Mobility Interventions and Strategies for Varanasi

Reincarnating Varanasi – Reincarnating India

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Prepared by

Mr. Sandeep Gandhi,

S. G. Architects, New Delhi

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1. INTRODUCTION

It is known that urbanization is an inherent by product of growing economies such as India. As India strives towards a booming economy with high growth rates, its population must cope with nuances of rapid urbanization. It is expected that by the time India turns 100, its urban population would have crossed 800 million people (National Urban Transport Policy). Thus authorities need to wake up to the challenge of catering to the mobility needs of not just the current but the growing population in their cities. Growing mobility demand has encouraged cities to invest in the development of long term mobility plans, which list detailed mobility strategies for a city.

One of the main objectives of developing detailed mobility strategies for a city is to prepare for impending mobility demand in advance. The provision of a mobility plan should allow cities to avoid potentially long term damaging local reactive measures to address mobility issues. As mobility is intrinsically related to land use and urban planning of a city, these should ideally be developed in an integrated manner. Mobility and urban plans together can influence and project future mobility requirements which can be planned for in advance. In addition mobility plans should be holistic in terms of addressing not only the entire mobility network of a city, but should also be sensitive to the requirement of different income groups.

2. VARANASI MOBILITY SCENARIO

Like any other Indian city, the mobility scenario in Varanasi is influenced by the size of the city, and more so by the economic profile of its population. The city has two distinct layers. The innermost layer which is bound between the river and the primary rail road is very dense with closely packed network of narrow streets; and accommodates more than 2/3rd of the current population in a small area of less than 25 sq.km. This inner dense layer, or the core area of Varanasi (Figure 10) is expected to have very short trip lengths with to majority walking to work. This is in line with the trip profile of similar sized Indian cities. For example Patna City Mobility Plan (CMP) (2009) states that this city which had a population of 2.0 million and a 110 sq km area within municipal limits has an average trip length of 5.8 km.

Figure 1: View of a typical street in Varanasi

2.1 CURRENT MOBILITY SCENARIO

It is understood that Varanasi Development Authority invested in the development of a detailed Mobility Plan which should contain important findings on the mobility scenario in the city; however since this report could not be accessed, our assessment of Varanasi mobility scenario is based on proxy secondary data and its validation through limited primary surveys as well Varanasi demographic data.

2.1.1 VARANASI STREET NETWORK

An estimate of total Varanasi street network has been made using available secondary data and Google Earth imagery. A 0.5 x 0.5 km area was selected in the middle of the core area for street length estimation. All streets in this area were observed and length and right of way (ROW) details recorded. Based on these observations it is estimated that streets occupy 21% of total area in core Varanasi. Total length of streets is estimated at approximately 28km per sq.km. Of these only 4% are roads with ROW greater than 20m and can be classified as sub arterial, 13% have ROW between 12 and 20m and can be classified as collector while the rest 84% have an ROW of less than 12m (some as narrow as 1m) and are thus classified as local streets (Figure 2).

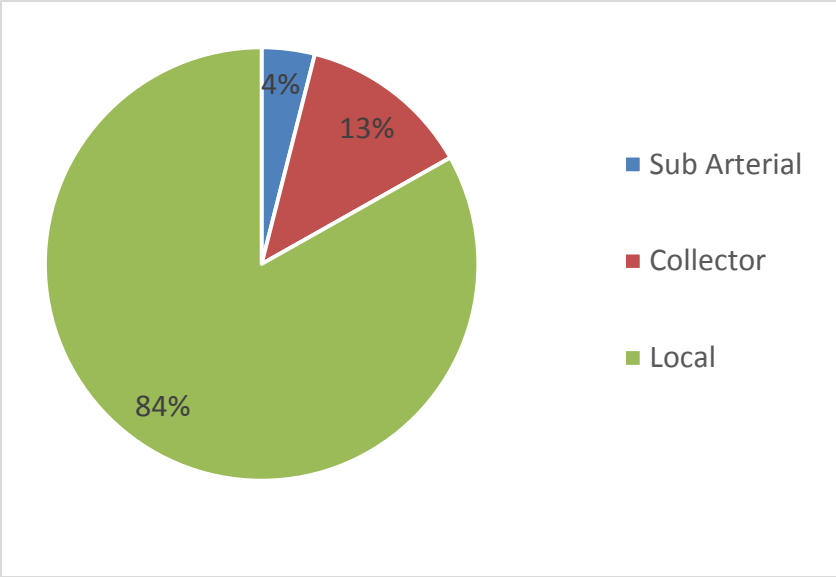

Figure 2: Street network in Varanasi

None of the streets in core Varanasi can be classified as arterial roads as they all have ROW less than 30m. However outside the core area, some streets which are part of the National Highway network have higher existing or planned ROW and can be classified as Arterial Roads. Based on the observations, our estimate of total Varanasi road network for an area of 160 sq.km (planned urban extension of Varanasi including core Varanasi) is approximately 2500km, while total street network in core Varanasi alone is approximately 690km.

2.1.2 VARANASI TRAFFIC AND TRIP PROFILE

For proxy traffic and trip data Patna city mobility profile (source: Patna CMP 2009) is used because of similarity in city size and characteristics. In addition Patna is similar to Varanasi in terms of per capita income profiles. For example average monthly income of a slum household in Varanasi is estimated to be between 2500 to Rs. 3750 (Source: Varanasi City Development Plan, 2006), which is similar to the average monthly slum household income in Patna at Rs. 3059 (Source: Patna CMP, 2008).

