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Influence of Supply-oriented measures on Road Traffic Congestion

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Summary

Transport Demand Management (TDM) is the approach in sustainable transport policy. TDM comprise of strategies to alter the travel behaviors and modal choices via demand-based method, permissible to accomplish effective transport planning. The two modules easing the traffic are supply-oriented measures and efficient management. The supply-oriented measures are one of the categories in the provision of the infrastructure. Supply-oriented measures are taken by many municipalities in order to ease the traffic congestion, it is to provide infrastructure to accommodate the demand from the users/ traffic.

As a center for the commerce and IT zone, Hyderabad is growing to accommodate more employees from other cities. The huge figure of population in Hyderabad is also influenced by usual population development also because of the employees transferring from adjacent cities due work. As a magnitude, congestion is seen particularly in the IT zone of the city which is Madhapur. A specific zone with 8 junctions are corridors are selected to analyze the traffic condition in the area.

The main focuses of the research to find the reason for the inadequate supply-oriented measures by the infrastructure and service provider of Hyderabad (GHMC and HMDA). The data obtained using qualitative approach. Thus, this study conglomerates explanatory methods, with in-depth interviews and observations as research tools by complimenting with secondary data sources.

The following research finds that there were inadequacies in the supply-oriented measures taken by the municipalities, as the provided infrastructure did not match with the standards from the Indo-capacity Manual. The inadequacy caused major traffic congestion and was seen in the- PCU values, spatial congestion and time delays. This gives us an overview of the inadequacy of the supply-oriented measures and how the Municipalities can ease it by adopting different methods.

Keywords: *Hyderabad, Transportation Demand Management, Municipality, supply-oriented measures, road traffic congestion, road traffic management, level of service, road users, spatial development.*

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Keywords Acknowledgements Abbreviations

IHS	Institute for Housing and Urban Development
GHMC	Greater Hyderabad Municipal corporation
HMDA	Hyderabad Metropolitan Development Authority
MoUD	Ministry of Urban Development
HCM	Highway Capacity Manual
TSIIC	Telangana State
IT	Information Technology
CSIR	Central Road Research Institute
HCM	Highway Capacity Manual
LOS	Level of service
IRC	Indian Road Congress
ATC	Advance Transportation Control
TDM	Travel Demand Management
NIC	National Informatics Centre
OECD	Organization for economic cooperation and Development
HOV	High Occupancy Vehicles
TTI	Texas Transportation Institute
TRI	Travel rate Index
CSI	Congestion Severity Index
VMT	Vehicle miles travel
CBD	Central business district
LCV	Light Commercial Vehicles
V/C	Volume/Capacity
KPI	Key performance Indicator
CEPT	Centre for Environmental Planning and Technology
COE	Center for Excellence
NGO	Non profitable government organization
CRRI	Central Research Institute
TDM	Travel demand management

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Chapter 1: Introduction

The following chapter gives an outline of the study, emphasizing the background of the problematic situation in the city and the key objective of the research. It further focuses on the research questions and sub-questions along with the limitation scope of the research.

1.1 Background of the study

Cities have some basic features in common, the diversity of urban forms, built and socio-cultural environment, economic bases, and institutional contexts. Transport represents one of these magnitudes, and they too need to be understood in terms of the history, culture, and functions for each city. According to Author Tsekeris and Geroliminis (2013), the cumulative environmental and economic worries elevated by the growing of private vehicles usage in an urban area has rose in degradation of environment. Creating huge losses in the economy due to loss of time in traffic congestion. The transportation demand places a key character in creating congestion in urban areas. As the economy and social development grow, it increases the mobility in the city promoting the use to private vehicles in the city. However, it has limited infrastructure of transportation and it is not always utilised to its fullest by efficient management process (OECD and ECMT, 2007). The major characteristics influencing the travel demand and leading to congestion are- Social economic growth , increase in the urban population (Chakraborty and Dutta, 2002), un-organised land-use patterns (OECD and ECMT, 2007), inefficient public transport operations, lack of facility of parking spaces on the roads (Brinkman, 2016) and increase in the urban freight transport and goods delivery (Bull, 2003).

Another crucial change was experienced by the major Capital cities of India was the growth of IT (Information Technology) parks. A key policy initiative by the Government of India was the "formation of the National Task Force on Information technology and software development" in year 1998. Its objective was to eliminate the job jams and boost IT industry of India (Chakraborty and Dutta, 2002) leading to massive expansion of companies and IT jobs in India. This lead to the migration of employees from one city to another in search of better jobs. With the varied job, employees migrated from once city to another. However, the Indian roads were not prepared for a huge change and are still coping up the increasing demands of infrastructure provision in the IT sectors. The unexpected inflow and outflow of people have led to chaos situation for the infrastructure provider.

Colak(2016) discusses that the quick urbanization and demand for transportation encumbrances road infrastructure, the interchange of vehicles and availability of road capacity on their paths determine the congestion levels. The approach of modifying demand and capacity be present in the possible limits of congestion mitigation by only adapting route choice. Further, the author mentions the advancement of technology and increasing penetration generating huge quantities of data that can be used to study and alleviate the claim for the supply of infrastructure. In the case of India, there is a lack of integration of Departments and usage of Technology.

Individually transportation mode segments the collective goal of satisfying a resulting transport demand and each mode of transport by filling the purpose of associate mobility. Transport is a facility which must be utilized instantly, dissimilar the resources it frequently conveys, the transport service cannot be put in storage (Rodrigue, 2017). Further the author Rodrigue (2017) claims that without movement, infrastructures would be impractical, and without infrastructure, activities will not occur, or would not happen in a cost-resourceful way. This reliance and dependency is measured according to two concepts: the supply of infrastructure plus efficient management of Infrastructure. Conferring to Schmid's conference proceeding (2013), "Supply-oriented measures often have negative side effects, it will not help to ease transport problems in the long term, and will be a heavy burden on city budgets." Transport supply measures consist of a combination which makes transportation probable. Which are categorized

as- “(i) Infrastructure: roads designed for circulation; (ii) means of transportation; vehicles; and (iii) The manner in which both are managed” (Stoper R. Peter, 2003). Urban transport supply tends to be classified in step with its capability, that it, the amount of persons who will be transported during a given amount of time. There are many factors impacting the capacity of transport infrastructure because of inadequate supply orientated measures (by the traffic management system) like physical characteristics of the network, funding, operated and maintained, to the presence of bottleneck congestion (Rodrigue, 2017).

In India the different Government organization, such as the State/ Local Municipalities are in charge for the maintenance and construction of Infrastructure, they have the authority to take the decision required pertaining its safety and usage. The Highways are of the jurisdiction of the National Highway Authority of India who are responsible for its maintenance and control(National Highways Authority of India, Ministry of Road Transport & Highways, Government of India, 2017), whereas arterial and sub-arterial roads in the city and villages are majorly owned by the state Municipalities. Where the municipalities are accountable for the construction and maintenance. The rules and regulations of keeping the traffic organized are managed by the Traffic Police department. Traffic is effectively been managed by the supply of infrastructure and Transport Demand Management strategies.

In order to scale back the congestion level within the cities, the Municipality has led to within the design and carrying out of variety of coming up with and management ways on the supply side, sufficing the present demand for infrastructure. The only strategy adopted by the Municipality is the supply of the infrastructure to avoid the current traffic congested situation. Transport supply measures consist of grouping of resources which make transportation possible such as building infrastructure, means of transport and efficient management of both of transportation and vehicles (iii) The way in which both are managed (Stoper R. Peter, 2003).

With the current situation and coping up future demands, the infrastructure needs to be upgraded and adopt different strategies. Municipalities frequently capitalise in road infrastructure assembly and maintenance to extend supply, though disagreements on weather additional road ease congestion continue. In order to understand the level of services benchmarking is highly required. Benchmarking is a procedure of computing the performances of urban transport elements in contradiction of a set of standards (CoE urban transport and CEPT University, 2013).

CSIR- Central Road Research Institute, New Delhi India has published the “Indian Highway Capacity Manual” (Indo- HCM) (2017) to serve as a basic guide for the decision makers towards capacity augmentation of various types of roads as well as pedestrian facilities. The main purpose of the manual is for the transportation and highway fraternity to follow the realistic capacity values evolved in the manual by under-taking the evaluation of existing road facility. The values given in the Indo-HCM 2017 is expected to provide a much-reliable source to update the Indian Road Congress (IRC) documents and standards to evolve new guidelines to address the current situations in the city. The chief objective of benchmarking is to understand countrywide physical characteristics of road traffic and to determine the level of Service (LOS) for varying type of services provides by the Municipality to address the current traffic condition in the urban areas.

1.1.1. Background of the city

Hyderabad shared capital of Andhra Pradesh and the Telangana State of India’s population is 6.8 Million according to the census 2011. Hyderabad with a total area of 650 Square Km making it center for trade, commerce and IT hub (Census 2011). The IT hubs grew enormously in the city and expanded the city to its limit creating traffic congestion in many parts of the city and causing chaos and time delays. Due to the growth of the IT sector in Hyderabad, the inflow and outflow of people became highly unpredictable. A study conducted by the National Institute of Technology Warangal (Prasad, 2017) on sustainable mobility initiatives in Hyderabad, says the Private vehicles will gradually increase

by 9.9% every year. The city is witnessing lack of infrastructure to accommodate the growing use of private vehicles.

1.2. Problem statement

With the city of Hyderabad expanding its border and attesting lack of infrastrcuture making the road traffic congestion is a common distinguished problem. As observed from the newspaper report (Deccan Chronicle)," the traffic bottlenecks was caused due to dificult and sharpe curves, reduction of carriageway due to obstructions like strcutures or wrongly parked vehicles", further it adds to the chaos casued due to the narrowness of the underpass leaving the traffic stuck from 8am-10am and 6pm-11pm. The research focuses on the level to which the provison of infrastructure and management effects the traffic congestion in the city of Hyderabad. The outsized development that followed in Hyderabad has made it gradually more problematic to sustain even minimum satisfactory levels in services, and in recent time urban services have mostly worsened. Transportation services are among the most severely affected. As Rodrigue (2017) mentions transportation as a market that consists of suppliers of transport services and users of those services. Well-operative transport markets ought to enable the transport supply system together with various activities set in numerous areas generates movements that has to be supported by the transport system. In Hyderabad, the influence because of growth alone has been combined by inflated rates of usage for each public and private transportation caused by the result of improved income levels in increasing wishes for private mobility. As mentioned by Schmid (2013), the failure in urban and transport planning is a closed loop starting from the need to transport supply-investment in transport supply further witnessing initial reduction of travel time and increase in travel of users which again increases the road congestion leading to the need to transport supply. The loop is a failure if the infrastructure provider fulfils the short term demand of the need of transport supply.

In 650 Square Km of Hyderabad's total area, 20% is the IT area in the city (Greater Hyderabad Municipal Corporation, 2018). The area with the IT Sectors in Hyderabad is known as Madhapur zone in the South part of the City. As the IT sectors developed it lead to the development of Housing, Recreational, Hospitals and Educational institutions. Additionally, India built its very first store IKEA in the city of Hyderabad in Madhapur zone. Due to which the inflow of people has increased. To avoid a bottleneck at the entry an underpass has been constructed by the Municipality at the junction for the vehicles to pass straight. Whereas the vehicle who intend to take right or left are limited with the option and are forced to travel longer and perform "U" turns to go to their designated areas (Sharad Mohindru Associates, 2017). This was a quick change which was received by the city. Hence it did not cope up with the existing infrastructure and started demanding. Hyderabad traffic context comprises 26, 00,000 vehicles on road making it fourth largest in India. The vehicle density is 723 vehicles per km, with no adequate provision of Infrastructure. There is a lack of connectivity and Advance Transportation Control (ATC) to support the current Requirement (Anand and Kumar, 2012).

The Hyderabad Traffic Management system comprises of the Municipality and the Traffic control department. The Hyderabad Municipalities are Greater Hyderabad Municipal Corporation (GHMC) - accountable for the maintenance and construction of bridges and roads, Hyderabad Metropolitan Development Authority (HMDA) is responsible for the overall city planning of Hyderabad, Telangana State Industrial Infrastructure Corporation Ltd. (TSIIC) is the initiator for providing Infrastructure through development of Industrial area. The land in Madhapur area is jointly owned by these Municipalities, the development and maintenance of the infrastructure are taken by the specific group and managed by the Cyberabad Traffic Police Department. There is a lack of coordination among the actors which is leading to inadequate provision of the infrastructure in Madhapur zone. There have been severe traffic issues faced in the zone which has not been solved despite the new provision of the infrastructure. The Municipalities of Hyderabad are utilizing multiple supply- strategy, despite the city is witnessing heavy traffic congestion. The road users/commuters are facing difficulties during their

journey due to delay in time (Bhagyaiah and Shrinagesh, 2014). Owing to heavy congestion city witnesses a huge loss of time, economy and damage to the environment. As transport supply is the volume of infrastructures and modes for transportation, which is generally expressed in terms of infrastructure (capacity), service (maintenance) and network (coverage) (Broaddus, Litman, et al., 2009).

In the context of Hyderabad, the Municipalities are held accountable for the supply-oriented measures for easing the traffic congestion in the city. According to the Ministry of Urban Development report (2010) investment in infrastructure has not always resulted in commensurate outcomes.

There is a need to conduct service level benchmarks to understand the Level of Service (LOS) which is broadly defined as, "a minimum set of standard performance parameters that are commonly understood and used by all stakeholders across the country" (Ministry of Urban Development, 2010). In India the study for service level benchmarking has been conducted for the only water sector, we need to understand the level of service provided to transport Infrastructure in order to avoid congestions and its effects on the economy.

1.3. Research Objective

The following research objective is to understand and explain to the effects of supply-oriented measures of the building urban road infrastructure and maintenance on the road traffic congestion in Madhapur, Hyderabad. The supply-oriented measures are split into- **supply-strategies**, **Traffic management** and further, to understand the level of adequacy of the supply-oriented measures the **level of road service** is analysed.

The research focusses on studying the in-depth effects on the road traffic congestion in Madhapur, Hyderabad. Firstly, the supply of infrastructure has examined based on case study findings and through observations. Secondly, to explain the conditions and initiatives of management of traffic. Thirdly, it will explain the adequacy of the service by measuring the level of road services. Lastly, the research will also analyse the external effects by the road users on the road traffic congestion in relation with the supply- oriented measures taken by the Municipalities. Greater Hyderabad Municipal Corporation (GHMC), Hyderabad Metropolitan development (HMDA) authority are the authorities providing Infrastructure. The Traffic Police department of Hyderabad helps in easing the traffic and maintain the non-chaotic situation.

1.4. Research Question

Main research question

What level of **supply-oriented measures** (supply- strategy, traffic management and level of service) by the Municipality influence the **road traffic congestion** in Madhapur zone, Hyderabad city?

Sub Research Questions

1. What level of **Supply- Strategies** affect the road traffic congestion in Madhapur zone, Hyderabad city?

2. What level of **Road Traffic management** affect the road traffic congestion in Madhapur zone, Hyderabad city?

3. What **level of service** affect the traffic congestion in Madhapur zone, Hyderabad city?

4. How does the **road user** affect the traffic congestion in Madhapur zone, Hyderabad city?

1.5. The significance of the study

1.5.1. Academic relevance

Congestion management is a generally studied topic. Public participation has a significant part in the putting into practice of policies, Low Emission Zone and Congestion Charge policies implemented in Europe has been effective in congestion mitigation research done in Europe (Pickford, Wang, et al., 2017). In India, they include congestion charging in tollways and have not specifically implemented any measures to mitigate congestion in the cities due to which India is facing huge economic losses. Academic studies are required to understand the scenario better by the service provider.

As mentioned in the official website of Greater Hyderabad Municipal Corporation (2018), they require detail study regarding the supplied infrastructure. The Institution of Urban Transport is actively engaged in the dissemination of knowledge about the importance of urban transport by publishing journals (Institute of Urban Transport, 2018), where they actively looking for transport-related issues. The study can be used by the policymakers to mitigate congestion and acquire in-depth knowledge. As it provides the details as to which area requires more attention with lower level of service and higher inadequacy of the supply-oriented measures. The literature referred during the literature review of the study had key area missing where the level of service was holistically defined to understand provision of the service. Although the research has been done to understand the traffic congestion, it lacks the reason of the infrastructure provision which is the first step taken by the service/infrastructure providers in the developing countries.

Example: The study done by COE Urban transport and CEPT University (2013) which is regarding Service level benchmarking for urban transport in Indian cities. This report contain the details of benchmarking of service provided but lacked analysing the infrastructure which is the main step of provision which the municipalities first adopt.

1.5.2. Societal relevance

Congestion has been a chronicle problem in the city of Hyderabad. The city has been advancing plans for developing new applications/ solutions for the citizen-friendly enforcement, but despite its effort of supply-side strategies, it is lacking to provide the desired service.

Congestion ascends from the volume of high traffic altering the service quality by a transportation system to satisfactory or preferred benchmarks (Sweet, 2011). A significant difference is a beginning of employment to differentiate travel conditions which are congested. The public-sector is responsible for the transport choose with varying thresholds as per to their policy objectives. The following study focuses on travel conditions comparing to the free-flow speeds, volume-to-capacity ratios and majorly understanding the perspective of the commuters regarding the supply-strategies used by the service provider. Undertaking the research will aid as contributions into policy and planning, and giving an insight to the Traffic Police Department of Cyberabad for the interventions for encouraging sustainable approach and understanding the perception of the road users.

The provisional agencies of the traffic and transport sector set framework for infrastructure objectives. One of the strategies included SAFAR (Safety always for all roads) (Telangana State Government, 2005) which focusses on vehicle related measures, driving related measures road improvement related measures. With an immediate action plan to convey monthly traffic advisory council meeting in all cities and towns involving public representatives and local NGOs and citizens. It has perceived as one of the important social welfare and economic developments of the region. In order words, the provincial infrastructure owns serves different interests and multiple functions with single goal of maintenance

and upgradation. The following research can help in upgrading the decision making of the provision of the infrastructure by the provincial agencies before setting the framework for the infrastructure.

1.6. Scope and Limitation

This study aims at explaining to what level of the supply-oriented measures reduces the road congestion in Hyderabad city, India. As the study requires a detailed understanding of the traffic condition, a specific area under a single Municipality will be done. Hence, to study the impact of expansion in IT area which is Madhapur will be studied in details. Madhapur is under the south zone of the city and is under the road ownership of TSIIC and GHMC. GHMC is responsible for the overall maintenance and construction of the new infrastructure. In the Madhapur zone, a list of 8 junctions and corridors has been selected according to the land-use pattern of the area.

1.6.1. Scope

Although economic and social benefits are significant by building a basic roadway system, once it gets congested it usually addressed through more cost-effective and beneficial with demand management agendas which result in the efficient usage of available capacity. The concepts used in the study involves the Travel Demand Management in which Supply of infrastructure-oriented measures will be studied. Further the road congestion in terms of the level of facilities and nature of congestion. Ending with the benchmarking of the service provided by the service and infrastructure provider.

The study will be undertaking in a neighborhood of Hyderabad, the joint capital city of state Telangana and Andhra Pradesh, India. A specific neighborhood is selected in order to focus on an important area where congestion is causing a huge problem and affecting the economy of city. Hyderabad is hub for trade and commerce of international centre for IT. As the city grew enormously by expanding to its greater limits lead to causing chaos and time delays. In order to reduce the congestion the municipalities came up with short mitigation solutions in the past 5-6 years, yet it is finding difficulties to solve the severe congestion problems of road traffic congestion. The IT sector will be analysed with selective junctions to study the road traffic congestion. The study uses case-study research strategy to understand the in-depth of the scenario further complimented by interviewing the in charge of law and Regulation of Traffic which is the Cyberabad Traffic Police Department and infrastructure provider and maintenance in-charge in Madhapur area which is Greater Hyderabad Municipal Corporation (GHMC). It is Inductive, it is backed by theory and will be complimented with observation and secondary data for more reliability and validity. To study the adequacy of the supply-oriented measures service level benchmarking is done.

1.6.2. Limitation

Due to the limited time frame of case-study, a zone is selected to conduct the research. The study does not involve people's perception regarding the service provided by the Municipality. The study is limited to focus on the specific parts in Madhapur zone, the commercial areas and the public spaces which receive the maximum vehicle flow.

As the study involves accessing of government data and reports, it is a challenge due to government organization and their availability.

Chapter 2: Literature Review / Theory

2.1 Introduction

The study attempts to analyze the accountability of supply orientated measures by Traffic management system in Hyderabad. The chapter reviews the existing literature explaining urban congestion and management system of the urban transport system. Further, it analyses the key measures of level of service which can justify the adequacy of the supply-measures and management.

2.2. Urbanization transport and urban structure

The cities have been portrayed by several urban experts as kind of dynamic interface instrument of movement (Transport), conduits of communication including information links, allocation of activities to accommodate by the settlers since ages. A numerous quantity of journeys in urban areas are caused by the rapid urbanization occurring around the world. By increasing the transportation supply, by constructing new main road and/ or arteries cities have predictably responded to the development in mobility. In the industrialized world, that has to create new urban structures, therefore, largely meant construct more roads to accommodate an ever-increasing quantity of vehicles. With the dependence on automobile being the most significant biased factor, numerous urban spatial structures have developed.

2.3. Urban Transportation

In determining the connectivity web and the distribution of activities in settlements, the movement in the settlement is a vital component. There are two distinguished ways of movement, one pedestrian and second vehicular movement (Dewar and Todeschini, 2004, p.47). The following research focusses on the vehicular urban Movement. The Urban Transportation needs to be understood in all forms and it can be broadly categorised as the following (Rodrigue, 2017):

2.3.1. Transportation and Urban Forms

Several ring roads being built around the major cities , has now become important characteristics of spatial structure of the cities due to the growth of the urban area, congestion difficulties and increasing significance of inter-urban movements. Many supply side strategies were designed and implemented to diminish efficiency loss due to the increase number of private vehicles in the urban areas which were raising concerns about the economic and environmental effects. The types of metropolitan scales can help the policy makes understand the pattern of energising the city centre and restricting urban sprawl by controlling the density and boundaries of the city. (McConnell et al., 2006)

Elements of urban forms comprises of urban transportation, urban transport modes, infrastructure and urban transport users. With three different transport modes- collective transportation (public transit), Individual transportation (cars, walking, cycling and motorcycle) and Freight transportation (Delivery vehicles).

The spatial imprint of the urban form is due to multiple factors, but the 3 main factors controlling the infrastructure placement are – road infrastructure, modes and user (Jain, Sharma, et al., , 2014). The city evolves bottom up by this method and changes and adapts to the demand.

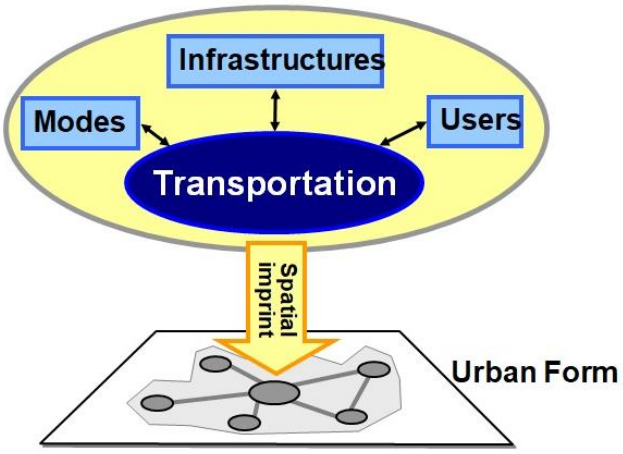


Figure 1: Explaining the transportation and urban form. (Jain, et al., , 2014)

The city with the spatial imprint is the medium or space for transportation, there are four major types of spatial division which could be recognised at the urban scale: (Rodrigue, 2017)

- "Type I- completely Motorized Network":

The following grid represents a "car dependent city" with a "limited centrality" with massive network of great volume highways, low to average land use densities and large parking lots.

Examples: Cities where urban growth occurred in the late 20th centuries cities like Denver, Los Angeles, Phoenix, and Dallas.

- "Type II- Weak Centre": The following network represents the "regular land use densities" and a "concentric pattern". Central Business development offers marginally more employments than it is possible to travel by car. It has an under-used public transportation system making it non-profit in most cases and this needs grants. It has emergence of a small centres in the peripheries with convergence of radial lines.

  Examples: Older cities that emerged in the beginning of 20th century cities as Melbourne, San Francisco, Boston, Chicago and Montreal.

  - "Type III- Strong center": The following network represents "high land use density" with high level of approachability to urban transportation. It has efficient public transit.

Examples: Cities having significant commercial and financial function, which raised in the late 18th century in the cities- Paris, New York, Shanghai, Toronto, Sydney and Hamburg.

- "Type IV- Traffic limitation": The following city network represents "average sized cities" having a "high land density" that were prearranged to limited usage of the car in central zones. It has limited driving and parking spaces by making the public transit used in the central area.

Example: Cities having a lengthy planning past targeting to provide public transit cities as London, Singapore, Hong Kong, Vienna and Stockholm.

2.3.2. Urban Land usage and Transportation

Mobility, especially in the form of motorised transport requires an increasing share of land, both within cities and in rural area. Cities in highly motorised countries dedicate much of their urban area for roads. Urban space has to serve a variety of human needs: Housing, working, social interaction, leisure and mobility. Land use planning serves this process of balancing competing demands on limited urban space (Petersen, 2004, p. 1). To design a prosperous and safe transportation society, it is very important to understand the relation between the transportation and land-use.

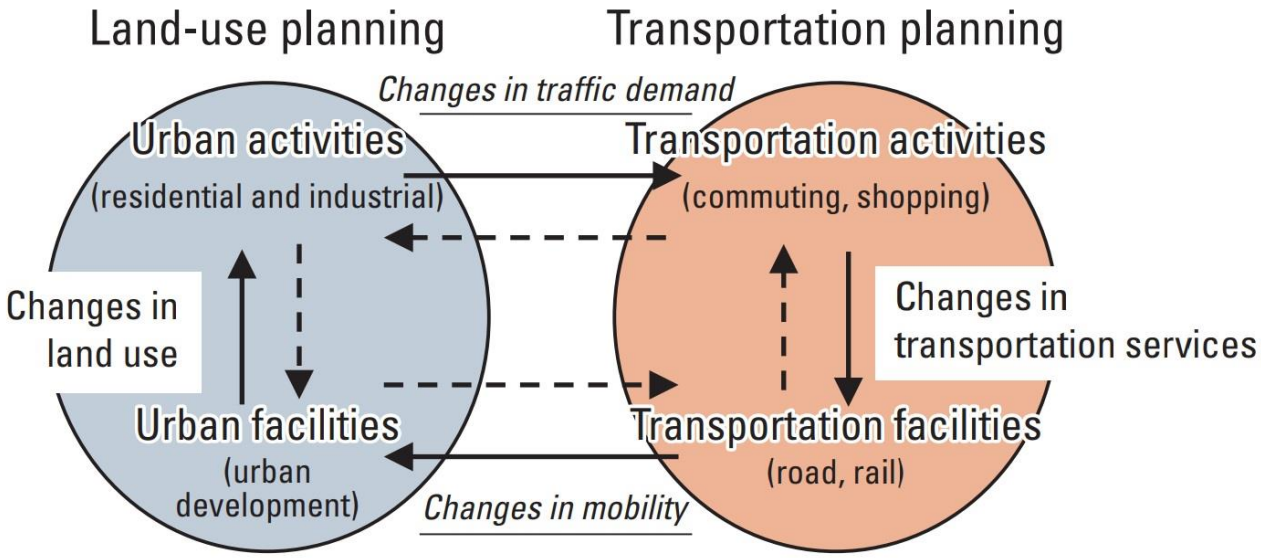


Figure: Relation between land use and traffic planning (Jain, et al., , 2014)

It is easy to plan land utilization and traffic flow in the city when it is growing in a slow pace. However when there is a sudden demand for land use, it accelerates the development of transportation, making it hard to keep up for the cities. This can be observed during the rapid economic growth times of the city. Many cities experience a high degree of economic growth will therefore experience heavy congestion and other transportation problems.

Further, according to Rodrigue (2017) urban land use patterns are natural and level of spatial gathering of activities. Land-use indicates a set of relations with other land uses such as the relation with its customer and supplier.

