Enhancing "*Mobility*" through Integrated Transportation and Traffic Management

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Executive Summary

During the course of preparation of a master plan for the transportation networks in Bangalore city, mapping the various initiatives and interventions planned towards addressing mobility, existing situation and implications of some of the proposed interventions was analysed. The inferences are based on existing transportation network; synthesis of various transportation related studies and proposed infrastructure initiatives (road works) in Bangalore. Broadly, they can be summarized as following five aspects:

I. Need for "reclassifying" existing road networks (arterial and sub-arterial) with effective geospatial database in the back-end.
II. The proposed Core Ring Road at surface grade may not be feasible.
III. Current interventions encouraging more independent motorable transport by way of road widening, construction of underpasses, flyovers and grade-separators would not ease traffic congestion when addressed in isolation.
IV. Factors affecting time and cost-overruns in infrastructure projects and ways to tackle are discussed.
V. Initiatives required for addressing effective planning for operations recommended.

Elaborating the above five aspects, factors leading to these are briefly noted below:

1. "Reclassifying" existing road networks based on a geospatial database
    a. BMP has notified 96 arterial roads and 118 sub-arterial roads following directions from the Honourable High Court.
    b. During the course of mapping these along with other ongoing and proposed interventions related to road infrastructure, it was found that there are significant inconsistencies in ascribing arterial and sub-arterial roads.

c. Initiatives like, IT-BT roads, Flood damaged roads, roads identified for widening etc. does not impress the notion of arterial or sub-arterial roads.
d. Studies carried out on transportation networks have identified corridors of high and medium density traffic flows. Some these corridors do not reflect among the list notified by BMP as arterial roads.
e. As a way forward, it is recommended to undertake "reclassifying" road networks based on criteria enclosed as Annexure A.
f. The entire road network should be mapped on a spatial database with the template recommended and used for operational planning and management of various road infrastructure works.

2. The concept of developing a core ring road at surface grade level in the proposed alignment may not be feasible for the following reasons:
    a. The notion of a core ring road (as an expressway) is to facilitate enhanced mobility by motorable vehicles without any obstruction of passage across any intersections with traffic movement as primary consideration and not access to property.
    b. However, the proposed alignment already has numerous properties being part of older and central city for which restricting any property access would become ill-conceived and impractical with construction of CRR at surface grade level.
    c. In the proposed alignment, the entire stretch is not conceived for "signal free passage" and hence very purpose of core ring road is defeated.
    d. With 50 intersections along the CRR and only about 13 junction improvements proposed (underpasses and flyovers) mobility along CRR would still instil waiting at various intersections.
    e. The entire alignment is not a fresh alignment, but over existing road networks alongside existing properties of various types. A review of the existing studies suggests that some of the segments of CRR are high and medium density corridors with some other interventions are conceived over these.

f. The alignment is mostly on already built-up area and constructing a 4-lane at surface grade would call for acquisition and consequent legal challenges across the entire alignment. Noting that some segments of CRR pass through older city areas, wherein existing road networks are 2-lane, it would be a challenging task to implement this project without any hurdles in the scheduled time.
g. There are already some interventions for junction improvements (like, Mekhri circle and Dairy circle) while another 13 interventions are proposed. Unless, all these interventions are taken up collectively instead of interventions in isolation, traffic congestion will not be arrested but aggravated.
h. However, an elevated core ring road might suffice to fulfil abovementioned objectives.

3. Current interventions encouraging more independent motorable transport by way of road widening, construction of underpasses, flyovers and grade-separators would not ease traffic congestion when addressed in isolation. The same when analysed under the perspective of Braess Paradox and Systems Analysis reveal that such interventions would only intensify the traffic congestion.
    a. Braess Paradox: In a congested road network, German scientist, Braess had demonstrated that adding a link within the network to ease congestion would be counter-intuitive. Thus, the average time spent in the entire network would only increase instead of reducing travel time.
    b. Systems Analysis: Based on systems analysis for current approaches in addressing mobility to ease congestion, it reveals that any measures by way of encouraging mobility of independent motorable transport by way of road widening, construction of underpasses, flyovers and grade-separators in the absence of favourable mass transit systems, traffic congestion will increase and encourages more outgrowth of city inducing more sprawl areas.

4. Analysis and discussion with BMP engineers on factors for time and cost-overruns in various infrastructure projects are outlined below while the ways to tackle are discussed in the report.
    a. Shifting of utilities
    b. Traffic diversion
    c. Acceptance by public/locals
    d. Handing over the site in the light of unclear title documents
    e. Administrative delays in getting appropriate approvals at various levels both internal (Council) and external (other agencies, like BMRCL)
    f. Escalation of costs of materials from the time of tender to actual issue of work order
    g. Acquisition of land
    h. Surprise legal hurdles
    i. Improper tender documents
    j. Accountability of BMP Engineers in-charge of the project and Contractor responsible for executing the project
    k. Incentives / Sanctions on BMP Engineers and Contractors towards successful execution of the project

5. A significant aspect relating to immediate steps to be taken up by BMP for addressing effective planning for operations are recommended. Tagged as Silicon Valley and IT City, it is apt for BMP to transform its organisation by adopting relevant technologies and Policies that aid in operational planning and management.
    a. An essential aspect required for operations planning and management is INFORMATION. Unfortunately, BMP does not stand in good position with regard to the nature of information relating to Mobility. Thus, an appropriate Cell addressing *Data Collection*, *Analysis* and *Sharing* for effective operations is suggested. Alongside the development of spatial

database for road networks, the Cell should integrate and coordinate the various activities outlined further.

b. As a means towards addressing mobility in general and traffic congestion in particular, Intelligent Transport Systems (ITS) are required for:
    i. Activity tracking and online tracking, monitoring of vehicular movement: This is possible by enforcing Radio Frequency-based ID (RFID) tags installed to all vehicles that ply within city limits. Such tags would flush in thousands of data clouds for vehicular traffic movement along various segments that can be tracked, visualised through appropriate systems for effective management. The same is elaborated in the report.
    ii. Automated / synchronised traffic signals: With the possibility of collecting data online through RFID, traffic signals can be effectively synchronised and automated.

c. Policies curtailing Congestion and Traffic Growth through some Smart Growth options:
    i. Enforcing additional cess/tax for vehicles plying in the central city.
    ii. Additional/heavy tax for vehicles discouraging independent motorable transport.
    iii. Introduction / encouragement of utilising bicycles for mobility in short distances and central areas without any motorable transport apart from mass transit.
    iv. Acknowledging implications of changing land use on mobility to discourage any inappropriate and inefficient land use.
    v. Effective enforcement and regulation of the above with strong administrative and political will.

d. Tracking progress through Performance Measures: In the absence of any performance measures the direction of interventions/progress or their effectiveness is unknown. A set of performance measures essential to track the progress of various interventions towards addressing mobility are elaborated in the report.

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List of Abbreviations

AR	Arterial Road
BDA	Bangalore Development Authority
BESCOM	Bangalore Electricity Supply Company Ltd.
BMP	Bangalore Mahanagara Palike
BMRC	Bangalore Metro Rail Corporation
BMRDA	Bangalore Metropolitan Region Development Authority
BMTC	Bangalore Metropolitan Transport Corporation
BWSSB	Bangalore Water Supply and Sewerage Board
CDP	Comprehensive Development Plan
CSDP	City Strategic Development Plan
CMC	City Municipal Council
CRR	Core Ring Road
CRRI	Central Road Research Institute
DoT	Department of Transport
GoI	Government of India

GoK	Government of Karnataka
IDIP	Infrastructure Development and Investment Plan
IISc	Indian Institute of Science
IRC	Indian Road Congress
IRR	Internal Ring Road
iDeCK	Infrastructure Development Corporation of Karnataka
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KRDCL	Karnataka Road Development Corporation Limited
KSPCB	Karnataka State Pollution Control Board
KUID&FC	Karnataka Urban Infrastructure Development and Finance Corporation
MUD	Ministry of Urban Development
MUEPA	Ministry of Urban Employment and Poverty Alleviation
NUTP	National Urban Transport Policy
ORR	Outer Ring Road
PRR	Peripheral Ring Road
SAR	Sub-Arterial Road
TDR	Transfer of Development Rights
TMC	Town Municipal Council
UDD	Urban Development Department, Govt. of Karnataka

1 Introduction

1.1 Mobility in urban areas

Mobility is an important aspect of any urban system. Most activities in an urban area involve mobility either for people or goods. Further, the efficiency of city functions is determined by the level of service achieved in terms of mobility of people and goods. Collectively mobility is mostly achieved through different modes of transportation. There can be individual modes of transportation for mobility of people (2-wheelers, passenger cars, etc.) to public transport (high capacity bus, metro-rails, etc.) apart from goods carriers like heavy goods transport vehicles and others that can ply on transportation network of the city. Typically in India, transportation network is characterised by the vast road networks aided by fuel-driven automobiles. Some cities may also have intercity rail networks or any form of mass transit system that cater to address mobility of people, thereby leaving the remaining transportation networks (mostly roads) for mobility of goods and some individual transportation.

The consequence of lack of integrated planning both at regional and national level has also had implications on the national economy as well. With the rise in usage of individual motor transport, the demand for petroleum products has seen a sharp increase bearing a significant impact on the foreign exchange reserves. According to the recent Economic Survey (Ministry of Finance, 2006) the sharp rise in global crude prices has resulted increased imports of petroleum, oil and lubricants (POL) by 46.9 per cent in April-January, 2005-06. The rise in oil imports has gone up from Rs. 136 crores in 1970-71 to Rs. 106875 crores during 2005.

In the light of rampant urbanization India is currently facing and the consequent urban sprawl, the implications above mentioned would persist in most of our cities. Apart from the local problems that are caused by large scale individual transportation, the dependence on foreign resources (oil) may not be self-reliant and sustainable. This problem is already impacting the national economy at a macro-level and hence the need of the hour is an effective national policy and mechanisms to address these issues. In this context, the Ministry of Urban Development, Government of India, has come up with the "National Urban Transport Policy (NUTP)" approved on 4th April 2006. However, effective mechanisms to address these issues primarily at city level aided by appropriate support from the central government are to be channelised and operationalised through the Jawaharlal Nehru National Urban Renewal Mission funding to these cities. A key distinction of NUTP (Ministry of Urban Development, 2006) is on the notion of addressing *mobility* of 'people' over 'vehicles'. Thus, the NUTP has the primary aim to ensure easily accessible, safe, affordable, quick, comfortable, reliable and sustainable mobility for all and thus outline the following objectives:

1. Reduce the existing levels of congestion,
2. Reduce the impact of motor vehicles on urban air pollution,
3. Improve road safety, and
4. Foster the use of sustainable technologies that minimize the consumption of imported fuels in urban transport and thus preserve the country's energy security.

It should be noted that among the above four objectives, by the shear magnitude of vehicles, a consequent congestion has resulted in most of our cities thus leading to urban air pollution and reduced road safety. Thus easing the levels of congestion is a key aspect that needs more attention. In this report, easing the levels of congestion has been elaborated in detail.

In the absence of effective mass transit systems in most cities of India, individual mobility has risen resulting in the rapid growth in the number of motor vehicles in these cities, far outpacing the growth in the urban population. Table 1 shows how the number of registered motor vehicles has increased, in Bangalore, during the last few years. The rising number of motor vehicles has led to severe congestion on the roads. As a result of the large number of vehicles on the roads, there has also been a rapid deterioration in the air quality. Again, as a direct consequence of air pollution, this is also resulting in health related risks. The growth in motor vehicle use has also led to an increase in the number of road accidents, thus compromising on the safety of road transport. Table 2 gives the year wise road accident statistics and the number of deaths caused due to road traffic in Bangalore.

Table 1: Vehicle Population in Bangalore City (Source: Bangalore Traffic Police, 2006)

Year	No. of Vehicles
1980	175325
1985	306589
1990	601059
1995	870659
2000	1438057
2005	2206909

Table 2: Incidence of Road Accidents (Source: Bangalore Traffic Police, 2006)

Year	No of Accidents			No of Persons	
	Fatal	Non-fatal	Total	Killed	Injured
1998	685	7675	8360	726	6358
1999	605	7291	7896	639	6026
2000	626	7765	8391	659	6347
2001	668	8358	9026	703	6929
2002	783	9073	9856	820	7577
2003	843	9662	10505	883	7980
2004	875	8226	9101	903	6921

1.2 Objectives of the study

A critical factor determining the level of mobility is the amount of congestion persisting in the urban areas. Thus mitigating congestion has to be a high priority for the agencies involved in managing urban area, which in the case of Bangalore, the local body, Bangalore Mahanagara Palike (BMP) is currently addressing. This report, *Enhancing Mobility through Integrated Transportation and Traffic* supports this effort by providing a review of studies on congestion across nations, best practices employed, strategies needed to be adopted and ways to tackle this problem. The emphasis of the study is also on arriving at indicators for measuring mobility, mainly captured by trends in travel time and congestion index. This effort, it is suggested, to make it more reliable through initiatives of an Intelligent Transportation System (ITS). The topic of enhancing mobility is obviously much broader than this focus. In view of the above discussed aspects hindering mobility in Bangalore city and the various initiatives undertaken by Bangalore Mahanagara Palike and other key stakeholders, the current study has the following objectives:

1. To review the different traffic and transportation studies undertaken on Bangalore
2. To analyse and evaluate for key road works like, construction of flyovers, grade separators and underpasses for time- and cost-overruns
3. To arrive at corrective mechanisms for minimising the time- and cost-overruns through the lessons learnt in previous implementations
4. To investigate the root causes (sources) of congestion in Bangalore City
5. Present performance measurement as a process for making things better

1.3 Indicators for measuring mobility

Among the recent trends in measuring mobility, by way of capturing the amount of congestion is mostly represented by volumes of traffic (level of service) plying on the road network. However a key deviation this report suggests is measuring congestion based on travel time. It is noted that while most transportation studies have used other types of metrics to measure congestion, travel time is a more direct measure of how congestion affects users.

Monitoring congestion is just one of the several aspects of transportation system performance that leads to more effective investment decisions for transportation improvements. Safety, physical condition, environmental quality, economic development, quality of life, and customer satisfaction are among the aspects of performance that also require monitoring. Congestion is intertwined with all of these other categories since higher congestion levels have been associated with their degradation.

Travel time is understood by a wide variety of audiences – both technical and non-technical – as a way to describe the performance of the transportation network. The congestion metrics suggested in this Report is based on this concept.

Travel Time as the Basis for Congestion Performance Measures

The performance of the highway system in terms of how efficiently users can traverse it may be described in three basic terms: congestion, mobility, and accessibility. While researchers have different definitions of these terms, we have found it useful to define them as follows:

- Congestion – Describes the travel conditions on facilities;
- Mobility – Describes how well users can complete entire trips; and
- Accessibility – Describes how close opportunities (e.g., jobs, shopping) are spaced in terms of the user's ability to access them through the transportation system.

Congestion and mobility are very closely related and the same metrics and concepts can be used to monitor both. Accessibility is a relatively new concept and requires a different set of metrics. Most the data that are currently available describe facility performance, not trip performance although new technologies are emerging that will allow for direct monitoring of entire trips. One of the principles that United States Highway Administration has established for monitoring congestion as part of its annual performance plan is that meaningful congestion performance measures must be based on the measurement of travel time. Travel times are easily understood by practitioners and the public, and are applicable to both the user and facility perspectives of performance.

Temporal Aspects of Congestion: Measuring congestion by times of the day and day of week has a long history in transportation. A relatively new twist on this is the definition of a weekday "peak period" – multiple hours rather than the traditional peak hour. In many metropolitan areas, particularly the larger ones, congestion now lasts three or more hours each weekday morning and evening. In other words, over time, congestion has spread into more hours of the day as commuters leave earlier or later to avoid the traditional rush hour. Definition of peak periods is critical in performing comparisons. For example, consider a three-hour peak period. In smaller cities, congestion may usually only last for one hour – better conditions in the remaining two hours will "dilute" the metrics. One way around this is not to establish a fixed time period in which to measure congestion, but rather determine how long congestion exists (e.g., percent of time where operating conditions are below a threshold.)