Average peak hour vehicular journey speed in Patna is estimated as 20km/h in 2008 and is forecasted to have a trip rate of 1 in 2013 (Source: Patna CMP 2009). Based on this it is assumed that average trip rate in Varanasi is 1 while current average vehicular journey speed is expected to be between 18 to 19km/h.

Because Varansi has a smaller size and population base than Patna and is not a capital city like Patna, Varanasi's per capita income and average trip length is assumed to be about 10% less than that in Patna. Mode share for Varanasi has been calculated based on 29 different primary observations in the city, along with mode share data

for 13 major junctions included in the Varanasi City Development Plan (CDP), 2006. Share of walk trips in Patna is 29% (Source: Patna CMP, 2009), and in Delhi it is 32% (source: Traffic Demand Forecasting Study for Delhi, 2010). Because of smaller city size and lower income levels the share of walk trips in Varanasi is assumed to be 37%. The numbers have also been validated with recent primary video based traffic volume counts conducted in Varanasi.

Figure 3: High share of pedestrian, cycles and cycle rickshaws traffic is evident on Varanasi streets.

Based on these assumptions it has been estimated that in 2014 the average household income in Varanasi is expected to be approximately Rs. 7400 per month; 47% of households would have an income no higher than Rs. 3000 per month1 while 67% of households would have an income of less than Rs. 6000 per month. It is assumed that minimal cost of using public transport (round trip) including feeder modes is Rs. 25 per day (return journey). In comparison the average cost of using the Metro for a return trip in Delhi is Rs. 41 (Goel and Tiwari 2012). If an average of 1.5 members in the family are expected to travel for work then 67% of the families in Varanasi today will not be able to afford even a subsidized public transport system[2].

Since income determines mode choice (especially in low income cities) it should not be a surprise that mode share in Varanasi closely mirrors affordability assumptions. 67% of trips in Varanasi are by walk, cycle and cycle rickshaw

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[1] *Income figures have been extrapolated from estimated 2008 numbers using an average annual growth rate of 9%. Income frequency distribution is assumed to be same as that for Patna.*

[2] *Based on the known maximum transport budget of 15% of family income*

and in that sense are non-motorised. 14% use some form of public transport which is mainly shared auto rickshaws (ideal for low trip length cities), while only 19% use private motorised modes which is mostly two wheeled motor vehicles (Figure 4). Also since the average trip length in Varanasi is estimated to be less than 5.3km, cycling and walking is expected to have a higher share in mode choice.

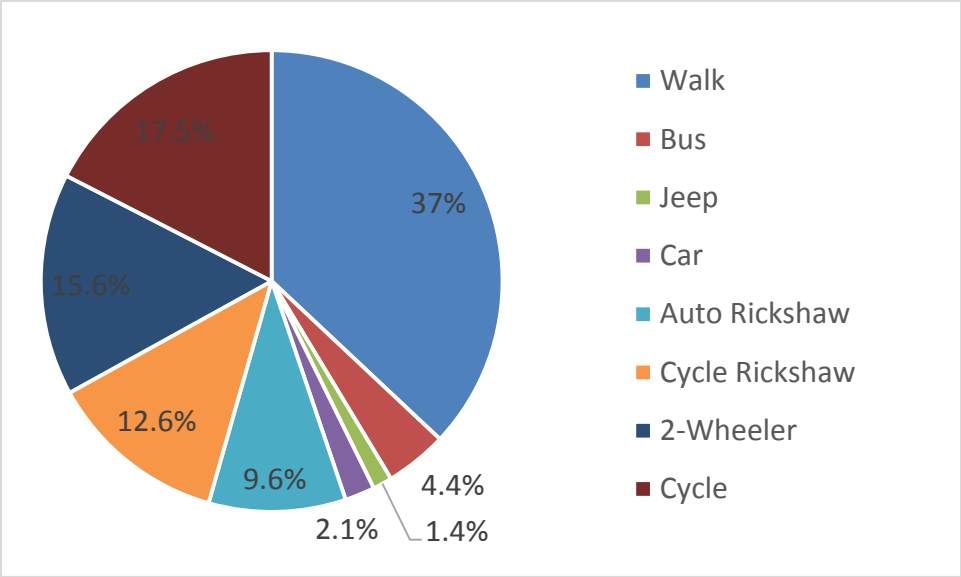

Figure 4: Varanasi Mode Share 2014

2.2 MOBILITY SCENARIO 2031

Varanasi development and mobility plans are targeted for 2031 as the horizon year. Since even at a 10% growth rate, Varanasi is likely to remain a very low per capita income city in 2031, it can be safely assumed that income levels will continue to guide mobility choices in the horizon year. Expected income levels and income profiles can therefore be used to project the mobility scenario in 2031. It is estimated that average annual household income in Varanasi in 2031 shall be Rs. 32,000 per month which translates to approximately Rs. 13,000 per month at current rates[3]. Using these figures it is estimated that 52% of households in Varanasi will not be able to afford even a subsidised public transport and thus shall continue to rely on non-motorised modes to meet their mobility needs.

