold income in the city was Rs. 216,000 (in 2013) which is expected to increase to 476,500 in 2036 (at the current value of money)[4]. This means that the city characteristics of Udaipur in 2036 will be comparable to characteristics of Chandigarh today (in a business as usual scenario). This is because the population of Chandigarh in 2011 was 961,600 and it was estimated to have an average household income of Rs. 514,536 in 2012[5]. Chandigarh has a per capita trip rate of 1.18, and in 2011, it had 41% trips by NMT, 28% by cars, 10% by two wheelers, 3% by auto rickshaw and 18% by buses. In comparison, Udaipur has a current per capita trip rate of 1.12; the current mode share distribution of trips in Udaipur is: 45% by NMT, 5% by cars, 28% by two wheelers, 15% by auto rickshaw and 7% by buses. Similarly, area under the Municipal limit in Udaipur is 64sq.km, while that of Chandigarh is 114 sq.km. It is estimated that in 2036, the Municipal limit of Udaipur will expand and will be similar to what is Chandigarh today[6].

However, unlike Chandigarh, Udaipur has a historic centre (with narrow lanes), and a hilly topography. This implies that it is unlikely that the share of NMT will increase further and the reliance on auto rickshaws will go down. It can also be said that because of the terrain and the physical character of the city, the reliance on motorized two wheelers may not show a considerable decline. However, because of increase in the Municipal limits, the trip size is likely to increase and thus some of the two wheeler trips may shift to buses and cars (also attributed to increase in income). Keeping this in mind and by interpolating modal share values on pattern of Chandigarh, the following mode share for Udaipur city in 2036 is projected[7]:

- NMT – 42%
- Cars – 25%
- Two wheelers – 11%
- Auto rickshaw – 5%
- Buses – 17%

Additionally, based on the trip rate and population, the total daily trips in the city as of today are estimated to be 588,600. Based on the comparison with Chandigarh, it is assumed that the per capita trip rate of Udaipur will increase to 1.175 in 2036. Based on this estimated trip rate and the projected population of the city in 2036, the total number of trips expected in the city in the horizon year are 969,500. This amounts to an increase of about 65%. Based on these estimates of current and horizon year, total daily trip distribution by modes has been presented in Table 1.

3. http://udaipursmartcity.in/about-us/
4. Based on annual average income growth of 9% and 5.5% rate of annual average increase in costs
5. Based on par capita income (2012) and an average household size of 4
6. RITES LTD. . (2009). *Comprehensive Mobility Plan for Chandigarh Urban Complex.* Chandigarh: Chandigarh Municipal Corporation
7. According to survey performed by SGA and ICLEI - SA

Table 1.: Projection for 2036 as per BAU 2036

Trips by Mode			
Mode	**2016***	**2036**	**Factor of Change**
NMT	2,64,142	4,02,359	152%
Two Wheeler	1,50,933	1,06,649	71%
Four Wheeler	43,507	2,42,385	557%
Auto Rickshaw	82,339	48,477	59%
Bus	47,320	1,64,822	348%

** Projected from 2013 data from Low-carbon Comprehensive Mobility Plan for Udaipur, prepared by UMTCL*

Under the given scenario, unscrupulous growth will be observed in four- wheelers, followed by public transport means like bus. Share of NMT will also grow with effective public transport. There is no significant rise in two wheelers and auto rickshaws. This scenario does not provide with sustainable solution as motorized modes are projected to grow significantly. But, the solution is simple to work as of now with the range possible.

BAU Scenario - Method 2

This method is the same as method 1, except that instead of using reference city mode share to estimate horizon year mode share for Udaipur, the mode wise trip distribution as per income levels for Udaipur has been used for projections. Projected income increase in the horizon year is used to project 2036 frequency distribution of annual household income. This provides percentage of households expected in three income groups' i.e. low income, medium income and high income; in 2036. As we know, income is directly proportional to trip rate of a household. Hence, the future percentage distribution of households in different income groups is used to project overall mode share for the city using the current trip distribution (by mode) in each income group.

Based on 2013 Udaipur city Low Comprehensive Mobility Plan (LCMP) data, and income projection for the city till 2036, it is estimated that in the horizon year, the average mode share in the city shall be:

- NMT – 35%
- Cars – 15%
- Two wheelers – 34%
- Auto Rickshaw – 12%
- Buses – 4%

When this breakup is used along with expected population of the city in 2036 (based on trip rates discussed in method 1), mode wise average daily trips in the city can be projected for the horizon year. These have been presented in Table 2.