Spatial Aspects of Congestion: Congestion spreads not only in time but in space as well. Queues from physical bottlenecks and major traffic-influencing events (like traffic incidents) can extend for many miles. Congestion measures need to be sensitive to this by tracking congestion over facilities or corridors, rather than just short highway segments. Table 3 presents a sample of congestion performance measures used by agencies to monitor trends.

Table 3: Sample Congestion Performance Measures

Performance Metric	Definition/Comments
Throughput	
Vehicle-Miles of Travel Truck Vehicle-Miles of Travel Person-Miles of Travel	Vehicle-miles of travel are the number of vehicles on the system times the length of highway they travel. Person-miles of travel is used to adjust for the fact that some vehicles carry more than a driver.
Average Congestion Conditions	
Average Travel Speed	The average speed of vehicles measured between two points.
Travel Time	The time it takes for vehicles to travel between two points. Both travel time and average travel speed are good measures for specific trips or within a corridor.
Number and percent of trips with travel times > (1.5 * average travel time) Number and percent of trips with travel times > (2.0 * average travel time)	Thresholds of 1.5 and 2.0 times the average may be adjusted to local conditions; additional thresholds may also be defined.
Travel Time Index	Ratio of actual travel time to an ideal (free-flow) travel time. Free-flow conditions on freeways are travel times at a speed of 60 mph.
Total Delay (vehicle-hours and person-hours) Bottleneck ("Recurring") Delay (vehicle-hours)	Delay is the number of hours spent in traffic beyond what would normally occur if travel could be done at the ideal speed.
Traffic incident Delay (vehicle-hours) Work Zone Delay (vehicle-hours) Weather Delay (vehicle-hours) Ramp delay (vehicle-hours and person-hours; where ramp metering exists)	Determining delay by "source of congestion" requires detailed information on the nature and extent of events (incidents, weather, and work zones) as well as measured travel conditions.
Delay per Person Delay per Vehicle	Delay per person and delay per vehicle require knowledge of how many vehicles and persons are using the roadway.
Percent of VMT with Average Speeds < 45 mph Percent of VMT with Average Speeds < 30 mph	VMT is vehicle-miles of travel, a common measure of highway usage.
Percent of Day with Average Speeds < 45 mph Percent of Day with Average Speeds < 30 mph	These measures capture the duration of congestion.
Reliability	
Planning Time (computed for actual travel time and the Travel Time Index)	The 95th percentile of a distribution is the number above which only 5 percent of the total distribution remains. That is, only 5 percent of the observations exceed the 95th percentile. For commuters, this means that for 19 out of 20 workdays in a month, their trips will take no more than the Planning Time.
Planning Time Index (computed for actual travel time and the Travel Time Index)	Ratio of the 95th percentile ("Planning Time") to the "ideal" or "free flow" travel time (the travel time that occurs when very light traffic is present, about 60 mph on most freeways).
Buffer Index	Represents the extra time (buffer) most travelers add to their average travel time when planning trips.
For a specific road section and time period:	

$$\text{Buffer Index (\%)} = \frac{95^{th}\text{ percentile travel time (minutes)} - \text{average travel time (minutes)}}{\text{average travel time (minutes)}}$$

2 Situation in Bangalore

Bangalore is the principal administrative, cultural, commercial and industrial centre of the state of Karnataka. The city of Bangalore is situated at an altitude of 920 metres above mean sea level. Geographically it is located on 12.95º North latitude and 77.57º East longitude. The Greater Bangalore [1] agglomerating the neighbouring outgrowth and municipal councils is proposed to spread over an area of 696 square kilometres. A tiny village in the 12th century grew through times to become one of the fastest growing cities in the world by 21st century and figured among the million-plus cities in India [2]. The city enjoys a pleasant and salubrious climate throughout the year. Its tree-lined streets and abundant greenery have led to it being called the 'Garden City' of India. This Silicon Valley of India has been identified as one of the technological innovation hub with a technological achievement index (TAI) of 13 [3] according to the Human Development Report (United Nations Development Programme, 2001). It has also been in the news for a variety of reasons. If at first, a sleepy Garden City of India woke to take on the IT revolution in the late last century, it also firmly re-established the myth, that '*The World is Flat*' in the words of Thomas Friedman (Friedman, 2004). The expansion of Bangalore in recent times, as a major economic centre with concentrated development of industries and commercial establishments has given impetus to the growth. However, this growth is reaching its threshold and the city is currently facing the crisis in terms of infrastructure, etc. Early 90's boom in the software sector with consequent infrastructure initiatives, has contributed to rise in population, mainly due to migration from other parts of India to Karnataka. It is now home to more than 250 high-tech companies apart from numerous establishments in manufacturing and processing industries. The population of Bangalore as per the 2001 census was 56,86,844 while it was 1,63,091 in the beginning of the last century (1901) (Figure 1). As an immediate consequence of this growth in the last decade, apart from creating a ripple effect in the local economy, there has also been an extensive pressure on infrastructure and resources like, water supply, energy, public transportation, land, etc. The local bodies and other parastatal agencies responsible for delivery of basic services are facing stiff challenges in catering to this

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[1] The Urban Development Department, Government of Karnataka has issued gazette notification vide No. UDD/92/MNY/2006, dated 2.11.2006 for constituting the Bruhat Bangalore Mahanagara Palike (Greater Bangalore City Corporation) merging the existing area of Bangalore City Corporation, 8 Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District.

[2] Bangalore is the fifth largest metropolis in India currently with a population of about 6.5 million.

[3] Almost on par with San Francisco, USA, while Silicon Valley, USA is number 1 with TAI of 16.

demand. With a booming economic activity, inward migration in search of livelihood, and availability of land favoured by salubrious climate all round the year, sprawl has been prevalent in and around Bangalore.

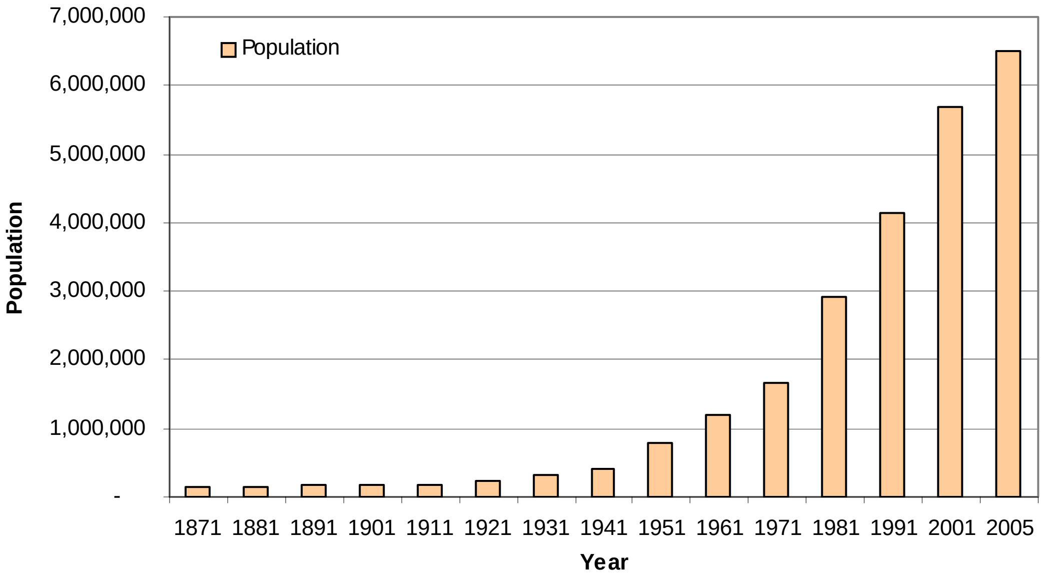


Figure 1: Population Growth of Bangalore City during 1871 - 2005

2.1 Status and trends of mobility in Bangalore

Addressing mobility in Bangalore city, an overview of the transportation and traffic reveals the following facts. Bangalore city is estimated to have vehicle population of about 2.2 million while the city population is about 6.6 million. Thus the vehicle to person ratio is almost 1:3, which is, by far highest than any other city in India. This has led to increased congestion in road networks across the city inducing frequent traffic jams. That apart manning traffic islands have also become unmanageable with the amount of traffic plying across junctions. In Bangalore, attempts made to address mobility are stereotypical, which is either by way of widening of roads or creation of new flyovers and underpasses. Another option explored while addressing mobility is restricting the right of ways (one-ways) for movement of traffic along the roads. In the last 10 years many roads have been converted into one-ways. Again, with more than two authorities responsible for mobility in the city, different components related to mobility are vested with different parastatal bodies.

Transportation forms one of the key functionalities in any urban area. People travel on a day-to-day basis essentially for work or education or others. In a city like Bangalore where the working population is easily around 2 million, on any given day the BMTC operates with 4144 schedules, 4262 buses, 60,475 trips, carry 3.5 million passengers, earn Rs.20.5 million per day and pay Rs.0.955 million to the Govt. as taxes! (BMTC, 2006) Further, according to the recent estimates, there are about 1.6 million 2-wheelers, 0.32 million motor-cars, 80,000 auto-rickshaws, and 0.17 million other vehicles totalling to around 2.2 million vehicles on road!

2.1.1 Road Network

Among the key modes of transport in Bangalore city, currently road-based travel is the only available option. The city itself has developed in radial direction along all the major highways that ply and intersect in the city. The National Highway 4, National Highway 7 and National Highway 209 intersect the city forming 5 important radial axes. The NH 4 is part of the National Golden Quadrilateral that connects all the four metros in the country. The other important radial axes are the State Highways plying to Mysore, Magadi and Bannerghatta. As well, there have been radial outer ring roads linking all these important highways. Within these outer ring roads are 'sinks of urban growth' that has developed rapidly over the last few years in spite of an effective network of roads that linked all these. In Bangalore, most of the major road networks are carrying much beyond their capacities. Additionally there have been interventions by some of the organisations, always in parts, to address this situation, by way of junction improvement measures or corridor improvements. However, there hasn't been any comprehensive and integrated management and operations effort initiated by any of these organisations.

The onus of maintaining road networks is with the City Corporation - BMP, and hence, BMP from time-to-time takes up road improvement programmes to ease congestion of traffic in the city. Indeed the investments required to address the situation again has to be mostly met by the local body, which are incommensurate with the explosion of vehicular traffic. However, now and then, there are studies that have addressed the problem of congestion in road networks by ways of suggesting numerous grade separators at various junctions and identification of corridors that require intervention.

On the aspects of mobility pertaining to road networks, apart from addressing the road length alone, the street lights, amount of pedestrian walkways / footpaths, skywalks, etc. are also need to be addressed comprehensively. The total road length in the BMP limits is about 3,500 km (while Greater Bangalore has about 5,000 km) of which about 320 km form the important roads as arterial and sub-arterial roads. However, the existing road length in Bangalore is less than the normative road length by about 11 % as per the prescribed standards of 17.33 km per sq. km (KUIDFC, 2006). Further, in all there are about 0.25 million street lights in Bangalore. As per the planning guidelines, there should be about 33 street lights per one km length of road, which in the case of Bangalore is better than standards. However, in the absence of effective proactive maintenance mechanisms, there is significant amount of expenditure incurred with regard to maintenance of street lights. It is noted that there is a pressing need for online tracking of street lights and their status over a spatial database, for effective and efficient maintenance of street lights. However on the aspects of pedestrian walkways / footpaths there was no adequate information that could be collated.

For addressing mobility through road improvements, there have been various studies that have attempted to identify the key corridors – road segments requiring interventions by other agencies. A review of these studies is discussed in next chapter. However, there are two common aspects in all these studies: the volume-based indices are used and interaction of land use with transportation is consistently ignored. As noted earlier, this report suggests using travel time based metrics to capture mobility and congestion in the transportation network than volume-based metrics. Although in a study by iDeCK and Rites (2005), they have identified 52 corridors as high and medium traffic intensity corridors, requiring different type of interventions by various organisations, BMP proposes to widen some of these roads. A key aspect ignored while addressing mobility is the land use associated with transportation networks. The lack of acknowledgement of implications owing to change in land use from residential to commercial or industrial, has significantly led to stereotypical approaches addressing mobility. The nature of land use determines the home-work-home, home-education-home, and home-other-home distances and corresponding travel-times. In general Bangalore has over a period promoted mixed land use, thus at some level led to inefficient usage of land. With compartmentalised approaches of widening of roads or construction of flyovers and grade separators, the problem of mobility is far from being solved.

2.1.2 Rail Network

Bangalore is well connected by railway to all important regions of India through a railway network converging at Bangalore City station. Railway lines from five different directions terminate at the Bangalore City station. The five railway lines, all now Broad-Gauge lines are:

1. Guntakal line from the North
2. Chennai line on the East
3. Salem line from South-east
4. Mysore line from South-west
5. Mumbai-Pune line from North-west

In spite of the five radial rail corridors, these are not currently used for any public transport. However at some point of time there were proposals to introduce Commuter Rail Service to utilise some these networks. A brief review on these is elaborated in forthcoming sections.

2.1.3 Air Travel

The Bangalore airport, which belongs to HAL, is located in south-east of the city. The airport was opened in 1947 for passenger traffic. During 1985 there were only about 13 flights each way per day while currently in 2006, there are about 160 operated everyday. With the growth Bangalore has witnessed over the last decade and post-liberalisation in the nineties, air travel has been boosted. Thus, today on an average there is flight taking-off or landing for every ten minutes.

Table 4: Total Domestic and International Passenger Traffic (Source: Airports Authority of India)

Year	2000-01	2001-02	2002-03	2003-04	2004-05
Bangalore Airport	2443479	2276250	2764283	3181248	4113383

From what is evident, Bangalore city has grown considerably in multi-dimensional fashion, while it is indeed a challenge for planning and administration to manage these operations and sustain. However, in the subsequent section, there is more thrust attributed to aspects road network for its sheer impact and implication on mobility in Bangalore city.

2.1.4 Vehicular Profile

A cursory look at the status (Table 1) and trend of vehicles in Bangalore are very alarming. It is estimated that the average number of vehicles per household has increased six-fold in the last 25 years from about 0.3 vehicles in 1980 to about 1.7 vehicles in 2005. From simple estimates of forecasting the possible number of vehicles in the current trend, by the year

2010, it would be around 4.5 million as against a population of 8 million. The systems analysis in Chapter # outlines the case with different possibilities driven by the various causes. However, for any systems analysis as well, it would be interesting to note the composition of vehicles by type (Table 5). It is easily seen that the composition of vehicular traffic is dominated by the individual mode of transport aided by large amount of two-wheelers (73 %) followed by cars (12.64 %).

Table 5: Composition of Vehicles by Type (Source: BangaloreIT.in)

Vehicle Type	% Composition of Vehicles
Private buses	0.03
Omni buses	0.81
Auto-rickshaws	3.72
Cars	12.64
Motor cabs	0.45
Maxi-cabs	0.37
Two-wheelers	73.24
Public Transport Buses (BMTC)	0.09
Intra-state Buses (KSRTC)	0.48
Ambulance vans	0.02
Delivery vans	0.73
Contract carriages	0.01
Goods vehicles	3.04
Construction purpose vehicles	0.03
Others	4.32
Total	100.00

Figure 2: Traffic plying across the Corporation Circle

2.2 Overview of organisations addressing Mobility

With more than two authorities responsible for mobility in the city, different components related to mobility are vested with different parastatal bodies summarised in Table 6.