By assuming the ratio of public transport and private motorised mode trips to be the same, we can estimate the broad mode share in 2031. It is expected that in the horizon year 53% of trips shall be by walk, cycle and cycle rickshaw (with a highest share of walk trips). 20% will opt for some form of public transport i.e. shared vehicles such as auto rickshaw, bus or mass transit system such as the Metro (the highest share shall be in the order of expected fare price i.e. Auto rickshaw, followed by bus, followed by Metro). 27% of trips shall be by private modes with a majority of motorised two wheelers.

3. VARANASI MOBILITY STRATEGIES

[3] *Based on average annual inflation of 5.5% and average annual income growth rate of 9%.*

Mobility strategies and recommendations for Varanasi have been derived after understanding the current and future mobility requirements (as presented in previous section) and the appraisal of the Varanasi, Comprehensive Mobility Plan (CMP), 2009 against current understanding of performance and requirements of mobility solutions suggested in the same.

3.1 Review of Varanasi CMP 2009

It is known that the Varanasi Development Authority (VDA) commissioned a study to develop the Varanasi Comprehensive Mobility Plan (CMP), which was submitted to VDA in 2009. Though the report itself is inaccessible, broad findings of CMP are known from various print media coverages of the same in that year. Following are some of the project/development recommendations of the mobility plan[4]:

1) Three ring roads (inner, middle and outer).
2) Elevated roads on the routes including Cantt Railway station to Bhelupur via Sigra, Maidagin to Godowlia, Lehartara to Chawkaghat via Cantt Railway Station, Kuchehri to Pandeypur.
3) Railway over bridge at Ashapur, Kuzzakpura, Manduadih and Hasanpur railway crossings.
4) Widening of Cantt-Padao, Lehartara-BHU, Cantt-Lanka, Mohansarai-Cantt., Cantt-Lahurabir, Varunapul-Lahurabir via Andhrapul, Padao-Ramnagar, Godowlia-BHU, Hukulganj-Pandeypur and Rathyatra-Bhullanpur roads.
5) Signalisation and beautification of city crossings.
6) Multi-level parking areas at commissionery compound, Cantt Railway Station, Maidagin park, Shahid Udyan, Tulsi Manas Mandir park, Beniabagh and Machhodari parks.
7) Two bridges on the Ganga at Samneghat and Baluaghat.
8) Underground rail transit between Lanka and Sarnath via Cantt Railway Station.
9) Light elevated rail transit between DLW and Mughalsarai, and from Kuchehri to Babatpur.
10) Low capacity buses on various routes.
11) Sub-ways at Cantt Railway Station, Maidagin, Godowlia and Pandeypur.
12) Skywalk between Maidagin and Machhodari, and from Godowlia (Girjaghar) to Dashaswamedh.
13) Underground market (Banaras Haat).
14) Ropeway on river Ganga at Dashaswamedh and Sant Ravidas Ghats.

Since detailed basis of these recommendations are not accessible, the said recommendations can be compared against the understanding of current and future mobility requirements in Varanasi as well against Urban Transport Policy recommendations as listed in the National Urban Transport Policy, 2006[5]. (NUTP)

The recommendations of CMP Varanasi, 2009 have been classified in to three broad categories. These categories are based on those listed in the NUTP, 2006. Further expected budgetary provision for each of the categories has been estimated and presented in

Table 1, along with expected mode share in 2014 and 2031.

[4] *Source: Article titled, 'Heritage City gets a facelift'; Times of India, Varanasi Edition; July 28, 2009*

[5] *NUTP, 2006 recommends prioritizing non-motorized and public transport over private motorized modes in cities*

Table 1: Category wise investment for mobility plan recommended projects

NUTP Priority	Project Recommendation	Expected cost (in crores)	Cost as % of total CMP project Budget	Mode Share 2014	Mode Share 2031
1	**Non-motorized Transport** (Walk, cycle and cycle rickshaw) 1. 3 Subways and 2 Skywalks	20[6]	0.3%	67%	53%
2	**Public Transport** (Bus, Metro, LRT) 1. 24km Metro rail network, a portion of which is proposed to be underground. 2. 18km long Light Rail (LRT) corridor. 3. Ropeway over river Ganga. 4. Mini Buses	4755[7]	64.7%	14%	20%
3	**Private Motorized modes** (Car, two wheelers) 1. Three ring roads totaling approximately 184km 2. Total 16km of elevated roads 3. Signalization and beautification of city crossings 4. Seven multi-level car parking 5. Two river bridges	2575[8]	35.0%	19%	27%

The mobility plan proposes a miniscule investment (less than 0.3%) of the total plan budget for mobility projects for the majority (67%) mode share of non-motorized transport. The recommendations prioritize motorized transport over non-motorized modes which are against the policy recommendations included in NUTP 2006. The project list included in the CMP 2009 recommendations hint at an 'infrastructure development' focus instead of 'mobility solution' focus. This is based on the perceivable disconnect between the proposed mobility solutions and ground realities of mobility requirements.

[6] *Based on an estimated cost of Rs. 4 crores per subway and skywalk*

[7] *Based on Rs. 150 crores per km as Metro development cost, 60 Crores per km as LRT development cost, Rs. 40 crores per km for ropeway development cost and Rs. 16 lakh per bus (for 100 buses).*

[8] *Ring road development cost based on 5% elevated length developed at 65 crores per km and 95% at grade length developed at Rs. 4 crores per km; Elevated roads developed at Rs. 65 crores per km; Signalization of 10 intersections at Rs. 1 crores per km; multi-level car parking at Rs. 4 lakh per vehicle for 250 vehicles each; river bridges at Rs. 80 crores per bridge.*

The objectives of developing mobility strategies and planning transport interventions in Varanasi is to improve the overall mobility scenario in terms of reducing travel cost, travel time, displeasure involved in travel as well as adverse health effects of transport (such as accidents and pollution). The CMP 2009 recommendations focus on realizing these objectives for the minority which can afford to spend over Rs. 600 per month on travel.
These recommendations not only offer zero benefit to a majority who will continue to walk and cycle to work; they offer negligible relief to those who would opt for public transport or private vehicles.