2.3.3. Urban Mobility

The consideration of urban movements involves their generation, the modes, and routes used and their destinations (Bull, 2003) :

- **Trip generation**: According to the author McGuckin Nancy, in the 2001 NHTS, nearly 20 percent of the home-to-work travel has non-work segments and 30 percent of the work-to-home travel has non-work segments. (McGuckin and Nakamoto, 2004, p.5). As the per survey conducted in Singapore of 34,000 households in 2016 articulates (Jiang, Ferreira, et al., 2016, p. 215), on an average weekday, 13.5 percent Singapore residents stayed at home, 33 percent visited two unique places, 30 percent three places, 14 percent four places, 5.5 percent five places, 2.1 percent six places, and less than 2 percent visited more than 6 places. "Moving in an urban area is usually done to satisfy a purpose such an employment, leisure or access to goods and services. Each time a purpose is satisfied, a trip is generated."

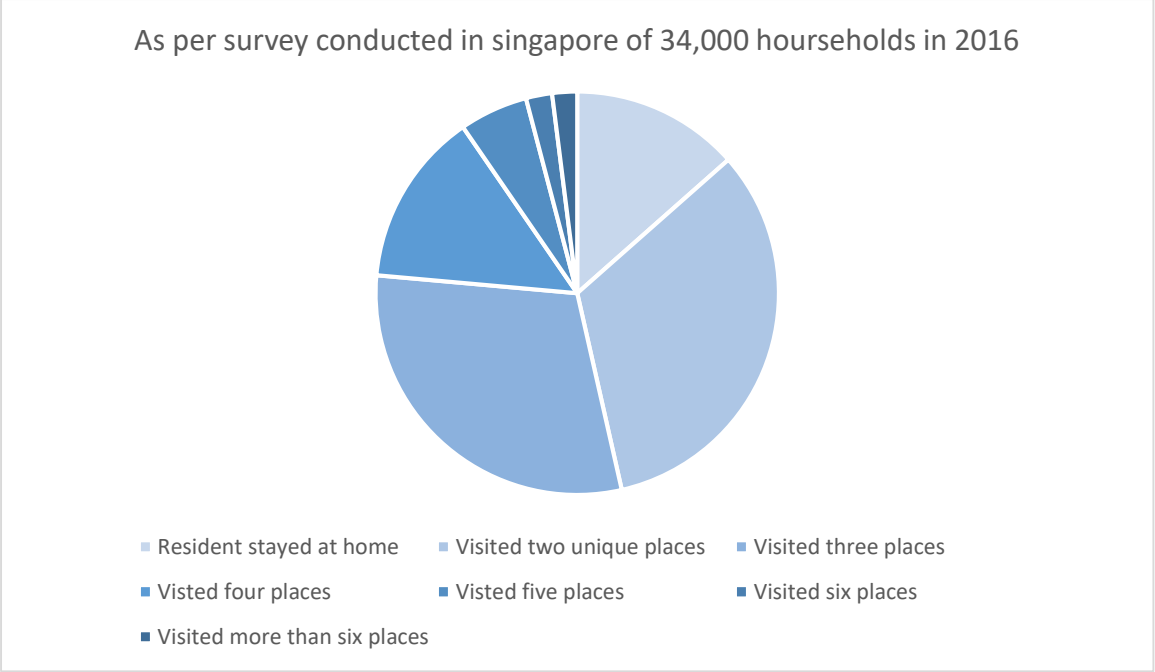


Figure 2: As per the survey conducted in Singapore of 34,000 households in 2016 articulates (Jiang, et al., 2016, p. 215)

- **Modal split**. The modal choice depends on a number of factors such as technology, availability, preference, travel time and income. It implies which transportation mode is used for the urban trip and is the outcome of modal choice.
- **Trip assignment**. Within the city, it comprises of the which courses or trips will be used. For example, as per general mobility pattern of a commuter is fixed for daily activities, the route may be altered if there is congestion or if extra activity, often described as trip chaining (McGuckin and Nakamoto, 2004).

The trip chaining and travel distances, and investigated their causal determinants using socio-demo-graphic and urban-form variables. Work by McGuckin and Murakami (1999) provided an early focus on trip chaining, and more recently Primerano et al. (2008) defined trip chaining as the combination of one or more secondary activities with a primary activity, via trips which start and end at home. Some studies have utilized trip chaining to measure tour complexity in terms of stop frequency within the tour (Liu, 2012; Wang, 2014). These studies found that gender, age of the individuals, and employment status play significant roles in trip chaining (McGuckin and Murakami, 1999; Liu, 2018; Kitamura andSusilo, 2005; Susilo and Kitamura, 2008). These studies also concluded that women, older adults, and workers tend to chain more trip segments.

Tour frequency has been found to be affected by employment-related variables, household structure variables, accessibility, location variables, and mobility-related variables (Bhat et al., 1999). Among household socio-demographic characteristics, number of adults' number of employees, number of vehicles, household income, home-to-work distance, work neighbourhood accessibility, and work residential accessibility were found to be significant determinants of tour frequency (Krizek, 2003). However, these studies combined tours for workers and non-workers in the same framework. Presumably, non-workers would not have work-related variables to influence their travel behaviours, and we expect significant differences in travel behaviour be-tween workers and non-workers.

2.3.4. Urban transport problems

The developing cities and transitional economies inevitably differ greatly in economic, political and demographic characteristics. Rapid population growth tends to be associated with below average proportions of land space devoted to circulations. The section below explains one such crucial cause which is road congestion.

2.3.4.1. Road Traffic congestion

Most of the industrialized world experienced substantial increases in car ownership over the past two decades, resulting in a rapid increase in total travel on the roads, and declining absolute market shares for public transport. In India, vehicle ownership intensified and experienced a 95% rise since 1991 (National Informatics Centre (NIC), et al., , 2018). With this burgeoning of the vehicle, ownership has been followed by the consequences of escalating road congestions.

"The dictionary defines congestion as an abnormal or excessive accumulation. Traffic engineers define congestion as the phenomenon that arises when the input volume exceeds the output capacity of the facility" (Stoper R. Peter, 2003). One implication of congestion is that it represents the maximum or excessive use of a facility. The term congestion can be also defined as the situation which occurs if the introduction of a vehicle into a traffic flow increases the travel times of the other vehicles by more than x percent (Bull, 2003, p.25).

As per OECD (2007, p. 28), "Congestion is a situation in which demand for road space exceeds supply". It is an appropriate description to identify the distinguishing factors of congestion: example, the insufficiency of Demand vs. supply of road space.

2.3.5 Outlines of congestion: Non- recurrent and Recurrent.

Congestion of vehicles is categorized as recurrent or non-recurrent based on the frequency of movement of traffic. As defined recurrent congestion is, "the result of factors that act periodically on the transport system, such as daily commuting or weekend trips" (OECD and ECMT, 2007). As defined non-recurrent congestion is, "caused by unexpected, unplanned or large events such as road works, accidents, special events etc."(OECD and ECMT, 2007). This type of congestion is causes due to sudden reasons and cannot be predicted it ultimately damages the part of the transport system. The segment of non-recurrent congestion is related to the presence and efficiency of incident reaction approaches and road schedule in addition to weathering conditions which are differing from network to network.

The causes of recurrent and Non-recurrent congestion can be summarized as (OECD and ECMT, 2007):

Recurrent: "Insufficient capacity, unrestrained demand and ineffective management of capacity."

Non-recurrent: "Incidents, work zones, weather events, special events, and emergencies."

The roadway when, in more than half of its total length (not essentially nonstop stretches), the average speed of the traffic flow less than 40% of the speed in unrestricted conditions is considered to be congested (Bull, 2003).

2.3.6. Characteristics of Urban Transportation causing congestion (Bull, 2003)

The following includes the delivery of urban land for transport infrastructure, operates with very distinctive features:

- Journeys are infrequently made due to a fundamental desire to travel but are generally because of the need to travel to the places where numerous types of actions are carried on,

such as work, grocery, educational, recreation, relaxation, etc., all of which took place in different locations.

- The demand for transport is highly variable and has peak periods in which a large number of journeys are concentrated because of the desire to make the best use of the hours of the day to carry on the various types of activities and have an opportunity to make contact with other persons.
- Transport takes place in limited road spaces, which are fixed and invariable in the short term. It is not possible to store up unemployed road volume for later use at times of superior demand.
- The forms of transport which have the most required features – security, comfort, reliability, and self-sufficiency, as in the case of private cars –are those which use the most road space per passenger.
- Especially in urban areas, the facility of road infrastructure to satisfy rush hour demand is extremely expensive.

Because of the above aspects, congestion occurs at numerous points, with all its negative penalties of pollution, heavy expenditure of private and social resources, and contrary effects on the quality of life.

2.3.7. The state of the roads and driving habits contributing to congestion

(a) Design and Maintenance issues

Inadequacy in design or maintenance provision of road systems causes needless congestion. In many cities there are frequent cases of unexpected changes in the number of lanes, failure to traffic lanes, bus stops located precisely where the road width becomes narrower, and other deficiencies which interrupt a smooth traffic flow. Similarly, road surfaces in bad condition, and especially the presence of potholes, give rise to increasing limitations on road capacity and the increase in congestion (IMT, 2000).

(b) Driving Habits

There are drivers with respect for other road users. In some cities, many drivers try to cut a few seconds off their journey times by forcing their way into intersections and blocking the passage of other motorists, thus causing losses to others which are much greater than their own gains. Please add more content here, since it is part of the framework (IMT, 2000).

(c) Availability of Information

A current major issue which increases congestion is ignorance of the prevailing traffic conditions. If a motorist with two possible routes, A and B, for reaching his destination knew that traffic conditions were bad on route A, he could use route B, where his own contribution to congestion would be less. A study of a theoretical city done in the University of Texas in the United States indicates that the fact of being well informed regarding the traffic conditions in of the road network can reduce congestion much more than the other measures (IMT, 2000).

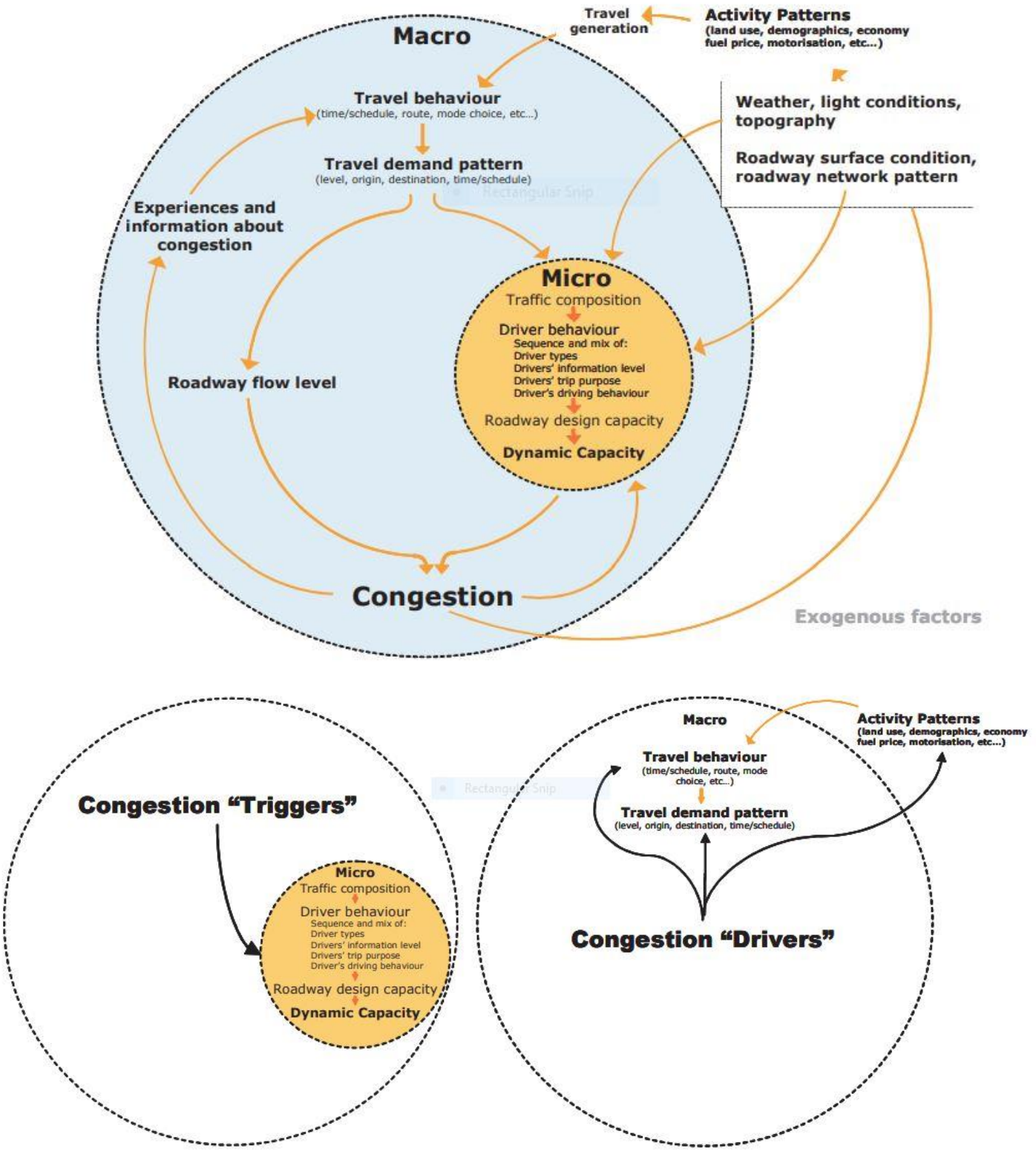


Figure 3: **Macro and Micro factors affecting congestion** ***(Source: (OECD and ECMT, 2007, p.63))***

The above figure 2 explains the macro and micro factors of increasing congestion (OECD and ECMT, 2007)

1. Activity patterns – it is determined by social, demographic and economic factors along with land-use patterns. The activity pattern is having an impact on travel behavior for individuals, households, and firms.

2. Travel behavior gives rise to a level of travel demand which is range out in the time and space.

3. This travel demand leads both to specific mixes of vehicles and drivers on discrete segments of the roadway network and a general level of traffic flow on the roadway network – for example at the micro level. It is at this level that the self-motivated capacity of the roadway is set through the interface of such factors as the mix of vehicle traffic speeds, types/lengths ,egress and ingress patterns, car following behavior and lane switching, etc. all under the effect of atmospheric conditions and the principal type of roadway pattern.

4. When the all-purpose flow on the network surpasses the dynamic volume of specific network links, bottleneck arises and is propagated upstream.

5. Feedback occurs as roadway users use their knowledge with congestion to familiarize their travel behavior and/or congestion leads to longer-term changes in activity patterns, which in turn further influence travel behavior, demand, etc.

2.4. Travel Demand Management (TDM)

A strategy in which unnecessary private vehicle use is discouraged and healthy and environmental-friendly mode of transport is promoted more to achieve the aim to capitalize on the competence of the urban transportation system, which is non-motorized transport and public transport in general. This strategy is called Travel Demand Management according to Broaddus et al (2009, p.8).

The responsibilities of transport agencies include designing, managing road network, building, managing transport services and regulations of vehicles. Their goal is to maximize supply through which traffic volumes and speed is increased and their policies and planning practices work in order to achieve this goal. A number of kilometers of paid roads, number of motor vehicles and vehicle kilometer of travel and parking spaces, with these indicators the supply side is relatively easily measurable. Difficult to measure is transport demand as it is based upon need and desire of mobility of people and the need for transport goods business. The transportation agencies, local, regional and national governments and private entries like employers can implement the Travel demand Management strategy.

2.4.1 Supply- oriented measures

A combination of different means like infrastructure and different type of transportation is included in the supply of the transport. It can be classified as

(i) Supply-strategy of Infrastructure: roads and bridge design (Supply strategy)
(ii) Road traffic management: Different means of transportation, vehicles
(iii) The level of service: The managing of both in an order (Stoper R. Peter, 2003).

Urban transport supply tends to be categorized according to its capacity, that it, the number of persons who can be transported in a given period of time. From the infrastructure standpoint, capacity is usually measured as the number of vehicles that can circulate in a given area in a certain period of time; this parameter is meaningful when analyzing congestion, but in a realistic manner it is allowing people to move around satisfactorily.

Additional arrangement of the policy was done by Meyer (1997), which has been characterised and are measured in three groups which is , demand management, supply management, and land-use management, as illustrated in figure 4. Supply oriented strategies and measures fall under the most public rejoinder of policymakers by solving the problem by simply expanding or adding to the

infrastructure which is existing. Supply management approaches are mainly- building new highways, transit facilities and widening of existing roads have the objective to upsurge the capability and carrying capacity of the infrastructure to meet the growth of volume and heavy usage of private vehicles (Rodrigue, 2017).

Land-use management, comprises of policies defining the use of land, in other words, which human activities will be conducted and which locations permits the construction. For example, trip-making patterns, volumes, frequency and modal distributions are related to spatial distribution and use of land. On one hand, it has the answers for supply management questions: how much, what type and where to supply when increasing transportation capacity of a city. On the other hand, it is crucial for demand management strategies when training the control on the trip generating characteristics of an area in order to safeguard that resultant demand is constant measures with remaining transportation infrastructure and standard level of service. Lastly, Travel Demand Management (TDM) includes various measurements aiming at influencing people to change their behaviours to more sustainable transportation modes to advance and develop urban life value.

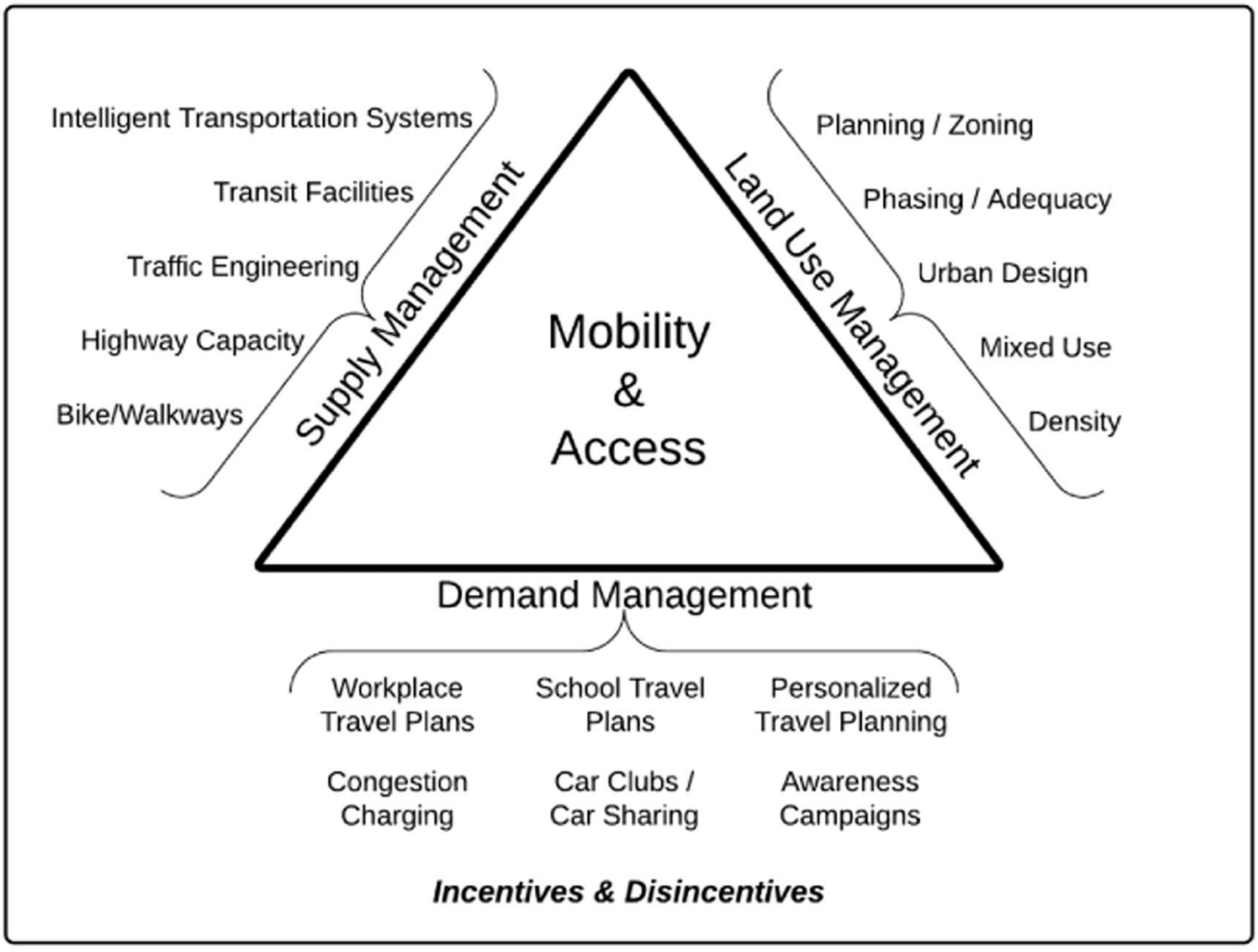


Figure 4: Elements of mobility and access management (Meyer (1997)). Management of supply (infrastructure), demand management and land are three important elements of sustainable mobility. Source: (Batur and Koç, 2017)

Significantly, the following figure suggests to be operative, the three different program contains the following categories- managing the demand and supply or travel behaviour of those who use transportation, managing the supply of the transportation system and managing the land use and/or development arrays that impact trip generation. (Meyer 1997)

The following research following research is based on the supply-oriented measures (Stoper R. Peter, 2003). Among different categories of Travel Demand Management (Broaddus, et al., 2009), supply-oriented measures in the following thesis is categorised as supply strategies of building infrastructure, Road traffic management (Bull, 2003) and Identifying the level of service of the asset (Central Road research institute-CSIR, December, 2017). Supply- strategies (Batur and Koç, 2017) are the policies used by the policymaker to provide infrastructure at the initial stage of congestion to alleviate the traffic. The road traffic management,

2.4.1.1. Supply strategy of Infrastructure: roads bridge design

Rapid growth can greatly increase traffic loads on arteries throughout a metropolitan area, among the different supply-side tactics for reducing congestion, building more roads or widening existing ones seems particularly appropriate in an area that has experienced rapid growth. Unfortunately, in the long run, building new roads or expanding existing ones does not reduce the intensity of peak-hour traffic congestion to any extent, particularly in the rapidly growing area, because commuters will quickly shift their routes, timing, and mode of travel (Liyin, Yuzhe, et al., 2011).

Transport infrastructure is a necessary input into the production of transport services which, in turn, are necessary to allow for the market exchange of final goods and inputs (including labour) – or for broader welfare benefits (e.g., travel time savings). Given its central economic role, transport infrastructure is often referred to as the backbone of a modern economy (OECD and International Transport Forum, 2013, p. 15) . Data on infrastructure investment and maintenance are collected at an international level by a number of institutions . (Stoper R. Peter, 2003)

The preferable breakdown into different types of asset will mainly depend on three factors: (i) the analytical needs; (ii) the availability of detailed data, and (iii) the required quality of the results" (Abe and Axhausen, 2018). In relation to the latter element, apart from the length of time-series data, the most critical element in the estimation of capital stocks is the service life of the various types of asset. For the depreciation and mortality functions, applied to the service life of transport infrastructure, one would probably use the same set of assumptions for the various types of asset, and if one would want to choose assumptions that differ across the various types of infrastructure it likely does not affect the results dramatically (Abe and Axhausen, 2018).

Supply-Managing the transportation system by adding new facilities or by making operational changes to improve system performance has been the most common response to transportation problems for many years. Actions such as the construction of new highways and transit facilities; the provision of improved traffic signalization schemes; the use of traffic engineering improvements such as turn lanes, one-way streets, reversible lanes, and turn prohibitions; the addition of new transit services or improving existing service by adding vehicles, increasing vehicle size, or increasing frequency of service; the provision of preferential treatment to those who use multi-occupant vehicles; and ramp metering are Illustrative of the types of actions that can be used to deal with congestion problems that occur every day (Batur and Koç, 2017).

In the extreme, that is, where new capacity can be continually added to accommodate the demand, these actions can significantly reduce congestion levels. In the long term, however, this additional capacity, if assigned to highway improvements only (e.g., additional lanes), will continue a heavy reliance on the automobile which could have serious implications to some on the urban mobility options available in the region. (Meyer 1997)

On the other hand, additional capacity improvements to transit could help alleviate the congestion problem. In areas which are densely urbanised, it is expensive to construct new elements, strong opposition might be countered during the implementation, and if at all feasible, then the entire process

is time consuming (Batur and Koç, 2017). It is for these reasons that other actions need to be considered.

2.4.2. Road traffic management - Different means of transport and management

Transport demand is a response to the need or desire to transport persons and goods from one place to another. The essence of demand is the mobilization of persons or things, it also has a traffic dimension, in terms of volumes of vehicles moving along the public roadways to carry out their objectives. The aforementioned concentrations of trips in the morning and afternoon generate an increase in the volume of traffic, known as peak times or rush hour, which translated into congestion on different streets and during different periods. (Bull, 2003)
There are different measures taken to ease the congestion by demand-side supply strategies.

Management of network infrastructure demand and usage in these other sectors helps maintain the levels of service provided to users at acceptable levels. Although there are generally occasional delays in telecommunications services or occasional electricity blackouts caused by excess demand, an important distinction from road systems is that such delays tend to be relatively rare. A second important distinction from road infrastructure is that when such delays do occur, the infrastructure managers take action to try to ensure they do not occur again.

Traffic management measures are aimed at improving the safety and flow of traffic, reducing traffic emissions and utilising traffic artery capacity more effectively. Traffic management is used to curb demand for transport and affect the selection of the mode of transport, route, or the time of travel or transport. In particular, it is utilised during the first stages of the four-step principle applied in the development of traffic conditions. Traffic management comprises the following elements: traffic information, traffic control, incident management, demand management, driver support and monitoring, and fleet and transport management. It also requires reliable, up-to-date status information on the transport system (Finnish Transport Agency, Road Department, 2010, p.6).

The low traffic management in the cities all over the work are brink of massive traffic explosion (Jain, et al., , 2014, p. 2) the situation has worsen owing to the following details:

1. **Unplanned cities**: The cities which evolved from bottom up manner, to scale up the capacity no provision were made, leading to bottlenecks at several junctions and corridors. Furthermore, many developing countries has received vehicular growth leading to conventional traffic management strategies failure (Brinkman, 2016).
2. **Alternate traffic means**: As the economy growth is observed, across various cities the number of vehicles has increased. This problem is compounded by the social stigma, where people view operating a private vehicle as a sign of prosperity.
3. **Archaic management**: Driving habits are also a crucial part of the non-recurrent traffic. Although been controlled by the law and order, the flow is uncontrollable and is optimized at respective junctions (Khanal and Sarkar, 2016).
4. **Tighter budgets**: A significant amount of investment is required to set up a traffic management infrastructure which can scale with the increasing traffic. Such an infrastructure not only involves measuring and analysing real-time traffic data but also focuses towards enhancing congestion detection, solving real time congestion and forecasting congestion scenarios. (Jain, et al., , 2014)

2.5. Asset Management & Maintenance (Identifying the level of service)

To make traffic flow faster and more smoothly over existing roads, many ways have being devised by highway engineers. These devised ways are designated to improve certain factors which keep the traffic

moving, they are not designated to alter the total volume of traffic. Measures for maintenance (Saidi, Kattan, et al., 2018)-

- Programmed repairs and improvements aimed at properly maintaining existing expressways, highways, and streets.
- Coordinated timing of traffic signals along arterial streets. The coordination of timing between different signals.
- Stable radio connection can be used with the nearest such vehicle to dispatch to any accident scene.
- Passing of information of the non-recurrent traffic.
- Up gradation of the required roads.
- Streets converted from two-way to one-way movement.
- Ramp signals to control the flow of vehicles entering expressways.
- Provision of street parking and providing more room for the traffic flow.

The peak hour times and congested expressways are affected by the combination of the following tactics. An asset when not in the condition of usage and is required to be replaces is known as the "retirement of asset". It can be "simultaneous exit", assets are retired which then reach average service life. (OECD, 2009) (Abe and Axhausen, 2018).

2.5.1. Level of service

The concept of level of service was officially introduced in the 1965 Highway Capacity manual and was defined as- Level of service is, "a qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating cost".(wachs, Samuels, et al., 2000a).

According to Aftabuzzanman (2007), measures of road traffic congestion are characterized in four sets-

(i) "Basic measures"
(ii) "Ratio measures"
(iii) "Level of service"
(iv) "Indices"

The main focus is on Level of service delivered by the government organization.