Table 6: Organisations addressing Mobility in Bangalore City

Sl. No.	Scope of Work related to Mobility	Organisation
1.	Roads and road maintenance including asphalting, pavements and street lighting; Construction of few Ring roads, flyovers and grade separators	Bangalore Mahanagara Palike and neighbouring Municipal Councils (8 CMCs + 1 TMC)
2.	Manning of traffic islands; Enforcement of traffic laws; Regulation on Right of Ways (One-ways)	Bangalore City Traffic Police
3.	Public transport system – Bus-based	Bangalore Metropolitan Transport Corporation
4.	Public transport system – Rail-based (Proposed)	Bangalore Metro Rail Transport Corporation
5.	Land use zoning, planning and regulation; Construction of few Ring roads, flyovers and grade separators	Bangalore Development Authority
6.	Motor vehicle tax; Issue of licenses to vehicles	Regional Transport Offices, Department of Transport, GoK
7.	Monitoring local environmental quality (mainly for air and noise pollution)	Karnataka State Pollution Control Board, GoK
8.	Urban infrastructure and Finance	Karnataka Urban Infrastructure Development and Finance Corporation (KUID&FC), GoK Undertaking

All this has severely paralysed the city's mobility due to lack of effective coordination amongst these organisations and lack of integrated (systems) approach to address this. Hence it is imperative to perform a systems analysis for mobility in the city and address coordination amongst different organisations by devising process-based coordination mechanisms. The outcome of systems analysis should be able to suggest alternatives and possible solutions to augment mobility in the urban area.

2.3 Review of Traffic and Transportation Studies in Bangalore

There have been several studies carried out on various aspects of traffic and transportation almost independently by various organisations. A brief review of the same is made in most recent such study, Rapid Traffic Study, by iDeCK and Rites (2005). It is noted that the first Comprehensive Traffic and Transportation Plan for Bangalore was prepared in 1963-64 by the Central Road Research Institute (CRRI), which was essentially based on the population, land use and area projections made by the Town Planning Department. By 1965, the Town and Country Planning Act came into effect and then a City Planning Authority was constituted which then prepared a Comprehensive Development Plan (CDP) for the year 2001 with a population estimate of 3.8 million. However, until the constitution of City Planning Authority, there existed City Improvement Trust Board (CITB), which was responsible for land use zoning and planning.

Subsequently in order to implement the CDP and to control the land use in the metropolitan area, the Bangalore Development Authority was created in 1976. The decade 1971-1981 saw the highest population growth rate owing to significant in-migration by about 75 % growth than the previous census estimates. This necessitated the revision of CDP which was prepared afresh and approved in 1984. By 1995, the CDP was again revised, this time the forecast year was 2011. At the behest of the Town Planning Department, a 'metro rail' for Bangalore was proposed in 1981. The Southern Railways, based on Lynne Committee which looked into these recommended a 2-corridor metro for 24 km along with 3 commuter rail lines and a 58 km ring railway at a cost of Rs. 6500 million at 1983 prices. However, for various reasons, as evident today, this was not taken up. Later in 1988, Rites was commissioned to carryout a transport study funded by the World Bank addressing issues concerning roads, traffic and mass transit. Yet again in 1993, Government of Karnataka established another committee to look into a mass rapid transit system for Bangalore, which reinforced the Southern Railway's recommendation made in 1983. Soon after, in 1994 a special purpose vehicle, Bangalore Mass Rapid Transit Limited was formed to take up the mass rapid transit system through a public-private partnership.

Meanwhile, the CRRI made another study on the status of Bangalore's traffic and proposed various road improvement programmes including 45 multi-grade intersections, 25 pedestrian underpasses and various corridor improvement programs. With change in the state government, there was another study, this time jointly with Ministry of Railways, was commissioned to Rites to study the introduction of commuter rail facility. However, in 2003, the Government of Karnataka, commissioned Delhi Metro Rail Corporation to prepare detailed project report on the introduction of mass rapid transit system in Bangalore. The study recommended two corridors, North-South and East-West, intersecting at the Kempe Gowda Bus Station with a total length of 33 km. A special purpose vehicle, Bangalore Metro Rail Corporation Ltd. (BMRC) was formed recently and currently this proposal is being taken forward for implementation. With over 20 years of ups and downs with regard to mass rapid transit system, Bangalore is now witnessing a possible metro in the near future (2008).

Amidst these recent developments, the road traffic has steeply increased throwing stiff challenges for the administration to manage the operations. Hence, the 'Comprehensive Traffic and Transportation Study' (CTTS) was commissioned to Rites in 2005, which is due for completion in December 2006 / January 2007. Again in the meanwhile, it was felt necessary that until the CTTS gets ready, there needs to be some initiatives to be taken for easing congestion in the road networks. And hence, iDeCK along with Rites prepared the 'Rapid Traffic Study' in November 2005. The Rapid Traffic Study identified 52 corridors as high and medium traffic intensity corridors requiring various types of intervention.

2.3.1 Tracing the recent history of infrastructure related initiatives in Bangalore

In the recent past owing to the exodus rise in vehicular traffic and the resulting congestion in road networks, there were calls from many quarters to manage and develop the existing road networks. Thus in 1998 under the Municipal Bond Road Scheme development of arterial roads were taken up. Meanwhile, the Bangalore Metropolitan Transport Corporation (BMTC) came out with all the motorable roads that were suitable for plying bus-based mass transit system. After this, the arterial and sub-arterial roads were taken up for development. In the same course, excluding the arterial, sub-arterial and municipal bond roads, the maintenance of some of the remaining important roads were taken up by outsourcing the same, while some never got implemented. By 2002, 100 % coverage of water supply and sewer line, mainly in newly developed residential areas was taken up by BWSSB with a funding of Rs. 180 crores raised by BMP. Subsequent to this, by the time of completion 100 % black topping of roads for all areas where BWSSB had completed water supply and sewer line was initiated. Funds was raised from HUDCO loan in several packages, Package 1 – Interior roads and Package 2 – Main roads, while the left ones in above interventions was taken up 2005 onwards.

At times, the government has faced brick-bats from industrialists for lack of effective infrastructure in Bangalore. A consequence of such brick-bats was the creation of a package called, IT-BT roads, which were initiated after the outburst of a leading entrepreneur on the status of infrastructure facilities in Bangalore, especially towards Electronic City where much of the important software industries operate. Subsequently a High Power Committee chaired by the Chief Secretary was formed comprising Principal Secretary / Commissioner's of key departments addressing this issue. About Rs. 20 crores fund was granted from the state government in order to take up these roads under a package called, IT-BT roads, and this work was entrusted to KLAC. Even while all this happened last year, there were heavy rains which caused flooding in some of the areas in South and South-east Bangalore. And thus, another package to take works related to restoration and development of these roads were taken up as Flood Damaged Roads. This work was also entrusted to the KLAC. Thus in the recent past, there have been numerous packages/projects created / tailored for addressing some of the road development works in a 'reactive' mechanism and compartmentalised approaches. Until recently, there were no efforts to integrate collectively ascertain the implications of all these on the overall road network.

2.4 Classification of Roads – Towards Standardisation

iDeCK and Rites have carried out a Rapid Traffic Study identifying 52 corridors as high and medium traffic intensity corridors. However, in the meanwhile BMP has also notified widening of 45 roads. That apart, BMP also has notified 96 arterial roads and 118 sub-arterial roads responding to the Honourable High Court. The alignment of inner core ring road involving about 50 road segments and junctions is also proposed to be taken up under JNNURM. However, irrespective of BMP's on classification of roads as arterial and sub-arterial, none of the above initiatives impress upon the same. A brief summary of these is given in Table 7.

Table 7: Roads and Corridor Details

Sl.No.	Road / Corridor	No of Segments	Total Length (km)
1.	Arterial Roads	96	240
2.	Sub-arterial Roads	118	191
3.	BMP Roads for Widening	85	144
4.	BDA Core Ring Road	50	29.5
5.	iDeCK-Rites Corridor	52	

It is noted that there are some overlap with regard to the different corridors identified by iDeck-Rites with BMP roads identified for widening and arterial roads notified by BMP. All these are highlighted in Table 8 and 9.

Table 8: iDeCK-Rites corridors and Arterial roads

Sl No	iDeCK-Rites Corridors	From	To	Arterial Roads	Remarks
1	Bellary Road	Kodigehalli Road	Kaveri Theatre	AR-39	Mekhri Circle to Hebbal
2	Palace Road	Mysore Bank Circle	Kaveri Theatre	AR-20	Mysore Bank Circle to High Grounds PS
3	Tumkur Road	Peenya Circle	Yeshwantpur	AR-1	Partial
4	Sankey Road	Yeshwantpur	Kaveri Theatre	AR-44	Partial, Minsk Square to Mekhri Circle
5	Outer Ring Road	Tumkur Road	New BEL Road	AR-4	
6	Jalahalli Road	Tumkur Road	MS Ramaiah Road		
7	MS Ramaiah Road				
8	CV Raman Road	Yeshwantpur	Mekhri Circle	AR-8	
9-A	Jayamahal Road			AR-40	
9-B	Jayamahal Road	Jayamahal Road	Bellary Road via RT Nagar Main Road		
10	Chord Road	Mysore Road	Yeshwantpur	AR-9 and AR-10	
11	Outer Ring Road	Magadi Road	Tumkur Road		
12	Magadi Road	Ring Road	Leprosy Hospital	AR-25	
13	Dr. RajKumar Road	Magadi Road	Kuvempu	AR-26	Upto Govt Soap Factory
14	Gnanabharati Road	Mysore Road	Outer Ring Road		
15	Mahakavi Kuvempu Road			AR-31	
16-A	Sampige Road	Central	Malleshwaram 18th cross	AR-11	
16-B	Margosa Road	Mariamma Temple Circle	Malleshwaram Circle	AR-30	
17	Mysore Road	City Market	Ring Road	AR-2	Upto B Univ
18	Binny Road	Sirsi Circle	Bangalore City Station	AR-13	
19	Sheshadri Road		KR Circle	AR-17	
20	Sheshadripuram Main Road	via KG Bus Station	Mysore Road	AR-20	Cottonpet Road
21	KG Road	Hudson Circle	Majestic	AR-15	
22	St. John's Church Road	St. John's Road	Murphy Road	AR-41	
23	Arabic College Road		Ring Road		
24	Wheelers Road	Wheelers Road	Banaswadi Road		
25	Cunningham Road				
26	Queen's Road			AR-54	
27	Infantry Road	Infantry Road	Miller's Road		

28	Kamaraj Road				
29	Cubbon Road	Cubbon Road	Dickenson Road	AR-37	
30	MG Road	MG Circle	Trinity Circle	AR-36	
31	Old Madras Road	Indira Nagar Road	Bayapanahalli	AR-42	Trinity Circle to Suranjan Das Circle
32	Indira Nagar 100ft Road	Old Madras Road	Airport Road	AR-56	
33	Airport Road	Trinity Circle	Outer Ring Road	AR-34	
34-A	Gen. Thimmaiah Road	Richmond Circle	Shoolay Circle	AR-51	
34-B	Gen. Thimmaiah Road	Shoolay Circle	Trinity Circle	AR-51	
35	Cariappa Road (Residency Road)			AR-58	
36	Brigade Road			AR-52	
37	Hosur Road			AR-65	
38	Bannerghatta Road	Hosur Road Junc	IIMB	AR-69	Dairy Circle to BTM Layout
39	Kastruba Road			AR-60	
40	Lalbagh Fort Road	Lalbagh Fort Road	Marigowda Road (up to Hosur Road)	AR-81	Kalasipalyam Main Road and KR Road to Lalbagh Fort Road
41	Mission Road			AR-93	
42	NR Road				
43	JC Road			AR-78	
44	RV Road			AR-75 & AR-85	
45	KR Road	Monotype	Vanivilas Gen. Hospital	AR-82	Monotpye to Prof. Shivshankar Circle
46	KH Road			AR-96	
47	Langford Road				
48	Raja Ram Mohan Roy Road			AR-45	
49-A	Jayanagar 11th Main	4th Block	80ft Road	AR-87	
49-B	Ashoka Pillar Road			AR-73	
49-C	JP Nagar 24th Main Road	80ft Road	Puttenahalli		
49-D	45th Cross	JP Nagar 24th Main Road Junc.	Kanakapura Road	AR-86	
50	South-end Road				
51	Kanakapura Road				
52	Avenue Road				

Table 9: iDeCK-Rites Corridors and Interventions Planned

Sl No	Corridor Details	From	To	Trip Intensity	Intervention Planned	Core Ring Road Segment
1	Bellary Road	Kodigehalli Road	Kaveri Theatre	High	Widening to 30 m	
2	Palace Road	Mysore Bank Circle	Kaveri Theatre	High	Widening to 30 m	
3	Tumkur Road	Peenya Circle	Yeshwantpur	Medium		
4	Sankey Road	Yeshwantpur	Kaveri Theatre	Medium	Widening to 30 m	YPRr to Prof CNR Rao Circle
5	Outer Ring Road	Tumkur Road	New BEL Road	Medium		
6	Jalahalli Road	Tumkur Road	MS Ramaiah Road	Medium		
7	MS Ramaiah Road			Medium		
8	CV Raman Road	Yeshwantpur	Mekhri Circle	Medium	Part of Core Ring Road	Overlaps with part of 4
9-A	Jayamahal Road			High	Widening to 30 m	Mekhri Circle to Jayamahal Road Junc.
9-B	Jayamahal Road	Jayamahal Road	Bellary Road via RT Nagar Main Road	Medium		
10	Chord Road	Mysore Road	Yeshwantpur	High		
11	Outer Ring Road	Magadi Road	Tumkur Road	Medium		
12	Magadi Road	Ring Road	Leprosy Hospital	Medium	Widening to 30 m	
13	Dr. RajKumar Road	Magadi Road	Kuvempu	Medium	Part of Core Ring Road	
14	Gnanabharati Road	Mysore Road	Outer Ring Road	Medium		
15	Mahakavi Kuvempu Road			Medium	Widening to 24 m	
16-A	Sampige Road	Central	Malleshwaram 18th cross	Medium		
16-B	Margosa Road	Mariamma Temple Circle	Malleshwaram Circle	Medium		
17	Mysore Road	City Market	Ring Road	High		
18	Binny Road	Sirsi Circle	Bangalore City Station		Part of Core Ring Road	
19	Sheshadri Road		KR Circle	High	Widening to 30 m	
20	Sheshadripuram Main Road	via KG Bus Station	Mysore Road	High	Widening to 24 m	
21	KG Road	Hudson Circle	Majestic	High	Widening to 24 m	
22	St. John's Church Road	St. John's Road	Murphy Road	High	Part of Core Ring Road	
23	Arabic College Road		Ring Road	Medium		
24	Wheelers Road	Wheelers Road	Banaswadi Road	High	Widening to 24 m	
25	Cunningham Road			Medium		
26	Queen's Road			Medium		
27	Infantry Road	Infantry Road	Miller's Road	Medium	Widening to 24 m	
28	Kamaraj Road			Medium		
29	Cubbon Road	Cubbon Road	Dickenson Road	High		

30	MG Road	MG Circle	Trinity Circle	High		
31	Old Madras Road	Indira Nagar Road	Bayapanahalli	Medium		
32	Indira Nagar 100ft Road	Old Madras Road	Airport Road	Medium		
33	Airport Road	Trinity Circle	Outer Ring Road	Medium	Widening to 30 m	
34-A	Gen. Thimmaiah Road	Richmond Circle	Shoolay Circle	High		
34-B	Gen. Thimmaiah Road	Shoolay Circle	Trinity Circle	Medium	Part of Core Ring Road	
35	Cariappa Road (Residency Road)			High		
36	Brigade Road			High		
37	Hosur Road			High	Widening to 30 m	Shoolay Circle to Cemetry Junc.
38	Bannerghatta Road	Hosur Road Junc	IIMB	Medium	Part of Core Ring Road	Cemetry Junc. to Dairy Circle
39	Kastruba Road			High	Widening to 24 m	
40	Lalbagh Fort Road	Lalbagh Fort Road	Marigowda Road (up to Hosur Road)	Medium	Widening to 30 m	Part of Core Ring Road from Dairy Circle to Lalbagh Main Gate
41	Mission Road			Medium		
42	NR Road			Medium		
43	JC Road			High		
44	RV Road			Medium		
45	KR Road	Monotype	Vanivilas Gen. Hospital	Medium	Widening to 24 m	Widening only from Subbaram Chetty Circle to MM Industries
46	KH Road			High		
47	Langford Road			Medium		
48	Raja Ram Mohan Roy Road			Medium		
49-A	Jayanagar 11th Main	4th Block	80ft Road	Medium		
49-B	Ashoka Pillar Road			Medium		
49-C	JP Nagar 24th Main Road	80ft Road	Puttenahalli	Medium		
49-D	45th Cross	JP Nagar 24th Main Road Junc.	Kanakapura Road	Medium	Widening indicated only in RITES report and not in BMP's list	
50	South-end Road			Medium		
51	Kanakapura Road			Medium		
52	Avenue Road			Medium	Widening to 24 m	