Table 2.: Projection for 2036 as per BAU Scenario 2

Trips by Mode			
Mode	**2016***	**2036**	**Factor of Change**
NMT	2,59,217	3,40,166	131%
2 Wheeler	1,68,757	3,31,736	197%
4 Wheeler	36,085	1,48,663	412%
Auto Rickshaw	87,220	1,10,123	126%
Bus	37,344	38,852	104%

**Projected from 2013 data from Low-carbon Comprehensive Mobility Plan for Udaipur, prepared by UMTCL*

Smart City Scenario

However, since Udaipur is now gearing to be developed as a smart city, it is expected that the proposed interventions (as listed in the smart city proposal) will significantly contribute to the share of public transport and maintain (if not increase) the current NMT mode share in the city. Based on this in a 'smart city scenario' the expected mode share in the horizon year is projected as:

- NMT – 45%
- Cars – 7%
- Two wheelers – 12%
- Auto Rickshaw – 12%
- Buses –24%

The mode share of average daily trips in the horizon year have been projected using the method described above. These have been presented in Table 3.

Table 3.: Projection for 2036 as per Smart City Scenario

Trips by Mode			
Mode	**2016***	**2036**	**Factor of Change**
NMT	2,66,829	4,36,293	164%
2 Wheeler	1,51,701	1,16,345	77%
4 Wheeler	29,687	67,868	229%
Auto Rickshaw	87,713	16,345	133%
Bus	52,694	2,32,690	442%

** Projected from 2013 data from Low-carbon Comprehensive Mobility Plan for Udaipur, prepared by UMTCL*

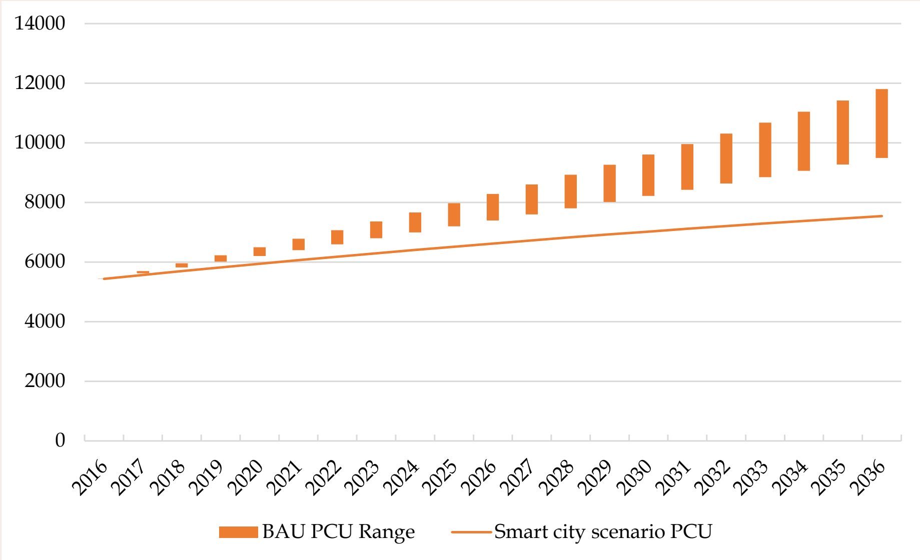
Projections are made in all three scenarios to provide a range of possibilities of modal shares in city corresponding to varying city growth mechanisms. Factor of change projected in trips by mode are as follows:

Table 4.: Trip Projections Across Different Scenarios

Mode	BAU Scenario -1	BAU Scenario -2	BAU Smart City Scenario
NMT	152%	131%	164%
Two Wheeler	71%	197%	77%
Four Wheeler	557%	412%	229%
Auto Rickshaw	59%	126%	133%
Bus	348%	104%	442%

Source: Projections made by a survey conducted by SGA and ICEI-SA

The modal share and percentage increase in trips in the horizon year, estimated by the two methods, provides an overall city picture in a BAU and a smart city scenario. In order to project horizon year demand at Kumharon Ka Bhatta Junction, the current year mode wise hourly trips have been multiplied by the factor increase (for each mode) in horizon year, under each of the above mentioned scenarios. These have been converted to PCU using the current observed average occupancy. The annual projected PCU up to horizon year, by the two methods provide the estimated range of demand at the said intersection in a business as usual (BAU) scenario. These have been presented along with annual projected demand in a smart city scenario in Table 4.