Metro offers very high trip speeds of an average of 32km/h within the network. Since this is a significant improvement of current estimates of peak hour journey speeds in Varanasi at about 19 km/h, it is often assumed that such systems will attract high ridership (on account of significant journey time savings). However most of the rail transit systems including that in Delhi continue to operate at a fraction of its estimated ridership (Source: Mohan 2008). This is because the average speed within the network does not necessarily reduce travel time, if access and egress time from the system constitutes a significant portion of the total journey time.

High and medium capacity urban rail transit projects such as Metro and Light rail projects have smaller networks and limited reach (because of high development cost). Proposal for the Varanasi rail based transit projects (Metro and LRT) is a total of 42km network. This is less than 2% of the total street networks in Varanasi. This is why rail based urban transport systems are heavily dependent on feeder systems in order to attract the high capacities they are designed for. Since feeder trips are the slowest components of a transit journey (as that is generally through mixed traffic and by slower modes such as walk or cycle rickshaw), an overall reduction in commuter journey time is likely only if the journey is long and the component on the train is a significant portion of the total journey. This is validated by studies conducted on the Delhi metro rail which finds that an average trip length on the Delhi metro is in excess of 20km, and more than 80% passengers on Metro travel longer than 10km (Goel & Tiwari 2012). Since an average trip length in Delhi is less than 10km and only 20% of trips in the city are longer than 10km, it should come as no surprise that there are little takers of the Metro (Source: Goel & Tiwari 2012). Mode share of Metro (of total trips in Delhi) was a dismal 3.6% in 2007 (Source: Rites Travel Demand Forecasting Study for Delhi, 2010) and is not expected to exceed 5%.

Figure 5: Artist's impression of Varanasi Street with an elevated Metro Corridor

As estimated above, Varanasi has about half the average trip length as in Delhi. Less than 5% of trips in Varanasi are expected to be longer than 10km. This trip profile is not expected to change significantly in 2031 when the city population is expected to be 2.6 million[9]. This means that the Metro Journey time would comprise significantly of feeder trip time which would make these trips longer and thus undesirable. Hence it can be assumed that Metro and LRT trips will attract mainly walk based feeders and are thus not expected to attract more than approximately 15,000 trips per day in an optimistic scenario[10]. This is less than 0.9% of the total trips in Varanasi (and its suburbs) making it an unviable option for the city.

Flyovers or grade separated (elevated or underground) roads have been a common tool to resolve congestion for transport and urban planners alike. These have been in popular use in Indian cities for 32 years after they were first introduced in Delhi during Asiad Games in 1982. Scores of flyovers get constructed in Indian cities every year, and all of them attempt to lift traffic out of congestion and increase their journey speeds (thereby reducing their journey time). However average traffic speeds have shown a constant decline in all cities (with or without flyovers). This is evident from data collected in Delhi, which shows that as the total km length of flyovers in Delhi have been increasing over the years to a total of 84km, the average traffic speed has fallen steadily from 28km/h in 2001 to 18km/h in 2013(source; 11) (Figure 6). This is because there exists a huge latent demand for private motorized trips, which increases use of cars and two wheelers, thus leading to increasing congestion. This increasing dependence on private modes is only addressed by high congestion levels which discourages non-essential trips and increased car usage. This is why most cities have stabilized traffic speeds between 15 to 18km/h (Source; 12).

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[9] *Based on comparison with trip profile of cities with population between 2.0 and 3.0 million.*

[10] *Based on: catchment of 250m on either side for maximum walk distance of 750m when stations are located 1000m apart, Metro is mainly used for work, leisure or education trips and 1.3 persons from each household (with total 5 members) undertake return journey or two trips daily, 35% of potential commuters in the catchment area can afford to pay for their return journey by metro, and 40% of this potential population which can afford journey by Metro actually shift to metro.*

[11] *Source: Various print media reports from 1982 till 2014, CTTS by Rites, 2001, CTTS by Rites, 2009, Tripp IIT Delhi traffic Study 2013.*

[12] *London – 19km/h, source: Forbes Europe, 21 April, 2008 ;Beijing – 15km/h, source: Evaluation of the Affect of Car use Restriction in Beijing by Sustainable Transport Research Centre, China; Bangalore – 14km/h, source: Traffic Demand Forecasting Plan for Bangalore, 2007; Shanghai – 16km/h, source: China Daily, 31 August 2012.*