Road Widening only
Part of Core Ring Road
Overlap amongst Core Ring Road and Road Widening, and conflicts

The above tables depict the overlap amongst Core Ring Road, Arterial roads and the roads identified for widening. From Table 8, it is evident that amongst the corridors identified as high and medium density corridors, not all are notified as arterial roads. It is noted that of 52 High/Medium density corridors, the 43 arterial roads correspond to 38 of these corridors. It is noted that the even among the arterial roads overlapping with the corridors there isn't much harmony. And so, it is imperative that the rest of these corridors should be notified as arterial roads. On the other hand, there are 45 roads identified for widening, of which only 19 belong to the corridors identified by Rites/iDeCK as High-Medium density corridors. However, noting the various differences and discrepancies with the details on arterial roads, there is a stronger and pressing need to reclassify the road network based on sound classification strategy rather than impromptu and reactive approaches of classifying the same. On the same lines, the road classification strategy is suggested in Annexure A, which is adapted and suitably modified for conditions in Bangalore. Accordingly, there would be Local/Link roads, Collector roads, Sub-arterial roads, Arterial roads and Ring Roads (Expressways). The key criteria emphasized for such classification is traffic movement versus property access. The characteristics that would establish the classification are given below:

1. Traffic movement versus property access
2. Typical daily motor vehicle traffic volume (both directions)
3. Minimum number of peak period lanes
4. Desirable connections
5. Flow characteristics
6. Legal speed limit, km/hour
7. Accommodation of pedestrians
8. Accommodation of auto rickshaws
9. Accommodation of cyclists
10. Surface transit
11. Surface transit daily passengers
12. Heavy truck restrictions
13. Typical spacing between traffic control devices, m
14. Typical right-of-way width, m

While noting that creation of information system / developing such database on existing road networks to ascertain the classification is very essential, such database can be used very effectively in operational planning.

At this juncture, an attempt was made to reason out the feasibility of core ring road at surface grade level towards practical implementation of the same. It is noted that the concept of developing a core ring road at surface grade level in the proposed alignment (Map 5) may not be feasible for the following reasons:

1. The notion of a core ring road (as an expressway) is to facilitate enhanced mobility by motorable vehicles without any obstruction of passage across any intersections with traffic movement as primary consideration and not access to property.
2. However, the proposed alignment already has numerous properties being part of older and central city for which restricting any property access would become ill-conceived and impractical with construction of CRR at surface grade level.
3. In the proposed alignment, the entire stretch is not conceived for "signal free passage" and hence very purpose of core ring road is defeated.
4. With 50 intersections along the CRR and only about 13 junction improvements proposed (underpasses and flyovers) mobility along CRR would still instil waiting at various intersections.
5. The entire alignment is not a fresh alignment, but over existing road networks alongside existing properties of various types. A review of the existing studies suggests that some of the segments of CRR are high and medium density corridors with some other interventions are conceived over these.
6. The alignment is mostly on already built-up area and constructing a 4-lane at surface grade would call for acquisition and consequent legal challenges across the entire alignment. Noting that some segments of CRR pass through older city areas, wherein existing road networks are 2-lane, it would be a challenging task to implement this project without any hurdles in the scheduled time.
7. There are already some interventions for junction improvements (like, Mekhri circle and Dairy circle) while another 13 interventions are proposed. Unless, all these interventions are taken up collectively instead of interventions in isolation, traffic congestion will not be arrested but aggravated.
8. However, an elevated core ring road might suffice to fulfil abovementioned objectives.

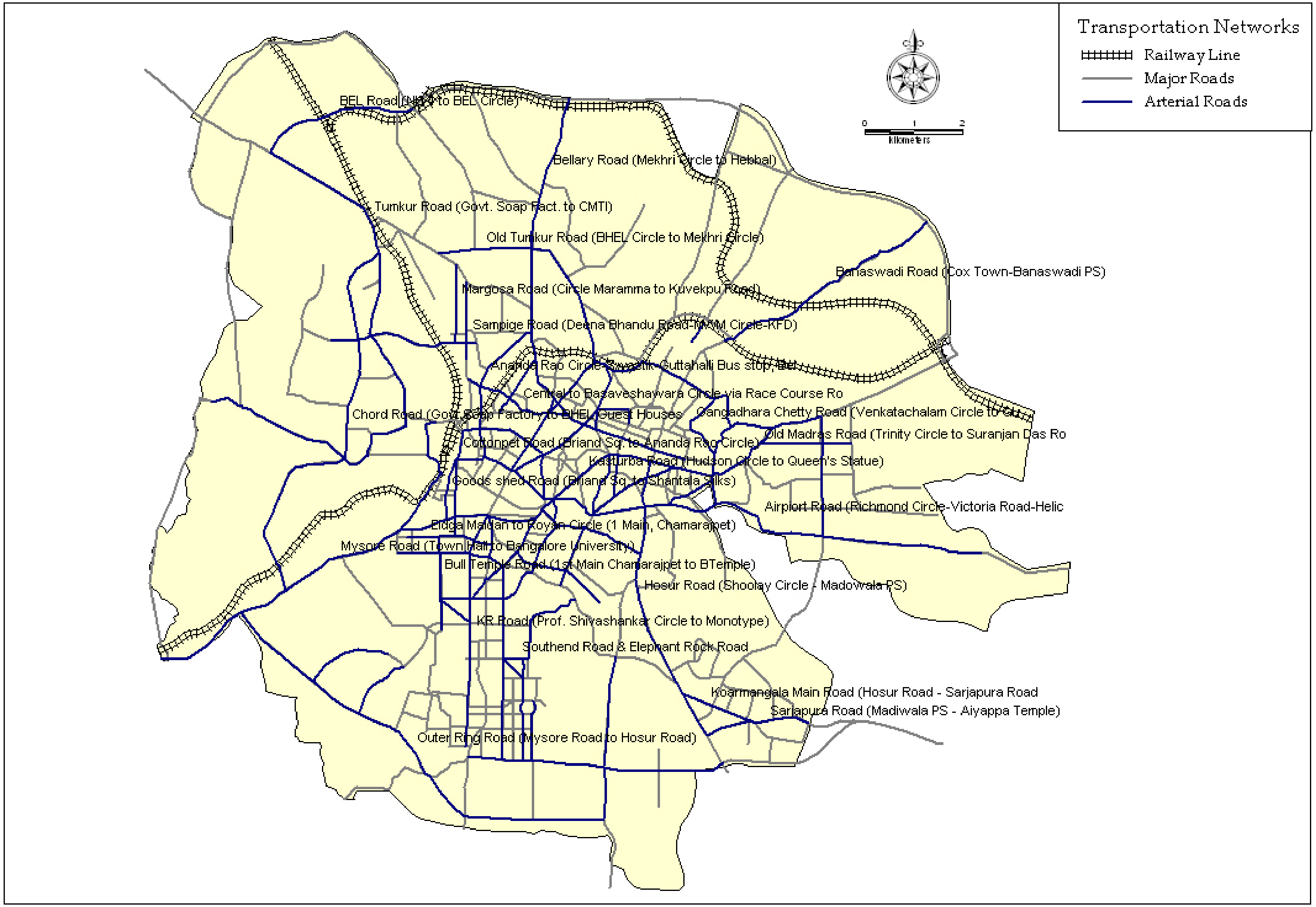
There has been some confusion regarding the various roads and the associated development / improvement programmes proposed through various packages in view of numerous classification and packages. Further there are also other proposals to be taken up for improving condition of traffic. In this regard, there is also lack of appropriate maps highlighting the different road segments identified under different proposals. Hence it was initiated to create spatial database for all these using GIS so that this can be used to chalk out necessary action plans.

2.5 Spatial database and maps Identifying junctions and segments for intervention

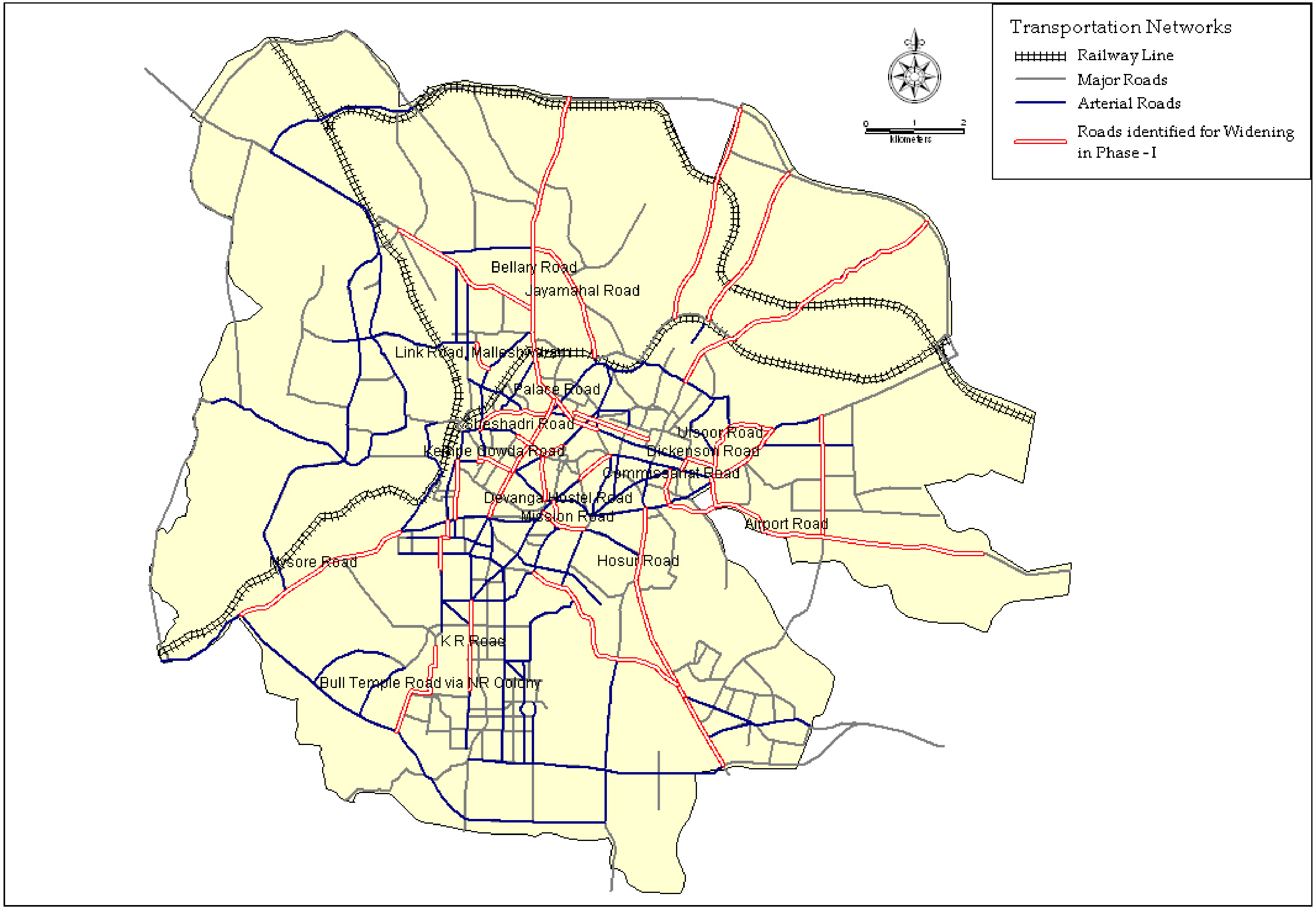
Based on existing transportation network; synthesis of various transportation related studies and proposed infrastructure initiatives (road works) in Bangalore the spatial database was developed depicting the various stages of interventions. Accordingly, mapping various initiatives and interventions planned towards addressing mobility existing situation and implications of some of the proposed interventions were undertaken. Amongst the different studies undertaken, the basis for the analysis of this study is based on studies commissioned by KRDCL in 3 packages (Annexure B).

The spatial database was prepared by mapping for the following:

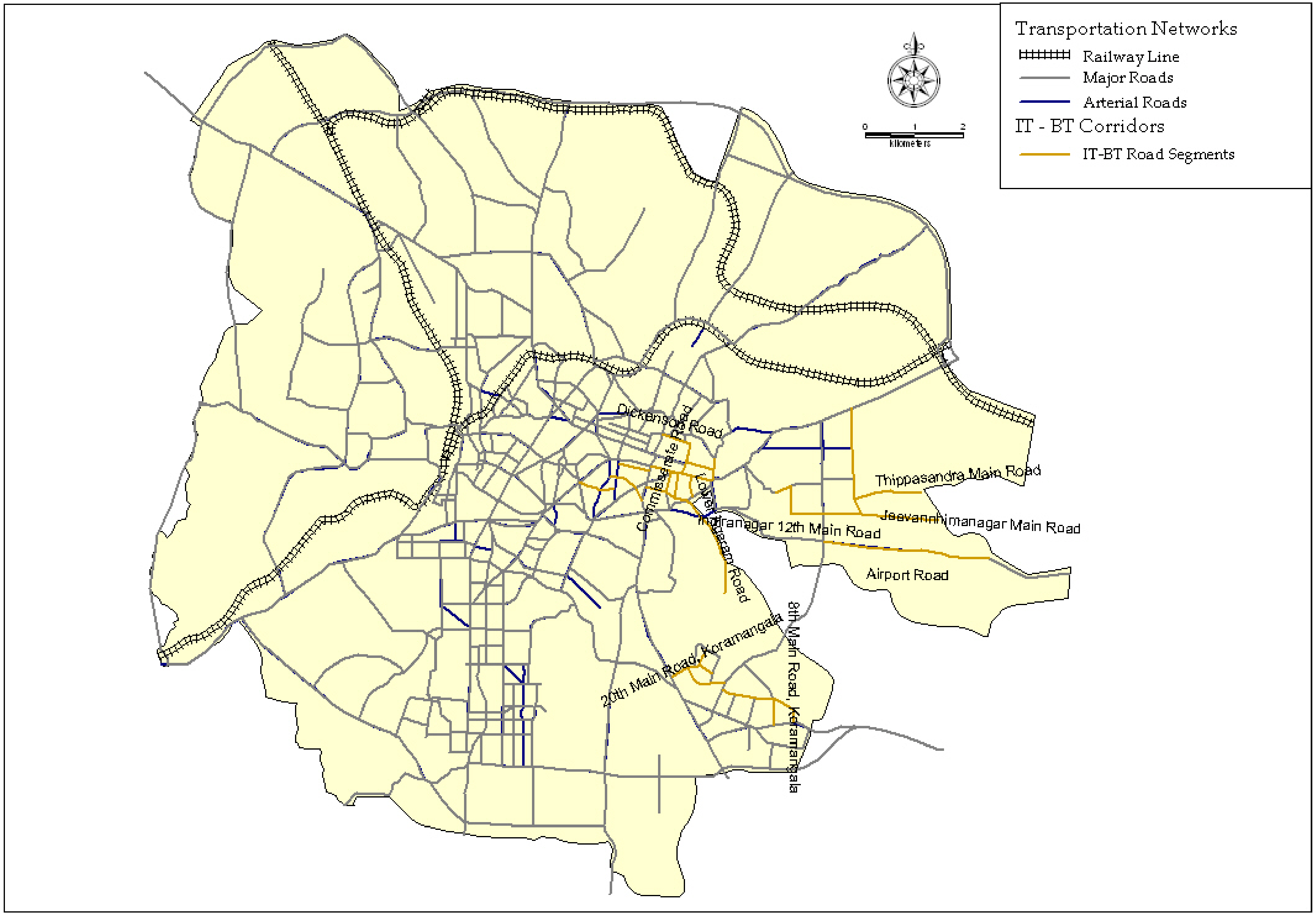
i. Major Transportation Networks - Map 1
ii. Roads identified for Widening under Phase – I - Map 2
iii. IT – BT Corridors - Map 3
iv. Corridors identified by Rites/iDeCK - Map 4
v. Core Ring Road: Segments and Junctions - Map 5
vi. Intersections identified by KRDCL - Map 6
vii. Project Status under JNNURM - Map 7