Conventionally, analysing congestion by the level of service is one of the most significant method. The notion has been adopted in 2000 Highway capacity Manual (wachs, Samuels, et al., 2000b) demonstrating a range of functioning conditions. Further, the recent copy of the Indo-Highway Capacity manual (Central Road research institute-CSIR, December, 2017) describes these clearly. The level of service is determined by characteristics of traffic flow such as, "volume by capacity ratio, vehicle density, average speed, and intersection delay, depending on facility type" (Central Road research institute-CSIR, December, 2017). LOS measures has six distinct classes extending- A to F. The main benefit of LOS measure is that it is comprehensive by most non-technical audiences (wachs, et al., 2000b).

2.5.2. Level of service

Performance measures/indicators are used in benchmarking and performance measurement. Benchmarking is, "a technique used to compare an organization's performance relative to a peer organization with similar contextual characteristics based on the activity under consideration." (T. Henning, Essakali Dalil, et al., 2011).

Benchmarking according to Barlund is the process of measuring the performances of various elements of urban transport against a set standard or target. It provides policymakers with tools to continuously seek enhanced performance for their urban transport (Henning, et al., 2011). It is also a basic part of the transport policy process (2000)."

"In a nutshell, benchmarking is a multi-layer strategy to achieve greater efficiency and higher quality services and encourage change" (Wobbe, 2000). Others define it as, a tool to provide an important reference for decision makers, planners and operators to monitor and evaluate the sustainability of urban transport at local, regional and national levels (Hongyang, Yulin, Hu, & Suoxiang).

Performance measurement is, normally an internally focused process where an organization measures its current performance against historical performance. The performance measures are quantitative measure or an index that statistically expresses a specific doings of an organization (T. Henning, et al., 2011).

2.5.3. Importance of level of service

To identify breaks, glitches in service levels and in-depth purpose behind their non-fulfillment of duties, measuring the performance of different transport facilities is necessary. These performance levels can be measured by indicators which help in baselines establishing, predicting problems, and trends identifications, options assessments and target performance setting. Benchmarking can be defined as- "comparing performance levels against set targets or best practice cases - has now been recognized as integral to ensuring accountability in service delivery with the Ministry of Urban Development (MoUD)", Government of India announcing "Service Level Benchmarking" for Urban Transport. (CoE urban transport and CEPT University, 2013).

According to Folz (2004) "Service Quality and benchmarking the performance of Municipal services is important because it systematically identifies the best practices employed by other jurisdiction which lead to superior performance". Whereas Dattakumar and Jagadeesh (2003) stated that " In benchmarking, public officials compare their jurisdictions' service performance statistics to those of an appropriate municipal counterpart, with the goal of understanding how they can close the gap between where they are and where they want to be. Key themes in benchmarking include performance measurement, comparison, identification of best practices and improvement".

CSIR - Central Road Research Institute (CRRI), New Delhi to network with academic institutes (by including IITs / NITs/ Central/ State Universities) on the lines of HCM (2010) of USA. The project led by CSIR - CRRI was completed in 2017 with regular monitoring at different levels to achieve the desired quality which has showcased once again the technical prowess and management expertise of CSIR - CRRI in handling large size projects.

The manual Indo-Highway Capacity presents a bird's eye view of the structure of the manual and the definition of generic terminologies related to traffic engineering and planning. Each of the subsequent chapters deals with the procedure for the estimation of capacity and Level of Service *(LOS)* through a series of steps and culminates with typical illustrative examples. These examples are expected to be of immense use for the analysts in understanding the essence of the Indo - HCM towards the estimation of capacity and Level of Service *(LOS)* of various types of roads *(both midblock sections and various types of intersections)* and different forms of urban pedestrian facilities dealt in this manual. Moreover,

this manual would provide a much-needed reliable source to update the IRC (Integrated logistics solutions) documents and standards for evolving new guidelines to address the missing links. Further, it is expected that this document can serve the society as a basic guide for the practicing engineers and decision makers towards capacity augmentation of various types of road and pedestrian facilities in India.

2.5.4. Typical Vehicle Types and Mode Classification in India

Sl.No.	Vehicle Type	Type of Mode
Motorized Traffic		
1	Two Wheeler (TW)	Motorized Two Wheeler including biked and scooters
2	Auto rickshaws (Auto) Three and Four wheeled	Al Motorized
3	Small/standard cars	Cars of engine capacity up to 1400 cc
4	Big cars and Vans	Cars/vans/jeeps/ having engine capacity more than 1400 cc
5	Mini Buses	Transport vehicle
6	Buses	
7	Light Commercial Vehicles (LCV)	Commercial pickup vans and Mini trucks (gross vehicle weight up to 9.0 tons)
8	Two/ Three axle Trucks	Heavy Goods vehicles (Gross vehicle weight up to 25.2 tons)
9	Multi-Axle Trucks	Heavy Goods vehicles (Gross vehicle weight up to 25.2 tons)
Non-Motorized Traffic		
10	Cycles	Slow Moving Vehicles
11	Cycle Rickshaws	
12	Animal Drawn vehicles	

Table 1: Type of vehicles and mode classifications in India (source: (LEA Associates south Asia Pvt. Ltd., 2013, Greater Hyderabad Municipal Corporation, 2018))

2.5.5. Traffic flow and capacity

The relationships between the volume of traffic (flow rate), speed and density are fundamental in understanding notions of capacity and level of service.

Equation 1

"q = k*v..... Equation 1.1

Where,

q = traffic flow rate *(vehicles per hour)*

k = density *(vehicles per km)*

v = speed *(km per hour)"*

(Central Road research institute-CSIR, December, 2017)

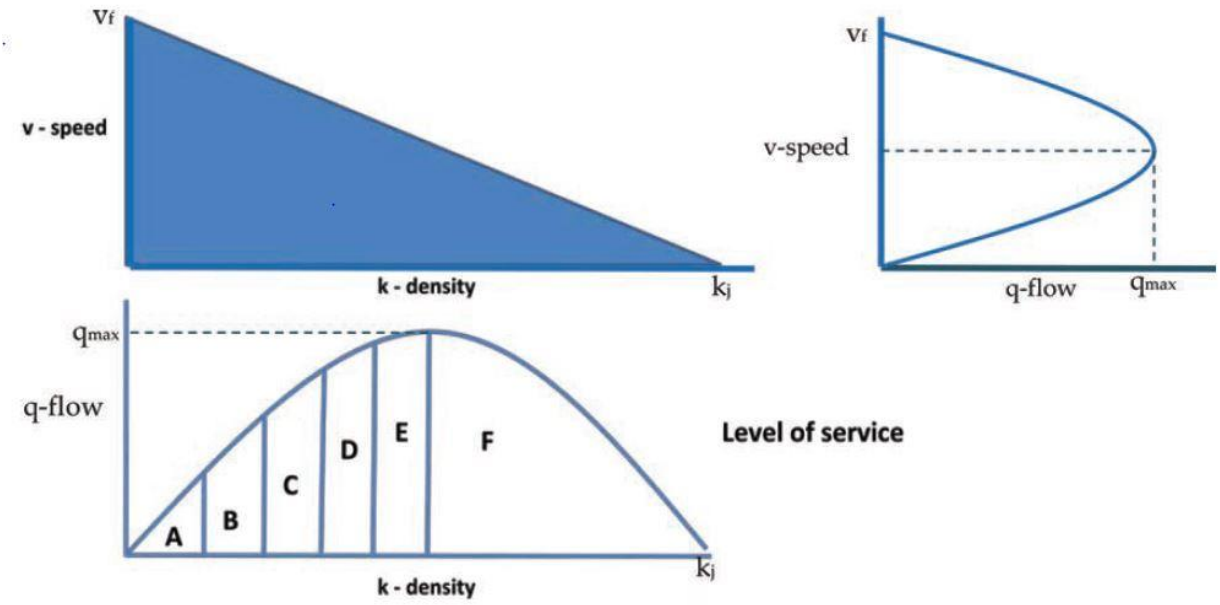


Figure 5: Flow, Speed and Density Relationships. (Central Road research institute-CSIR, December, 2017)

(The figure shows a generalized, theoretical representation of these relationships)
Broadly, LOS - A to LOS - F represents the following traffic operations:
"LOS A: Free Flow
LOS B: Reasonably Free Flow
LOS C: Stable Flow
LOS D: Approaching Unstable Flow
LOS E: Unstable Flow
LOS F: Oversaturated flow conditions of traffic." (Central Road research institute-CSIR, December, 2017)

Where **Traffic flow** is defined as, "The amount of traffic on a road is generally measured as either traffic volume or traffic flow. Traffic volume is the total number of vehicles that pass over a given point or section of a roadway in a given interval of time."(Central Road research institute-CSIR, December, 2017). Traffic flow is the same hourly rate at which the vehicles cross over a given moment or section of a roadway for an interval in less than one hour (Central Road research institute-CSIR, December, 2017)

2.5.6. Benchmarking of Urban Roads

The term 'Urban Road Segment' refers to the length of road with control arrangements at both of its ends, i.e. the upstream and downstream intersections are controlled intersections.

Urban roads are generally classified based on the functional characteristics and configuration.
However, as the functional classification varies from city to city in India. The typology of roads considered in this manual includes the following:

Divided Roads (in each direction of travel with 0.25 m curb shyness on either edge of the road):

- 7.5 m road width i.e. Four-lane Divided Road
- 11 m road width i.e. Six-lane Divided Road
- 14.5 m road width i.e. Eight-lane Divided Road
- 18.0 m road width i.e. Ten-lane Divided Road

Undivided Roads: (Road width of 7.0 m plus 0.25 m curb shyness on either edge)

• 7.5 m road width i.e. Two-lane Undivided Road

2.5.7. Level of service of urban roads

In general, it is an established fact that the term 'capacity' and 'LOS' will have a close relationship. Capacity refers to the quantitative measure of road section and LOS represents the qualitative measure of the road section *[(Bhuyan and Rao 2010, 2011, Patel and Joshi, (2012)]*. In a given road facility, actual flow will be a varying parameter depending on the time of the day with the capacity being constant. The main objective of level of service is to indicate the flow of traffic to traffic service quality.

The objective of LOS is to relate given flow rate of traffic to the traffic service quality. Speed has been considered as the principal factor affecting the LOS of an urban road segment under ideal conditions. Stream speed has been considered as the basic parameter for the estimation of LOS in the present study and Clustering technique has been used for grouping of the speed data. The suggested LOS for the range of stream speed, Volume Capacity Ratio and percentage of free flow speed are presented in Table 1 and Table 2 for two-lane undivided and divided urban roads respectively.

Table 2: LOS of Two lanes Undivided Urban Roads based on stream speed, V/C Ratio and FFS (Free flow speed). (Central Road research institute-CSIR, December, 2017)

Level of Service	Volume/Capacity Ratio	Percentage of Free Flow speed
LOS A	≤ 0.35	≥ 89
LOS B	0.36-0.55	88-55
LOS C	0.56-0.70	54-21
LOS D	0.71-0.85	20-12
LOS E	0.86-1.00	11-6
LOS F	>1.00	<6

Table 3: **LOS of Multilane Divided Urban Roads based on stream speed, V/C ratio, and FFS (Central Road research institute-CSIR, December, 2017)**

Level of Service	Volume/Capacity Ratio	Percentage of Free Flow speed
LOS A	≤ 0.15	≥ 84
LOS B	0.15-0.45	83-76
LOS C	0.46-0.75	75-59
LOS D	0.76-0.85	58-41
LOS E	0.86-1.00	40-22
LOS F	>1.00	<22

Table 4: Typical representation of traffic flow for varying LOS on a typical multilane divided urban. (Central Road research institute-CSIR, December, 2017)

LOS	Description	Illustration
LOS A	Represents a condition of free flow. Individual drivers are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is high. The general level of comfort and convenience provided to the road users is excellent.	
LOS B	Represents a zone of stable flow, with the drivers still having reasonable freedom to select their desired speed and maneuver within the traffic stream. The level of comfort and convenience provided is somewhat less than the Level of Service A because the presence of other vehicles in the traffic stream begins to affect individual behavior.	
LOS C	This also is a zone of stable flow but marks the beginning of the range of flow in which the operation of individual drivers starts getting affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires vigilance on the part of the user. The general level of comfort and convenience starts declining at this level.	
LOS D	Represents the limit of stable flow, with conditions approaching unstable flow. Due to high density, the drivers are severely restricted in their freedom to select the desired speed and maneuver within the traffic stream. The general level of comfort and convenience is poor. A small increase in traffic flow will usually cause operational problems at this level.	
LOS E	Represents operating conditions when traffic volumes are at or close to the capacity level. The speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult and is generally accomplished by forcing a vehicle to give way to accommodate such manoeuver. Level of comfort and convenience is extremely poor, and the driver's frustration is generally high. Operations at this level are usually unstable. Small increases in flow or minor disturbances within the traffic stream will cause breakdowns.	

LOS F	Represents zone of forced or breakdown flow. This condition occurs when the amount of traffic approaching a point exceeds the amount which can pass it. Queues form behind such locations. Operations within the queue are characterized by stop and go waves, which are extremely unstable. Vehicles may progress at a reasonable speed for several hundred meters and may then be required to stop in a cyclic fashion. Due to high volumes, break-down occurs, and long queues and delays result.	

2.5.8.The capacity of base sections

Speed - Flow model for the two-lane undivided urban road. The suggested capacity of Two-lane undivided roads is 2400 PCUs/hour.

The Design Service Volume *(DSV)* for the above class and width of urban roads has been computed for LOS - C and presented in Table 4 and Table 5 for the given V/C ratio ranges.

S. No.	Typology of the Road	Capacity (PCUs/hr)	Lane Capacity (PCUs/Hr)	Design service volume (PCUs/hr)
1	Two-Lane Undivided	2400	1200	1680
2	Four-Lane Divided	5400(2700)	1350	3780(1890)
3	Six-Lane Divided	8400(4200)	1400	5880(2940)
4	Eight-Lane Divided	13600(6800)	1700	9520(4760)
5	Ten-lane Divided	20000(10000)	2000	14000(7000)

Table 5: Standards Capacity (Central Road research institute-CSIR, December, 2017)

2.6. Summary of the literature findings

The following table provides the summary of the literature and the data used from the authors.

variables	Topic		Summary	Author s
Independent Variable	Supply oriented measures	Supply strategy	1. Supply- strategies mainly involves of proving of infrastructure to ease the traffic congestion. 2. The provision of infrastructure comprises of provision of roads, transit facilities, highway capacity, walkways/ bikeways and traffic engineering. 3. Managing the land use or the development patterns are essential as it influence the travel demand.	Stoper R. Peter, Batur and Koc., 2017, Meyer 1997, Broaddus, et al., 2009
		Road traffic management	1. Management of network infrastructure demand and usage at acceptable levels to maintain the levels of service provided. 2. Traffic management measures are aimed at improving the safety and flow of traffic, reducing the traffic emissions and utilizing traffic artery capacity more effectively.	Jain, Sharma, et al., 2014, Bull 2003, Khanal and Sarkar, 2016,

			3. Unplanned cities, economic growth, driving habits and budget are the reasons to poor traffic management in cities.	
		Level of service	1. Level of service is a measure of qualitative of effect on the speed and travel time, comfort, convince and freedom to maneuver. 2. The indo-capacity manual has defined the concepts based on the Indian context to measure the capacity of the road to the users.	Saidi, Kattan, et al., 2018, OECD, 2009, Abe and Axhausen, 2018, Aftabuzzanman 2007, Wachs, Samuels, et al, 2000b, Central Road research institute- CSIR, 2017
Dependent variable	Road Traffic congestion		1. Road traffic congestion is a major urban transport difficulty. 2. The main causes of road traffic congestion are the poor design and maintenance issues, some driving habits leading to non-recurrent traffic and insufficient information available on traffic conditions.	Stoper R. Peter 2003, Bull 2003, OECD and ECMT 2007,

Table 6: Summary of the literature review (Source: Author)

2.7. Conceptual Framework

The study focuses on the supply-oriented measures by the Municipality influencing the road traffic congestion in Madhapur zone in the city of Hyderabad. Following the main research question, the dependent variable-Road Traffic congestion influenced by Independent variable- Supply oriented measures.

At a conference in India regarding the Urban Mobility, which presented failure in urban transport and a framework regarding the measures to be taken to mitigate the congestion. It involved improvement in efficiency of travel, vehicle, and system. The transport planning department involved efficiency for the improvement of urban planning and land-use guidelines which according to Broaddus (2009) is the concept of Transport Demand Management.

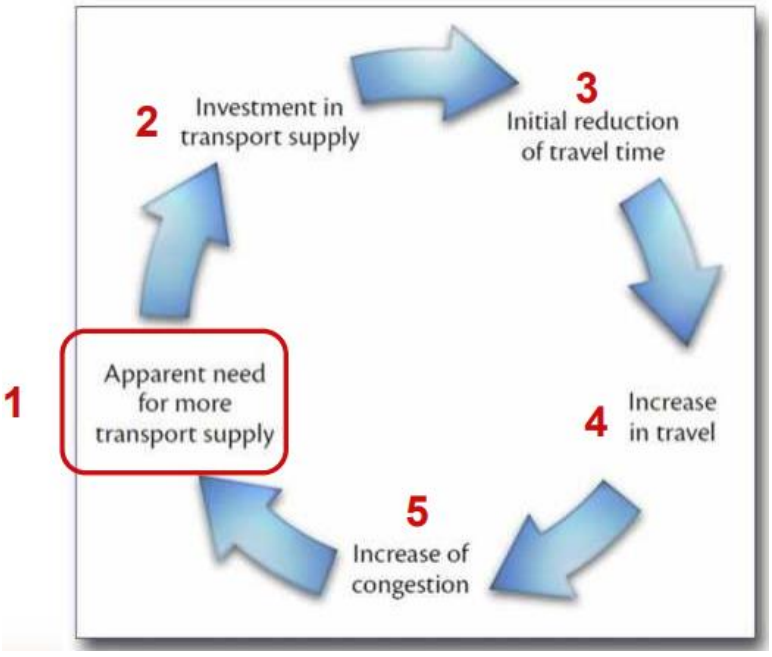


Figure 6: **Failures in urban and transport planning (Source: (Schmid, 2013))**

The figure represents how the demand of transport infrastrcuture and investmenet in supplying of infrastrcuture can initially reduce the congestion, but later as the there is increase in the travel it also leads of increase in the congestion bringing the situtation to sqaure one.

In addition, a study was done by COE urban transport and CEPT University (2013) to help in standardization of procedures for benchmarking to arrive at performance level indicators. In order to understand the adequacy of the level of service provided by the Municipality and Traffic Police the benchmarking of urban services is used.

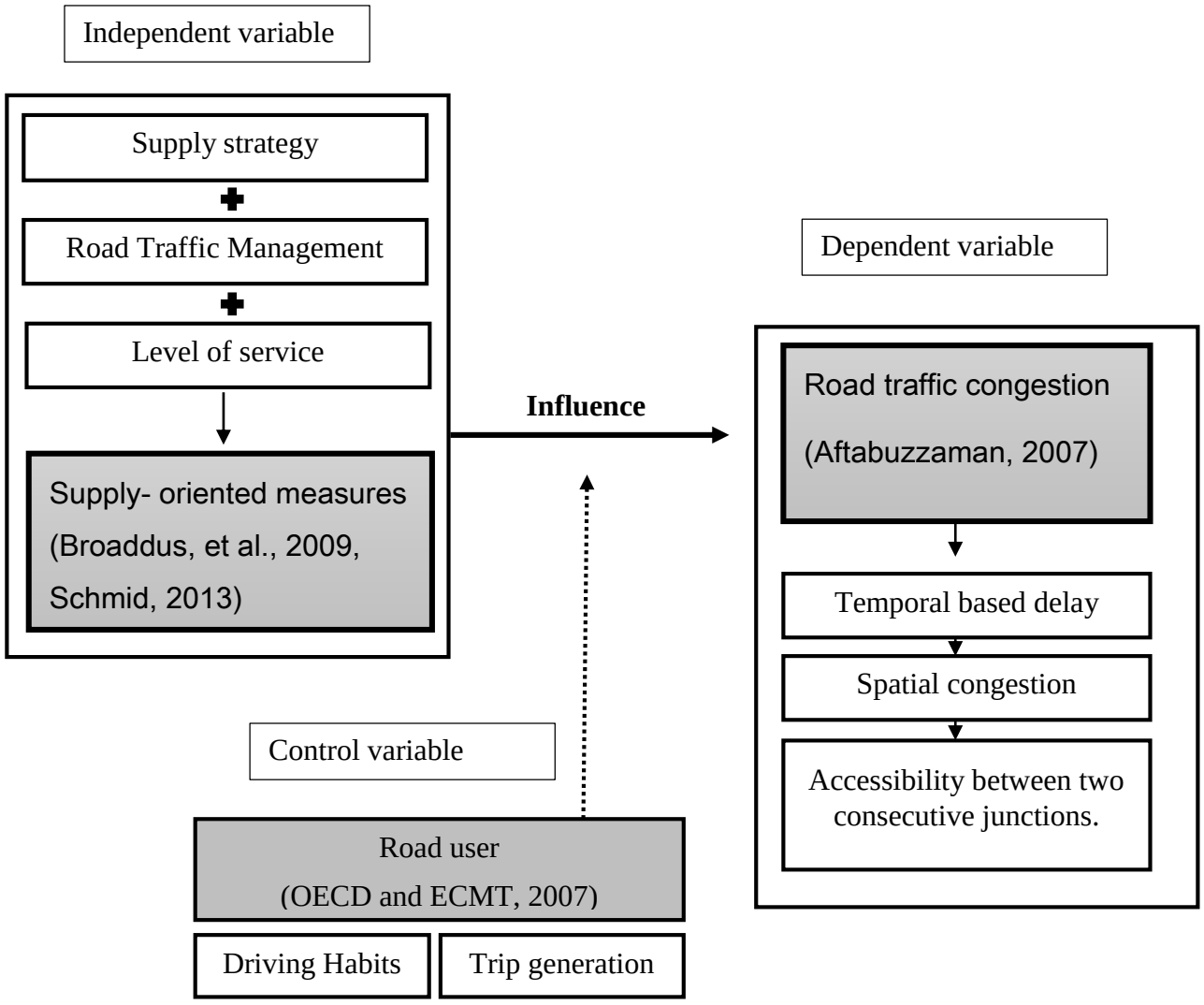


Figure 7: Conceptual Framework

The conceptual framework intends to explain how the supply-oriented measures of infrastructure provision influence the road traffic congestion in the city, which is causing spatial congestion and travel time delay of the road users. The supply-oriented measures by the municipality are the (i) provision of the infrastructure (supply measures) (ii) traffic management (iii) Efficient management of both (service levels) (Stoper R. Peter, 2003). In order to understand the level of adequacy and the level of service (LOS) provision, of the urban services is studied. This will provide us with a clear picture of what the supply-oriented measures are and how they are providing urban service. Apart from the supply-oriented

measures from the municipalities, the road traffic congestion is also being affected by the road users which is indirectly controlling the supply-oriented measures. The trip generation changes the pattern of vehicles movement and density of movement. Further, the driving habits of the road users impacts the non-recurrent traffic congestion.

Chapter 3: Research Design and Methods

3.1. Introduction

The following section showcases the description of approaches used in the study. It starts with the operationalization of the variables and indicators, specific sample size and sampling techniques with the procedure adopted for data collection. Furthermore providing a brief description of the study area and the techniques used for data analysis.

3.2. Main research question

What level of **supply-oriented measures** (supply- strategy, traffic management and Level of service) by the Municipality influence the **road traffic congestion** in Madhapur zone, Hyderabad city?

3.2.1. Sub Research Questions

1. What level of supply-side strategies affect the road traffic congestion in Madhapur zone, Hyderabad city?

2. What level of Traffic management affect the road traffic congestion in Madhapur zone, Hyderabad city?

3. What level of service affect the traffic congestion in Madhapur zone, Hyderabad city?

4. How does the road users affect the traffic congestion in Madhapur zone, Hyderabad city?

3.3. Operationalization of variable and Indicators

Van Thiel (2014) defines operationalization as, “the transition from theory to empirical research. In this phase, theoretical concepts are translated into entities that can be observed or measured in the real world.” The literature review (chapter 2) described alternative viewpoints of concepts and causes which contributes to the Road Traffic congestion. Several methods were adopted to understand the service level of the provision of supply-oriented measures to understand its adequacy. The study aimed to explain the most significant causes of contributing to the supply-oriented measures at the most congested part of Madhapur zone, Hyderabad, therefore, the units of analysis are corridors and road junctions. According to the literature review the supply-oriented measures can be categorised into Supply- strategies, Traffic Management and level of service with road users being the control variables affecting road traffic were the road user grouped as trip generation and driving habits. Finally, Level of service ultimately explains the influence on the road traffic congestion in Madhapur zone, Hyderabad city.

3.3.1. Definition of key concepts

The following table gives an overview of the concepts and definitions.

Table 7: The definitions of key concepts employed in the research are shown in the following table.

Concepts	Definitions
Supply- strategy	Supply strategy refers to the construction of infrastructure. (Broaddus, et al., 2009)
Supply oriented measures	Measures were taken to fulfill the demands of transport infrastructure. (Schmid, 2013)
Road traffic congestion	"A road is considered to be congested when, in more than half of its total length (including not necessarily continuous stretches), the average speed of the traffic flow was less than 40% of the speed in unrestricted conditions. (Bull, 2003)"
Level of Service	"It is a process of measuring the performance of various elements of urban transport against a set of standard or target. It provides policymakers with tools to continuously seek enhanced performance for urban transport. (T. F. P. Henning, Muruvan, et al., 2010)"
Traffic Management	"Travel Management is strategies which aim to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and promoting more effective, healthy and environmental-friendly modes of transport (Broaddus, et al., 2009)."
Road Users	The Road users is used as a control variable to understand the purpose of visit or the trip generation and the driving habits to determine the social, demographical and economic factors of the region(Chakraborty and Dutta, 2002).

3.3.2. Introduction of Variables and Indicators

The following research includes one dependent variable and two independent variables. Control variables were included due to its effect on the dependent variable.

3.3.3. Dependent Variable: Traffic congestion

With the aim of understanding the congestion level in Madhapur zone, it is important to find out the reasons and the measures taken to mitigate it, in a study conducted in India of urban transport (CoE urban transport and CEPT University, 2013, Aftabuzzaman, 2007) lists the variables for understanding the service provision to ease the congestion.

The Indicators as

(1)Temporal-based delay- Travel time to analyze the speed based measures and Average speed along with the annual hours of delay caused due to congestion, secondly temporal delay in order to measure the annual hours of delay, average commute time, congested time, travel time Index, Travel time rate, travel time in congestion Index.

(2) Spatial Indicators measured as congested lanes in Kilometre and Network connectivity Index.

(3) Level of accessibility between two consecutive junctions.

3.3.4. Independent Variables 1: Supply- strategies

A study was done by COE urban transport and CEPT University (2013) to develop operational guidelines for undertaking service level using Ministry of Urban Development (MoUD), to help in

standardization of procedures to arrive at performance level indicators. Hence with the help of study/ toolkit following variables and indicators were identified for the research- to understand comprehensively the accessibility in the area, integration of the service providers, level of facilities provided to public transport, pedestrian infrastructure parking spaces and road safety.

Further, Capacity Indicator needs to be studied in order to understand the saturation Index of the roadway

The study will give us an in-depth understanding of the situation in the Madhapur zone of Hyderabad.

3.3.5. Independent Variables 2: Traffic Management

Travel Management is strategies which aim to increase the urban transport system efficiency and avoiding the needless usage of the private vehicles and promote healthy environment and public mode of transportation (Broaddus, et al., 2009). Through this concept, it is intended to study the efficient management of traffic the sub-variables defined from the literature are- vehicle ownership trends, the priority of Public Transport and information on traffic condition. The following variables provide us with detail information about the profile of traffic and level of infrastructure of public transport.

3.3.6. Independent Variables 3: level of service

The level of service defines the state of the infrastructure in terms of its indicators. It is important to understand the provision of the infrastructure by the Municipalities. The level of service indicates a measure which determines to which level the service is ranked comparing with a given set of standards.

3.3.7. Control Variable: Road users

The Road users is used as a control variable to understand the purpose of visit or the trip generation and the driving habits to determine the social, demographical and economic factors of the region (Chakraborty and Dutta, 2002, Dewar and Todeschini, 2004). Apart from the supply-oriented measures, the road users have an unavoidable effect on the traffic congestion. In some conditions recurrent and some non-recurrent. To avoid the recurrent congestion, the supply-oriented measures are taken by the municipalities. Hence, it is required to understand the third constant intervention causing the road traffic congestion.