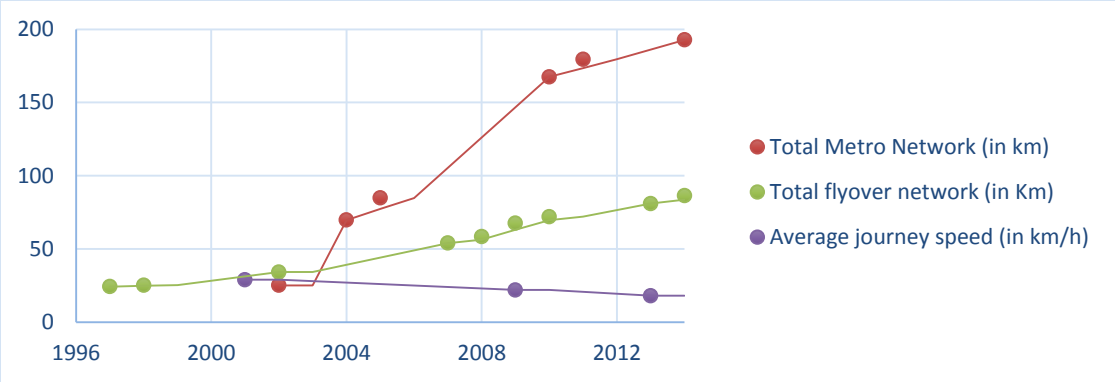

Figure 6: Graph showing the trend of decreasing average journey speed despite increasing flyover and Metro network in Delhi

Figure 7: Artists impression of a view of our elevated road on a Varanasi street

Adding flyovers locally increases capacity leading to short term local relief, while in the long term vehicular speeds continue to fall as any increase in capacity is quickly overcome by increased trips. While even short term benefit of flyovers is unlikely to affect more than 3% of the population[13], the by-product of resultant increased trips is inadvertently, an increase in pollution and accidents will have a negative health impact on the entire city. This is why most developed cities have stopped the construction of any urban freeways and are in fact bringing down those which already exist (example: Seoul, South Korea).

[13] *Estimation based on total percentage of grade separated infrastructure on Arterial Road Network of Varanasi (6%), percent of private motorised trips (19%) and average trip length (5.3km).*

3.2 Mobility Recommendations

The economic and tip profile of Varanasi clearly suggests that a majority will continue to use non-motorized modes of transport including walking, cycles and cycle rickshaws. Thus efforts on reducing travel cost, travel time, and increasing travel comfort as well safety, will yield best results if they are focused on these modes. Standard capital and infrastructure intensive mobility solutions such as urban rail and flyovers will not just ignore but go against the long term interest of almost all residents and thus should be avoided.

3.2.1 Focus on Streets

As discussed above, large infrastructure investments such as those in flyovers and urban rail will not yield any reduction in congestion levels, which are expected to increase in Varanasi till average vehicular speed stabilizes at around 15 to 18km/h in the city. Since vehicular congestion cannot be resolved, our effort should focus instead on removing people from congestion. As most people will continue to walk and cycle, it is these trips that need to be moved out of congestion.

Primary surveys conducted on major roads in Varanasi[14] create a clear picture of mid-block vehicular demand on these streets. Analysis of data from these surveys show that Varanasi's streets have a maximum of 2600 PCU per hour per direction demand when non-motorized vehicles are included, and a maximum of 2100 PCU per hour per direction when cycles and cycle rickshaw are excluded. This means that almost all streets in the city currently process traffic volumes which is well below their capacity[15]. This implies that high congestion and reduced travel time is not attributed to capacity limitation, but to high friction between vehicles with different speeds (including pedestrians). This indicates that any capacity enhancement efforts (including flyovers) would continue to be counterproductive, till friction on these streets is addressed.

It can be argued that it is not just slow moving modes such as pedestrians, cyclists and cycle rickshaw which create friction for faster motorized modes, but static functions sometimes called "encroachment" on the streets also result in significant friction. These include hawkers or street vendors, spillover of local shops, street parking of private vehicles, auto rickshaws, cycles and cycle rickshaws. Though these static functions may seem as obvious impediments to free movement of people, goods and vehicles, which justifies there removal; it is estimated that these functions are the prime source of income for 22% of Varanasi population, and thus should be conserved and accommodated[16].

These arguments make a case to focus mobility improvement efforts on the streets of Varanasi for the following three reasons:

1) Vehicular traffic congestion can be addressed on all streets by segregating slow moving vehicles and traffic from faster motorized modes.

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[14] *Video based traffic survey of Varanasi streets conducted on August 20 and 21, 2014.*

[15] *Based on IRC recommendation for Level of Service A, i.e. 1200 PCU per hour per lane; and current street sections, available carriageway width and number of lanes for movement of vehicles.*

[16] *13% dependent on hawking and vending, 4% dependent on cycle rickshaw, 3% dependent on auto rickshaw and 2% dependent on shops facing streets. These estimates based on hawker data in Bihar cities from www.spurbihar.com, land use data from Varanasi CDP, 2006. Auto Rickshaw driver estimates are based on 20 trips per driver per day. Cycle rickshaw puller estimate is based on average daily income figures from CDP 2006 and total cycle rickshaw trip estimates.*

2) Since majority commuters are walking or cycling, 67% of population can benefit from higher speed, safety and comfort by simply providing them with their reserved space in the form of walkways and cycle tracks.
3) Businesses from the street can take advantage of better street designs if related functions and requirements are accommodated in the plans; improving the income levels of 22% of the population.