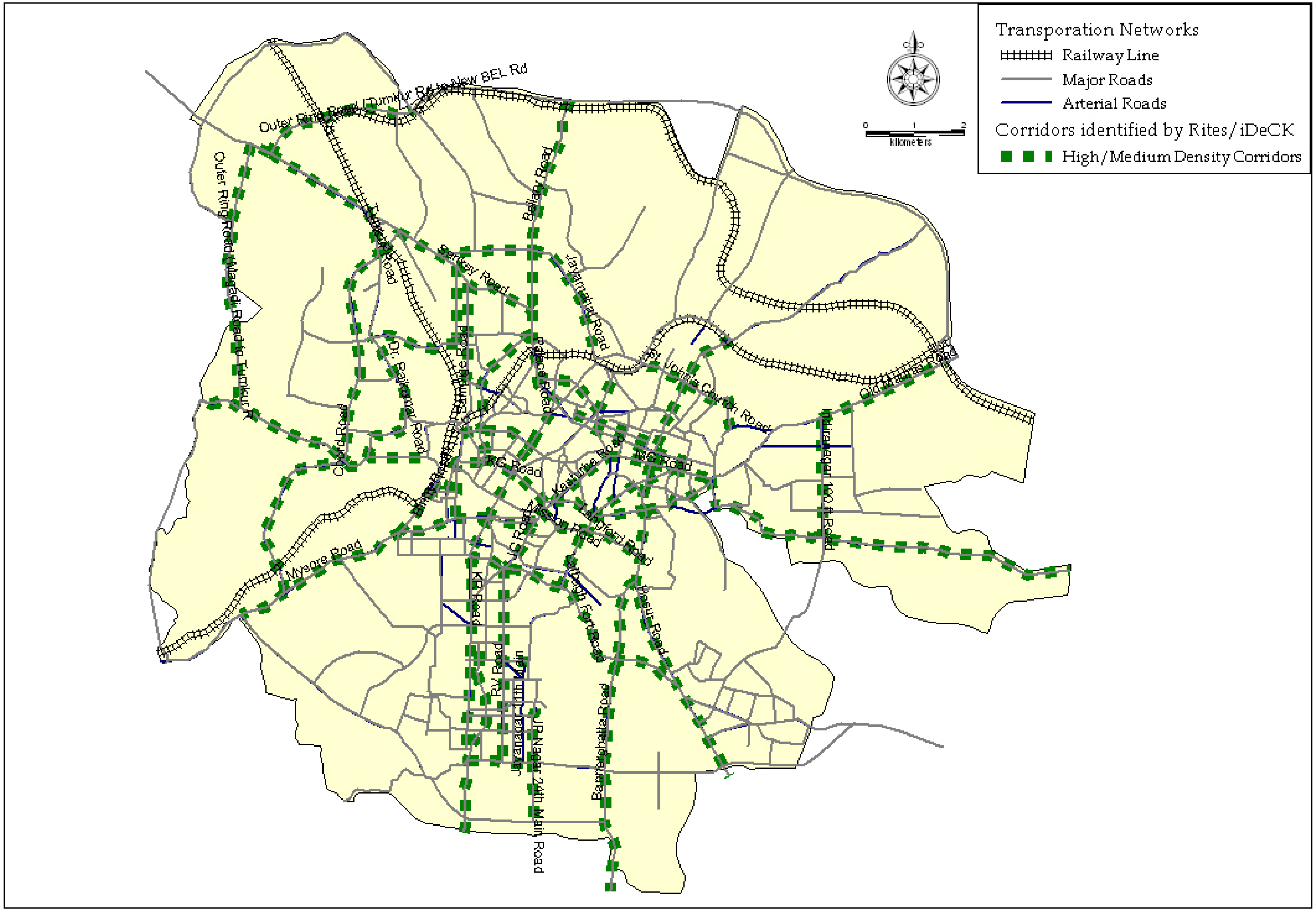
Map 1: Major Transportation Networks



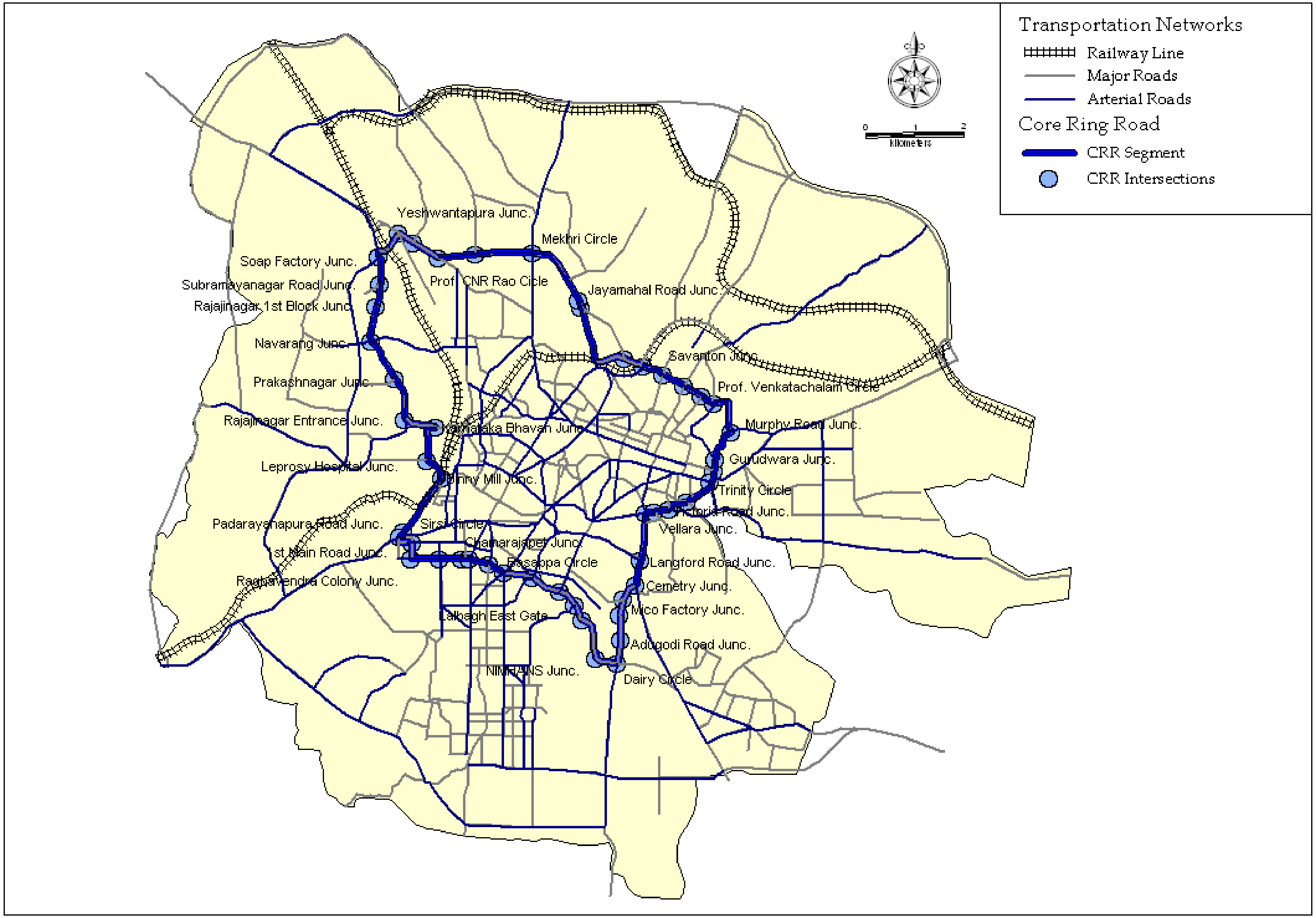
Map 2: Roads identified for Widening



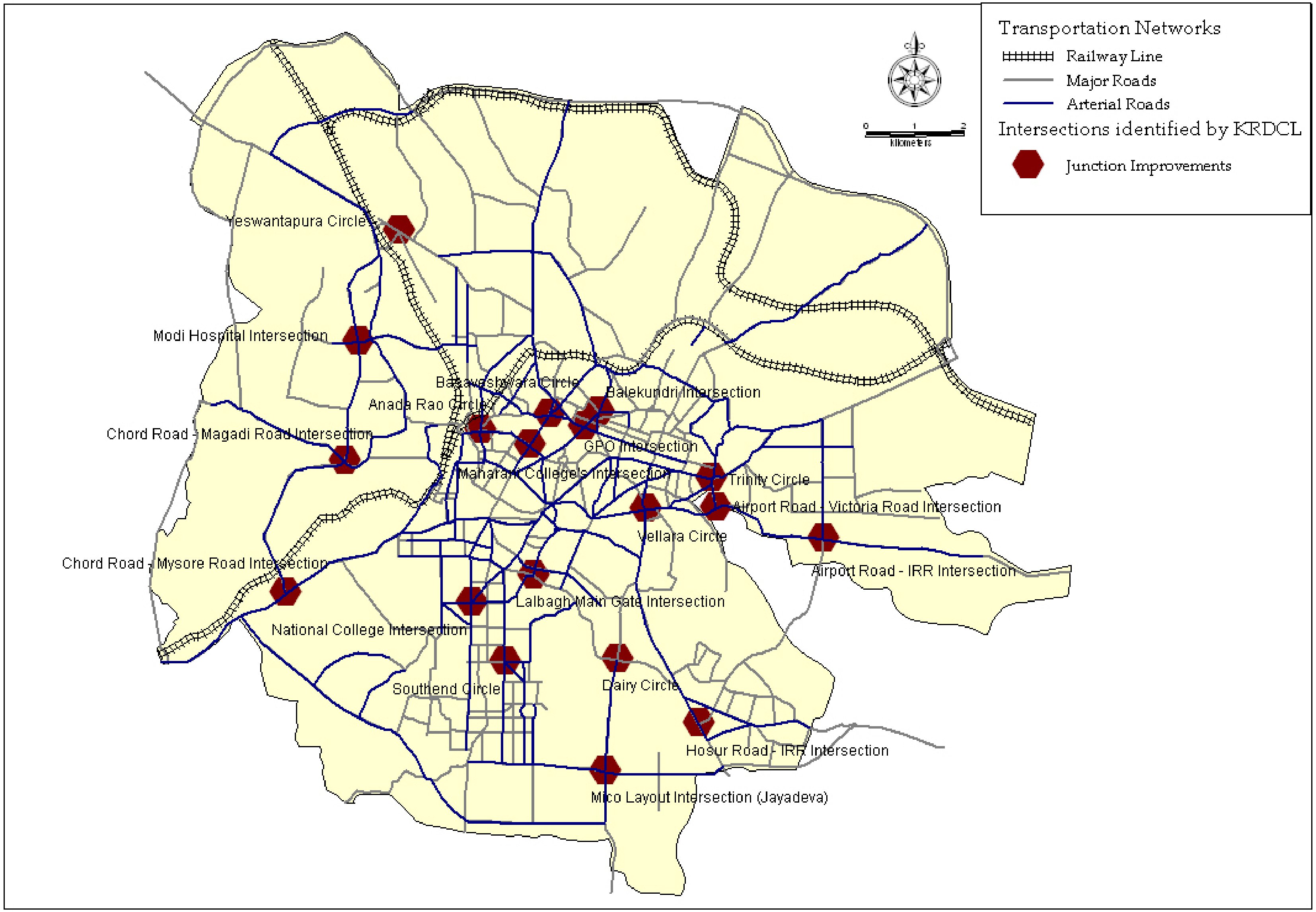
Map 3: IT - BT Corridors



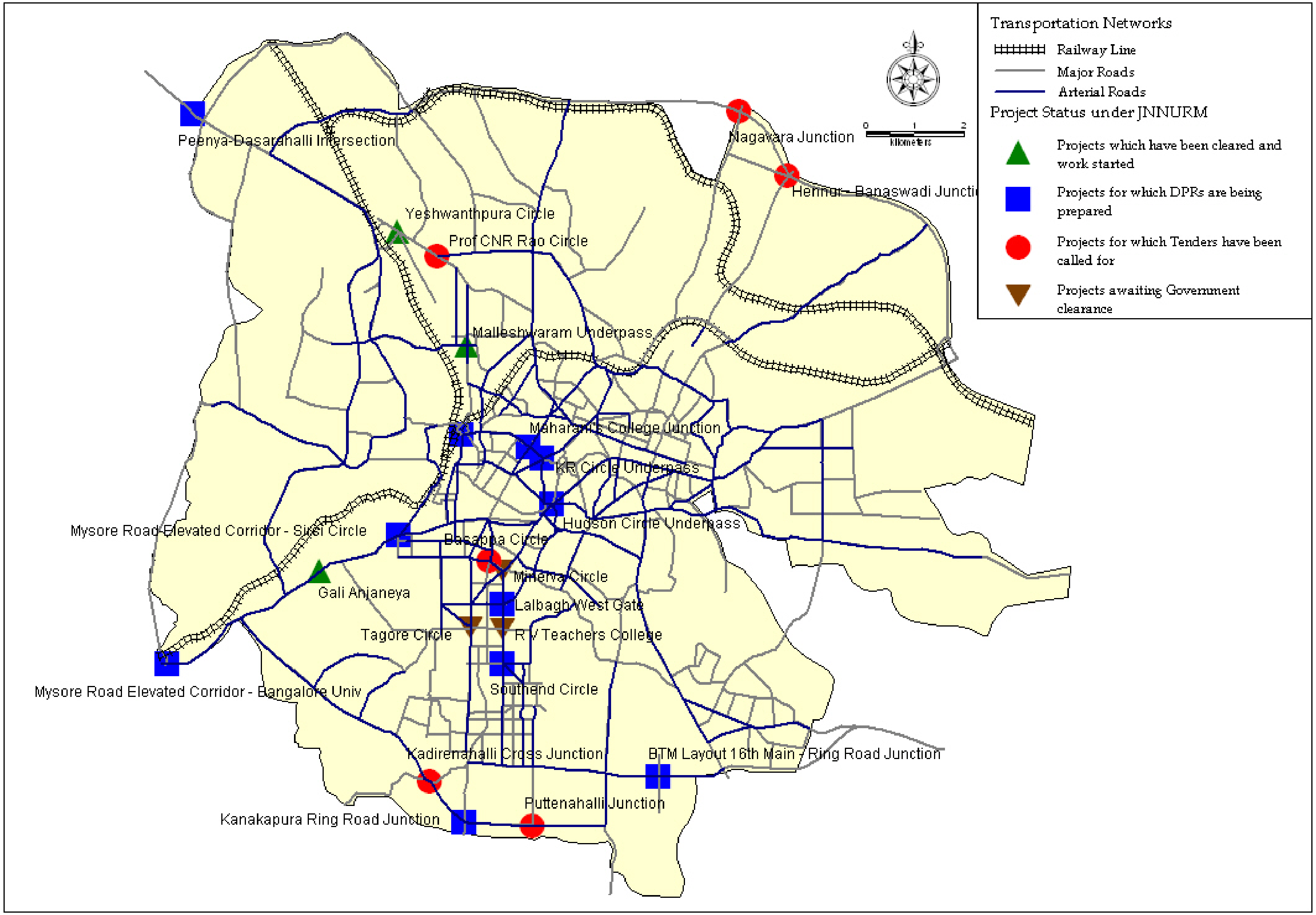
Map 4: High-Medium Corridors identified by Rites/iDeCK



Map 5: Core Ring Roads - Segments and Junctions



Map 6: Intersections identified by KRDCL



Map 7: Project Status under JNNURM

Box: 1 Corridor Development in light of BRAESS Paradox

The Braess Paradox was originally presented by German scientist, Braess (1968). In a congested road network, Braess had demonstrated that adding a link within the network to ease congestion would be counter-intuitive. It consists of a phenomenon which contradicts the common sense: in a traffic network, when a new link connecting two points (e.g. origin and destination) is constructed, it is possible that there is no reduction regarding the time necessary to commute from the origin to the destination. Actually, frequently this time increases and so the costs for the commuters. Thus, the average time spent in the entire network would only increase instead of reducing travel time.