Control variables were found as important variables while analyzing the state of road traffic congestion (OECD and ECMT, 2007). The following control variables are associated with dependent variable and were accordingly analyzed to understand its impact on road traffic congestion.

With the aim of understanding the congestion level in the city, it is also important to find out the variables affecting outside the scope of the supply from the municipalities in order to gain an insight regarding the congestion in the city.

3.3.8. Operationalization table

The following table presents the operationalization of concepts with variables and their corresponding measurable indicators.

Concepts	Variables	Indicators	Measurement of Indicators	Type of Data
TDM- Supply oriented measures (Broaddus, et al., 2009, Schmid, 2013, Central Road research institute-	**Supply-measures**	Infrastructure provision	Level of provision of roads, bridges, underpass, pedestrian infrastructure.	Qualitative Data
		Land-use Pattern	Percentage of spaces	Quantitative Data

CSIR, December, 2017) **(In-dependent variable)**	**Traffic Management**	Vehicle trends and ownerships	Percentages of different types of vehicles	Quantitative Data
		Information of Traffic	Level of Information provision	Qualitative Data
		Public transport prioritisation	Level of prioritisation	Qualitative Data
	Level of service	Volume of the vehicles by capacity of the road ratio	Volume/Capacity	Quantitative Data
		Road Safety	Fatality Rate	Quantitative Data
Urban Movement (Bull, 2003, OECD and ECMT, 2007, Dewar and Todeschini, 2004, Chakraborty and Dutta, 2002) **(Control variable)**	**Road user**	Trip Generation	Purpose of visit to Madhapur	Qualitative Data
		Driving Habits	Driving habits, accidents	Qualitative Data
Transport Infrastructure (Bull, 2003) **(Dependent variable)**	**Road traffic congestion**	Temporal/ Delay based indicators	Average commute travel time	Quantitative Data
			Congested time	Quantitative Data
		Spatial Congestion	Congested lane	Quantitative Data
			Network connectivity Index	Quantitative Data
		Accessibility between two consecutive junction s	Accessibility	Qualitative Data

Table 8: Operationalization of the variables and indicators

3.3.9. Defining the Indicators

The following table provides a definition of the sub-Indicators used in Operationalization table, adapted from author Aftabuzzaman (2007) and (CoE urban transport and CEPT University, 2013).

Sub-Indicators	Definitions
Road Density	"Total road length(i) divided by Built up area(h)"
Annual/monthly hours of delay	"Hours of extra time traveled due to congestion."
Average commute travel time	"Average commute trip time."
Congested time	"Estimate of how long congested "rush hour" conditions exist."

Congested lane in km	"The number of lanes/ roads which has been congested in the neighborhood."
Network connectivity Index	"An index that accounts for the number of nodes and interchanges within a roadway network."

Table 9: Definition of the indicators (Source: (CoE urban transport and CEPT University, 2013)

3.4. Research strategy

3.4.1. Research Techniques

The research employs a case study approach, using the case of congestion in Madhapur zone of the city of Hyderabad and how it is affected by the inadequate supply oriented measures taken by the Municipality. In such a circumstance where it involves the study of real-life setting focussing on a limited number of the situation and studying them keenly. Case- study research strategy is used to conduct the research (Van Thiel, 2014). According to Zainal (2007), "a case study method is a robust research method particularly when a holistic, in-depth investigation is required. Through this methods, a researcher is able to go beyond the quantitative statistical results and understand the behavioral conditions through the actor's perspective." As the following study is trying to understand the qualitative and quantitative factors leading to the inadequacy of the service provider for the in-depth analysis. (Zainal, 2007).

From the above discussion, to achieve the detailed explanation of the situation and extensive description of the phenomenon, a Co-Variation approach of the case study research is the chosen. Co-variation approach attempts to answer the questions by comparing the different cases and by systematically comparing the variations of these features with variations of the relevant potential effects of the outcome or the dependent variable (Mahoney, Goertz 2006 p. 230-1). In the following study, it focuses on 8 different junctions which are studied under the similar indicators. Co-variation approach helps comparing different cases of the junction and their infrastructure provision to analyse the effects of the road traffic congestion. This way the solutions used at particular junction can be incorporated in future which has similar consequence/ development. Co-variation fit in this case as it studies different infrastructure provision at 8 different locations in order to analyze it with the standards obtained from the reports and manuals. The precondition hypothesis deduced from the theory was the inadequacy of the infrastructure provision in Madhapur at the specific 8 junctions where the road traffic congestion was high (RW.ERROR - Unable to find reference:315).

As the study adopts Co-variation explanatory case-study method typology, with the objective of the study, is seeking to explain to what level of the supply-oriented supply by the road traffic management system affect the road traffic congestion in Hyderabad. Stemming from this, the study seeks to establish the relationship between the independent variable of **supply-oriented measures** and the dependent variable of **road traffic congestion**. This study will pursue to collect a combination of quantitative and qualitative data through structured and semi-structured interviews and observations. To complement the study collection and analysis of secondary data and reports, particularly the maps, master plans and reports of supplied infrastructure. (Punch, 2009)

3.4.2. Data collection methods, Instruments and scope of the study

The following section provides details of the scope of the research with the data collection methods and instruments used to collect data.

3.4.2.1. Scope

The city of Hyderabad is a hub of trade and commerce of international center for IT (Information Technology). The density of the city is 10,477 people per square km with a total

area of 650 square km and population 6.8Millions (Census 2011). There was an increase in the IT sector which grew enormously by expanding the city to its greater limits and created traffic congestion in the city causing chaos and time delays. In order to reduce the traffic congestion in the IT zone of the city, the service providers (GHMC and HMDA) proposed short time mitigation solutions in the past 5-6 years, yet finding it difficult to solve the severe problem of road traffic congestion. The following research focusses on understanding the causes of road traffic congestion due to the inadequacy of infrastructure provided by the service providers (GHMC and HMDA). To obtain deep understanding "Madhapur zone" which has a higher concentration of the IT sector is chosen to analyze the situation. The infrastructure provided in the Madhapur zone will be studied in details and benchmarked. The section below describes the method of the data collection and analysis.

3.4.2.2. Data collection methods and instruments

The research uses case-study as the main data collection method. The data collected will be the primary, secondary data and observations. The three sources of data are collected in order to compliment the study and findings. The primary data will be a combination of structured and semi-structured interview, scheduled with the arrangement of open-ended questions will be used to collect revealed preference data from the commuters.

3.4.2.2.1. Primary Data collection

The primary data is collected via interviews and rechecking by observations at the site. The interviews were open-ended semi-structured interviews and structured interviews. Firstly, the interviews will be conducted on Infrastructure and service providers- GHMC and HMDA, to understand their perspective of the service provided. Secondly, the interview will be conducted on the traffic police of Cyberabad (Madhapur zone) to understand the perspective of the controller of the traffic.

The Infrastructure and service provider will be interviewed via a combination of the structured and semi-structured interview to categorize the reason behind the lack of provision or inadequate provision. With the aim to avoid deviation and limited time due to their tight schedule a combination is used. The head of the Planning Department, Maintenance team and the in-charge for each service will be interviewed keeping the aim of understanding each facility in detail.

Further, the traffic manager- the traffic police/ constable will be interviewed via a semi-structured interview as they are the ones on the field witnessing the problem, they will provide an insight of the whole scenario. The Traffic Police Department is responsible for easing the traffic and maintaining the flow, they can provide their knowledge gained by experiencing the scenario during the time work.

3.4.2.2.2. Secondary Data collection

The statistics will be collected regarding the demand for infrastructure and proposed plans by the infrastructure provider in order to compliment the study. The following documents will be analyzed-

- The capacity of the road user/ figures or vehicles per hour based analysis.
- Level of the provision of the infrastructure as per the plan and the road Density.
- Land- use maps to derive the percentage of the commercial: Residential: Educational: Hospitals: Offices etc.
- The plans or reports of infrastructure to be delivered.
- Congestion analysis- annual/ monthly report.
- Spatial indicator showing the saturation Index of the road.
- Vehicle ownership data.
- Speed analysis report
- A number of Traffic police provision per junction according to the standards.
- Level of accessibility between two consecutive junctions from Google maps.

- Time-Frequency of the buses and the number of buses allotted per route.
- Fatality rate.
- Financial reports of the infrastructure.
- Existing benchmarking of urban services- hardware infrastructure and maintenance.

3.4.2.2.3. Observation

A keen observation will be done of the infrastructure provided and service delivered. The statistics will be collected regarding the demand for infrastructure and proposed plans by the infrastructure provider in order mainly to compliment the study.

As per the official website of Cyberabad Traffic police (2018), the current status of traffic congestion is majorly seen in 8 junctions. As the data collection obtains data from two sources- the service provider and infrastructure provider, the overall study will a holistic knowledge of the reason behind congestion in Madhapur.

The following observation will be made on the site to measure and check the services. The set of 10 observations will be done during peak hours and non-peak hours and data will be crossed checked.

1. Lane priority is given to the public transport
2. The number of traffic police per Junction.
3. Encroachment on the footpath, supported by Photographs.
4. Footpath width less than 1.2m

The following observations are made to compliment the study with the missing details from the primary and secondary sources. The filed visit was for 25 days hence, the primary method of observation was used for only complimenting basic missing data.

3.4.3. Sample size

In order to collect primary data on the causes and effects of traffic congestion in Madhapur area, the approach of interviews was used to gain sufficient coverage of people at the junction or stretch. The study focused on interviewing people who are responsible to manage the traffic at the junction which are the traffic police or constables and the people responsible for the supply of the infrastructure which are the town planners and engineers. As stated, semi-structured interviews were conducted with open-ended questions allowing the respondents to express the real causes of the congestion on the road junctions and stretch. Due to the limited time, in total 15 interviews will be conducted. Table 10 showcases the description of interview respondents. Annex 2 presents' further details regarding the interview questions and responses.

Respondent group	Description	Quantity
Traffic Police Commissioner	To understand the policies, rules, and initiatives	2
Traffic Police Constables at the junctions	To understand the current scenario at the junctions	12
City Planner and Engineers	To understand the planning process and key elements taken into account.	3

Table 10: **Distribution of interview respondents**

A total of 15 interviews were conducted, the traffic police constable at 8 junctions were interviewed. The main junctions had 2-3 constables and other junctions had 2 junctions. This records the reasons for congestion at the junctions. Each junction was studied and the constables on duty were interviewed. Further, the Commissioner and sub-Commissioner of Cyberabad was interviewed in-order to receive the data on traffic management in Madhapur. Lastly, the Main City Planner of Hyderabad along with

City Engineer and Madhapur (south zone) Engineer was interviewed. The 3 head of the departments provided the required information regarding the provision of the infrastructure.

The main data required was from the all the actors involved in traffic management. Hence the head of the departments were chosen, they were accountable for the changes and had profound knowledge of the entire situation. Therefore an interview of head of the department was sufficient to provide the necessary answers. Further the third tier who are the police constable at the junction, who were minimum two at each junction. As the study evolves to understand the infrastructure provision and traffic analysis at 8 junctions and intermediate corridors, hence the constable at each junction was interview. The constable at each junction can describe the scenario better from his experience. In summary 12 constables from 8 different junctions were interview (Minimum 1 from each junction) and the main head of the department of Hyderabad Municipal Corporation, Hyderabad Metropolitan department and Cyberabad Traffic Police Department.

3.5. Data analysis

The three set of data collected will be analyzed separately and studied holistically. The primary data is obtained from interviews and observation along the secondary data from the reports and government archives.

3.5.1. Secondary data analysis

The data collected from the reports and manuals will be analyzed first to understand the level of provision of the services provided. Microsoft Excel's descriptive analysis is used to generate the pie charts representing the percentages of the data collected via the secondary data sources. This will provide us with the base of the study with the details of the service provided by the service providers- GHMC and HMDA in the reports. This secondary data, will complement the primary data of interviews and observations. The reports and manuals collected are from the Municipalities achieves.

3.5.3. Observations

Once the data collected from the secondary sources- reports and manuals are analysed the list of the provisions and initiatives are formulated. Further, the provision of the infrastructure is observed at the site to cross check. After which the check for the number of police constables are done in order to see their availability at the junction. The observation was made to cross check the provisions, apart from this the general traffic observation was made to understand the level but it cannot be generalised as the duration of collecting data was for 1 month. In this short period defining the traffic congestion based on observation will be biasness.

Lastly, the observations will be supported by pictures to compliment the data and check the infrastructure exists at the site. Each junction will be observed and checked with the standards of the provisions of infrastructure.

3.5.2. Primary data analysis

The interviews will be analyzed by using Atlas.TI to understand the frequencies and co-relation between two variables. The interviews will be studied and quoted to compliment the data collected from the secondary sources. The interviews will provide us the viewpoint of the service provider- GHMC and HMDA, along with traffic police and constable of Cyberabad.

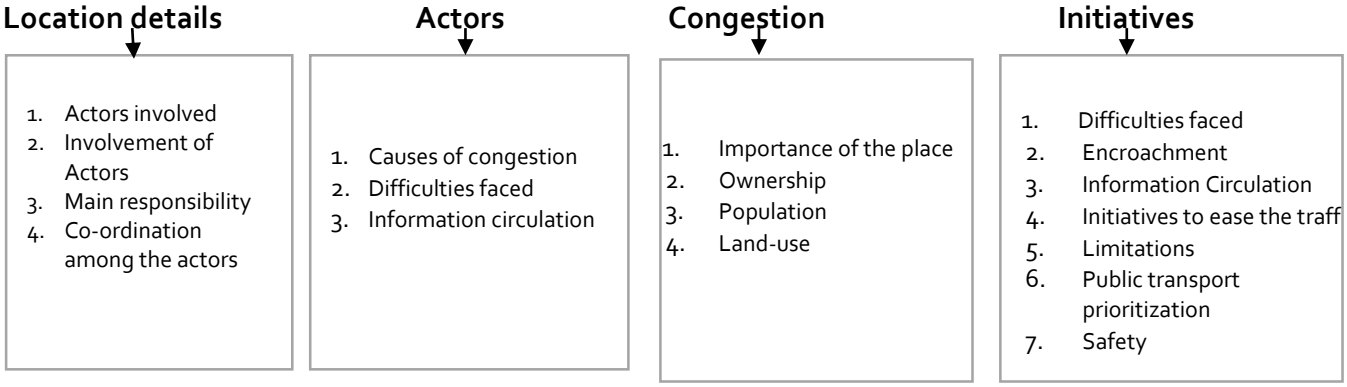
A total of 6 interviews were conducted to understand their initiative for the provision of infrastructure and what measures were taken by them to ease the traffic congestion in Madhapur zone.

List of the people who were interviewed

1. City Planner HMDA
2. Deputy Hyderabad Engineer
3. Deputy South zone Engineer

4. Engineer In-Charge of Cyberabad & Lingampally area.
5. Assistant Commissioner of Cyberabad
6. Deputy Commissioner of Police –Cyberabad.

The interviews were conducted to understand the level of provision of infrastructure and initiative taken by them to ease to traffic congestion.



The following table shows the codes used in the Atlas.Ti to understand the frequencies and indicators. Further the table below explains the frequencies of the codes used. This helps to understand the number of time the respondent pressurized about.

Name	Grounded	Groups
actors	4	[Actors]
causes of congestion	6	[congestion]
Co-ordination among actors	6	[Actors]
difficulties	3	[congestion] [Initiatives]
Encroachment	2	[Initiatives]
Importance of the place	12	[Location details]
Information circulation	2	[congestion] [Initiatives]
Initiatives to ease traffic	13	[Initiatives]
Involvement of Actors	2	[Actors]
LandUse	3	[Location details]
Limitations	5	[Initiatives]
Main Responsibility	3	[Actors]
Ownership of Land	2	[Location details]
Population	1	[Location details]
Public transport prioirtization	3	[Initiatives]
Safety	3	[Initiatives]

Figure 8: Explains the frequency of codes (source: Atlas.Ti, Author)

In the following research Atlas.Ti was used to arrange, resemble and manage the transcripts of the interview. Further it helped in analysing the interview to obtain the relation between the dependent and Independent variable was analysing the correlation between the indicators.

3.6. Validity and reliability

The following research is an explanatory research. A high level of reliability is required that explains most of the acquired and available data consistently. The three main sources of checking the data are: (i) Research method or instruments (ii) Biasness (iii) Sample (Van Thiel, 2014, p.51).

3.6.1. Reliability

3.6.1.1. Accuracy

The strategy used to collect to the data for the study is ‘case study’ as it examines real-life setting (Cohen, Manion, et al., 2011). The study involves the mixed method case study, along with the fixed

time frame. The measurement instrument defines the accuracy of the study. In the following study the primary data is collected via interviews of the actors involved in the traffic management along with observation done by the author. The sample size of the interview majorly were the actors involved in traffic management in Madhapur area. The engineers, planner, policy makers and traffic managers. From each department the main head was chosen to provide adequate information. Along with that that traffic constable at each selected junctions were interview, the proportion of selection of the members was dependent on the information provider. Each head of the department provided the required information as they had the knowledge of the entire process, whereas the constable at the junction could describe the scenario of the traffic at the particular junction and the adjacent ones. Hence, all the constables at the 8 junctions were interview to understand the situation at their positions.

Secondary, the major source of secondary data is from achieves from the Municipalities of the study done. The data obtained from the secondary data is analysed by observation to check the existence of the provided infrastructure and management. Further, questionnaire is formulated to understand the level of provision and reason of decision making. The following way helps the author to find the linkage between provision of infrastructure and level of service provided.

3.6.1.2. Consistency

The secondary sources are mainly obtained from the Municipality archives. They are the study done to understand the level the congestion in the city. The major studies were initiated by the Municipalities in order to provide certain infrastructure such as the metro rail. The main reports were

- "Executive summary on development, validation and calibration of UTP mode, Scenario and Travel demand management" 2012 done by Comprehensive Transport study (CTS) for Hyderabad Metropolitan area (HMDA)".
- "The area traffic management plans" published in 2011, for immediate action done by Comprehensive Transport study (CTS) for Hyderabad Metropolitan area (HMDA).
- "Field survey" 2012 reports done by Comprehensive Transport study (CTS) for Hyderabad Metropolitan area (HMDA).
- "Indo Capacity Manual" 2012-2017, by council of scientific and industrial research (CSIR), New Delhi.

The following reports consisted of the data which helped to understand the provision done by the Municipalities (other reports were also referred). The following research adds to the existing data and explore the details in a particular area by making a prototype study.

3.6.2. Validity

3.6.2.1. Internal Validity

The following study intents to understand the effects on the supply-oriented measures on the road traffic congestion. The independent variable – supply oriented measures comprised of the supply-strategies, traffic management and level of service, the following variables are operationalised in correlation to the vehicle orientation and volume. This helps to develop a relation with the road traffic congestion count and reason of the delay and spatial congestion. Further the measurement of the indicators are taken from the Indo-Capacity Manual which describes the standards and explain the scenario in the real-life setting.

3.6.2.2. External Validity

The chosen strategy - case study research permits to explain the research issue in-depth way. However, it is difficult to generalise the findings in the case. In the following case, the study of the 8 junctions have specific findings and the case picked in the IT sector is very unique. Nevertheless, the general analysis of the traffic through analysis of maps and PCUs values complimenting with primary interviews allow to reveal the reasons behind congestion due to the supply-oriented measures.

Chapter 4: Research Findings

The chapter explains the findings from the field visit via Interviews and secondary data collection. The author had 25 days to conduct the following data collection.

4.1. Background of the research

4.1.1. Hyderabad city:

Hyderabad is Capital city of Telangana and is the main in the state and most-crowded city. It is a major urban Agglomeration in India. It is the fourth largest city in India and among the top populated cities after Delhi, Mumbai, and Kolkata. Hyderabad city is the currency is the administrative capital and economic and financial capital of the joint states. Hyderabad is one of the major software Hub in the south of India. It is the hub of trade and commerce and International center for IT (information technology). The density of the city is 10,477 people per square km [area- 650 square km and population- 6.8Millions (as per census 2011)] It is among the top dense cities in Hyderabad with Delhi being highest at 12,100 people per square km (Demographia, 2017).

Figure 9: **Location map of Hyderabad (Source: Demographia, 2017)**

4.1.2. Background of Study zone in Hyderabad city- Madhapur zone:

Madhapur is a major IT hub, in the city of Hyderabad. The heart of this area is called HITEC city, having the highest concentration of IT/ITES positioned. Madhapur has transformed from a rocky small village since the early 1990s into the modern IT hub. Hyderabad has contributed to the IT growth in the country. The IT sector is located in the south direction of the city, named "Cyberabad" in Madhapur area. Also, set up a planning commission for urban Development named- Cyberabad Development Authority (CDA) (Greater Hyderabad Municipal Corporation, 2018).

It has become the preferred meeting place with international conferences and meeting take place at the newly developed and buzzing chains of hotels. The area also contains a lot of prestigious educational institutes providing international schooling experiences and National Institutes. The area has become a special attraction for businesses where investors are buildings complexes, High-rise apartment, high-

end restaurants, and departmental store. With professionals of IT, sector prefers to stay in and around Madhapur, apartment buildings have been on the rise and are demanding for quality stay and food.

Due to their work schedule of the IT employee which is round the clock, the area is always lit and is in the working process.

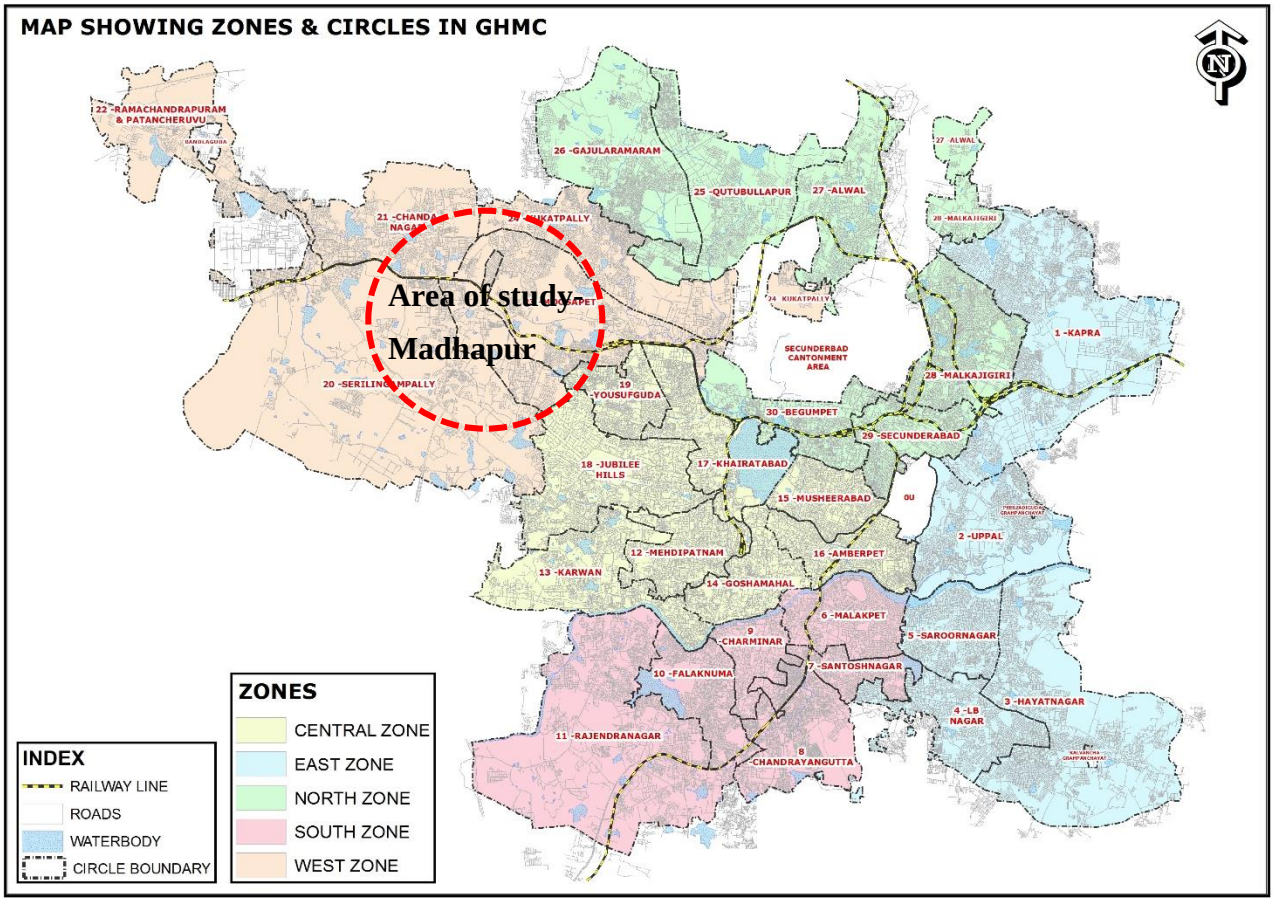


Figure 10: Zonal map of Hyderabad

Source: (Greater Hyderabad Municipal Corporation, 2018)

4.1.3. Municipalities in Hyderabad

4.1.3.1. Introduction to the municipalities

To maintain and provide adequate facilities to the people residing in Hyderabad and surrounding Municipal Corporation of Hyderabad (MCH) has emerged. In the year 2007, it merged with 12 Municipalities and the suburbs to form Greater Hyderabad Municipal Corporation (GHMC). According to the Act G.O. Ms. No. 570 MA and UD (I1), in 2008 The Hyderabad Metropolitan Development Authority (HMDA) was formed reviewing 7,257 Square Km. covering the greater extends of Hyderabad. Also, the state set up a corporation to cater to the infrastructure provision in 2014, TSIIC (Telangana State Industrial Corporation), it was formed to identify and develop potential growth centers in the entire state of Telangana whose capital is Hyderabad city. These three departments are jointly in charge of the service and infrastructure provision in Hyderabad.

4.1.3.2. Responsibilities and profile of the respondents of each municipality and Actors involved

Greater Hyderabad Municipal Corporation (GHMC)
GHMC is primarily responsible for administering and providing basic infrastructure to the city. Its key role is the building and maintenance of roads, streets, and flyovers. Public buildings and spaces such as the schools, parks. It is also responsible for garbage disposal and street cleanliness along with the health and sanitation maintenance. GHMC co-ordinates with HMDA, HMR, Hyderabad Traffic Police, for delivering basic urban services (Greater Hyderabad Municipal Corporation, 2018).

Hyderabad Metropolitan Development Authority (HMDA)
HMDA is mainly responsible for planning, coordination, organising, supporting and safeguarding the development plan of the Hyderabad urban Region. It coordinates the activities for development among the municipal corporations and other local authorities. It prepares the Metropolitan plan and Metropolitan Development at the city level. (Hyderabad Metropolitan Department Authority, 2018)

Telangana State Industrial Corporation (TSIIC)
TSIIC focuses on the entire area in the state of Telangana whose capital city is Hyderabad. The Telangana State Government initiated the corporation to provide infrastructure by developing industrial areas. It develops "plots/sheds, roads, drainage, water, power, and other infrastructural facilities." (Telangana State Industrial Infrastructure Corporation, 2018)

The Cyberabad Traffic Police
The Cyberabad Traffic police are primarily responsible for managing traffic accompanied by the cooperation of municipalities. According to the Cyberabad Traffic police, maintenance and provision of infrastructure services are not in their part. However, they are in charge of maintaining law and order of the road traffic. Moreover, according to the Traffic police of Cyberabad, the changes by the municipal in building or altering infrastructures such as road and bridges are causing hassle among the travelers. The traffic police are constantly keeping a check on the traffic and have given the authority to the local constable to adjust the traffic signals according to the scenario to effectively manage the traffic wait time (Cyberabad Traffic police, 2018).

According to the Cyberabad traffic police (2018), their main role is to patrol and monitor traffic flow. Specifically at the intersections and the crossings along with the streets with a large flow of vehicles and pedestrians for easing circulations (Cyberabad Traffic police, 2018).

An important aspect observed was the location factor, all the respondents emphasized the fact that the IT industries are located in this zone which is Phase I, Phase II and Phase III. According to the Head of Traffic Police department, Cyberabad said, "Every day we are expecting around 10-12 Lakhs Supportive services and IT employees." (1Lakh= 0.1 Million)

4.2 Study area

The following study focuses on the main corridor in Madhapur, where the concentration of commercial and public spaces are high. 8 main junctions are identified in the corridors.