Source: Projection by SGA and ICLEI-SA

Figure 8.: Annual PCU Projection at Kumharo ka Bhatta Junction

These projections when compared against the projections included in the flyover proposal (discussed above) reveal that in the worst case BAU demand is expected to be more than 25% lower than original (2014) projections for horizon year, i.e. 2036. Projected range of PCU in BAU for 2036 is 9496 (Method 1) to 11811 (Method 2). They also show that even though PCU demand at the intersection shall increase in the smart city scenario, it shall remain less than 50% of the original projected demand in the horizon year. Projected demand at the intersection in terms of PCU per hour in 2036 in smart city scenario is 7548. The projection models used for the above projections attribute the increase in the PCU to the following:

- Overall increase in trips due to population and per capita trip rate increase in the city.
- Mode share shift due to increase in income and policy interventions (BAU or smart city scenario)

Alternate Solutions

Against the proposal for the flyover, two alternatives have been discussed. These include: the do-nothing scenario and an at grade intersection improvement approach (with roundabout). Pros and cons of all three proposals have been discussed below.

Business as Usual (BAU)

The current signalized intersection (with the same signal phase design) with the current geometry is retained in this alternative and no provision for cyclists and pedestrians is included. This condition when compared to traffic projections for 2036, suggest that level of service (LOS) and safety condition will deteriorate for both vehicular and non-vehicular traffic. It is expected that the vehicular traffic queue length on all arms will increase by 3.24 %.

Flyover

A 590 m long flyover has been proposed at this intersection. However, an assessment of flyover design reveals that even in the horizon year, this intersection will witness demands much lower than what is warranted for a flyover. Additionally, flyovers are capacity augmentation means, and since this intersection is unlikely to be capacity constrained in the near future, developing a flyover may be inappropriate solutions for this intersection. Also, the flyover proposal includes no provision for significant number of bicyclists which use this intersection. Due to ROW constraints the proposed flyover is limited to 12 m carriageway width. This means that the flyover will not support more than single lane traffic in each direction at speeds greater than 30km/h[8].The space occupied for flyover in the middle implies that carriageway width available for turning traffic is limited to 6m, footpath width to less than 2m, with no space for cyclist infrastructure, or buffer for side friction such as parking (including IPT parking), vending activities, landscaping etc. The flyover proposal also leaves no space to accommodate any public transport infrastructure such as dedicated bus lanes or even space for bus stations (near the junction). Thus the plan is likely to go against the smart city objectives of encouraging public and non-motorized transport in Udaipur. A list of pros and cons for undertaking the development of proposed flyover at this intersection has been listed below.

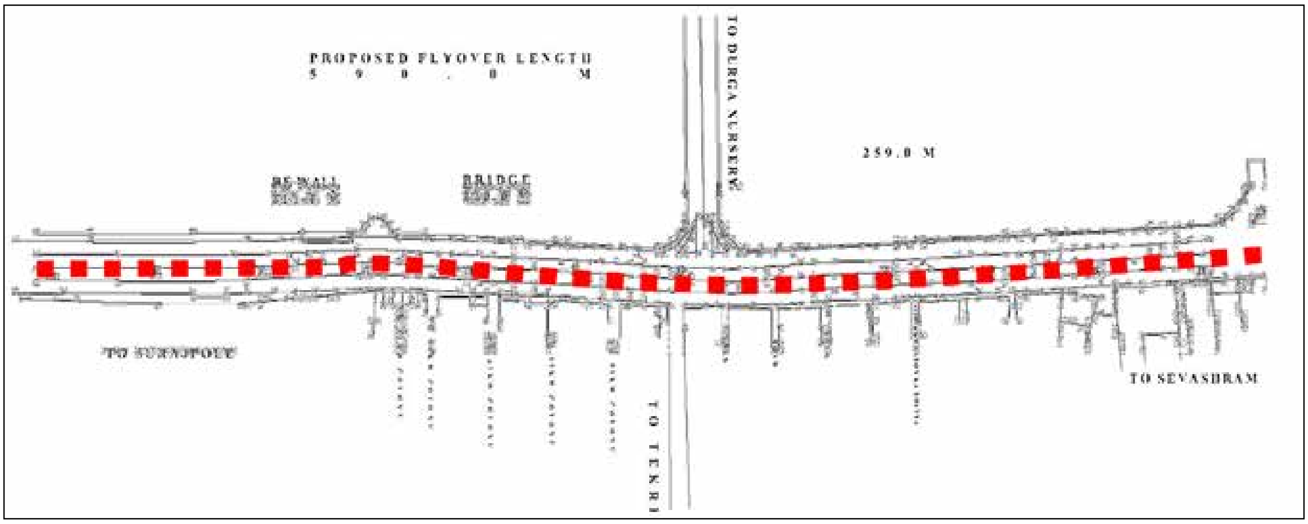


Figure 9.: Proposed Flyover

For

1. By the construction of flyover, 47% of total traffic at intersection, i.e., 16,160 PCU per hour in straight direction could pass smoothly and uninterruptedly through this flyover.