Following the seminal work by Braess, many authors have been proposing applications and modifications on the formulation of the problem in order to avoid the paradox. Most of the work addressed to avoid the paradox has been only successful in an un-congested network. From the perspective of the economics of traffic, Arnott and Small (1994) analyse three paradoxes in which the usual measure for alleviating traffic congestion, i.e. expanding the road system, is ineffective. The resolution of these paradoxes—among them the Braess Paradox—employs the economic concept of externalities (when a person does not face the true social cost of an action) to identify and account for the difference between personal and social costs of using a particular road. For example, drivers do not pay for the time loss they impose on others, so they make socially-inefficient choices. This is a well-studied phenomenon more generally known as The Tragedy of the Commons. Regarding the Braess Paradox, in the scenario analysed by Arnott and Small the travel time for each of the two original routes is 20 min, while after the addition of the new route the travel time for the equilibrium situation rises to 22.5 min for each route.

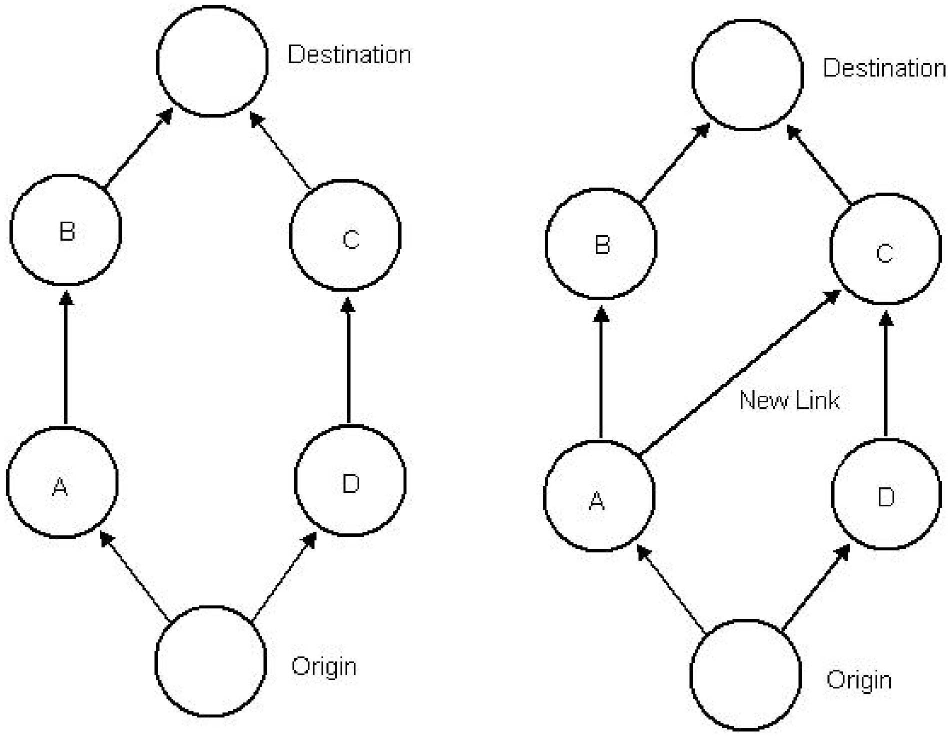


Figure B1: Occurrences of Braess Paradox in Congested Network when a new link is added

Thus, in light of Braess Paradox, Bangalore road networks which are already congested, adding any new links by way of flyovers and underpasses would prove counter-productive.

Credits:
Bazzan, A.L. & Klugl, F. (2005), and Braess, D. (1968)

3 BMP's Initiatives in Addressing Mobility

BMP has proposed to take up various programmes to ease congestion of traffic in the city. Most of these are in various stages of conceptualisation to implementation. Among them are: widening of roads, resurfacing of major roads, construction of grade separators, flyovers, underpasses, construction of skywalks, multilevel automated car parking, and pavement improvements.

The road widening is proposed to be taken up under two phases. In the phase 1, 45 roads with about 91.2 km and in phase 2, another 40 roads with about 52.8 km would be widened. The details of the roads identified for widening in phase 1 is presented in Annexure C. Further, within phase 1, 12 roads are identified to be taken up in priority for about 30.2 km. Mostly roads would be widened for about 24 m or 30 m.

3.1 Upcoming proposals addressing mobility under JNNURM

With enormous impetus under JNNURM for enhancing basic urban infrastructure and governance, several infrastructure projects addressing mobility are being posed under the same. The details of some of major infrastructure projects relating to road works are shown in Table 10 and Map 7. In all there are about 23 active projects, of which work has been started for 3 projects while Detail Project Reports are being prepared for 10 projects, tenders have been called for about 6 projects and 3 projects are awaiting state government's clearance.

Table 10: Project Status under JNNURM

Sl. No	Project Status
Projects which have been cleared and work started	
1	Malleshwaram Underpass
2	Yeshwanthpura Circle
3	Gali Anjaneya
Projects for which DPRs are being prepared	
4	Kanakapura Ring Road Junction
5	South-end Circle
6	Lalbagh West Gate
7	BTM Layout 16th Main - Ring Road Junction
8	Maharani's College Junction
9	Khoday's Circle
10	Peenya-Dasarahalli Intersection
11	Mysore Road Elevated Corridor from Sirsi Circle to Bangalore University
12	KR Circle Underpass
13	Hudson Circle Underpass
Projects for which Tenders have been called for	
14	Prof CNR Rao Circle
15	Basappa Circle
16	Kadirenahalli Cross Junction
17	Puttenahalli Junction
18	Nagavara Junction
19	Hennur - Banaswadi Junction
Projects awaiting Government Clearance	
20	R V Teachers College
21	Tagore Circle
22	Minerva Circle

4 Systems Analysis for Addressing Mobility

Systems dynamics is an approach to modelling the dynamics of population, ecological systems, and economic systems, and the relationship between all three. Modelling under *system dynamics* framework serve as a useful first step in making some reasonable assumptions about the pattern a particular system might produce. However, by no accurate means and more in depth analysis, modelling is attempted with few assumptions and outputs as logical conclusions. Systems model were devised out of a long, inductive process whereby computer modellers, using formal modelling techniques, noticed systems characteristic patterns in different systems. Thus, modelling the existing condition of traffic congestion and methods adopted to ease this are investigated with this modelling technique by building – Causal Loop Diagrams. The systems approach for addressing traffic congestion has almost become a classic textbook case while demonstrating / studying the implication of road widening for easing congestion in road network. Such an example can be found in John Sterman's (2000) "*Business Dynamics: Systems Thinking in a Complex World*".

Systems thinking use diagrams, graphs and pictures to describe and structure interrelationships and behaviours of situations. Every element in a situation is called a variable, and the influence of one element on another element is called a link; this can be represented by drawing an arrow from the causing element to the affected element. In systems thinking links always comprise a 'circle of causality', or a feedback loop, in which every element is both cause and effect. Typically the process of systems modelling begins with a clear statement of the problem, followed by gathering necessary data and identifying the key variables contributing to the problem. The variables are mapped on to what is referred to as Causal Loop Diagrams. With the gathered data and establishing relations with the variables amongst the variables are the Stock Flow Diagrams created. It is possible to simulate the behaviour of the system through Stock Flow Diagram and plot the behaviour of key variables, test for different hypothesis and study the implications of specific interventions. A limitation of this report is that the systems' modelling is concluded only with a Causal Loop Diagram. However, a detailed systems modelling can be taken up once all the relevant data are gathered and the possible nature of interventions in to the system are noted.

4.1 Identifying the variables – Identifying the causes for Congestion

The problem in question is the pressure to reduce congestion and the interventions that are approached towards this and systems modelling is attempted to analyse the consequences of these approaches. Accordingly, based on the author's study and analysis the key variables identified were:

a) Travel time
b) Desired travel time
c) Pressure to reduce congestion
d) Interventions by Road widening / other construction
e) Road capacity
f) Attractiveness of driving
g) Adequacy of public transport
h) Public transit fare
i) Trips per day
j) Average trip length
k) Traffic volume
l) Public transit ridership
m) Vehicles per person
n) Vehicles in the region
o) Extent of city within desired travel time
p) Population and economic activity

4.2 Representations through Causal Loop Diagrams

Representations through Causal Loop Diagrams (CLD) are popular form of system dynamics modelling, providing a flexible modelling approach where the nature of the relationship between each pair of variables can be expressed. The typical approach to cause-effect modelling, the 'disjointed viewpoint' and 'linear, control viewpoint' of one cause leading to one effect, is replaced by a 'Causal-loop, Nonlinear Feedback Viewpoint' where multiple effects are the result of multiple factors, as described in Figure 3 below. It is very obvious from the Causal Loop Diagrams that there are multiple feedbacks, the reinforcing feedback and balancing feedbacks.

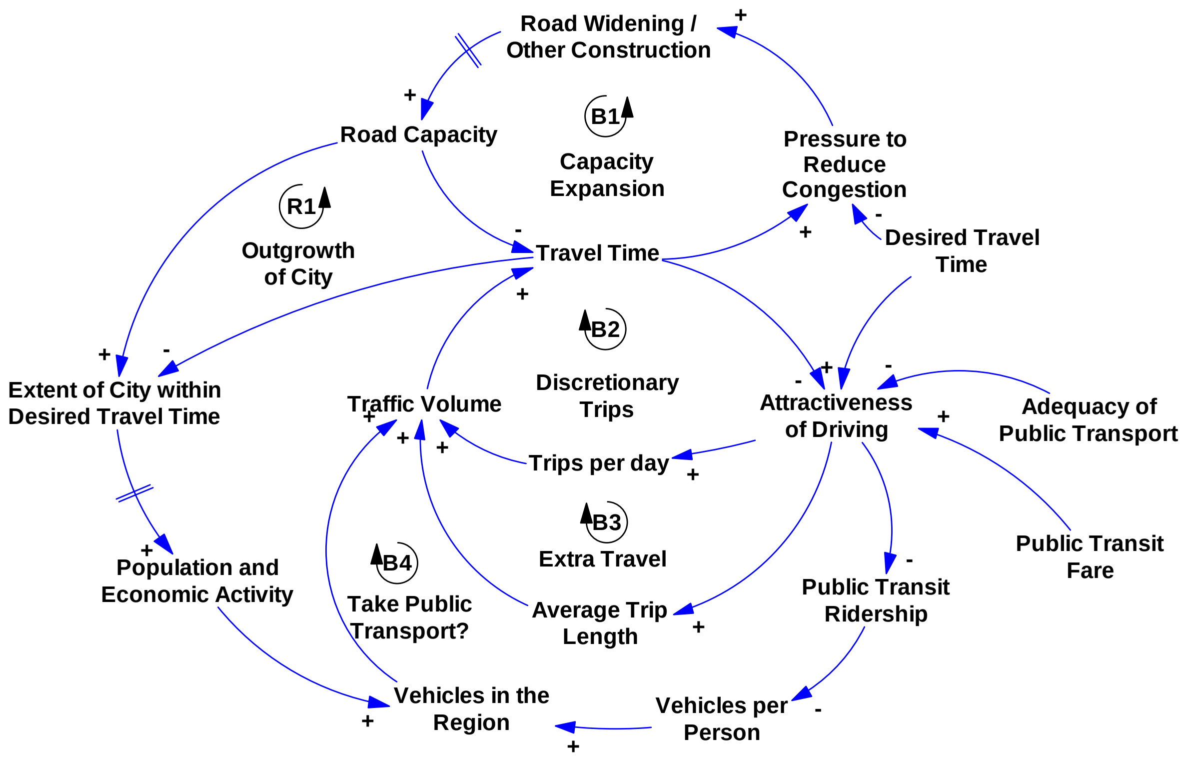


Figure 3: Causal Loop Diagram of Existing Practices to Reduce Congestion and Implications

4.3 Systems Analysis

Analysing the feedbacks generated – reinforcing and balancing, the resultant dynamics emerged through the existing practices reveal that existing practices are actually proving counter-productive. The five feedbacks generated in this system – CLD are:

- Reinforcing Feedbacks: R1 – Outgrowth of City
- Balancing Feedbacks:
  - B1 – Capacity Expansion
  - B2 – Discretionary Trips
  - B3 – Extra Travel
  - B4 – Availing Public Transport

Reinforcing loops, by definition, are incomplete. Somewhere, sometime, it will encounter at least one balancing mechanism that limits the spiralling up or spiralling down effect. The reinforcing feedback, R1, results in outgrowth of city by the creation of an outer / peripheral ring road which is created as part of capacity expansion, caused by another balancing feedback, B1. Reinforcing feedbacks often generate exponential growth and then collapse. Figure 4 demonstrates the evidence of this reinforcing loop in and around Bangalore – congestion, lead to outer ring roads, which lead to new suburbs, leading to more congestion.

Over the 8-year trends observed through remote sensing satellite images the rapid-growth around Bangalore reveal how quickly urban sprawl takes over the landscape.

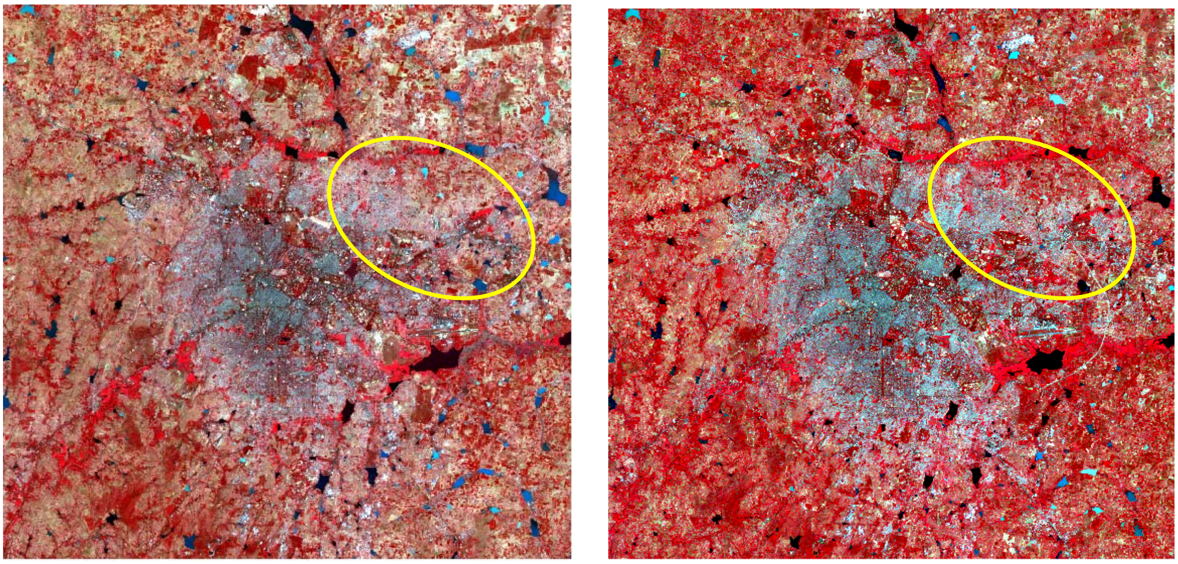


Figure 4: Urban Sprawl across Bangalore, 1992-2000

Balancing loops are forces of resistance that balance reinforcing loops. They can be found in nature (such as climate) and indeed other systems, and are the processes that fix problems and maintain stability. Systems that are self-regulating or self-correcting comprise of balancing loops. Balancing processes are bound to a constraint or target which is often set by the forces of the system, and will continue to add pressure until that target has been met. The balancing feedback, B1, emerges and simply remains to operate as long as there are road widening and other constructions leading capacity expansion. As a counter to this is the only reinforcing feedback of outgrowth of the city. Further, with increased traffic volume and consequent travel time, there is little attractiveness to driving that can contribute to discretionary trips and extra travel. In the absence of adequate public transport and significant public transit ridership there is little incentive for people to avail public transport. A significant characteristic of every system, and often the most ignored, are delays. Delays in loops occur when a link takes a relatively long time to act out, and can have an enormous influence on a system, often exaggerating the behaviour of parts of the system and hence the general behaviour of the whole system. Delays are subtle and often neglected, yet they are prevalent in systems and must be actively considered. The Systems Analysis offers insights into the existing practices and suggests the need to re-look / reinvent the approaches towards addressing the problem of congestion as existing practices are counter-productive.