As HMDA is accountable for the City maintenance and planning, the following Land-use map has been obtained (Hyderabad Metropolitan Department Authority, 2018). The following Land-use map in the Figure 9 represents the land-use patterns in Madhapur area and surroundings where the IT sectors are located. The legend showing blue represents commercial cum office spaces which are mostly concentrated at the linear corridor from JNTU junction to Bio-Diversity junction. The stretch from Hi-tech city to Bio-Diversity park junction has a mixed use typology with dominance of commercial and public spaces. The commercial spaces mostly consisted of software firms, hotels and MNCs.

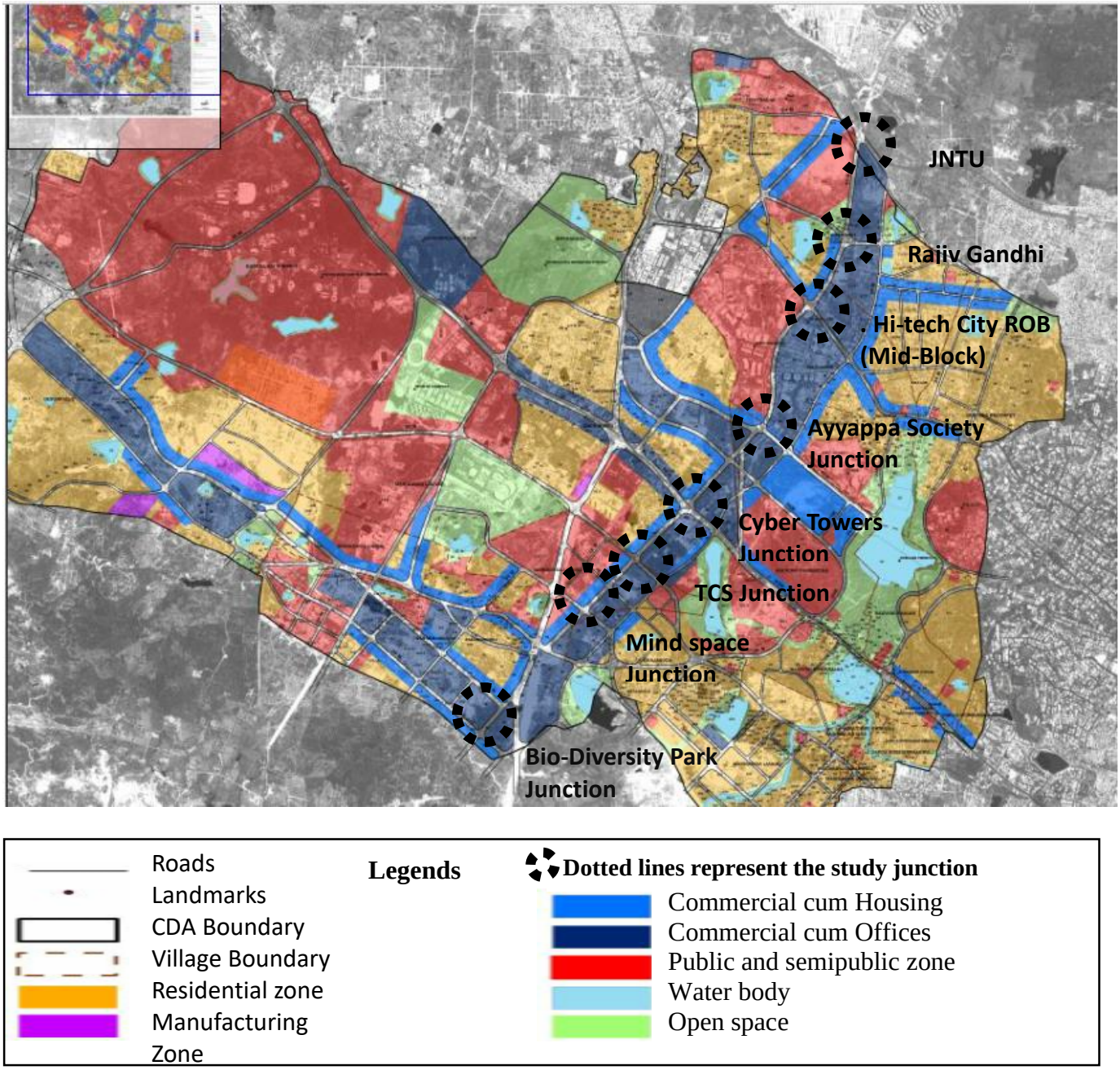


Figure 11: Land-use pattern Madhapur (source: Master plan for Cyberabad by HMDA and Comprehensive Transportation Study (CTS) for Hyderabad Metropolitan Area (HMA) 2011)

4.2.1. Corridor details and Junction details

"As mentioned in the official website of the Traffic Police Department of Hyderabad (Cyberabad Traffic police, 2018) 8 junctions witness major congestion these junctions will study and the 2 traffic police from present at each of the junction will be interviewed. The 8 major junctions according to the Hyderabad Traffic Police (Cyberabad Traffic police, 2018) with the details the provision of the infrastructure and existing infrastructure at the corridor and junctions are-

- **Biodiversity Park Junction** is formed with the confluence of Hitech city main road and old Mumbai highway (i.e. Gachibowli road). This is a 'T' junction with all the arms of the intersection being divided carriageways with medians whose widths are 11m, 2m and 2.5m for the arms in direction of Mind space, Gachibowli, Mehdipatnam respectively. The ROW (Right of way) of the road towards Mind space is ranging from 17 to 50 m and ROW's of old Mumbai highway in the direction of Gachibowli is ranging from 13 to 40m and for Mehdipatnam sidearm is 30 to 46m.
- **Mind space Junction** is formed with the confluence of Hitech city main road with the Inorbit mall road and Ramky towers road. This is a 4-armed signalized intersection with a rotary radius of 18 m and guiding medians. The ROW's of the Hitech city main road are ranging from 10m to 36m in the direction of cyber towers and 19 to 49m in the direction of Bio-Diversity Park. The ROW's of Inorbit mall road and the road towards Ramky Towers are ranging from 13m to 59m and 16m to 34m respectively. The junction is operating as rotary with guiding channelizes each width of 4m, 28m, 18m and 8meters in the direction of the road to cyber towers, Inorbit mall, biodiversity park, and Ramky Towers respectively.
- **TCS Junction** is formed by the confluence of Hitech city main road and the road towards value labs. This is a 3-armed signalized intersection with the minor access road to TCS main entrance gate close to the junction. The ROW's of the Hitech city main road are ranging from 14m to 36m and 16m to 32m towards Mind space and cyber towers respectively and ROW for the road towards value labs is ranging from 13m to 26m. All the arms of the intersection are divided with medians whose width is about 2m, 1.5m, and 1m for the cyber tower, Mind space, and value labs respectively. Traffic from TCS access road is also guided using temporary cones into the junction. There is a TCS building just beside the Hitech city main road and lemon tree hotel at the free left from Mind space to value labs.
- **Cyber Tower Junction** is formed with the confluence of Hitech city main road from JNTU to Bio Diversity Park and Hitech city road from jubilee check post to Kondapur. The ROW of JNTU side of the Hitech city main road is ranging from 22m to 40m and 21m to 55m on the Mind space side of the Hitech city main road. The ROW's of the road from Jubilee check post to Kondapur are ranging from 14m to 31 and 14m to 33m on jubilee check post and Kondapur sides of the junction respectively and ROW for the Hitech city flyover is ranging from 7m to 13m.
- **Ayyappa society Junction** is formed with the confluence of Hitech city main road from JNTU to Bio Diversity Park and Ayyappa society road leading to Ayyappa society to Shilparamam. The ROW of JNTU side of the Hitech city main road is ranging from 14m to 38m and 9m to 38m on the side of the cyber tower. While the ROW's of Ayyappa society road towards Ayyappa society and Shilparamam sides are ranging from 9m to 34m and 10m to 31m respectively. The medians on the Ayyappa Society road are 14m wide.
- **Hitech city ROB Mid-Block junction** is the midblock flyover connecting KPHB road and Hitech city main road. This flyover has an uninterrupted flow of traffic. The ROW of the flyover is ranging from 7m to 18m. This is a divided road with median whose width is around 2m. U-turns are provided starting and ending of the flyover in both directions.

- **Rajiv Gandhi roundabout** junction is formed by confluence of JNTU road, KPHB 9th phase, and KPHB 6th phase roads. This junction functions as a rotary. The intersection with each arm leading to JNTU, Brand Factory, Malaysian Township, Hitech city, KPHB 9th phase respectively and the ROW of the JNTU road towards JNTU is ranging from 18m to 35m while the ROW of KPHB road towards Hitech city is ranging from 9m to 35m and ROW of KPHB 9th phase road and brand factory are ranging from 10m to 43m and 9m to 27m respectively and the ROW of the road leading to Malaysian township road is ranging from 5m to 14m This junction works with a rotary of diameter 42m and guiding medians at the intersection are 2m, 14m, 16m, 1.5m and 8 m wide in the direction JNTU road, KPHB 9th phase, Hitech city, Malaysian township and brand factory respectively.
- **JNTU Junction** is formed with the confluence of National Highway 9 and JNTU Road. It is a 'T' Junction and a minor road leads to Pragathi Nagar. The ROW of JNTU road at the junction is ranging from 7 to 27m while the road from Miyapur Side has ROW ranging from 32 to 67m and Kukatpally side has ROW ranging from 27 to 55 m. There are lots of shopping attractions on the road towards Kukatpally and Hitech city from the junction. There is also a service road approaching the junction from Kukatpally side of the junction. The JNTU is located on the left side which has direct access from the intersection. There are lots of shopping attractions on the road towards Kukatpally and Hitech city from the junction."

4.3. Key Findings of the research

The following section describes and explains the findings of the study, it is divided in the order of Independent Variable, Control Variable and Dependent variable. The following order is chosen to explain the effects of the independent variable on the dependent variable and the key role of control variable.

4.3.1. Supply- oriented measures: Independent variable

Supply-oriented measures are the actions taken to fulfill the demand for transport infrastructure. As Schmid (2003). The Independent Variables- Supply oriented measures are categorized in three sub-variables- Supply- strategy, Traffic Management and level of service, for the holistic understanding of the provision of the infrastructure.

4.3.1.1. Supply- strategy

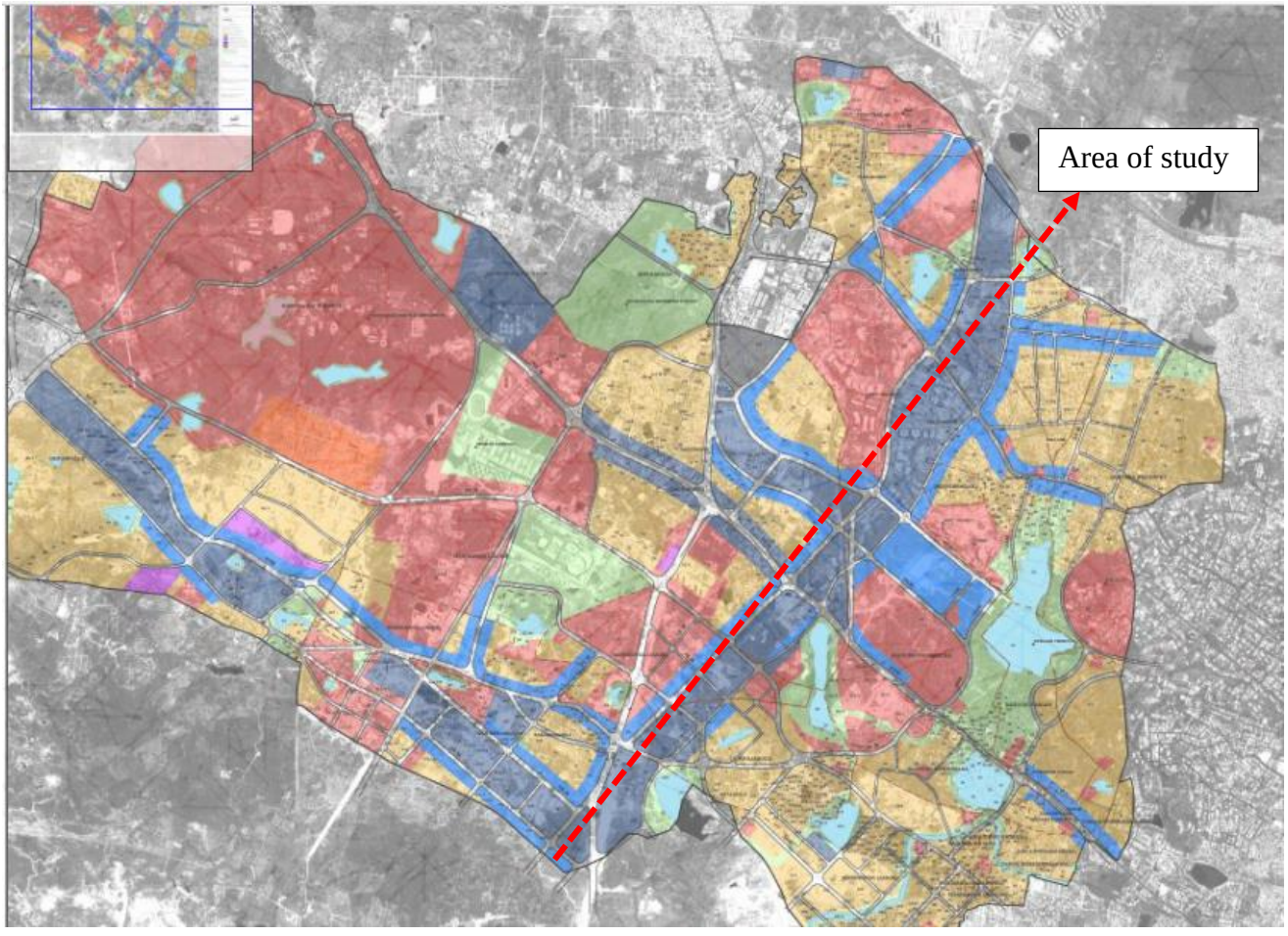
Introduction: The supply- strategy is defined as the construction of infrastructure (Broaddus, et al., 2009). In India, the NHAI (National Highways Authority of India) caters to National roads and infrastructure and the local State and City Municipality caters to the local roads in the State. In the City of Hyderabad, 3 Municipalities are responsible as mentioned- GHMC, HMDA and TSIIC. As according to Broaddus (2009), he mentioned that the responsibility of transport agencies are to include designing, managing road network, building, managing transport services and regulations of vehicles (Broaddus, et al., 2009). Further adding by Meyer (1997), the supply strategies in integration with efficient land-use planning can reach to the goal of traffic alleviation.

In the case of Hyderabad, as a primary tactic of the Municipality to address the rapid growth of increase in traffic loads on arteries in a metropolitan area is through a supply- strategy such as building more roads or widening existing ones. They are also responsible to allot the plot area for construction, hence the land-use patterns development is due to the decisions taken by the Municipalities (Greater Hyderabad Municipal Corporation, 2018). To analyze the existing supply- strategies of the Municipality in the recent time, the infrastructure is compared to the standards and volume in the vehicles. The standards have been used from the Indo-Capacity Manual (Central Road research institute-CSIR, December, 2017).

4.3.1.1.1. Land use pattern

Land use patterns define the space allotment of land. This caters to the agglomeration of the spaces such as commercial, housing, entertainment etc. This is decided by the Municipalities in order to understand the demand in a particular area. The land use of Madhapur is not just commercial but also comprises of residential, educational, public and semi-public along with few pockets of green spaces, as said by the City Planner of HMDA (Hyderabad Metropolitan Department Authority). Further added by the Commissioner of the Cyberabad Police Department, regarding a good management plan requirement due to the bustling traffic day and night major because of the vibrant activities after work hour. The area not only caters to MNC but also has developed different entertainment zones such as malls, multiplexes and food joints etc. Lastly, adding by the South Wing Engineer that, due to the availability of the MNC, the employees are mostly living around Madhapur area, this is further expanding and attracting more entertainment and commercial spaces.

As the repondents focussed on the development due to the presence of the MNC, the land-use map obtained from the Municipalities showed similar results. The map of the Land-use pattern in the figure 9 showcases the volume of commercial spaces, housing spaces, entertainment area, educational and industrial area.



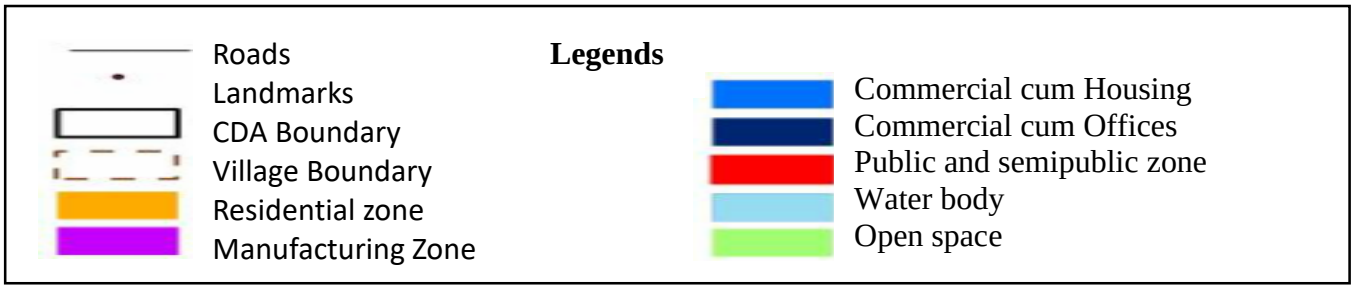


Figure 12: Land-use pattern Madhapur (source: Master plan for Cyberabad by HMDA and Comprehensive Transportation Study (CTS) for Hyderabad Metropolitan Area (HMA) 2011)

As observed from the figure 9, the concentration of the commercial space is all along the main road, where the flyover and underpass are present. Due to the following agglomeration of the commercial spaces the main road receives heavy traffic flow. From the map it is observed that the volume of commercial spaces is 30%- 40 % lengthways the roads. Secondly, the agglomeration of the public spaces are towards the shilparammam area. This area is mostly exhibition, garden and gathering of public spaces. The public spaces volume is about 40% in the entire Madhapur area. Further, the small pockets are filled with housing spaces and green area with less than 5% of institutional spaces.

Additionally, as part of the observation the area was bustling with commercial spaces on the either sides of the road. There were several new development which were in progress. This clearly defines that that agglomeration happening around the main road is leading to severe congestion. Lastly as also mentioned by the respondents, development in this case is leading to exhaustion of the existing infrastructure and is demanding an expansion.

4.3.1.1.2. Infrastructure provision

The infrastructure provision are mainly involved of the initiatives taken by the municipalities to ease the traffic. One of the important provision of the infrastructure as said by the GHMC Deputy Engineer is the construction of the metro rail which has been taken up by the State government. One lane has already started and is successfully running from east corner to west corner. The other routes, in which Madhapur is involved will be completed in the end of 2018. As per the current requirement of the Madhapur area, provisions made are mainly involving of expansion of roads, construction of bridges and underpass. The details of the infrastructure is presented in table 11 which was obtained from the interviews. Further, table 12 compliments the data of the road widening and maintenance done by the municipalities.

As observed from the table the hitech city junction flyover, Gachibowli flyovers, kukatpally flyover and bio-diversity Park are the four flyovers which cross over a junction reaching to the next one with the lengths of 705 meters, 950 meters, 910 meters and 1200 meters respectively. Whereas the other flyovers and underpass are connecting from one junction to another in order to move the traffic in the same lane quickly of lengths ranging from 300-350 meters. Further, the GHMC Deputy Engineer added a point that on November 2017, all roads have been incorporated with 316 Million rupees in Madhapur for maintenance and widening. Further added by him, that for now there is no maintenance and upgradation of the roads as they are waiting for the metro construction in the specific area. But according to the reports and observations the two underpass has been constructed in the year 2017-2018. One caters to the traffic from IKEA at Mindscape Junction and other one at the Ayyappa society.

The two underpass at Ayyappa society and Mindscape Junction are of 15 meters, but the underpass at Ayyappa society is 2 lane with one way traffic and Raheja Mindspace underpass is of 4 lanes with to and fro traffic. As mentioned by the traffic constable at the junction of Ayyappa society, the junction did not receive any change after the construction of the underpass. The traffic flow remains unchanged and the junction still receives traffic congestion. Where at the Mindscape junction, the underpass was built to divert the traffic and make it a flow for the traffic moving to IKEA store. The underpass lets the traffic pass straight when they do not want to visit the store. But if the traffic intends to take a ‘right’ or ‘left’ it requires to travel straight and perform ‘U’ turn in order to take ‘right’ or ‘left’ turns.

The following table explains the supply-side measures provided by the GHMC, HMDA, and TSIIC.

Sl.no	Name of the flyover and Underpass	Connectivity	Length of the flyover	The width of the Flyover Project cost	Lanes + missing detailing Compared with the standards from (Central Road research institute-CSIR, December, 2017)
1.	Hitech City Junction	Kukatpally to IT park and Madhapur	705meter	15 meters (4 Lanes)	7.5 m +7.5 m The absence of 0.25m curb
2.	Gachibowli Flyover	Gachibowli	950meter	15meters (4 lanes)	7.5 m +7.5 m Absence of 0.25m curb
3.	Kukatpally flyover	Hitech city to Kukatpally	910meter	15meter (4 Lanes)	7.5 m +7.5 m The absence of 0.25m curb
4.	Jubliee Hills road no- 45	Road no. 45 stretch	Under construction	15meters (4 Lanes)	7.5 m +7.5 m Absence of 0.25m curb
5.	Jubilee Hills Check post	Check post	Under construction	15 Meters (4 Lanes)	7.5 m +7.5 m Absence of 0.25m curb
6.	Bio-Diversity Park	Bio-diversity park to Gachibowli	1200 km	45 meters (6 Lane) 1.2 meter of green space	Extra Width
8.	Underpass Ayyappa Society	Ayyappa society	300 meters	15 meters (2 lanes)	Extra Width (One-way Traffic flow)
9.	Raheja Mind space Underpass	Mind space junction	350 meters	15 meters (4 lanes)	7.5 m +7.5 m The absence of 0.25m curb

Table 11: Infrastructure provision by the Municipality (Source: Interview + google maps)

The following secondary data is obtained from GHMC office. It states the road widening details taken place in Madhapur area along with the details of its maintenance. As per the records, the roads were mostly widen and strength up-to 9m in order to accommodate the traffic. As observed the road widening took place in most of area where the flyover or the underpass ran perpendicularly. For example, the Silparammam road is a perpendicular road to Hitech City Junction flyover. It is observed that the traffic flowing on the flyover has an ease to pass across easily. Additionally, when the traffic performs a 'right' turn towards silparammam it has wider carriageway, but during the 'left' turn there is no provision of wider carriageway or flyover making the traffic block the area.

In Cyberabad Development Area (CDA):	
1	**Silparamman Road**: Strengthening & Widening of Road Reach I & II from Indira Gandhi statue to Kavuri Hills Road (9.00 Meters wide Carriageway).
2	Development of loop road for **traffic diversion during construction of Hitech City Flyover**, reach-III (from Kavuri Hills road to Madhapur road via Krithika layout).

3	Development of Link Road for traffic diversion during construction of Grade Separators at Hitech City Junction from Madhapur to IT park via Patrika Nagar.
4	**Widening of Existing Spinal Road Reach-I from JNTU Junction to Rain Tree Park Length**: 1.40 Km.
5	**Strengthening & Widening of Road** from Botanical Garden to Old Bombay Road Total Length 3.7 Km Forest Length 1.10 Km Village 0.40 Km.
6	The road from 8th Batallion Road (Kondapur Main Road) to NAC Road Via Hanuman Nagar and Izzat Nagar (Length 1.10 km).
7	**Widening of Existing Road** from Judges Colony to Old Bombay Road: The road is widened to 24 Meters from 7.5 Meter.
8	**Strengthening of Existing Road** from State Art Gallery to Madhapur Police Station through Kavuri hills: The existing road is strengthened.
9	The road from Kavuri hills road Junction to Shilparamam Reach-I was taken up. It is a 2 Lane carriageway with a width of 9 Meter width and a length of 1.75 km (Length 1.75 km with 2 carriageway of each 9.0 Meter).
10	**Development of Road over Bund** in Front of Convention Centre at Hitex: The road on the existing bund of the lake in front of ICC with a **pedestrian pathway** are completed.
11	**Link road connecting Madhapur Main road**: A road 18 M wide and 360 Meter long connecting Madhapur road at COD to the road on the western side of Durgam Cheruvu. About 300 M has been completed. The work in the stretch of 60 Meter has been held up due to the courts status quo on land acquisition.

Table 12: Road widening and maintenance (Source: (Greater Hyderabad Municipal Corporation, 2018))

The following road works were done in period of 5-6 years. As mentioned above, most of the work done was of widening of roads and its maintenance. The road development over the bund in front of a heavy congested location which is the convention centre of the Madhapur area named HITEX (NAC), pedestrian pathways were constructed. Apart from this, the footpath are only provided at regular intervals. The GHMC and HMDA mostly widen the road at the junctions.

Conclusion: A major factor observed from the findings was the existing land-use pattern showing the concentration of commercial area in the corridors spreading from Bio-Diversity junction to Kukatpally junction. As observed from the map of the land-use pattern above it clearly understood that due to the concentration of commercial and IT hubs, people movement is high due to the activity pattern. As defined in OECD and ECMT (2007), "when all the purpose flow on the network surpasses the dynamic volume of specific network links, bottleneck arises and is propagated upstream." As mentioned by the traffic commissioner of Cyberabad, the timing at which people move in their vehicles are the same or at a similar timing. Creating bottlenecks at every junction.

Due to the inadequacy in the planning of land-use and the provision of infrastructure by the service provider- GHMC and HMDA, it leads to temporal based delay and spatial congestion of the traffic. As per the data collected from the interviews the responses, it primarily focuses on the presence of IT and commercial sector presence.

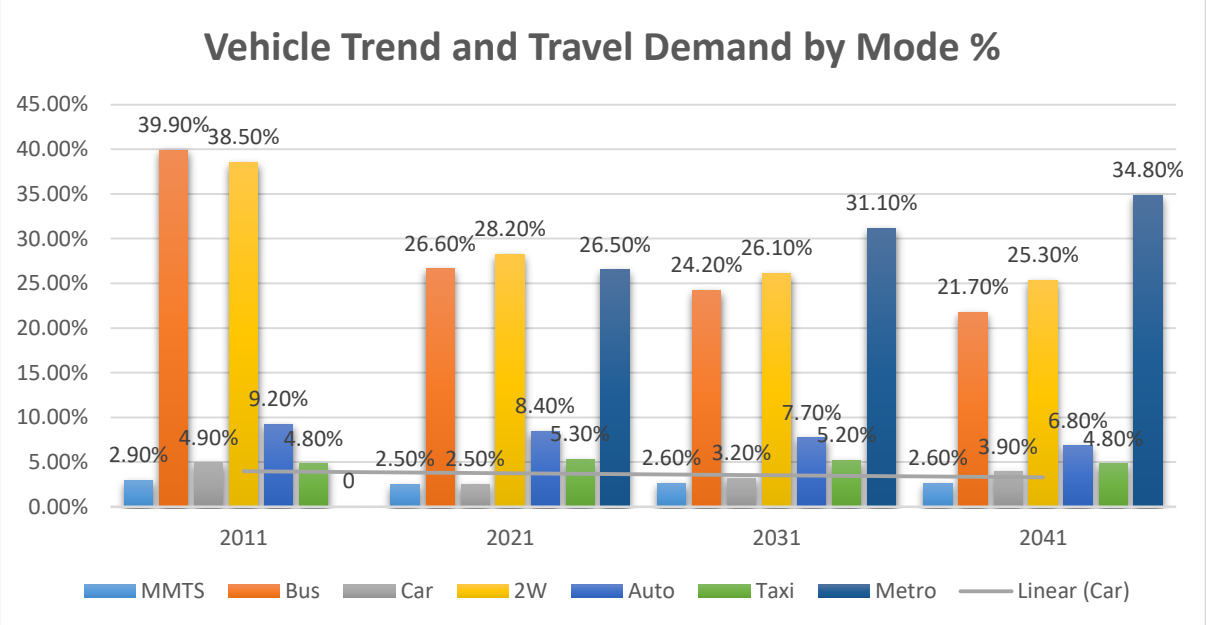
The following obtained data from the research finding compared to the standards from the literature is different and considered inappropriate. As the required standards do not match the existing provision of the infrastructure. As observed from the above table the curb or 0.25meter is missing which leads to non-segregation of traffic on the road, leading the vehicles to move on the sidewalks or on the other side of the lanes. The provision of new infrastructure are causing chaos at multiple junctions, firstly, building of flyovers at regular intervals to clear the present traffic without catering to the future. Secondly, the unplanned land-use patterns.