Based on this, recommendations and sample plans for different category of streets have been developed. These are presented below:

Arterial and Sub Arterial Streets

Streets, equal to or wider than 30m ROW, are classified as arterial streets. Currently most streets in core Varanasi do not match this classification though the Varanasi Development Authority has recommended land acquisition for the widening of multiple roads to widths in excess of 30m[17]. Our assessment however shows that almost all streets in Varanasi has traffic which can be accommodated in two or less lanes per direction. This implies that excess land acquisition and damage to urban fabric of this heritage city can be avoided by developing sub arterial roads in the core area, with widths ranging between 20m to 27m. Sub arterial roads are proposed with 4 lane (3.1m wide each) carriageway; min 1.2m wide cycle lane or min. 2.2m wide cycle track, and minimum of 1.8m wide (barrier free) footpath in each direction. Any available space or widening of the ROW shall be utilized to accommodate designed hawkers spaces, street furniture, cycle parking, cycle rickshaw parking, auto rickshaw parking, limited on street car or two wheeler parking, bus stops, etc. All sub arterial streets shall include junction improvements (including ITS based signaling systems) lighting provisions (designed for average 40 lux and 40% uniformity), street signs, pavement marking, drainage systems and other integrated utilities (Figure 8). It is estimated that a total of 23km of sub-arterial road network would need to be developed within core Varanasi at an estimated cost of Rs. 200 crores which includes the cost of acquiring 44,600 sq.m for widening (Rs. 32 crores).

Figure 8: Artists impression of a sub-arterial road in core Varanasi post planned improvement.

[17] *As per recommendations in Varanasi Master Plan, 2013 and CMP, 2009*

Better right of way of way exists outside the core area especially on highways entering Varanasi. As this area is urbanized and developed as part of the proposed Varanasi extension, these highways should adopt the role of urban arterial streets with a maximum speed limit of 50km/h. This requires these highways, to be transferred to the Municipal Corporation from the point they enter the municipal limits. This issue is discussed further below.

However better right of way and presence of large commercial and industrial functions along these proposed streets suggest that these shall be provided with service lanes on either one or both sides. These service roads shall be additional provisions in the planned redevelopment of the arterial roads which shall include besides these, all the other provisions and features of sub arterial roads as mentioned above (Figure 9).

Figure 9: Artists impression of an arterial road in Varanasi extension, post planned development

It is known that increased density of road network improves a ciy's mobility scenario, by reducing trip length (thus travel time) and improving accessibility. Network density of arterial roads for cities is recommended to be, based on a 1.5 to 3km grid. This implies that current proposed conversion of National and State Highways to arterial roads will not allow sufficient density in Varanasi extension. To improve this as a network of rural roads have been identified to be upgraded to arterial roads and will thus require significant land acquisition. However since this area is currently sparsely built, such acquisition should have minimal social impact.

It is expected that the development of these arterial roads totaling about 150km in length shall cost about Rs. 1940 crores. This includes the cost of acquiring about 6 lakh sq.m. land (Rs. 151 crores). Figure 10 presents the proposed plan for Varanasi with the proposed arterial and sub arterial road network (marked in dark green).