5 Analysing for Time- and Cost-overruns: Experiences from Previous Initiatives

Bangalore Mahanagara Palike at any given point of time is responsible for delivery and implementation of various public works especially on provision and maintenance of infrastructure like road works, street-lighting, solid waste management, etc. However, with ubiquitous pressure on delivering basic services and infrastructure to its citizens it is of utmost importance that there aren't any time- and cost overruns in the implementation of various projects. Yet infrastructure related works envisaged by BMP faces severe road block at various stages resulting in time and thus cost-overruns for successful and timely completion of these projects. And so, as a first step it was attempted characterise some of the key issues responsible for time and cost – overruns.

5.1 Key issues responsible

In order to arrive at the key issues responsible for the time and cost overruns, discussions with various Engineers of BMP were undertaken. The factors responsible for these delays indicate the lack of effective coordination from other line agencies. The factors for time and cost-overruns in various infrastructure projects are outlined below while the ways to tackle are listed in the report.

- Shifting of utilities: Most road networks carry either water supply pipe or a sewage line along one of its shoulders, while there can be additionally telecommunication related utilities lying underneath. Often, even after the work-order for the execution of the project is granted by BMP, shifting of utilities owned by various agencies actually cause significant time-lags in initiation of the projects.
- Traffic diversion: Some of the infrastructure projects like construction of flyovers or underpasses would result in blocking certain right-of-ways at the junctions where the projects are taken up. This would minimally result in diverting the traffic plying over this junction. Again in most instances obtaining the necessary clearances and opting for alternative routes during the execution of the project are contributing to the time-over runs of the project.
- Acceptance by public/locals: It is noted that some of the infrastructure projects are conceived under the pretext of larger common good, while there are definitive resistance from the locals or people directly affected by the projects. Thus, even if a project has

cleared all necessary hurdles of project approval and funding, it might actually face stiff resistance from the public further delaying the completion of the project.

- Handing over the site in the light of unclear title documents: In instances like road widening and other road construction works, at times it is the unclear title deeds/documents with the residents/owners of the adjacent property.
- Administrative delays in getting appropriate approvals at various levels both internal (Council) and external (other agencies, like BMRCL): Apart from the above factors, sometimes right at the initial stages of project conceptualisation and subsequent execution, BMP internally needs to take clearance from the council of elected representatives. In few other instances, wherever the projects are coming up in the region where the Metro is coming up, BMP has to take official clearance from the concerned organisation, BMRCL. These clearances are often responsible for time-overruns.
- Escalation of costs of materials from the time of tender to actual issue of work order: The bill of materials required for the project would sometimes face with escalation of cost with respect to the cost quoted during the conceptualisation of project to the day of implementation of the project.
- Acquisition of land: Overcoming different hurdles acquiring the necessary land for taking up the infrastructure work, is yet another factor responsible for time and cost overrun.
- Surprise legal hurdles: At instances where there are stiff resistances from the public or others, the project itself may face surprise legal hurdles for successful implementation.

5.2 Ways to tackle

The successful completion of infrastructure projects without any time and cost overruns are to be achieved by the local body in order to save for the additional cost incurred and retain faith from the public on the capabilities of a local body to deliver services and implement projects professionally. Some of the possible ways of tackling this are listed below:

- Ensuring coordination amongst stakeholder organisations
- Effective information dissemination of the proposed project
- Increasing accountability of BMP Engineers in-charge of the project and Contractor responsible for executing the project
- Incentives / sanctions on BMP Engineers and Contractors towards successful execution of the project

It is noted that key factor responsible for time and hence cost overruns is the lack of effective coordination amongst stakeholder organisations and effective information dissemination of the proposed project. Thus it is imperative that effective mechanisms for ensuring coordination amongst the stakeholder organisation are created and put in place. Further, with effective information dissemination of the proposed projects, there can less confusion and hence opposition from the public, while it will be most effective when there is community participation at the project conceptualisation stage. With community participation at the project conceptualisation stages, there would be little resistance to these projects, besides it is the community who should be benefited by these projects.

At present there isn't any mechanism that acts as checks within the system to ensure that responsible / concerned officials are held accountable for the successful implementation of the project. Even simple information display boards on status of projects and the concerned official at a public place should create minimal checks to ensure timely implementation of the project. On the same lines, there can be incentives offered to the contractor who have contributed to the timely completion of the project.

The mechanisms suggested here require only minimal mechanisms to display the status of the projects corresponding to concerned officials, while decision on other mechanisms like offering incentives are to be taken through policy decisions taken at the highest level of the local body. This chapter only broaches this subject very briefly, noting that a detailed study and analysis can offer better insights into successful and effective implementation of infrastructure projects towards establishing best practices.

6 Future Initiatives - Mechanisms for Ensuring Coordination

Among the key challenges that the city corporation faces towards successful implementation and completion of various infrastructure projects related to mobility can be summed up in three heads: Lack of effective coordination; Lack of complete/essential information and Lack of benchmarking practices or performance measures to track progress. Each of these is elaborated in slight detail in the subsequent sections. The argument put forward here is that without complete picture (information) on the ground, there cannot be any coordination and in the absence of these there will certainly be no benchmarking. However, in some isolated instances there are examples of some initiatives resulting as *Best Practices* even within the purview of BMP, which unfortunately are not replicated. Innovative mechanisms of implementation though earn the tag of Best Practices, they at times fail to be repeated or replicated and mostly it is difficult to sustain over a period of time these practices. Further, such practices might have resulted from the lead taken by the executive head in these institutions and the best practices initiated by one head need not stay on when the incumbent head moves on another assignment. Hence, it is on the onus of the executive heads to put mechanisms and systems in place that these practices are sustained and replicated. As a first step towards achieving this, it is essential to integrate planning and operations effectively. As noted in Chapter 2.2, with numerous organisations addressing mobility, notably many on daily operations and the other on planning. In this regard, the theme that is put forward in the subsequent section is on integrating planning and operations for ensuring mobility.

6.1 Integrating Planning and Operations

The theme that is put forward for day-to-day operations is to ensure a sustainable best practice through planning for operations through coordination and a common geographic unit for these operations.

6.1.1 Planning for Operations through Coordination

From the analysis and experiences with the style of local governance and administration, the operation plans drawn are ineffective in addressing smooth coordination. Essentially much of the chaos is contributed due to the disengagement with the planning organisation and the organisation involved with daily operations. A stark contrasting fact with the planning organisation is its lack of acknowledgement of any city functions: mobility, jobs, economy, energy, etc. The planning organisation on the one hand is focussed on land use plans and its regulation alone with any acknowledgment of integrating land use with transportation for enhancing mobility. On the other hand, the local administration has to wake overnight to act for daily operations management with little realisation on the implications of the planning organisation ignoring the city functions. With numerous organisations responsible for addressing mobility, it is imperative that at least these organisations get together in acknowledge their interdependencies formally through appropriate mechanisms. Thus the possible way out to break the gridlock, is facilitating systems and practices that ensures feedback and coordination effectively. Essentially the interplay of these organisations involved with mobility has to be acknowledged and bridged from short-to-medium time frame planning undertaken by BDA to near-to-short term operations undertaken by BMP. Thus, it is essential to link the daily-operations with the planning of 10 year time period so that future chaos is arrested.

A Coordination committee or an empowered committee to address these under a singe umbrella would possibly be the option. To begin with it is essential to sensitise all the key stakeholders on their interdependencies and the need for constant feedback and hence coordination. Subsequently the coordination committee will have to create processes and mechanisms ensuring the above objectives. This committee also has to charter the entire workflow of the various activities and ensure systems for speedy approval and implementation of these activities.

6.1.2 A Common Geographic Unit: Key for Coordination

A key reason for the persistence of lack of effective coordination is the absence of "common geographic unit". Much of the mess, the planning or the administration currently facing are the implications of having different geographic units for different stakeholder organisations. Again as noted in Chapter 2.2, with multiple organisations addressing mobility, it is rather incomprehensive that none of these organisations have a common geographic unit! In the absence of common geographic unit, there is no way that any data can be collated and assimilated collectively which leads to isolated interventions evident from the current practices. Noting the notification of Greater Bangalore and the amalgamation of neighbouring municipal councils and villages into the agglomeration, the landscape of Bangalore has been formally extended. However, with the demarcation of regions, zones and wards based on possibly census and settlement patterns, it is imperative a common geographic unit is mooted with the involvement of all the stakeholders in this region. By ensuring that all other stakeholder organisations comply with the same geographic unit, planning for operations will become very effective. The advantage of having common geographic unit would also ensure easy collection, collation and dissemination of the data at a common place. Thus the integration and coordination has to begin with the small step of having a common geographic unit.

6.2 Gathering Information: Technological Interventions

Bangalore is currently experiencing a sea of challenges in urban governance and at the same instance an opportunity in taking on this challenge. The challenges are self-evident: speedy and efficient delivery of service and ensuring access to these across the cross-section of the society. From managing infrastructure, to collection, transfer and safe disposal of solid waste, to delivery of education and health services, to regulating building plans, and so on the civic administration is flooded with many activities that relate to daily operations. However, as evident from the current practices, there is a dearth of information at every level. Specifically on mobility, in the absence of effective road classification strategy and even compliance to existing classification, the nature of data available are sparse. Given the multitude of organisations addressing mobility, no factual data are collected with regard to status of traffic across key junctions or segments, status of roads with respect to asphalting and potholes, status of pavements and streetlights, all on a spatial database. Thus it is highly recommended that the administration invests on data collection, analysis and sharing for effective operations. This can only be anchored and coordinated by the civic administration as the key organisation responsible for delivery of basic services to its citizens.

Noting practices worldwide, like in London, the head of city, the Mayor, is the executive head responsible for all issues under mobility including the Transport for London, Metropolitan Police Authority and the London Development Agency. This has created a mechanism for all stakeholders to be united under a single head / authority enabling effective information gathering, sharing and coordination. Unlike London, administration in Bangalore is a different setup. However, the notification of Greater Bangalore by the state government calls for greater coordination and better delivery of services. In this regard, the civic administration should initiate actions and mechanisms in a way that this goes a long way in recognising the needs and collecting all the necessary information across different service delivery organisations. A possible way out is through specific administrative reforms towards the same.

Further specifically on addressing mobility, gathering information periodically can aids in activity tracking that can suggest optimal routes for vehicular movement in real time ensuring effective traffic management. Gathering Information aiding in activity tracking, analysis and decision-making for daily operations of traffic, forms the foundation of Intelligent Transport Systems. Intelligent Transport Systems with real time information helps online tracking, monitoring of vehicular movement, which will aid in automating / synchronising traffic signals.

Activity tracking and online tracking, monitoring of vehicular movement is possible by enforcing Radio Frequency-based ID (RFID) tags installed to all vehicles that ply within city limits. Such tags would flush in thousands of data clouds for vehicular traffic movement along various segments that can be tracked, visualised through appropriate systems for effective management. Then the challenge is for technology to decipher the data and represent the data clouds over a spatial domain for effective decision-making. Given the fact that leading institution in the country, the Indian Institute of Science is also in Bangalore, IISc can spearhead towards anchoring for the same in technology with opportunity for private players to participate in terms of IT infrastructure and services. The civic administration in coordination with other service agencies can be assured of real time data dissemination for decision-making. The advantages of radio-tagging vehicles are that the administration would know the nature of traffic at any junction/segment and the profile of vehicular traffic in that segment. This would also curtail on any possible violation of traffic rules and incidence of crime. The radio-tagging may be made mandatory similar to the norms for mitigating environmental pollution through emission certificates that has to be obtained periodically every six months. The administration may charge additionally towards the costing of one-time set-up costs of such facility and let the owners of individual motor transport to contribute for their radio-tags.

With the possibility of collecting data online through RFID, traffic signals can be effectively synchronised and automated. Such a facility can also lead to developing an Integrated Dynamic Decision Support Systems incorporating all the above. The ITS will be essentially based out of this Decision Support System aided by an effective mechanism of data gathering. The decision support system can aid in testing for different scenarios through prototype simulations and numerous tools. One such micro-simulation of road traffic is shown in Figure 5.

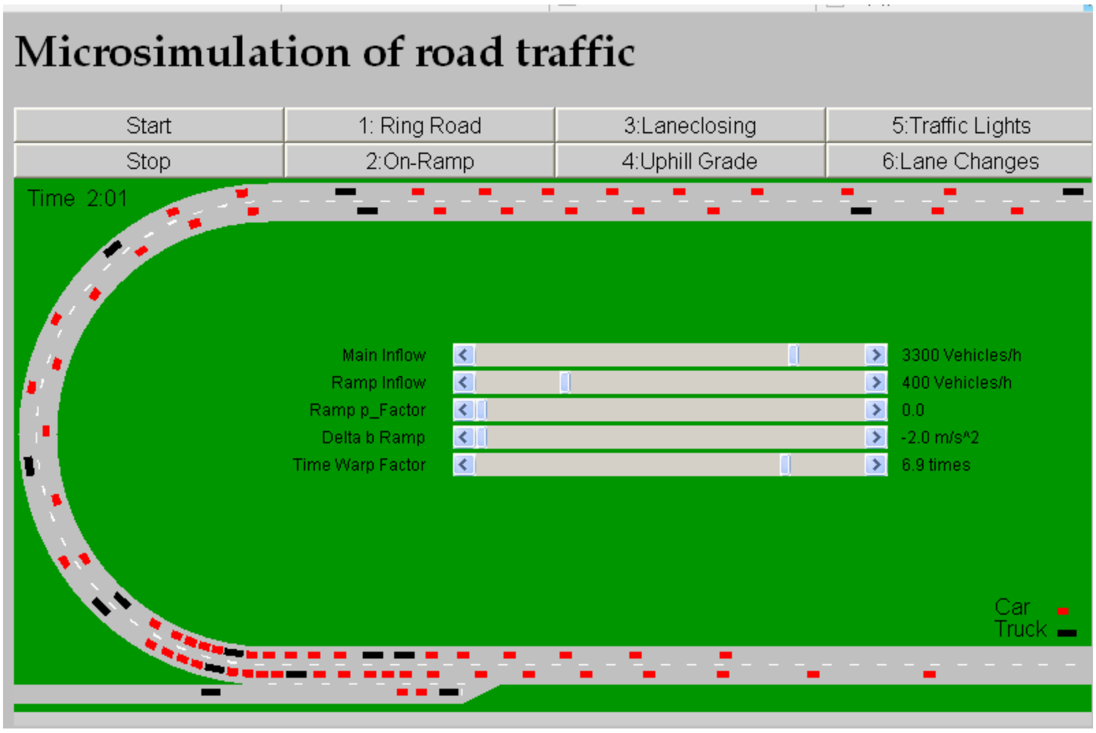


Figure 5: Micro-simulation of road traffic by Martin Treiber[4], (2005)

Besides these there are tools like AGENTS – "A Game theoretic Evolutionary Network Traffic Simulation" and SUMO – "Simulation of Urban Mobility" for developing robust decision support systems based on strong theoretical and factual data.