4.3.1.2. Traffic Management: Independent variable II

Introduction: Travel Demand Management is the a strategy in which unnecessary private vehicles use is discouraged and healthy and environmental mode of transport is promoted more to achieve the aim to capitalize on the productivity of urban transport infrastructure (OECD and ECMT, 2007). As defined in the literature the greatest cause of peak-hour congestion is the wish of the commuters to ride alone in their vehicles. The following section explains the vehicle trends and travel demand by mode and the information provided by the traffic managers to the public and further ends with the public transport movement or prioritisation on the road.

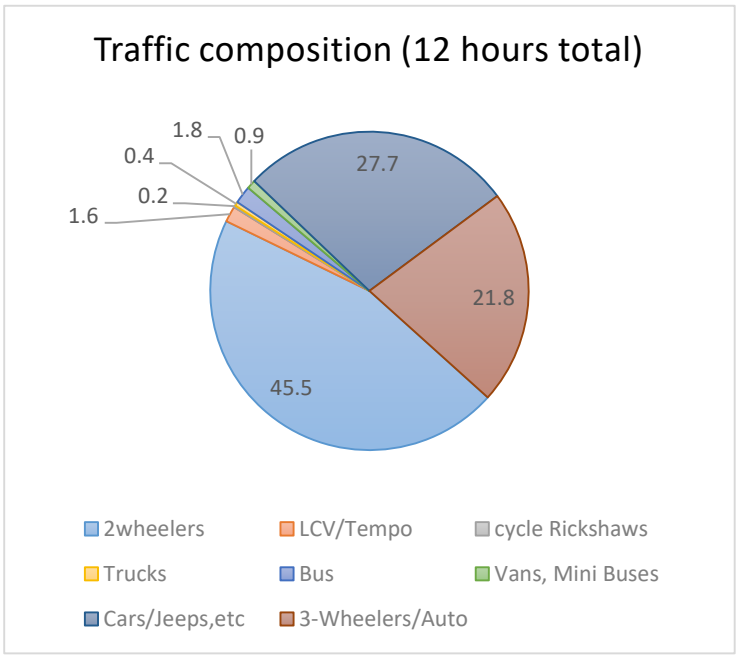
4.3.1.2.1. Vehicle trend and travel demand by mode

The vehicle trend is an observed phenomenon which is obtained from the data studied over a time. Hence in the following study the data is adopted from the reports and manual, further being supported by the interviews of the police constables. In the case of Hyderabad, the vehicle ownership trends obtained from the comprehensive report (2015). The typical vehicle types used in Hyderabad, especially in the area of Madhapur are (LEA Associates south Asia Pvt. Ltd., 2015) 4 Wheelers (Cars, vans), 2 Wheelers (Motor bikes), Buses, Intermediate public transport (3Wheelers-Auto), LCV/ Tempo. The resulting graph shows the vehicle trends and the travel demand by mode in Hyderabad (4 wheeler and 2 wheeler). It is perceived that the ratio of usage of private vehicle amounts to 43% whereas the usage of public transport is 42.8%, rest being intermediate transport system in the year 2011. The vehicle trend is assumed a slight drop is assumed in the year 2021 after the construction of the Metro rail. The graphs hold true in the overall case of the city, but as seen in the table 13 the vehicle ownership trends/ usage of the vehicle in Madhapur is different compared to the entire city.

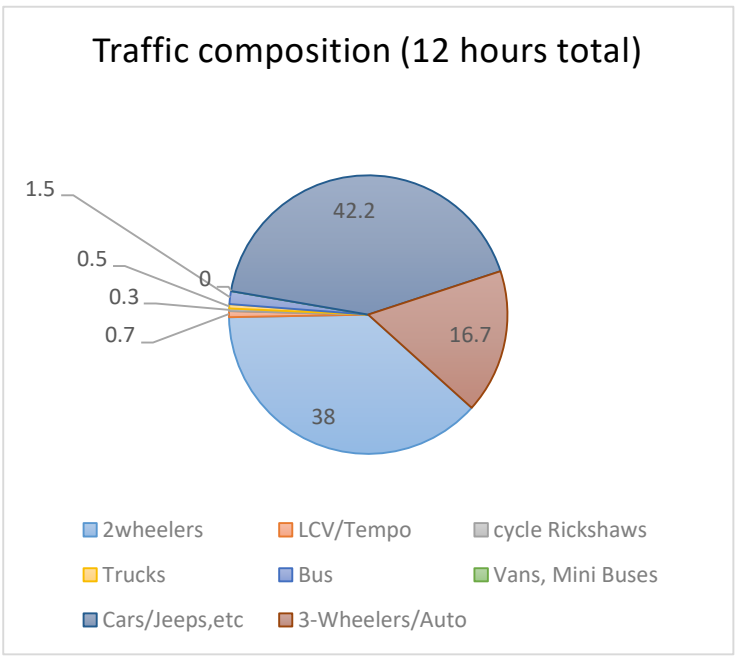


Year	MMTS	Bus	Car	2W	Auto IPT (3Wheeler)	Taxi	Metro	Person trips (Millions/day)
2011	2.9%	39.9%	4.9%	38.5%	9.2%	4.8%	-	8.9
2021	2.5%	26.6%	2.5%	28.2%	8.4%	5.3%	26.5%	12.1
2031	2.6%	24.2%	3.2%	26.1%	7.7%	5.2%	31.1%	16.5
2041	2.6%	21.7%	3.9%	25.3%	6.8%	4.8%	34.8%	22.5

Table 13: The vehicle ownership trends in Hyderabad during the year 2011 and projections of 2021, 2013 and 2041. (LEA Associates south Asia Pvt. Ltd., 2015)



Traffic composition at Cyber tower Junction



Traffic composition at Mindscape junction

Figure 13: Traffic composition in Cyber Tower junction and Mindscape Junction 2011. (LEA Associates south Asia Pvt. Ltd., 2015)

The above graphs presents the data from Cyber tower junction and Mindscape junction. As recorded from the traffic constable at the junction of Cyber Tower,

"This junction receives the highest traffic jam compared to rest of the junctions at the Cyberabad area"

[Respondents- Traffic Police constable at Cyber Tower]

The following statement is considered due to the location of the junction which connects Madhapur to different area. Hence it acts like a traffic accumulator point.

It holds the central traffic control room of Madhapur and has 4 constables from morning 8 am to an evening at 12 pm. The data was acquired from the feasibility report (LEA Associates south Asia Pvt. Ltd., 2013) which states the data of the traffic composition at two junction. These junctions are crucially picked due to its position and connectivity to other junctions. The traffic composition of the other junction have not been recorded. In the following data as the Cyberabad Junction is located at the main area as described by the Traffic constable, is assumed to carry the following traffic forward to other junctions.

The above graph, it is witnessed that the usage of private vehicles in higher which is 45.5% 2 Wheeler (Motorbike) and 27.7% 4 Wheeler (Cars). The usage of the public transport is minimal making it 1.8% in Cyber tower junction in 2011. The Mind-space junction is an interesting junction due to the construction of the IKEA store in Hyderabad. It is the first ever store in India at the junction of Mindspace. A study done on traffic management and signage plan for IKEA Hyderabad (Sharad Mohindru Associates, 2017) justifies the location of construction of IKEA as the location is central and links to all important inter-city and intra-city network. The junctions are occupied with private vehicles of 4 wheeler and 2 wheeler. The GHMC Engineer emphasis on the high usage of private vehicles,

"1 car one 1 person, if you see in the Madhapur area one car is driven by one."

[**Respondent**- GHMC Engineer South Wing-Srilingampally]

As recorded from the respondents it was witnessed that one of the major issues of congestion in Madhapur area is a high usage of private vehicles. The statement by the GHMC Engineer specifies that

the 45.5% of car user are mostly used by a single person. This implies that the single person usage of car increases the percentage of private vehicle usage and causes unexpected traffic increase in the area.

4.3.1.2.2. Level of Information on traffic

The Municipalities are responsible for the infrastructure provision and the Traffic Police are responsible of the traffic control and maintaining law and order. The commissioner of the Cyberabad Traffic police defined his level of authority in the traffic control up to the maintenance of law and order and implanting challans and planning for route diversion.

Furthermore, as defined in the literature the current major issue causing congestion is the ignorance of the prevailing traffic condition. The level of provision of information on traffic in Madhapur is an interesting factor. As recorded from the interviews, the respondents witnessing the traffic (traffic constables) at the major junctions, said that the information is being passed to the Cyberabad Police department after which it is further circulated via local radios, WhatsApp messages and newspapers.

Further, they added if the congestion increases unexpectedly then they immediately inform their seniors who arrive at the junction and propose diversions for the vehicles to choose an alternative route. When complimented with the Commissioner of Cyberabad Traffic Police, he stated that the decision of traffic alteration is taken by the senior officials and if the condition is deteriorating then all the stakeholders are informed of the condition and the decisions and advisory is done. The stakeholder's involvement is a key issue and they comprise of IT companies officials, GHMC Engineers, Commissioner of traffic police Cyberabad and assistant commissioner of traffic police Cyberabad. Further, the decision is being published in the local newspaper for the general public awareness. As a statistic from the study conducted in the University of Texas explaining, the fact of well-informed regarding the traffic conditions can possibly reduce the congestion (IMT, 2000).

4.3.1.2.3. Level of Public transport Prioritization

The public lane prioritization is giving special lane provision to the public transport for rapid, movement. In Hyderabad the public transport mainly comprises of the public buses and Vans. As observed in Madhapur, there was no lane priority given to the public transport. The buses move in the lane 1, which is for the high speed moving traffic. The buses pick this lane to move smoothly, but unaware of blocking the fast moving traffic. This is majorly due to lack of the policy or provision of lane priorities.

As mentioned by the Commissioner of traffic police of Cyberabad, there are 40+ bus stops in Madhapur. The public buses do not have priority lanes for faster movement. They travel on any lane according to convenience. Further, added by the Commissioner, the buses are free to move around and there is no intention of prioritization of lanes for the public transport for faster movement. Lastly, the City Planner of Hyderabad Metropolitan Development Authority (HMDA) said Madhapur was part of suburban area of Hyderabad until 90s. After the development of the MNCs, it grew its popularity. The roads were still trying to cope up. Under these circumstances the periodization required huge economy of road expansion all over. Hence, there is not Bus rapid transport provision.

4.3.1.3. Level of service: Independent variable III

The level of service of road is acquired to understand the provision of the infrastructure. The level of service is gained by the understanding the capacity of the infrastructure provided and the usage of the space. As from the Standards obtained from the Indo Capacity Manual stated in the literature explaining the factors and ranges of LOS to specify the flow of traffic and indicates the capacity of the corridors. Engineer of GHMC from the south wing, states that the infrastructure which is already constructed are the two underpass and they propose to construct further at other major junctions. According to him the proposed infrastructure will solve the traffic problems in the city. By this statement it was understood

that the Engineers are concerned for only new construction without understanding the scenario of the region. Further by analysing the reports of volume and capacity it was understood that the volume is increasing the capacity is falling short to accommodate. Due to which the Engineers are only focussing on the extending the specific zone of congestion. Furthermore, added by the City Planner who looked at the entire problem holistically said that there are few scopes of road expansions in Madhapur area as it is reaching its saturation with all the commercial businesses on either side of the main road.

The secondary data obtained from the preliminary study of the Hyderabad specifies the volume and capacity of the corridors. The capacity refers to the quantitative measures of road section further representing the LOS as the qualitative measures of the road sections. The objective of LOS is to relate the given flow rate of traffic to traffic service quality. The following ratio of volume and capacity ratio was obtained from the Preliminary report (LEA Associates south Asia Pvt. Ltd., 2013).

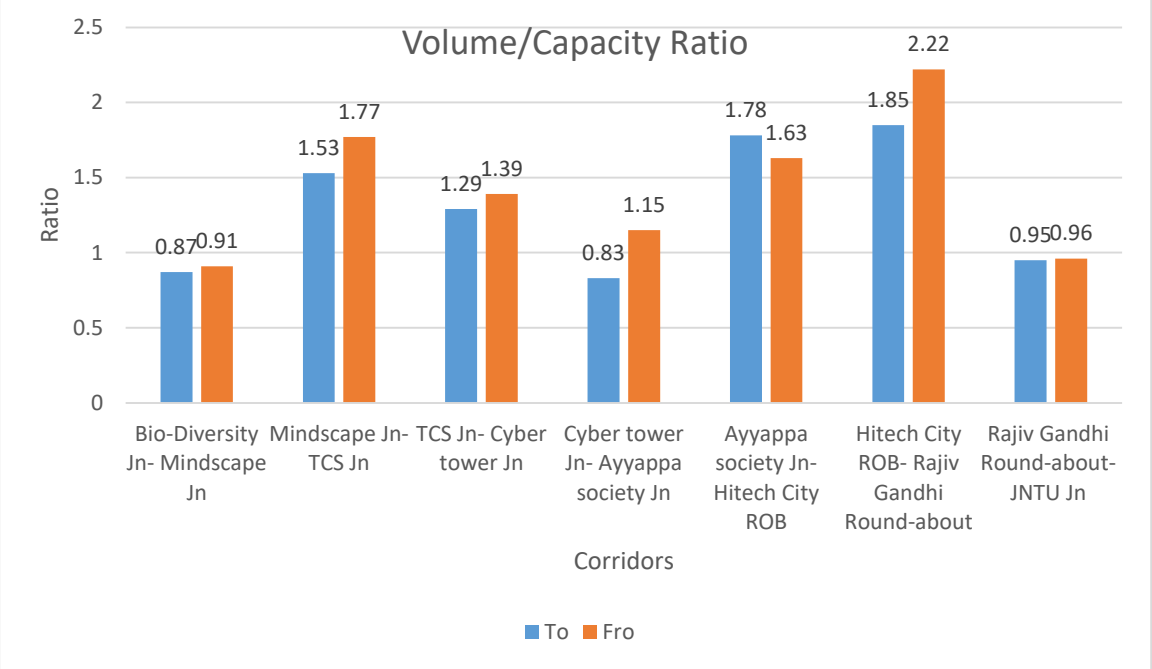


Table 14: Volume/ Capacity Indicator

From the following table explains the ratio measure, which indicates the capacity of the road and the volume of the user. The volume/ Capacity ratio was high in the Hitech city ROB- Rajiv Gandhi Round implicating the traffic flow condition approaching a point of exceeding the capacity of the road. Due to which break-downs occurs and leads to long formation of queues and delays. A similar case is observed at Cyber tower Jn. - Ayyappa society Jn and Mindspace Jn. –TCS Jn. When asked regarding the volume of the traffic, the GHMC Engineer, clearly said that the road is a 4 lane (two way) and is always packed.

It is highly significant to recognize the level of service of the infrastructure provided by the service provider- GHMC and HMDA, in order to understand the reasons of road traffic congestion. The Indo-Capacity Manual (Central Road research institute-CSIR, December, 2017) defines standards of the road infrastructure. As from the literature study and the values obtained from the Preliminary project report (LEA Associates south Asia Pvt. Ltd., 2015), the following table explains the V/C ratio and Level of service of the corridors. The following data is obtained from secondary sources due to the limited time frame to collect the data in the field visit.

Sl. No	Corridor Name	V/C ratio	Level of Service
1	Biodiversity park- Mindspace Jn	0.87	E
	Mindspace Jn.- Biodiversity park	0.91	E
2	Mindspace Jn.- TCS Jn.	1.53	F
	TCS Jn.- Mindscape Jn.	1.77	F
3	TCS Jn.-Cyber tower Jn.	1.29	F
	Cyber tower Jn.- TCS Jn.	1.39	F
4	Cyber tower Jn. – Ayyappa society Jn.	0.83	E
	Ayyappa society Jn. – Cyber tower Jn.	1.15	F
5	Ayyappa society Jn. –Hitech city	1.78	F
	Hitech city- Ayyappa society Jn.	1.63	F
6	Hitech city- Rajiv Gandhi roundabout	1.85	F
	Rajiv Gandhi roundabout – Hitech city	2.22	F
7	Rajeev Gandhi roundabout to JNTU Jn.	0.98	E
	JNTU Jn. – Rajeev Gandhi	0.99	E

Table 15: Presents the Volume/ Capacity ratio of Traffic volume on road along Bio-Diversity park- JNTU corridor with the level of service

LOS E- Traffic Volume=Capacity

LOS F- Traffic Volume > Capacity

Mostly the corridors have an existing lane configuration of 6(3+3) lane in both directions except the stretch on Hitech city ROB is 4(2+2) configuration whose width is 3.5m/lanes. Most of the corridor has footpath at a regular interval along its length and all the arterial and sub-arterial roads at these 7 junctions are having mostly 4 and 6 lane arms. **The land use pattern around this corridor was in the form of commercial, shopping malls, restaurants, hotels, automobile showrooms, banks etc., residential, Industrial with software companies. This corridor is very well populated and having lighting facilities, utilities, and trees.**

Most of the public transport in this corridor is maintained by Government RTC and also private transport like cabs and auto rickshaws (3Wheelers IPT) is running in a substantial manner. **The traffic is heavy with personal, commercial, business and work based trips** on all the approaches on this corridor. Since these junctions of the corridor help people moving to software companies located at Madhapur, Hitech city and Kondapur they are experiencing rapid growth of traffic intensity in the past few years resulting in severe traffic congestion and delays in traffic. **At Present these junctions are operating with traffic signals. The existing corridors and junctions are insufficient to meet the current Demand of the traffic. As their volume/ capacity ratio is higher, the Level of Service for all the corridors is ranging from level E-F.**

Where **LOS E states**, "Represents operating conditions when traffic volumes are at or close to the capacity level. The speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult and is generally accomplished by forcing a vehicle to give way to accommodate such manoeuver. Level of comfort and convenience is extremely poor, and

the driver's frustration is generally high. Operations at this level are usually unstable. Small increases in flow or minor disturbances within the traffic stream will cause breakdowns."

LOS F states, "Represents zone of forced or breakdown flow. This condition occurs when the amount of traffic approaching a point exceeds the amount which can pass it. Queues form behind such locations. Operations within the queue are characterized by stop and go waves, which are extremely unstable. Vehicles may progress at a reasonable speed for several hundred meters and may then be required to stop in a cyclic fashion. Due to high volumes, break-down occurs, and long queues and delays result." Please insert quotes from respondents under level of service as independent variable III. Also explain how the tables as a secondary data, support in triangulating the primary data where ever applicable throughout the thesis also for other variable below.

4.3.2. Road user: Control variable

The Road user, is having an unfavourable effect on the traffic congestion. It is an unavoidable effect such as leading to the non-recurrent traffic situations and trip generations. As said by the City Planner of HMDA, the area of Madhapur in the tenure by the end of the financial year 2003-2004 the software exports from Hyderabad reached 1 billion dollar and it became the fourth largest exporting city in the country. This states that the Hyderabad will be receiving more employees from other states for working in this IT and ITES fields in Hyderabad. Thus, increasing the population and density in the Madhapur area. Both the Engineers of the South Zone and Deputy Engineer Hyderabad mentioned that area is very important in terms of its location as it is the major IT hub in the city.

In the following section two major indicators are discussed- trip generation and driving habits of people.

Trip generation: An element of urban movement involves the factors such as trip generation, modal split, and trip assignment. The following elements from the literature explain that the trip is generated due to work purpose, access to goods or services or leisure (Bull, 2003). In case of Hyderabad, Madhapur area being the IT hub of the city most of the trips are made due to work purpose. As said by the Commissioner of Traffic Police (Cyberabad),

> "Every day we are expecting around 10-12 Lakhs[1] supportive services and IT employees visiting these areas. So it most quickly populated area means of transportation from other areas connecting this place."

From the literature above, the macro and micro factors leading to congestions travel demand patterns affected by the travel behavior- in the case of Madhapur most of the visits are work-related and the travel behavior such as the time/schedule, route and mode choice (OECD and ECMT, 2007, p.63). As recorded from the interview of the GHMC Deputy Engineer mentioning about the movement of the job-holder round the clock, making the area a continuous movement of traffic. Further, the interviewed respondents- the traffic police at the junction also discussed their perceptions of the purpose and traveling schedule, mostly stating visits as the work visit due to the IT hubs. The respondents at each junction mentioned peak timing around 9am-12noon and 7pm-11pm.

The congestion drives in the case of Madhapur is clearly seen as the location of the IT hubs, where the movement of the traffic is at 24 hours schedule leading to continuous traffic movement. The activity pattern is realted to the land-use pattern provided by the Municipality. As seen in the literature from OECD, the congestion is triggered by the micro and macro factors, which is travel demand patterns, travel behaviour and activity pattern. Similarly, in the case of Madhapur the driving macro forces is the location, and micro factor is high usage of private vehicles with low occupancy.

[1] 1 Lakh people = 0,1 Million people

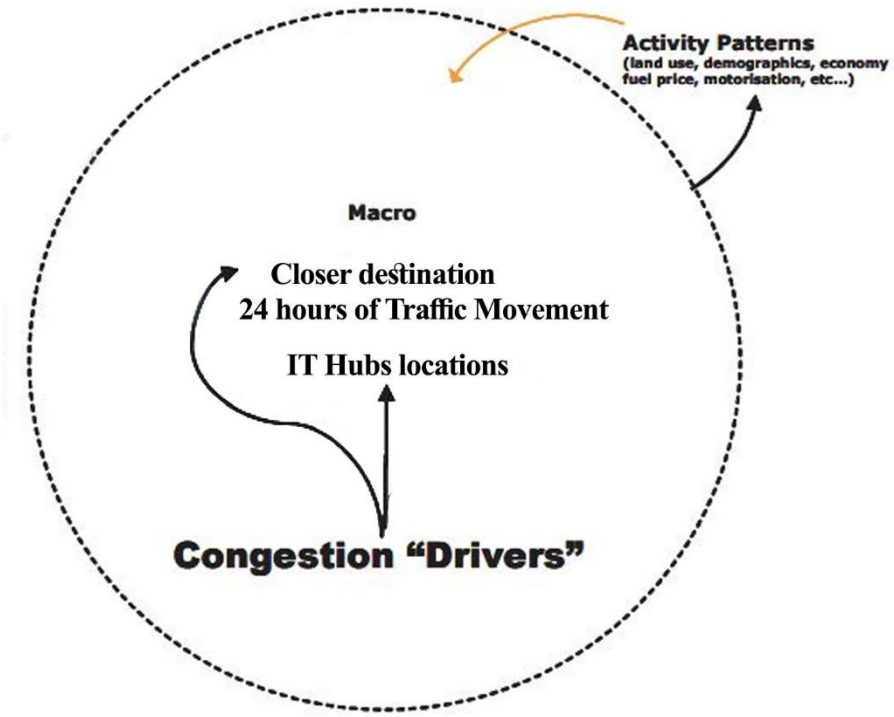


Figure 14: Macro factors affecting congestion in Madhapur area (source: Author)

(Redeveloped from Macro factors affecting congestion *(Source: (OECD and ECMT, 2007, p.63)*)

Road safety

Many developing countries has experienced a rapid growth in the vehicles in the recent years. The dissimilar modes presences travel results in unsafe roads (Khanal and Sarkar, 2016). As mentioned the state of road and driving habits contribute to congestion which is related to driving habits causing and ultimately leading to congestion in the city (OECD and ECMT, 2007). The respondeds at the junctions stated that the level of safety is minimal, and the report given by the Commissioner of the Traffic Police Cyberabad states the following-

Sl.no	Traffic Police station	Name of the Police Station	Total accident	Fatal	Non-Fatal	Deaths	Injured
1	Madhapur	Madhapur	98	20	78	20	74
2		Raidurgam	79	18	61	18	54
		Total	177	38	139	38	128
3	Gachibowli	Gachibowli	92	16	76	17	80
4		Narsingi	153	60	93	63	130
2016		Total	245	76	169	80	210

Fatality rate 2016: (source: Cyberabad Traffic Police Department)

Sl.no	Traffic Police station	Name of the Police Station	Total accident	Fatal	Non-Fatal	Deaths	Injured
1	Madhapur	Madhapur	165	18	147	19	136
2		Raidurgam	191	19	172	19	91
		Total	356	37	319	38	227
3	Gachibowli	Gachibowli	130	16	114	16	104
4		Narsingi	195	54	141	62	130
2017		Total	681	107	574	116	461

Fatality rate 2017: (source: Cyberabad Traffic Police Department)

Sl.no	Traffic Police station	Name of the Police Station	Total accident	Fatal	Non-Fatal	Deaths	Injured
1	Madhapur	Madhapur	62	4	58	4	52
2		Raidurgam	80	5	75	5	62
		Total	142	9	133	9	114
3	Gachibowli	Gachibowli	104	10	94	11	61
4		Narsingi	82	13	69	13	83
		Total	186	23	163	24	144

Fatality rate 2018: (source: Cyberabad Traffic Police Department)

Table 16: Fatality rate in Madhapur and Gachibowli in the year 2016- 2018

The Commissioner of the Cyberabad Traffic Police in his interview showed concern for the pedestrian safety and said that it is a major issues. It requires infrastructure and provision for the pedestrian. Further he adds, 'J' Walking is seen everywhere and based on the facts of the above table 1/3rd of the road accidents are pedestrian deaths. Even as understood from the above table 33 percent of the accidents are fatal.

From the above table it is perceived that the Non-fatal accidents are more common than the fatal accidents. The highest number of fatal deaths has been witnessed in Gachibowli area. This area has high speed moving traffic at off peak hours, due to this the road becomes unsafe for the pedestrians and two-wheelers. The number of deaths in 2017 was116 and the non-fatal ones were 574. The following accidents and deaths are causes of lack of pedestrian infrastructure and footpaths. It leads to formation of non-recurrent jams which lasts for very long making the traffic stagnant for hours.

Footpath and parking provision: The effect on traffic was seen due to lack of parking spaces and pedestrian footpaths. In the corridor the parking requirements are mainly met with the supply provided by the individual building at the corridor. However at the same location, two-wheelers and car/jeeps are observed to park on street as observed during the site visit. The Engineer of the south wing mentions- Firstly, the forms of transport which have the most required features- security, comfort, reliability, and self-sufficiency which is lacking and secondly the parking spaces are a problem resulting very small intensity of the range making the entire system paralyze.

From the observations, footpaths are provided at intervals not at a continuous stretch making the pedestrian unsafe to walk. There is no encroachment seen so far. Crossing at the junctions is not signalized, people follow the vehicle traffic signals and cross the road at their own risk. As also mentioned above the pedestrian safety is at risk.

Figure 15: Parking on the streets and lack of footpath provision

4.3.3. Traffic congestion: Dependent Variable

Traffic congestion is considered when, "the average speed of the traffic flow is less than 40% of the speed in unrestricted conditions" (Bull, 2003). One consequence of congestion is the representation of the extreme or excessive use of infrastructure or a facility. In the case of Madhapur area, the data collected primarily from the interviews, observations and complimented by secondary data. The resulting sections defines the findings of the following indicators temporal delay, spatial congestion and accessibility between two consecutive junctions.

4.3.3.1 Temporal Delay

The interview responses primarily focused on the fact that the congestion caused in the area of Madhapur is due to the presence of IT sector, from above literature the demand for transport is highly adjustable and has most of vehicles travelling during the most desired time and causing peak hour traffic (Bull, 2003). In Madhapur as said by the respondents, in terms of location it the main hub for Multinational companies and important location for economic growth. As said by the Deputy Engineer of Srilingampally (Cyberabad) the employee work round the clock and the area receives a continuous movement, in his statement he mentions-

> *"*Due to IT hub location many job-holders are moving around the clock, […..]
> Traffic is there all the way coming going- coming going."
> [**Respondent**- Deputy Engineer]

From the above land-use pattern map (Figure 9), it is shown that the commercial area is concentrated in the corridor spreading from Bio-Diversity Junction till Kukatpally junction. There are 8 junctions connecting following corridor. The following findings were received from the interview of the traffic constable at the junctions. The respondent answered the following through his experience at the junction. As a logged phenomenon, all the traffic police constable at the 8 junctions mentioned its peak hour as 9am-12noon and 5pm-9pm during weekdays. As recorded the following indicators through enquiring from the traffic police whose has been in the duty for a few months respectively. Each of the indicators has been measured at the 8 different junctions in order to understand the congestion levels.