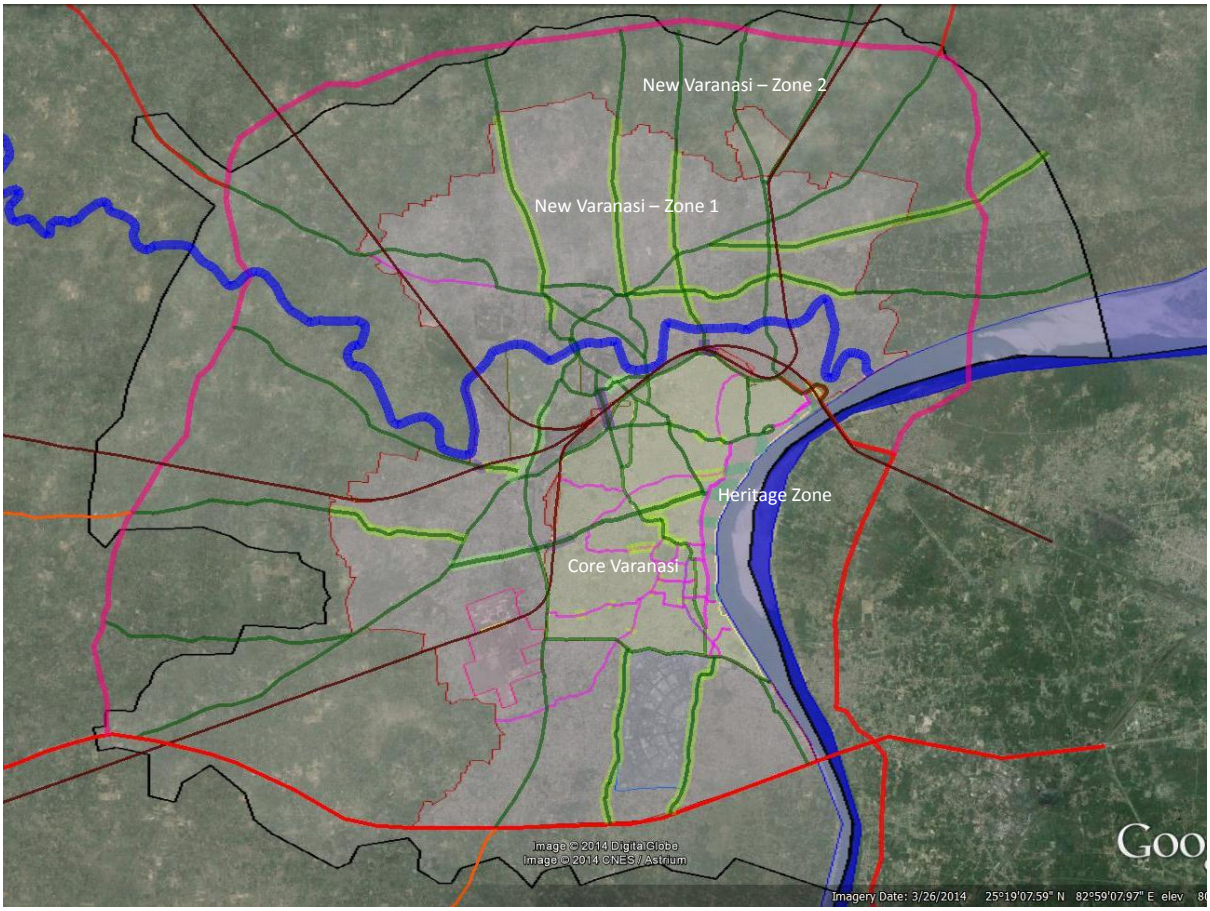

Figure 10: Plan showing Varanasi Extension (or New Varanasi zone 1) and the core Varanasi, along with proposed network of arterial roads (in dark green), land acquisition (in light green), network of proposed collector streets (light magenta), National Highways (Red), State Highways (orange), proposed express bypass (dark magenta) and existing rail roads (brown)

Collector Streets

Collector streets function to connect neighborhoods and local streets with arterial and sub-arterial streets. Since core Varanasi has a well-defined road network; streets that serve the function of linking sub-arterial roads with neighborhoods and strengthen the network can be easily identified and improved. A total of 40km network of streets with a proposed right of way of between 12 and 20m have been identified as collector streets. This network includes some bottlenecks which would involve land acquisition. Suggested features of collector streets which includes one vehicular lane (2.75 to 3.1m wide each[18]) in each direction, pedestrian walkways, lighting, hawker spaces, cycle lanes (not on all streets), street furniture, street parking, provisions for other utilities, sign boards, pavement marking, etc. In addition traffic calming in the form of speed tables, rumble strips, chicanes, etc. is proposed to ensure maximum design speeds of 30km/h on this network in order to ensure safety of all

[18] *As per recommendations for 30km/h roads included in Urban Road Codes, MouD and ASVV (Crow Manual) The Netherlands.*

vulnerable road users (Figure 11). The estimated cost of collector road network development is Rs. 150 crore. This includes the cost of acquiring 13,000 sq.m. of land (Rs. 9.8 crore).

Figure 11: Artists impression of a collector street in Varanasi after proposed development

Local Streets

Core Varanasi has a very dense network of narrow local streets which are mainly pedestrian streets. It is estimated that the core city has a total network of 647km local streets. Most of these streets have traditional stone paving which is still in good condition. It is proposed that these local streets be upgraded by repairing and improving the surface condition, adding adequate sign boards and pavement marking, providing footpaths (only on streets with ROW between 9m and 15m), providing lighting, improving other utilities and adding traffic calming measures to ensure that vehicular speeds do not exceed 15km/h. It is expected that a total of Rs. 690 crores will be required to upgrade all local streets within the core area of Varanasi. No land acquisition is expected or required for this up gradation (Figure 12).

Figure 12: Artists impression of a local street in Varanasi after proposed development

In total it is estimated that the above suggested development and improvement of 840 km of streets in Varanasi will significantly improve transport and mobility situations for 85% of the residents[19]. In addition it will positively affect the economic wellbeing of 22% of its residents.

[19] *Based on population and road network density in core Varanasi and proposed Varanasi extension*

3.2.2 Develop Bus & Auto Based Public Transport

Two types of public transport systems are in existence in Varanasi. The city has a bus based public transport system which includes 135 mini buses provided by the central government as a grant under JnNURM, and it has an estimated fleet of over 7,000 auto rickshaws a majority of which function as shared public transport on fixed routes (carrying 3 to 5 passengers) at a fixed fare. It has been discussed that economic and other constraints would result in very low patronage of mass transit systems, making them unviable for the city. However as the city expands in to the proposed Varanasi Extension, and new arterial road networks in the said area are developed (as discussed above), there is likely to be an increased in demand for low and medium capacity public transport systems. This demand would be mostly comprised of new trips but is also likely to include significant trips of those who might shift from shared auto rickshaws as their trip length increases. This generates the requirement to upgrade and expand the current bus based public transport system. MoUD norms suggest an estimation of bus fleet for a city based on 1 bus for every 2500 residents. This totals to a total of 640 buses for Varanasi. A uniform applicability of this norm is however debated. This is because smaller cities like Varanasi have a lower mode share for public transport. An estimate of fleet requirement for Varanasi based on city context, suggests a total fleet size requirement of 500 buses[20]. This is less than, but close to the figure derived from MoUD norms.