Against

1. As per IRC SP – 90 Manual, traffic flow required for construction of flyover in minimum of 5,000 PCU / hour, which is far more than existing situation, i.e., 3,400 PCU/hour.
2. Cost involved with the project is pretty huge in comparison to delivered benefits.
3. Aligned activities in the abutting area restrict tremendous growth opportunities of urban density, if managed properly.
4. Flyover at Sewashram exists at about 1,200 m from this location.
5. Traffic channelization and junction redesign could help sorting existing issues.
6. Main problem is allocated of creation of bottleneck on the arm leading to Tekri.
7. Economic loss due to land value depreciation of the abutting area of flyover.
8. Societal acceptance hazard as Gurudwara is affected due to flyover.
9. No probable growth of activities on one side of Flyover, due to dead boundary wall of institutes like College of Science and Residential wing of College of Fisheries.

8. As per ASVV Record 15 (CROW, The Netherlands) minimum lane width for speeds equal to or lower than 30km/h is 2.75m, however minimum lane width requirement for light vehicles at speeds up to 50km/h is 3.1m and that for heavy vehicles is 3.3m. These widths are excluding lane marking width and shy away which shall be a minimum of 0.1m wide each.

10. Absence of channelized junction indicates absence of severe traffic problem.
11. Sewashram flyover at a marginal distance of 1km.
12. User survey reflects issue in arm connecting the junction to Tekri rather than on College Road.
13. Construction of flyover will solve the problem of the junction for now, by shifting the pressure to another junction.

Alternate Design Proposal

National Urban Transport Policy (NUTP) 2006 and the objectives of Udaipur Smart City Proposal (SCP) suggest that non-motorized and public transport shall be prioritized in urban area. In line with these recommendations, Udaipur City plans to develop dedicated pedestrian, bicycle and public transport infrastructure as a part of smart city development process. As these endeavours are replicated across the city (over time), it is envisaged that Udaipur city will soon emerge as a city which encourages the use of non-motorized and public transport over private motorized modes, and all streets in the city shall be planned and developed (with infrastructure) to meet this vision. In line with this approach, it is advisable that any road-based project development process is validated against this vision.

Intersection improvement at Kumharon ka Bhatta should accommodate an infrastructure which ensures a safe and reserved ROW for pedestrians as well cyclists, and space for accommodating infrastructure which supports context-relevant activities currently observed on the street (such as pedestrian and landscaping space to support shopping and religious activity on the street along with spaces for parking of IPT, bus stops, etc.). In addition to meeting the city-wide vision, the junction improvement needs to meet local objectives of reducing traffic queues during peak hour. These objectives can be met by modern roundabout development at this intersection.

Since peak hour traffic loads is unlikely to increase beyond 2,400 to 3,400 PCU per hour per direction, on any one arm of the intersection, a two-lane modern roundabout is an appropriate choice as a solution to improve this intersection. The roundabout as a solution for this intersection is advantageous as it is an ideal option to solve a low demand high friction intersection. Additionally, the development cost of a roundabout is significantly less than a grade separated option, and it can handle a wide range of traffic demand[9], simultaneously ensuring safety for all users[10]. It also does not require widening of carriageway width, allowing space for provision of cycle and pedestrian infrastructure as well elements to cater to local/ contextual requirements.

Roundabouts follow design principles that are different and have become a subject of great interest and attention over the last few years in various cities around the world. The intersection design practice has changed substantially because of the good performance of roundabouts and their acceptance by the public. This is because roundabouts are designed for lower speeds, and the dimensions are determined by the number of branches, required capacity, and by the turning radii of larger vehicles. Deflection of the vehicle paths, through the roundabout is a critical design element affecting the safety of the roundabout. The entering traffic must accommodate the circulating traffic. At low traffic loads, vehicles enter without stopping; at

9. At lower demands, the intersection can function as standard roundabout, whereas at higher (saturation) demands) the roundabout may be signalised to provide a more efficient and safer option than a standard signalised intersection.
10. Roundabouts are referred to as sleeping policemen as they prevent traffic conflicts even at night when there is no compliance for signals due to low volumes. Additionally roundabouts equipped with peripheral cyclists and pedestrian infrastructure along with raised crossings (on all arms) not only ensure safety of vulnerable road users but also enforce 'entering vehicle give way to exiting vehicle' behaviour (essential for functioning of modern roundabout design)

higher loads, entering traffic must wait for a gap in the circulating stream. Further, to increase roundabout capacity, entries are flared to provide more than one entry lane, and the circulatory roadway is widened (Transportation Research Board, 1998).