1. The average commute travel time (CoE urban transport and CEPT University, 2013, Aftabuzzaman, 2007). It represents the average of the commute time between 2 consecutive junctions.

The delay in the commuting causes a huge hassle. The City Planner specifies that during the peak hours, the main road connecting Madhapur from different parts of the city ae very congested and makes the trips delayed by almost 1-2 hours. The major issue of traffic has worsen since the metro rail project has come up which has made the traffic conditions even worst.

Further as observed from the graph below obtained from the interviews conducted of the constable recording the average commute travel time between 2 consecutive junctions are different by 1-4 minutes. It is observed that to go from bio-diversity park junction to Mindscape it takes 6 minutes and whereas mindscape to bio-diversity takes 2.4 minutes. This is mainly due to the construction of the underpass which makes it easy for the one sided traffic to move quickly compared to the other side. Further, the wide difference is seen in Mind space junction to TCS- the different of 'to' and 'fro' is 1.9 minutes. Lastly, the different is seen between Cyber tower junction to ayyappa society. In all the cases it's a similar scenario of construction of underpass. The presence of underpass at Mindscape junction and Ayyappa society as mentioned above has created slow moving traffic on one side.

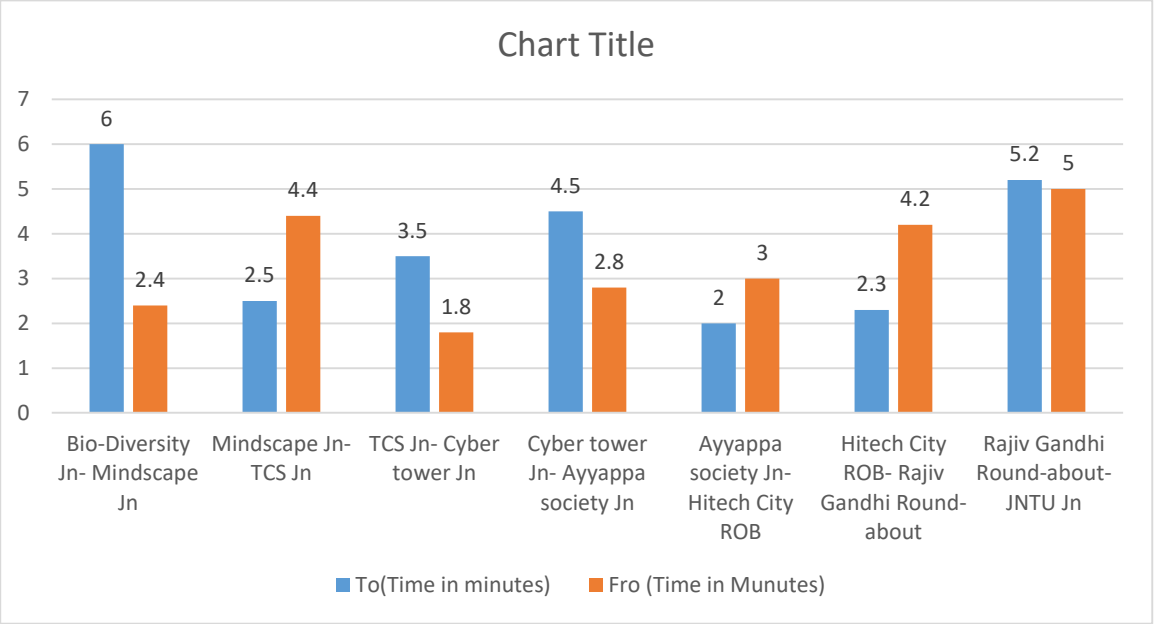


Table 17: Explaining the average commute travel time 'to' and 'fro' the junctions. (Source: Primary Data)

2. Congested time which represents the estimate of congested rush hour conditions.
   The following graph explains the congested time/rush hour of the traffic congestion. The data below explains the time of congestion at the junctions, as recorded from the traffic constable at the junctions the common answers received was 4 hours. At mindscape junction and Ayyappa society the congestion hour lasts for 2 hours due to the non-stop flow from the underpass.

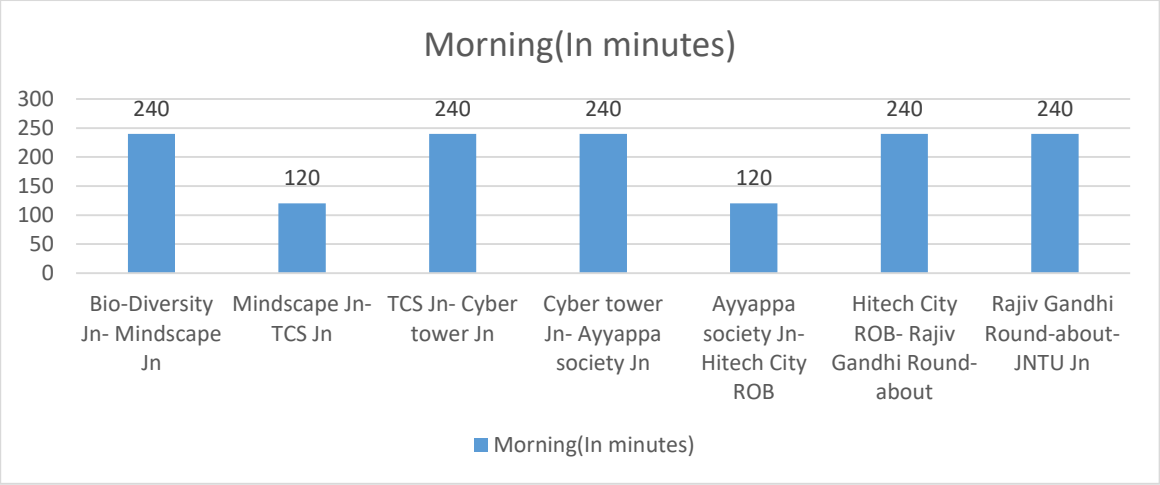


Table 18: congestion time hour. (Source: Primary Data)

The following data obtained from the primary data collection (interviews) provide us with the status of the congestion levels in Madhapur at each junction. With this, we can understand the delay caused and measures which the service provider can take.

As observed in table: 16 average commute travel time and table 17 the congested rush hour, it is understood that to go from bio-diversity park junction to Mindscape it takes 6 minutes and whereas mindscape to bio-diversity takes 2.4 minutes. This is mainly due to the construction of the underpass which makes it easy for the one sided traffic to move quickly compared to the other side. Further, the wide difference is seen in Mind space junction to TCS- the different of 'to' and 'fro' is 1.9 minutes. Lastly, the different is seen between Cyber tower junctions to ayyappa society. In all the cases it's a similar scenario of construction of underpass. The presence of underpass at Mindscape junction and Ayyappa society as mentioned above has created slow moving traffic on one side. Hence, due to the construction of the IKEA store the traffic volume in the entire junction increased from 4135-5515 PCU (from Bio-Diversity Jn- TCS junction) to 14393 PCU, which is an increase in 61% of traffic Passenger Car Unit (PCU). Hence, as the municipality is supplying catering to the current demand by fulfilling the needs then, but ignoring the land-use pattern and future needs.

4.3.3.2. Spatial congestion

As the cities are portrayed as a dynamic interface instrument of movement of people, it is important to provide a space allocating the activities of the movement. Transport supply of building new highways or transit lines responds to the growth in the mobility. From the literature, Hyderabad is a partially motorized network (Type I) and limited strong center (Type III) representing it as a semi-auto dependent city with prominent centers and high-density urban centers with partial-developed public transit systems (Rodrigue, 2017). From the Comprehensive Transport study for Hyderabad Metropolitan Area (HMA) explains the projections of modal shift clarifying the city of Hyderabad partially dependent on the motorized vehicles and partially on the public transits. (LEA Associates south Asia Pvt. Ltd., 2013) The following tables showcases the projection of the usage of private transport vs. the public transport. As of 2011 the private and public transport in overall Hyderabad context shares the same percentages, but as of 2021- 2041 prediction of increase in the private vehicle is witnessed.

Year	Private Transport	Public Transport	Auto (Intermediate public transport)	Total
2011	45.7%	42.5%	11.8%	100%
2021	55.5%	30.7%	13.8%	100%
2031	57.9%	29.3%	12.9%	100%
2041	59.2%	29.2%	11.6%	100%

Table 19: Forecast of Motorised person trips by mode: Daily source: (LEA Associates south Asia Pvt. Ltd., 2013)

Due to high usage of the private vehicles and city being Type I and Type III, the exhaustion of the road is witnessed. From the above literature, "a road is considered to be congested when the average speed of the traffic flow was less than 40% of the speed in unrestricted conditions." (Bull, 2003). The indicator used for measurement of the congestion in terms of Km is the number of lanes/roads which has been congested in the neighborhood. Firstly, from the primary data collected, the respondents clarified the following at respective junctions-

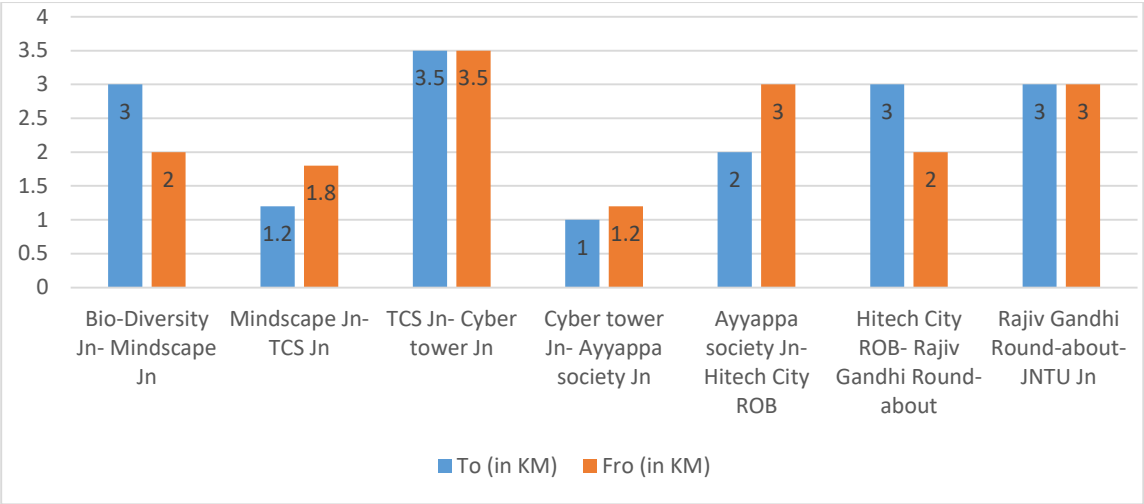


Figure 16: Representing the road traffic congestion in Km at each junction to and fro. (Source: Primary data)

As observed from the above graph, the spatial congestion at the junctions ranges from 1-3.5 km maximum being at the TCS- Cyber tower junction. The cyber tower junction is highly congested as it is the main junction connecting to the other areas. There are 4 constable placed at the junction of the cyber tower to guide the traffic for an easy movement. The traffic is jammed for 3.5km at the junction. The least traffic congested is at Ayyappa society of 1.2 km. whereas the other junctions experience about 2-3 km of congestion.

4.4. Analysis of each junction in relation to the provision of the infrastructure and PCU values: Summary of chapter 4

The following section provides the details of the provision of infrastructure, infrastructure management and level of service (Independent variable) at the junction in relation to the passenger car units which are creating the traffic congestion (Dependent variable).

The network connectivity index was studied to find out the interchanges and number of nodes within the roadway network. Each junction was studied to understand the spatial division at the junction and the corridor. The following section show the junction details obtained from secondary data (LEA Associates south Asia Pvt. Ltd., 2015). At each of the following junction, the traffic volume per hour was studied because it helps the service provider to design the traffic facility to have the capacity to handle the peak hour volume. An important factor expressing the traffic volume is Passenger car Unit (PCU). PCU's traffic volume is obtained by multiplying the PCU factor for each mode with their respective number of vehicles. These factors are recommended by IRC -SP41-1994.

Type of vehicle	2W	3w	Car	Min Bus	Bus	Truck (HV)	LCV	Cycle	others
IRC -SP41-1994	0.5	1	1	1.5	3	3	1.5	0.5	6

Table 20: PCU value of each vehicle. PCU adopted the report IRC -SP41-1994

Passenger Car Unit (PCU) of traffic volume is obtained by multiplying the PCU factor for each mode with their respective number of vehicles. The above values mentioned specifies the PCU at each junction to and fro. The PCU is a metric used to assess traffic flow rate. The following data is useful to understand the vehicles crossing a point on the road, design, and provision along with the extension of the existing road, traffic trend and patterns, and planning for one traffic regulation. The higher the PCU value the higher traffic congestion with the heterogeneous traffic. With the following data, it can be understood where is the provision of infrastructure is a need and lacking.

The section below explains the spatial division of the junctions with the number of vehicles traveling per day. The vehicle count and the PCU value at the peak hour is specified to understand the traffic flow in the junction. The following data is obtained from secondary data collection. (LEA Associates south Asia Pvt. Ltd., 2015) and Google maps. The data explains the connectivity between the junctions and numbers labelled explain the junction's positions. The details of each junction with the relation to traffic congestion at each junction is presented below.

4.4.1. BioDiversity Junction

From the below figure it can be observed that the peak hour traffic entering the Bio Diversity Park intersection is 14,001 PCUs at present in which 36% of traffic comes from 2 lane arm Gachibowli of which 55% go straight towards Mehdipatnam. The other two arms i.e. Mind space and Mehdipatnam arms carry 32% of traffic each direction. The most prevalent mode of traffic at this junction is 2 wheelers with 51.4% for the 16-hour volume followed by 35.2% cars. It can further be observed that the total junction traffic volume in the peak hour for the base year 2015 is more than the 10,000 PCUs. As per the IRC-92: 1985.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
				Vehicles	PCU	Vehicles	PCU	
3-Arms	Signalized	170,641	137,864	14,708	11,219	17,508	14,001	14,001

Table 21: Bio-diversity Junction details (LEA Associates south Asia Pvt. Ltd., 2013, Central Road research institute-CSIR, December, 2017)

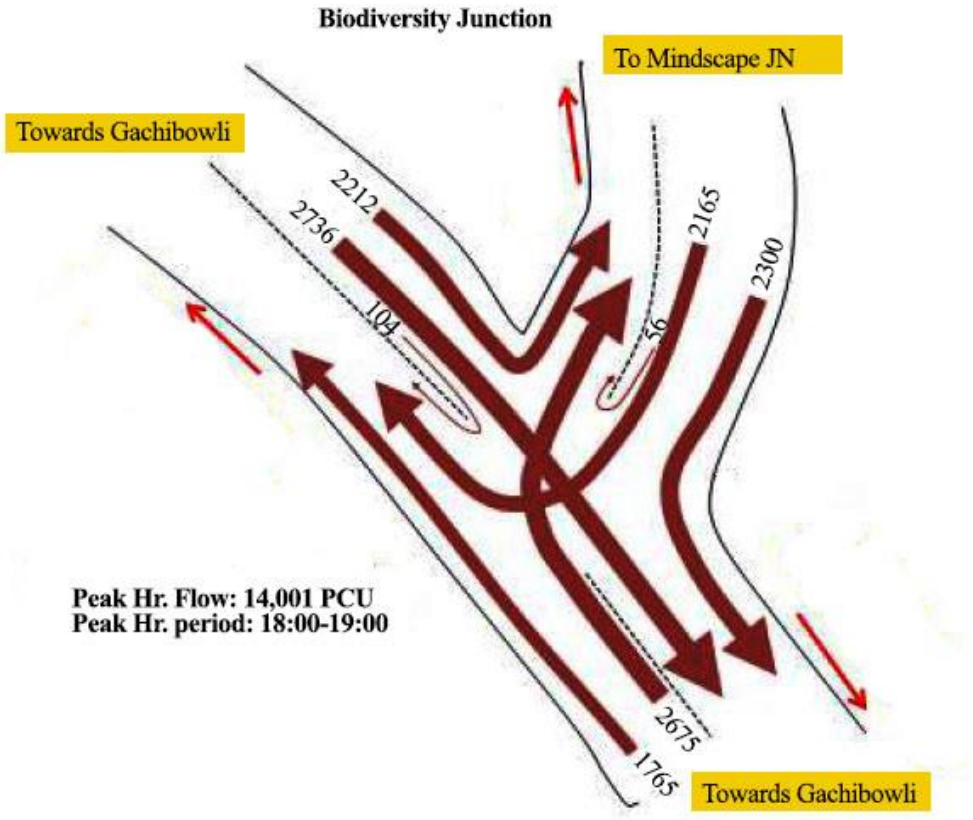


Figure 17: Bio-Diversity Junction Details (LEA Associates south Asia Pvt. Ltd., 2013)

In summary- Bio-Diversity junction has a flyover of 1200meter length of 6 lane with 1.2 meter green space divider. It is connecting the junction of Bio-diversity to Gachibowli transferring the traffic from Mindspace to Gachibowli directly. The junction is dividing the area of Gachibowli and Madhapur and is the entry point to the area of Madhapur. The perpendicular Gachibowli road has witnessed road

widening and strengthening at regular intervals. The 7.5 meter road was widen to 24 meter. As seen from the figure, the traffic PCU entering the junction is 2675 +2212 PCU/Hr and exiting the junction is 2165 +2300 PCU/Hr. According to the standards (Central Road research institute-CSIR, December, 2017), the following PCU/Hr lane capacity is to be carried by six to eight-lanes divided roads. The existing road is of 6 lanes making it insufficient to carry the traffic. The Volume/ Capacity ratio of the Bio-Diversity Jn- Mind-space Jn (to and fro) is 0.87 and 0.91 which falls the under the category of 'E LOS' stating congestion of the road.

4.4.2. Mindscape Junction

From the below figures it can be observed that the peak hour traffic entering the Mindspace Intersection is 14,393 PCUs in which 50% of traffic comes from 3 lanes of the arm from Hitech City of which 86% go straight towards Bio Diversity Park. The other three arms i.e. Bio Diversity Park, Ramky towers arm and Inorbit mall arm carry 33%, 4%, and 13%traffic respectively. The most prevalent mode of traffic at this junction is 2 wheelers with 44.3% for the 16-hour volume followed by 40.6% cars/jeep. It can further be observed that the total junction traffic volume in the peak hour for the base year 2015 is more than the 10,000 PCUs. As per the IRC-92: 1985**.**

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
				Vehicles	PCU	Vehicles	PCU	
4-Arms	Signalized	188,520	154,084	16,270	12,449	18,229	14,393	14,393

Table 22: Mindscape Junction details (LEA Associates south Asia Pvt. Ltd., 2013, Central Road research institute-CSIR, December, 2017)

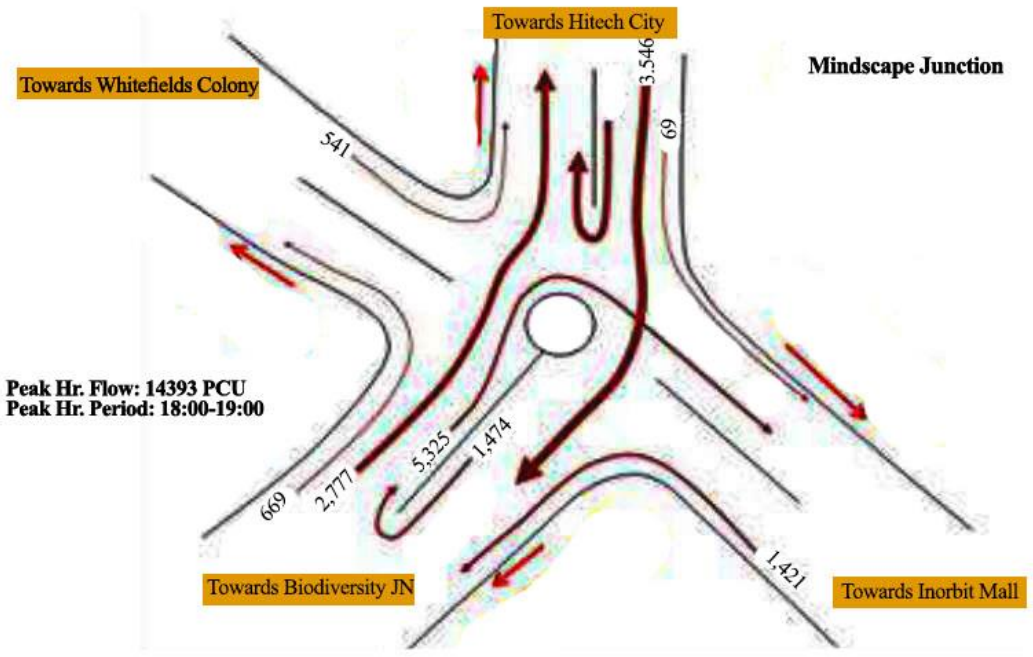


Figure 18: Mindscape Junction Details 2015(LEA Associates south Asia Pvt. Ltd., 2013)

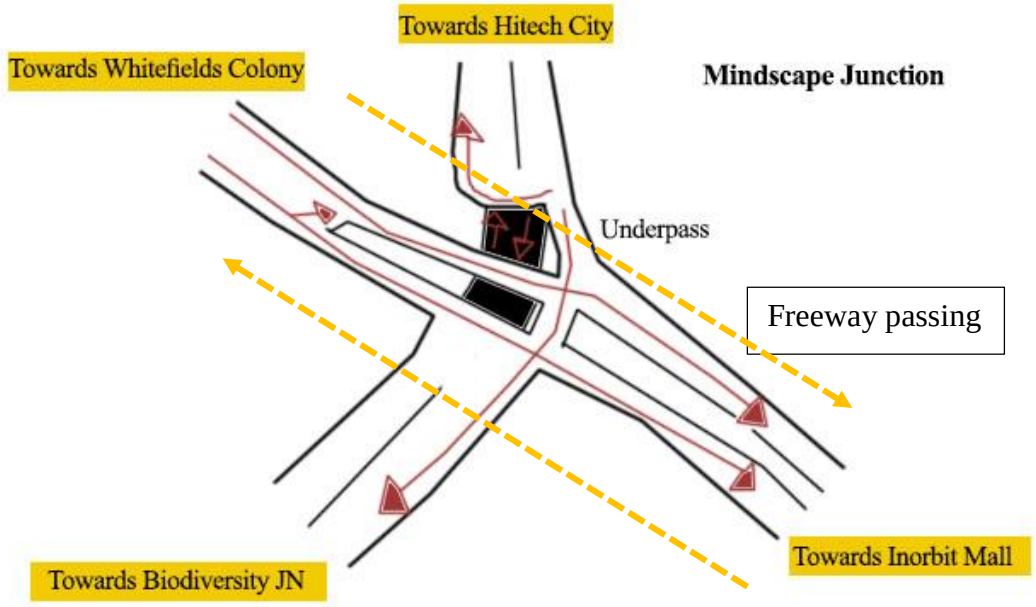


Figure 19: Mindspace junction details 2018 (source: Author)

The following junction has witnessed a major change in the 2017, due to the IKEA store. It was the first ever store in India, which is built at the Mindscape junction. For the traffic moving towards IKEA from the TCS junction, there is a provision of Underpass of 350 meter with 15 meter width. The purpose of the underpass was to make the traffic flow easily who do not intent to visit the store. But the traffic intending to perform a right or left turn is forced to travel straight and perform 'U' turn and then take desired turn. The traffic recorded from the PCU/Hr. to and fro Hitech-city and Biodiversity Jn are 5325+2777 and 3546 respectively. According to the standards (Central Road research institute-CSIR, December, 2017) from the level of service the following PCU/Hr. should be carried by six- eight lane road. The present road capacity is of 4 lanes, there is not initiatives of road widening in this corridor. The volume/Capacity in the corridor mindscape-TCS jn is 1.53-1.77 which falls under the category of 'F' LOS making the road heavily congested.

4.4.3. TCS Junction

From the below figures it can be observed that the peak hour traffic entering the TCS intersection is 15,510 PCUs in which 58% of traffic comes from 3 lane arm Mind space Junction of which 68% take straight towards Hitech City. The other two arms i.e. Value labs arm and Hitech City arm carry 12% and 22% traffic respectively. The most prevalent mode of traffic at this junction is 49% of Two-wheelers for 16-hour volume and followed by 36% of cars. It can further be observed that the total junction present traffic volume 15,510 PCUs in the peak hour for the base year 2015 is more than the 10,000 PCUs. Hence the traffic at this junction is expected to grow rapidly and cross the 10,000 PCUs.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
				Vehicles	PCU	Vehicles	PCU	
3-Arms	Signalized	178,185	148,350	17,748	13,586	19,244	15.510	15,510

Table 23: TCS junction details (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

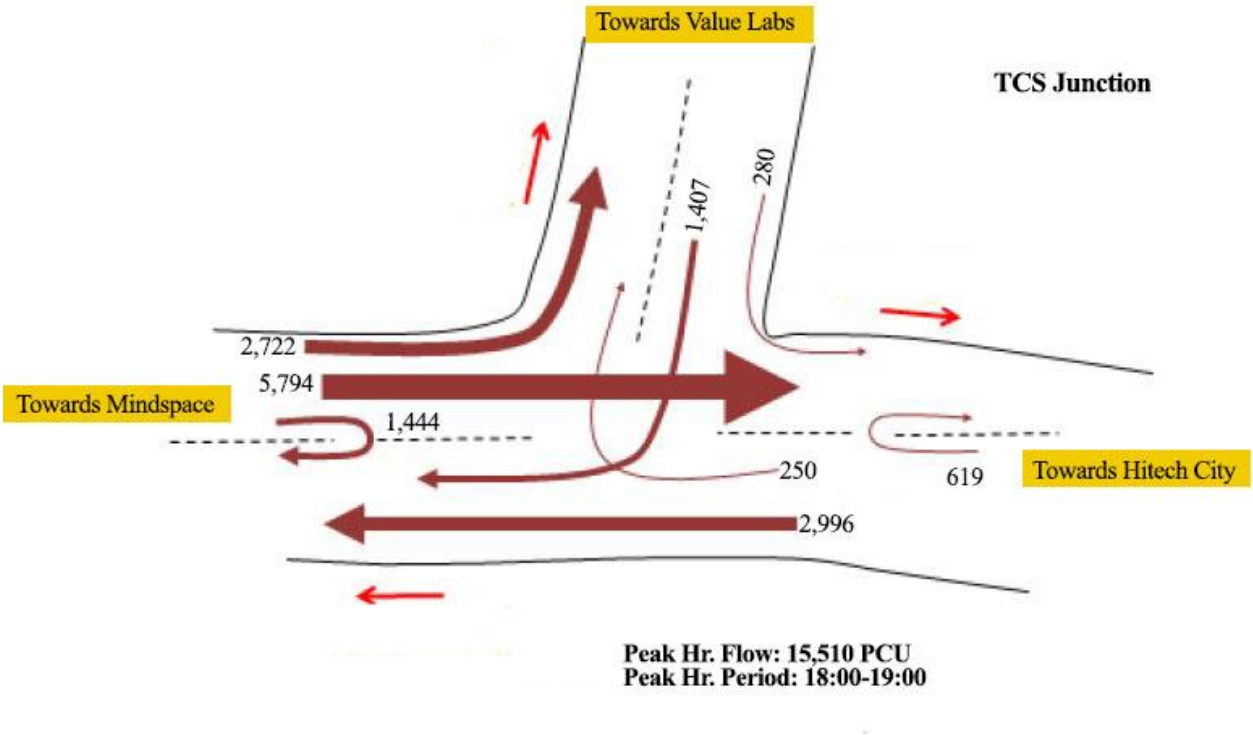


Figure 20: TCS junction details (LEA Associates south Asia Pvt. Ltd., 2013)

The following junction did not receive any change since past 5-6 years. According to the PCU value in the lane towards mindscape and hitech city is 5794 PCU/Hr. and 2996 PCU/Hr (to and fro), which according to the standards (Central Road research institute-CSIR, December, 2017) should be carried by four-six lanes road. But the following traffic is carried by 4 lanes road nearing to the capacity exhaustion. The volume/ Capacity ratio in the corridor of TCS Jn- Cyber tower Jn is 1.29 and 1.39 to and fro respectively. It falls under the category of 'F' LOS which indicates the corridor is heavily congested.