Figure 13: Shared auto rickshaw in Varanasi

[20] *Based on arterial road networks, expected route length, expected number of routes and planned headway*

To meet its operational and economic requirement, the proposed bus system is expected to operate at a headway of between 6 to 10 minutes. This may be acceptable for commuters with longer trip lengths but would not attract low to medium trip length commutes, which will still be served mostly by shared auto rickshaws. Thus shared auto rickshaws will continue to be a significant contributor to public transport in Varanasi. In order to eliminate competition between these modes and to increase their efficiency; it is proposed that an Special Purpose Vehicle or a Varanasi public transport institutional arrangement integrates the two services, by bringing the shared auto rickshaw (as well all buses) under the same regulatory mechanism, which ensures good service quality through close performance monitoring.
It is estimated that a total of Rs. 365 crores would be required to put in place a robust integrated public transport system. This would include purchase or development of the following:

- Additional bus fleet required – 365, including 40 Low floor buses and 325 Mini buses
- 4 Bus Depot
- 10 Terminal
- 600 Bus Stops
- Intelligent Transport Systems (ITS) and Passenger Information System (PIS) integration (including PIS and GPS on bus stops, buses and auto rickshaws)
- Establishment of a Special Purpose Vehicle or new urban public transport body for regulating and managing both the bus service as well shared and single auto rickshaw service (in line with Alwar Vahini and G-Auto)
- Integrated (common) Control Centre
- Regulated fare structure

3.2.3 Develop Express Bypass

Varanasi CMP, 2009 proposes the development of three ring roads. The total length of these ring roads is estimated (from description provided in Media reports) as 184km, i.e. 110km long outer ring road, 48km middle ring road and 26km inner ring road. While the inner ring road proposes to bound core Varanasi, the middle and the outer ring road are on the edge and far outside the municipal boundary respectively. All three ring roads are planned for signal free fast traffic, and thus the inner ring road will be developed by widening and developing grade separated junctions on the exiting road network.

In a radial city like Varanasi, ring roads help complete and densify the street network which improves mobility by reducing trip length (and thus travel time). However the requirement of a ring road within urban limits with specific intention of fast and express movements of vehicles is contested, because of the safety and accessibility concerns for majority non-motorized mode users. This is why the development of inner ring road is not proposed.

The outer ring road can be useful for connecting highways which may serve as a bypass and limit truck traffic from entering the city (a concern for increased pollution, congestion and accidents). However a large circumference of the outer ring road makes it unviable as a detour for truck traffic. It is suggested that the middle ring road, with modified alignment and shorter length of 40km, may be better suited to take this role. It is proposed that this ring road be developed as an express bypass connecting five national and state highways on the edge of Varanasi extension. The development of such an expressway is expected to cost approximately 800-900 crores and may be taken up by NHAI. Land for the same may be transferred by the state government to NHAI in exchange of the

highways extending inside the ring, which shall be handed to the Varanasi Nagar Nigam for development as urban arterial roads (Figure 10). The development of this proposed express bypass[21] is expected to contribute to improved mobility scenario in Varanasi, by restricting through heavy vehicle traffic outside municipal limits and by allowing conversion of highways within municipal limits to urban arterial roads with a maximum speed limit of 50km/h.

3.2.4 Other Interventions

Besides the above mentioned interventions additional strategies suggested below are expected to contribute to mobility improvement in Varanasi. Some of these strategies are included in the Varanasi CMP, 2009.

1) Four railway over bridges at different rail crossings are proposed in the Varanasi CMP, 2009. It may be a good idea to develop these bridges, however these may be integrated with planned development of railway stations as a part of the proposed urban plan for Varanasi.
2) Seven multi-level car parks are proposed to be developed as part of Varanasi CMP recommendations. These may be developed at critical locations, however it is recommended that the same be undertaken after finalizing an overall Varanasi Parking Policy and associated parking norms as well tariffs[22]. It may be recommended to develop large area wide integrated parking contracts assigning surface and multi-level car parking to the same contractor in order to ensure better enforcement and implementability of parking norms.
3) Two bridges are proposed on river Ganga. These may be developed after finalizing the alignment of the proposed express bypass, which also proposes the development of additional river bridges.
4) There is a proposal to develop a ropeway across river Ganga in the Varanasi CMP, 2009. Because of its limited reach and accessibility, this system is unlikely to serve the mobility requirements of the city; however the same may have viability as a tourist infrastructure.
5) Hundreds of tourist buses/vehicles and nearly 17000 Intermediate Public Transport (IPT) vehicles such as auto rickshaws and cycle rickshaws lack space for parking and servicing. These currently park along the streets at night. It is proposed that multiple parking and servicing sites be identified and earmarked for these vehicles.

3.2.5 Institutional Re-Structuring

The proposed mobility strategies focus mainly on mass development of city streets. It is understood that such a development would answer the mobility needs of more than 85% of the population. It is expected that since most Indian cities have similar economic and travel characteristics, such an intervention would be beneficial in all such cities. However none of the city CMPs raise this issue in their findings or recommendations. This may be because street development and improvement has not been recognized as a formal mobility improving strategy. Possible reason for this could be that the format of mobility plans is mostly borrowed from western societies which have very different requirements and focus.

The other reason why street based interventions have not been identified as affective mobility strategy is because unlike other strategies such as development of metro, BRT, elevated roads, etc. for which both capacity and institutional structures exist; there is none for street development. This is evident from the current structure of Municipal corporations, Development Authorities and Public Works Department, which have, neither street planning or design capacity nor any such position.

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[21] *It is proposed that Express Bypass should be developed as per International Highway Safety Guidelines*

[22] *As per known best practices, it is recommended that parking tariffs shall be based current land prices with surface parking attracting a premium.*

It is therefore recommended that in Varanasi City, Institutional framework should be modified to include formal departments of corporations solely responsible for urban street development and maintenance. This would require support both at a policy and legal level. It is expected that without such an intervention, mobility strategies listed in this report would either remain on paper or be largely be ineffective, if at all implemented.

References

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