Thus, considering all the above points and design considerations, a two-lane roundabout is proposed at the Kumharon ka Bhatta junction. It is a four arm round about. However, the arm approaching the junction from Tekri side is a narrow road, about 7m wide and approach lane width is considered as 2.75 m here. The other three approach arm of the junction i.e. Durga nursery road, towards Sewasharm and towards Suraj pole or university road are 18 m, 24 m and 24 m wide, respectively. Being 18 m in width, the Durga nursery road is worked out with the provision of painted cycle track (1.2 m wide) and approach lane width of 5.7 m. Although sufficient space for footpath is available but for the desirable width a little land acquisition may be required on the Durga nursery arm. The area is marked in red colour in the proposal. For the other two arms with 24m ROW the approach lane width is considered as 6.7 m with desirable cycle infrastructure and footpath provisions. Overall, the roundabout design is incorporated with proper cycle infrastructure and pedestrian facilities. Design attributes for differently abled people have also been considered.

The design details and the proposed plan at Kumharon ka Bhatta junction is presented below:

Figure 10.: Detailed Plan for the Junction

Analysis and Conclusion

For the purpose of this report, the horizon year has been assumed 20 years from present, i.e. 2036. It has been presented above that a more accurate assessment of projections for PCU at Kumharon ka Bhatta junction are between about 9,500 to 11,800 PCU in (peak) hours in a business as usual scenario, and are under 8,000 PCU in the 'smart city scenario'. This difference is attributed to how total hourly trips at this junction are expected to be distributed in different modes in 2036. Based on this assessment, it can be said that even in the most inefficient scenario, peak hour demand at this junction will exceed 10,000 PCU, not before 2036; while in the other scenarios; it is not expected to cross this mark till the horizon year.

Based on different literature and standards (Manual for Grade Separators and Elevated Structures, 2010) (Transportation Research Board, 1998) (Ourston, 1993) the three alternate options were evaluated. Maximum capacity limit for each of these alternatives has been presented in table below:

Table 5.: Capacity limit of different alternatives

Alternative	Min capacity	Max Capacity	Reference
BAU	5,000[11]	10,000	IRC-SP-90 -2010
Flyover	10,000[12]	15,000	IRC-SP-90 -2010
Roundabout	3,000	8,000[13]	Wide roads and narrow roads

A quick comparison between projected demand at the junction in horizon year and expected maximum capacity of different designs suggests that a flyover may not be warranted as a solution for this intersection at least till 2032. This means that any decision to plan or build one can be deferred till 2030. Thus, as in immediate improvement at Kumharon ka Bhatta, an improved signalized junction or a roundabout (with improved road geometry) can be proposed, and shall be effective in addressing all capacity related issues at this intersection.

In addition, based on the evident safety and efficiency improvements offered by a modern two-lane roundabout over a signalized four arm junction, it is recommended that the junction be upgraded to a modern two-lane roundabout junction. It is proposed that the roundabout shall remain unsignalized till about 2024, by which time the traffic at the junction is projected to reach between 6,400 to 7,600 PCU in peak hour (based on different projection scenarios). After 2024, the roundabout may be signalized to boost its peak hour volume handling capacity, while retaining all its positives of improving safety and efficiency for all modes (even during non-peak hours).

It can also be concluded from the findings of this report that positive policy direction (such as promoting more efficient sustainable modes and discouraging private vehicle use) can be an effective long-term solution in countering congestion in the city, without the need for huge investments in grade separated carriageway infrastructure. Such grade separated infrastructure is not unsustainable and only minority (private vehicle) oriented as they only provide short term capacity solutions while compromising on safety and efficiency of all modes.

11. Not applicable in BAU scenario at Kumharon ka Bhatta junction. This capacity may only be achievable after improvement in geometry, junction layout and signal phasing.
12. Based on estimated 5000 PCU capacity increase over signalised intersection, achieved by addition of max. 5000 PCU per hour capacity 4 lane elevated carriageway.
13. Ourston, L. (1993). Wide roads and Narrow roads. Transportation reserch Board. Washington.D.C.