The data gathered can be assimilated and presented through various metrics and ways of representation. The metrics can be organised as indicators and represented in a similar fashion like that followed by the Florida Transport Authority (Table 11). The activity tracking of vehicles can be represented online and can be displayed at any specific locations as need be. One such representation of status of vehicular movement along national highway in North-west Germany is shown in Figure 6.

[4] Available online: http://www.vwi.tu-dresden.de/~treiber/MicroApplet/index.html Last accessed January 10th 2007.

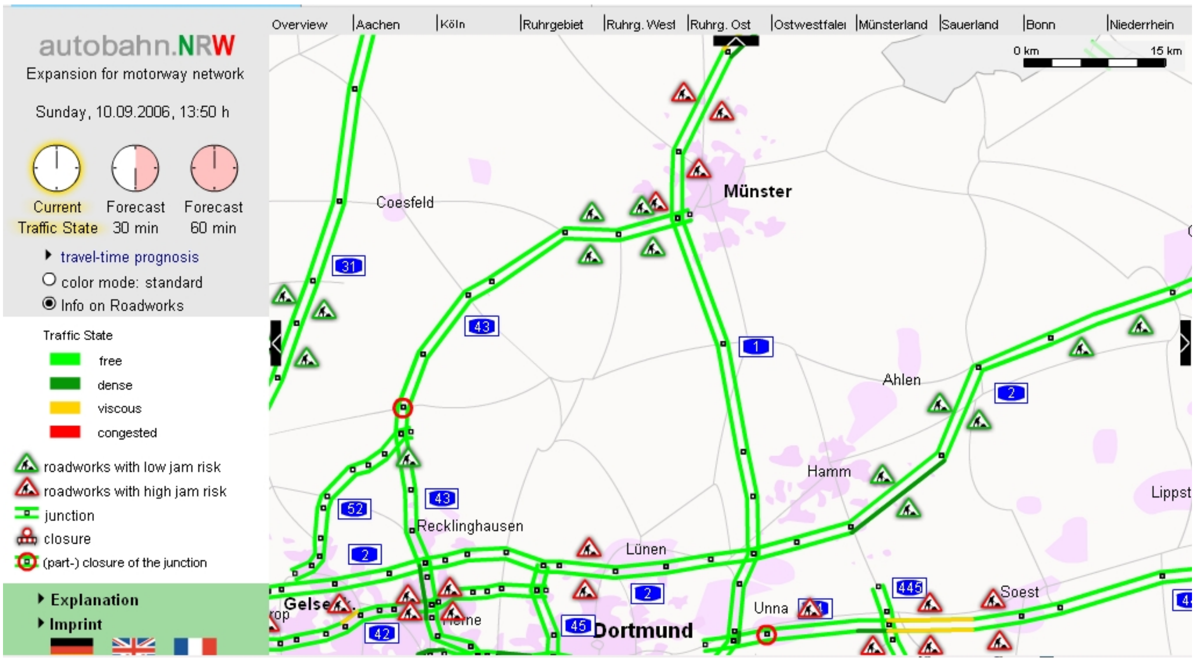


Figure 6: Representation of Traffic Status Online along the National Highways (autobahns) of North-western state of Germany

Table 11: Possible Metrics / Indicators

Indicator	*Timelines*	*Change From Prior Period*		*Change From Prior Year*	
		Percent (%)	*Direction*	*Percent (%)*	*Direction*
Population	Annual	1.8%	▲	2.4%	▲
Registered Vehicles	Monthly			4.2%	▲
Fuel Sales (Price per litre)	Weekly			-7.9%	▼
Fuel Sales (Quantity)	Monthly	-2.3%	▼	8.3%	▲
Net Emissions	Weekly	-6.1%	▼	-1.7%	▼
Public Transit (persons)	Monthly	-9.4%	▼	-10.3%	▼
Pedestrians	Weekly				
Vehicle Miles Travelled	Monthly	-36.2%	▼	-5.8%	▼
Motor Vehicle Traffic Volume	Monthly	-4.2%	▼	-2.4%	▼
Driver Licenses (Issued)	Monthly			2.3%	▲
Road Mileage	Monthly	-15.7%	▼	-12.9%	▼
Tourism	Quarterly	39.7%	▲	-0.8%	▼
Safety (Fatalities)	Monthly	-17.4%	▼	-22.0%	▼
Airline Activity	Monthly				

Note: The figures mentioned in the table are only indicative and not actual.
Adapted from Florida Transport Indicators, Source: http://www.indicators.cutr.usf.edu/summary.htm

6.3 Tracking progress through Performance Measures

In the absence of any performance measures the direction of interventions/progress or their effectiveness is unknown. A set of performance measures essential to track the progress of various interventions towards addressing mobility. Citizens, elected officials, policy makers and transportation professionals required to measure the performance of the transportation system to answer the following questions:

- How can services be enhanced for improving mobility?
- What are the outcomes of investment in transportation?
- What is the efficiency of investment addressing mobility?

Mobility performance measures are needed to answer these questions and to track performance over time. They also provide accountability and link strategic planning to resource allocation. By defining specific measures, the civic administration will be able to measure the effectiveness of programs in meeting its objectives. Mobility performance measures, adapted from the Florida Mobility Performance Measurement Program, are used to characterize the success of transportation, in terms of:

1. Quantity of service (number of people served) - Collective user perspective, and measure of a program's success.
2. Quality of service (degree of traveller satisfaction with the service provided) - Usually related to travel time.
3. Accessibility of service (ease of engaging in activities) - Related to existence of service, and difficulty of using it.
4. Utilization (how much of the available capacity is used) - Indication of whether the system is properly sized, matching supply to demand.

Together, the four concepts of quantity, quality, accessibility, and utilization provide a comprehensive picture of mobility to individual users, the general public, and decision makers. Table 12 notes some of the mobility performance measures. The performance metrics and indicators can be made available to public to keep track of progress made over the last period and constantly monitor to ascertain the direction of investments and supporting decisions. The performance measures together with the information and indicators will significantly contribute to the quality of decision-making for better informed citizens with direct feedback on the nature of initiative and investments made.

Table 12: Mobility Performance Measures

Dimension of Mobility	Mobility Performance Measure	Definition
Quantity of Travel	Ridership	Total passenger trips
Quality of Travel	Auto / Transit Travel Time Ration	Door-to-door trip time
	Reliability	On-time performance
Accessibility	Coverage	% person minutes served
	Frequency	Buses per hour
	Span	Hours of service per day
Utilization	Load Factor	% seats occupied

6.4 Conclusions

The chapter noted significant aspects relating to immediate steps to be taken up by BMP for addressing effective planning for operations. Alongside the key aspects: Planning for operations; Gathering information and Performance measures of enhancing mobility, certain policies are also suggested to address congestion and movement of individual motor transport in the central city. Some of the policies curtailing Congestion and Traffic Growth through some Smart Growth options are noted below:

a. Enforcing additional cess/tax for vehicles plying in the central city.
b. Additional/heavy tax for vehicles discouraging independent motorable transport.
c. Introduction / encouragement of utilising bicycles for mobility in short distances and central areas without any motorable transport apart from mass transit.
d. Acknowledging implications of changing land use on mobility to discourage any inappropriate and inefficient land use.
e. Effective enforcement and regulation of the above with strong administrative and political will.

The objective of the report was to comprehensively address the issue of Mobility in Bangalore. This report an outcome of mapping the various initiatives and interventions planned towards addressing mobility, existing situation and implications of some of the proposed interventions in Bangalore city. Though some of the aspects of mobility, especially relating to pedestrian movement are less addressed, the report has integrated various studies addressing mobility and involved mapping important initiatives. Based on existing transportation network; synthesis of various transportation related studies, best practices across the globe and proposed infrastructure initiatives (road works) in Bangalore, the report has come out with key suggestions for enhancing mobility. The report suggests integration of various stakeholders for effective coordination and notes critical aspects relating to the same. Noting that information is an integral part of decision-making the report suggests ways to achieve this. As a way of establishing best practices, the report suggests tracking progress through performance measures that can support for the investments made. The report brings a synthesis of various issues towards Enhancing *Mobility* through integrated Traffic and Transportation Management.

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Annexure

Annexure A: Classification Criteria for Roads

Characteristic	Local/ Link Roads	Collectors	Sub-arterial Roads	Arterial Roads	Ring Roads (Expressways)
Traffic movement versus property access	Property access primary function	Traffic movement and property access	Traffic movement primary consideration; some property access	Traffic movement primary consideration; subject to property	Traffic movement primary consideration; no property access
Typical daily motor vehicle traffic volume (both directions)	< or = 2,500	2,500 - 8000	8,000 - 15,000	> 15,000	> 25,000
Minimum number of peak period lanes (excluding bicycle lanes)	One (one-way streets) or two	One (one-way streets) or two	Two	Two/Four	Four
Desirable connections	Locals, collectors	Locals, collectors,	Collectors, arterials	Collectors, arterials, expressways	Arterials, expressways
Flow characteristics	Interrupted flow	Interrupted flow	Uninterrupted except at signals and crosswalks	Uninterrupted except at signals and crosswalks	Free-flow (grade separated or elevated)
Legal speed limit, km/h	40-50	40-50	40-60	50 – 60	80-100
Accommodation of pedestrians	Sidewalks on one or both sides	Sidewalks on both sides	Sidewalks on both sides	Sidewalks on both sides	Pedestrians prohibited
Accommodation of auto rickshaws	Permitted	Permitted	Permitted	Permitted	Prohibited
Accommodation of cyclists	Special facilities can be provided				Cyclists prohibited
Surface transit	Generally not provided	Permitted	Preferred	Preferred	Express buses only
Surface transit daily passengers	Not applicable	< or =1,500	1,500-5,000	> 5,000	Not applicable
Heavy truck restrictions (e.g. seasonal or night time)	Restrictions preferred	Restrictions permitted	Minimal restrictions	Minimal restrictions	No restrictions
Typical spacing between traffic control devices [1], m	0-150	215 - 400	215-400	215 - 400	Not applicable
Typical right-of-way width [2], m	10-18	15-22	18-24	20-28	>45

Notes:

1. Traffic control devices means traffic control signals, pedestrian crossovers and 'Stop' signs.
2. Even 20 m rights-of-way do not exist on many older arterial roads. New arterial roads should have wider rights-of-way. Wider rights-of-way (within the ranges given) are sometimes required to accommodate other facilities such as utilities, road furniture, bicycle facilities, and landscaping.

This classification is adapted from the "Road Classification System - A Consolidated Report".

Annexure B: Traffic Volumes and Congestion Indices of Important Intersections (Source: KRDCL, 2002)

Sl. No.	Name of Intersection	Traffic Volume in pcu/hour		Congestion Index	
		Morning Peak	Evening Peak	Morning Peak	Evening Peak
1.	Airport Road – IRR Intersection #	11,162	10,821	1.38	1.34
2.	Airport Road – Victoria Road Intersection	8,147	8,435	1.60	1.65
3.	Ananda Rao Circle #	15,125	12,480	1.58	1.30
4.	Balekundri Circle	10,516	11,653	1.00	1.11
5.	Basaveshwara Circle	12,868	11,604	1.28	1.15
6.	Chord Road – Mysore Road Intersection	9,212	7,788	1.92	1.62
7.	Chord Road – Magadi Road Intersection ##	11,234	11,076	1.39	1.37
8.	Dairy Circle #	11,010	9,581	1.57	1.37
9.	GPO Intersection	11,662	11,132	1.77	1.69
10.	Hosur Road – IRR Intersection	6,311	4,947	1.01	0.79
11.	Lalbagh Main Gate Intersection	8,151	13,984	1.76	3.02
12.	Maharani's College Intersection	11,142	8,535	1.52	1.16
13.	MICO Layout Intersection	10,820	10,690	1.34	1.33
14.	Modi Hospital Intersection	8,105	8,117	1.38	1.46
15.	National College Intersection #	9,478	7,774	0.96	0.87
16.	South End Circle	12,011	13,037	0.89	0.97
17.	Trinity Circle	12,566	12,521	1.68	1.62
18.	Vellara Circle	11,827	10,982	1.52	1.41
19.	Yeshwanthapura Intersection	7,553	8,028	0.95	1.04

- Completed
- Construction in progress

Annexure C: List of Roads Identified for Widening under TDR for Phase 1

Sl. No.	Name of Road	Length in km	Existing width (avg) in metres	Proposed width in metres
1.	Bellary Road	7.60	23.00	30.00
2.	Palace Road	1.75	18.60	30.00
3.	Sheshadri Road	0.50	21.20	30.00
4.	Nrupathunga Road	1.10	22.00	30.00
5.	Vidhana Veedhi	0.20	28.50	30.00
6.	Mission Road	1.00	19.00	30.00
7.	Devanga Hostel Road	0.50	15.00	24.00
8.	Sankey Road	3.40	20.25	30.00
9.	Jayamahal Road	2.80	20.40	30.00
10	Hosur Road – 1	1.60	23.66	30.00
11.	Hosur Luskar Road	4.30	20.13	30.00
12.	Victoria Road	1.60	14.00	24.00
13.	Lower Agaram Road	2.40	11.66	24.00
14.	Sarjapura Road	3.35	25.37	30.00
15.	Hosur Road – 3	4.30	15.60	30.00
16.	Dickenson Road	0.30	22.50	24.00
17.	Ulsoor Road	0.50	15.00	24.00
18.	Kensington Road	0.32	25.40	30.00
19.	Murphy Road	1.70	22.00	30.00
20.	Old Madras Road	1.70	15.66	24.00
21.	Airport Road	5.20	23.03	30.00
22.	Cottonpet Main Road	1.20	13.00	24.00
23.	Avenue Road	1.10	9.95	24.00
24.	Mysore Road	3.90	22.87	30.00
25.	Mahalakshmi Layout and Nandini Layout Main Road via Aiyappa Temple and Singapore Layout	2.70	-	24.00
26.	K. R. Road	1.16	-	24.00
27.	Sultan Road	0.42	-	24.00
28.	1st Main Road, Chamarajapet	0.15	22.00	24.00
29.	3rd Cross, Chamarajapet and Bull Temple Road	1.00	-	24.00

30.	Link Road, Malleshwaram	0.63	11.00	24.00
31.	Padarayanapura Main Road	1.86	12.00	24.00
32.	Bull Temple Road via N. R. Colony, Chennamma Tank Bed and 30th Main, Banashankari 3rd Stage	1.10	17.50	24.00
33.	K. G. Road	0.60	15.00	24.00
34.	Dr. Ambedkar Road (Tannery Road)	2.43	15.00	24.00
35.	Hennur Road	3.62	-	24.00
36.	Banaswadi Road and Wheeler Road via Banaswadi	6.35	16.12	24.00
37.	Magadi Road	2.40	18.00	30.00
38.	Kurubarahalli Main Road	1.00	-	24.00
39.	17th Main J.C. Nagar in Ward No. 13	1.50	-	24.00
40.	5th Cross, Malleshwaram	1.00	23.00	24.00
41.	Commissariat Road	0.74	-	24.00
42.	Race Course Road	1.66	16.83	30.00
43.	Kasturba Road	0.77	21.40	24.00
44.	Suranjan Das Road	3.85	-	30.00
45.	Infantry Road	1.83	-	24.00