4.4.4. Cyber tower Junction

From the below figures it can be observed that the peak hour traffic entering the Cyber Towers junction is 12,629 PCUs in which 31% of traffic comes from 3 lane arm Jubilee Check Post Junction of which 58% take straight towards Kondapur. The other three arms i.e. Mindspace, Kondapur arm, and JNTU arm carry 25%, 23% and 21%traffic respectively. The most prevalent mode of traffic at this junction is 2 wheelers with 52.8% for the 16-hour volume followed by 26.6% cars/jeep. It can further be observed that the total junction present traffic volume 12,629 PCUs in the peak hour for the base year 2015 is more than the 10,000 PCUs.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
4-Arms	Signalized	195,158	154,748	14,846	11,953	16,502	12,629	12,629

Table 24: Cyber tower junction details (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

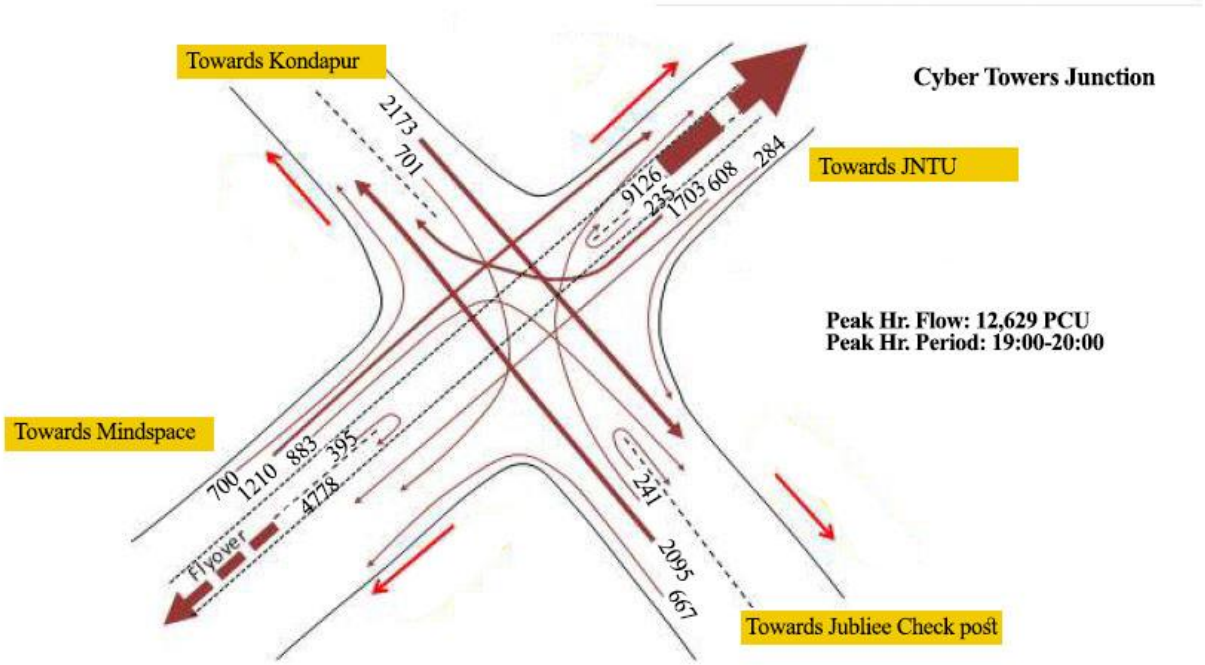


Figure 21: Cyber tower Junction details (LEA Associates south Asia Pvt. Ltd., 2013)

The Cyber tower junction is the main junction in the corridor from Bio-diversity to JNTU junction, as this junction perpendicularly connects to the other area which has dense population of public spaces. The cyberabad Traffic police watch centre or the control room is present at the junction. There are 4 constables always placed. There is a flyover connecting TCS junction to Ayyappa Jn, carrying 9126 PCU/Hr. and 4778 PCU/Hr. traffic (to and fro) and rest of the traffic travelling below the bridge is 1210 PCU/Hr and 1703 PCU/Hr. (to and fro respectively) The following traffic according to the standards (Central Road research institute-CSIR, December, 2017) should be carried by eight lane road and closing to ten lane road. The current road is of eight lane which is insufficient to the current usage of the road. The volume/ Capacity of the corridor Cyber tower to Ayyappa society is 0.83 and 1.15 to and fro respectively. This falls under the category of 'E' and 'F' LOS stating the road is partially and fully congested.

4.4.5. Ayyappa Society junction

From the below figures it can be observed that the peak hour traffic entering the Ayyappa society intersection is 8,657PCUs in which 32% of traffic comes from 2 lane arm Ayyappa Society arm of which 54% takes right turn towards Kondapur. The other three arms i.e. Cyber Towers arm, Shilparamam arm, and JNTU arm carry 25%, 21% and 22% traffic respectively. The most prevalent mode of traffic at this junction is 2 wheelers with 49.7% for the 16-hour volume followed by 32.9% cars/jeep. It can further be observed that the total junction present traffic volume 8,657 PCUs in the peak hour for the base year 2015 is less than the 10,000PCUs. The traffic at this junction is expected to grow rapidly and cross the 10,000PCUs in the next few years.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
4-Arms	Signalized	126,623	101,245	10,644	8,606	11,450	8,656	8,656

Table 25: Ayyappa Society junction details (Central Road research institute-CSIR, December, 2017)

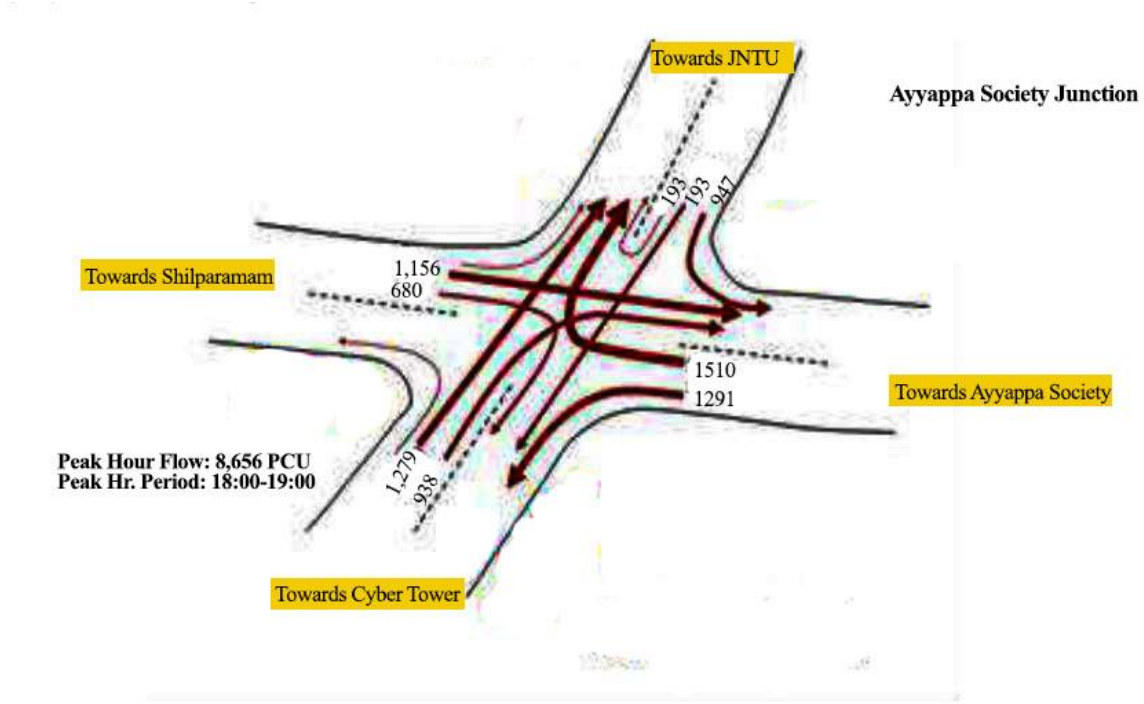


Figure 22: Ayyappa Society Junction 2015 (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

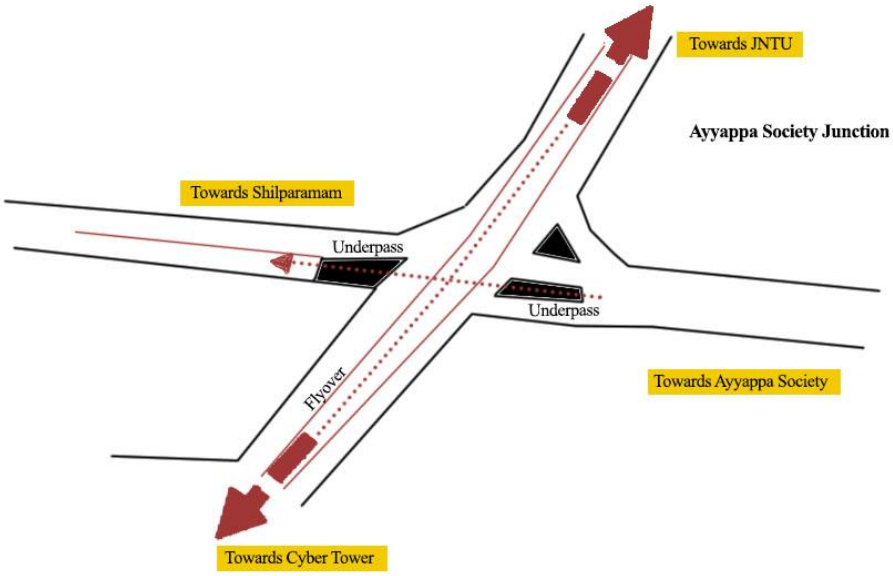


Figure 23: Ayyappa Society Junction 2018 (Source: Author)

The following junction received a change of building of an Underpass connecting Ayyappa society and shilparammam area. There is a flyover running perpendicular to this which starts at the TCS junction crossing over Cyber tower junction landing 400meter after the Ayyappa society junction. The underpass has been built in the year 2017 with width length of 300 meter and width of 15 meter comprising of two lanes. The underpass carries one way traffic from shilparammam towards Ayyappa society. According to the traffic constable the area hasn't received any change in congestion after the construction of the underpass. The Volume/ Capacity ratio of ayyappa society jn- hitech city is 1.78 and 1.63 to and fro respectively making it fall under 'F' LOS, which is heavily congested.

4.4.6. Rajiv Roundabout junction

From the below figure it can be observed that the peak hour traffic entering the Rajiv Gandhi Chowk intersection is 11,791 PCUs in which 66% of traffic comes from 3 lanes of the arm from JNTU arm of which 94% go Straight towards Hitech City. The other three arms i.e. Brand Factory arm, Malaysian Township arm, Hitech City arm and KPHP 9th phase arm carry 4%, 3%, 16%, and 11%traffic respectively. The most prevalent mode of traffic at this junction is wheelers with 57.5% for the 16-hour volume followed by 29.9% cars/jeep. It can further be observed that the total junction traffic volume 11,791 PCUs in the peak hour for the base year 2015 is more than the 10,000PCUs. As per the IRC-92: 1985.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
5-Arms	Signalized	158,999	121,889	15,924	11,791	14,073	9,785	11,791

Table 26: Rajeev roundabout junction details (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

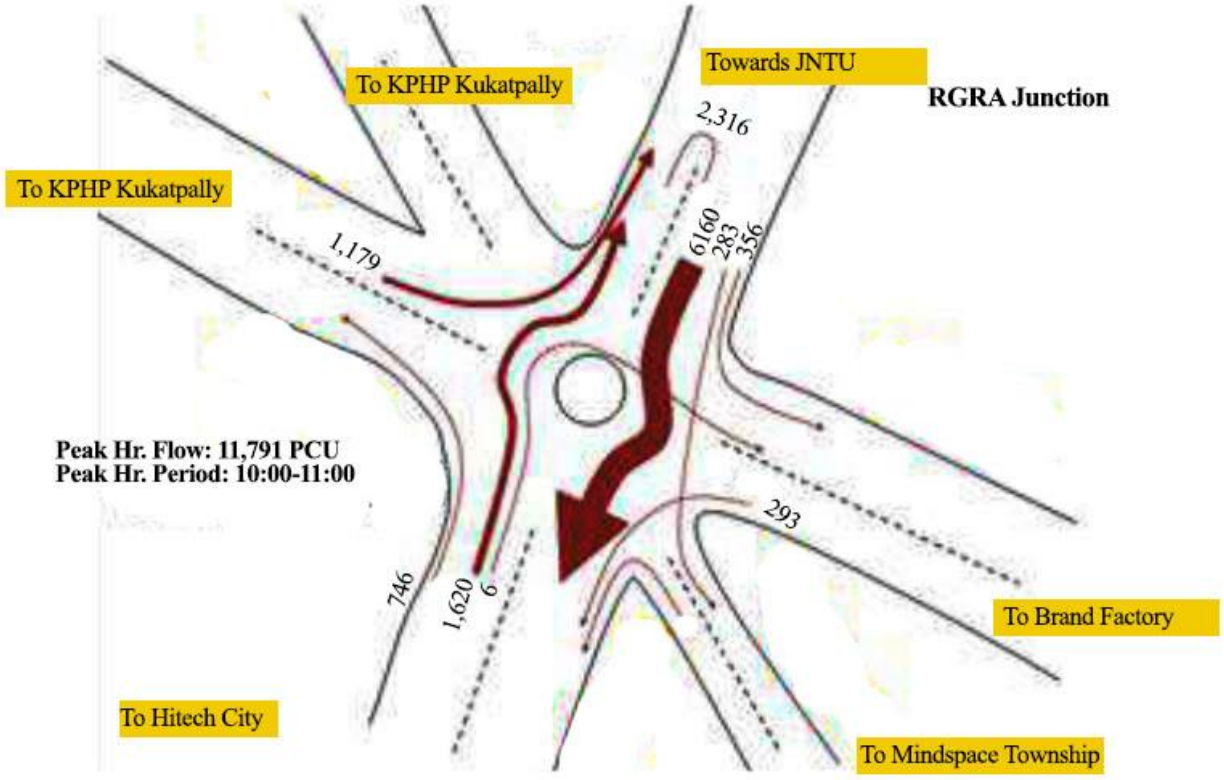


Figure 24: Rajiv Gandhi Chowk Junction (LEA Associates south Asia Pvt. Ltd., 2013)

The following junction did not receive any changes since 5-6 years. The traffic flowing from JNTU towards Hitech city is 6160 PCU/Hr. which is according to the standards (Central Road research institute-CSIR, December, 2017) should be carried by eight or closing to ten lane road. But the existing road is six lane, not sufficient to suffice the current traffic flow. The Volume/capacity ratio of the corridor is 1.85 and 2.22 to and fro respectively. The following junction has the highest ratio capacity indicating the worse congestion in the entire corridor from Bio-Diversity to JNTU. The following Volume/ Capacity ratio represent 'F' LOS and states the traffic to be heavily congested.

4.4.7. JNTU junction

From the below figures it can be observed that the peak hour traffic entering the JNTU intersection is 15,899 in which 49% of traffic comes from 4 lanes of the arm from Miyapur arm of which 100% goes Straight towards Kukatpally. The other three arms i.e. Rajiv Gandhi Chowk arm and Kukatpally arm carry 15% and 36%traffic respectively. The most prevalent mode of traffic at this junction is 2 wheelers with 57% for the 16-hour volume followed by 20.1% Auto Rickshaws. It can further be observed that the total junction traffic volume 15,899 PCUs in the peak hour for the base year 2015 is more than the 10,000PCUs. As per the IRC-92: 1985. Warrants for a grade separator interchange. This required higher grade treatment.

No. of legs	Signalized/ un signalized	Total vehicle	Total PCU's	Morning peak		Evening peak		Peak hour PCU
3-Arms	Signalized	229,790	178,659	21,313	15,899	19,866	14,385	15,899

Table 27: JNTU junction details (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

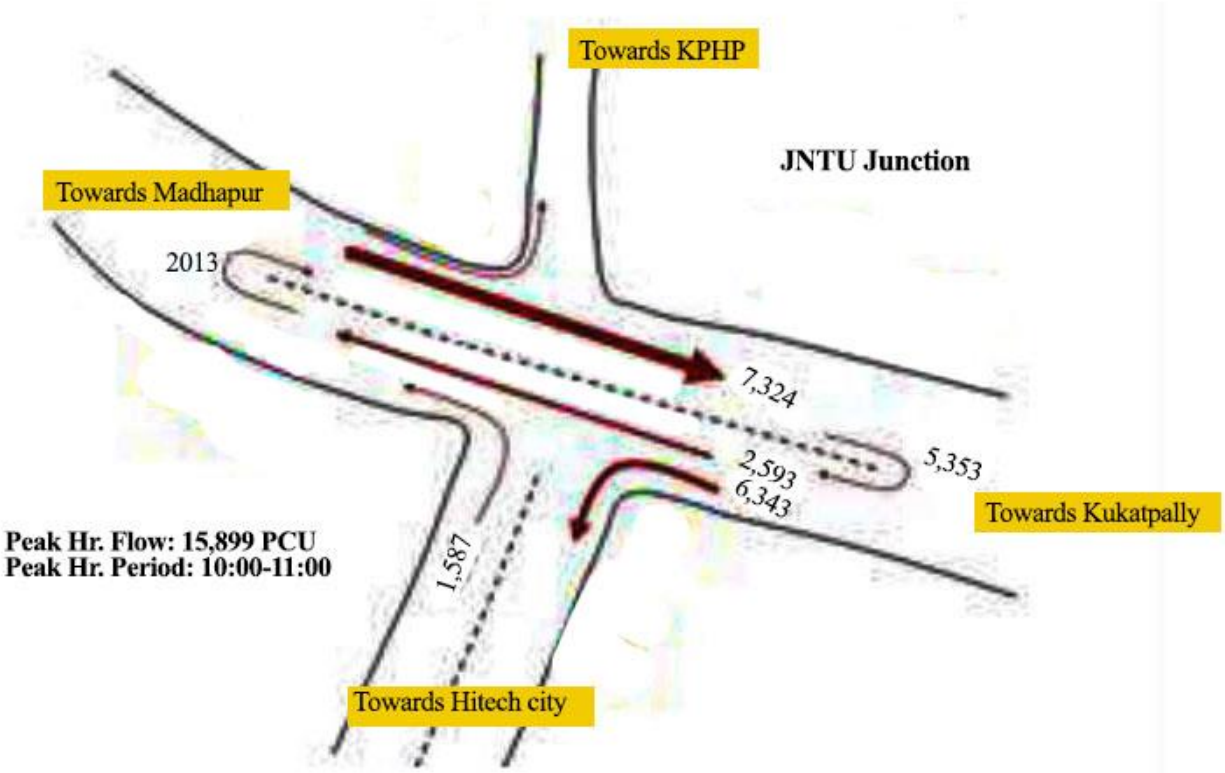


Figure 25: JNTU junction (LEA Associates south Asia Pvt. Ltd., 2013)

The following junction has not received any changes in past 5-6 years. The traffic flowing from Kukatpally to Madhapur and back are 2593 PCU/Hr and 7324 PCU/Hr respectively. Further the traffic flowing from Kukatpally to Hitech city junction is 6343 PCU/Hr, according to the standrards the following traffic should be carried by six- eight lane roads, in the current situation the road width is of four lane making it insufficient for the current road to carry. The Volume/capacity ratio of the corridor Rajiv Gandhi round about to JNTU Jn is 0.95 and 0.96 to and fro respectively. The corridor is at 'E' LOS which states the traffic is congested and with the number nearing to 1 it makes the traffic at 'F' LOS stating it is heavily congested.

5. Conclusions

5.1 Introduction

The following chapter presents a overview of the findings in line with literature review. The following chapter is segmented into 3 sections answering the research questions. Section one presents the answers to the research questions, section two provides additional knowledge and future research, and the final section provides recommendations.

Hyderabad city is primarily facing growth and extension of its urban area.[2] Several ring roads have been built around the city, making it an important characteristic of spatial structure of the city. From the increase in the use of private vehicle ownership, there has been an increase in the economic growth and environmental concerns, it has resulted in the design of employment of a number of management and planning strategies on the supply side to diminish efficiency losses.

The city of Hyderabad represents a mix of Type I- Completely motorized network and Type II city-weak centre, the city has a clear dominance of the motorized vehicles with major activities happening at multiple centres and periphery of the city. Madhapur is located at the periphery of the city, a major IT zone presence in the south part of the city, causes the traffic from all over the Hyderabad to move towards that area. It not only blocks Madhapur, it also congests the roads which lead to Madhapur. Further, due to the development the land use pattern has seen a vast change in the patterns, making the area primarily into commercial and public zone with a mixture of housing (in the internal areas). Due this development and exhaustion of the infrastructure and quick changes, the Municipalities are arriving at quick measures to mitigate the current congestion by supplying of over bridges, underpass and widening of road. As there is demand, there is an immediate short term provision. Junctions with the underpass at Ayyappa society has not made any difference in the congestion levels (as mentioned by the traffic constables at the junctions). Further, the underpass at Mindscape has made half the traffic to pass freely and created a hassle of extra travelling for others. The passenger car unit (PCU) values per hour at every junction ranged from the value of 0.89- 2.22 PCU/Hr. indicating the range of level of service between E-F.

5.2. Conclusions

The resulting section focusses on the contributing to achieve the main objective of the research which is to:

Explain the effects of supply-oriented measures of the road infrastructure provision on the road traffic congestion in Madhapur area in the city of Hyderabad.

As mentioned in the conceptual framework it states that the intention of the research is to find the influence of supply-oriented measures on road traffic congestion. The Independent variable is split into supply- strategy, road traffic management and level of service, each of the variables is studied in detail to understand its effect on the road traffic congestion. Apart from the supply-oriented measures, the control variables which are the state of the road and driving habits are also analyzed. The answers to the research is based on the fieldwork conducted in Hyderabad in the duration of a month. In relation to the above-mentioned scope, the research mainly focuses on the understanding of the traffic condition in relation to the supply of the road infrastructure by service provider- GHMC and HMDA. With detailed study of 8 junctions. The three sub-research question is a formation of the main research question and is further answered below.

[2] Refer to Annex 3 for Morphological maps

The sub-research questions are answered holistically in order to answer the main research question, which are–

*5.2.1. What level of **supply- strategies** affect the road traffic congestion in Madhapur zone, Hyderabad city?*

Stoper R. Peter (2003, p. 4) mentioned, "The goal of most of the national governments is to increase economic growth of the nation, therefore increasing GDP". Hence the first approach of the Municipality to mitigate congestion is by supply strategies. These are derived from the supply-oriented measures which the service provider provides to mitigate the traffic and for the maintenance of the road. The supply strategies are focussing mainly on the provision of the road infrastructure. The asset is important and mainly depends on the need, required quality of results and availability of data (Abe and Axhausen, 2018). In Hyderabad, Greater Hyderabad Municipal Corporation (GHMC), Hyderabad Metropolitan Development Authority (HMDA) are responsible for the provision of the road infrastructure and decide the land-use patterns and giving building permissions. According to the author Stoper R. Peter (2003), he categorizes urban transport supply conferring to capacity which is the number of people transported in the given time. As the supply- strategy is to provide infrastructure, means of transportation and managing both in an order. Allowing the provision to be linked with the usage (Volume) and the capacity of the infrastructure.

The land-use pattern plays an important role in mobility and access (Batur and Koç, 2017), it is the deciding factor and leads to trip generation. In Madhapur the land-use pattern is mainly of IT Park, commercial and public spaces with integration of housing. Clearly from the land-use map of Madhapur states 30-40% volume of commercial spaces along the lengthways of the main road. Due to which the trips were generated in the area for commercial, entertainment, work and leisure purpose. Hence, it experiences an increase in vehicles number in Madhapur.

The 8 junctions represents the main junctions connecting the corridor from Bio-Diversity Park to JNTU. The municipalities has few strategies in the corridor to avoid the congestion of the heavy movement of the vehicles. The area of Madhapur has received infrastructural changes in the past 5-6 years. With the aim of limiting the traffic congestion in the IT sector zone.

Sl. NO	**Junction/ Corridors**	**Initiatives**	**Year**	**Volume/ Capacity**	**PCU [Peak Hours]**	**Effect on Traffic**
1	Bio-Diversity Junction	Over bridge of 45 meter width	2010	0.87 & 0.91- E	1-2 4165 & 4343 PCU/Hr.	Jammed for 240 minutes at peak hour, Takes more than 6 minutes to go to next junction.
2	Mindspace Junction	Underpass due to IKEA	2017	1.53 &1.77-F	2-3 5515 & 6377 PCU/Hr. Current PCU value Undefined	Jammed for 120 minutes at peak hour, Takes more than 4.4 minutes to go to next junction. Plus due to the construction of underpass, half of the traffic are forced to perform 'U' turns.
3	TCS Junction	-	-	1.29 &1.39-F	3-4 2639 &4995 PCU/Hr.	Jammed for 240 minutes at peak hour,

						Takes more than 3.5 minutes to cross the junction.
4	Cyber Tower Junction	Widening of road and availability of overbridge to cross from TCS junction to land after Ayyappa society junction.	>2010	0.83 &1.15-F	4-5 2976 & 4154 PCU/Hr.	Jammed for 240 minutes at peak hour, Takes more than 4 minutes to go to the next junction. At time of heavy traffic the flow of the traffic is slower and the traffic constable increases the wait time to adjust the flow.
5	Ayyappa Society	Underpass with one way traffic	2017	1.78 &1.63- F	5-6 6426 & 5860 PCU/Hr. No change in the traffic flow (Data obtained from interview)	Jammed for 120 minutes at peak hour, Takes more than 3 minutes to reach the next junction. The flow of traffic from Ayyappa society to next junction is uninterrupted due to the construction of the underpass taking the perpendicular traffic from below.
6	Hitech City	Overbridge 15 meters width	2012	1.85 &2.22- F	6-7 6676 & 7988 PCU/Hr.	Jammed for 240 minutes at peak hour, Takes more than 4 minutes to reach the next junction. The flow of traffic depends on the movement on the over bridge. Any accidents or breakdown of vehicles causes huge hassle.
7	Rajeev Gandhi Round about Junction	-	-	0.98 –E	7 to 8 3421 PCU/Hr.	Jammed for 240 minutes during the peak hours, Takes more than 5 minutes to reach the next junction. During some peak hours, the traffic movement becomes worse.
8	JNTU Junction	-	-	0.99- E	8-7 3457 PCU/Hr.	Jammed for 240 minutes during the peak hours, Takes more than 5minutes to go back to the junction. It is heavily jammed due to the

						presence of the university at the junction.

Table 28: Summary of the initiatives from the municipalities. (Source: Chapter 2 and 4)

The main initiatives were building of over bridges and underpass along with widening of roads. The municipality catered to the presence situation and took measures accordingly. Despite of the measures taken the traffic conditions remained unchanged. Even as recorded from the interviews of the constables at the junction, they confirmed that the supply-strategies were insufficient to full-fill the requirements.

Lastly, as seen in the table: 28 the summary of the initiatives were just shifting the traffic temporarily from one junction to other. In all the cases the percentage of free flow was in the Level of service of E and F with free flow percentage being 22-40 percent and lesser. Thus, the supplied infrastructure and land use pattern had no increase in the free flow percentage causing the bottleneck of the traffic.

5.2.2. What level of Traffic management affect the road traffic congestion in Madhapur zone, Hyderabad city?

The main aim of traffic management is, "to measure the safety and flow of traffic, reducing traffic emissions and utilising traffic artery capacity more effectively" (Jain, et al., , 2014). An element of urban movement is the purpose of visit or the purpose of trip generation. The macro and micro factors leading to congestions travel demand patterns affected by the travel behavior- in the case of Madhapur most of the visits are work-related and the travel patterns possess parallel time schedule, route (Rodrigue, 2017). The Municipalities in Hyderabad-GHMC, HMDA along with the Cyberabad Traffic Police are responsible for the traffic management in the city.

The poor traffic management in the cities throughout the work are brink of massive traffic explosion the situation has worsen due to the following in the case of Madhapur-

1. Unplanned cities (Brinkman, 2016)- The city of Hyderabad was evolved bottom up and due to the increase development and increase in the ownership of private vehicles there is an exhaustion of the road infrastructure.
2. Alternate traffic means (Jain, et al., , 2014)- As an effect of social stigmatisation in the IT sector, the area has witnessed a massive increase in private vehicles ownership of motorised two-wheeler and four wheeler.
3. Archaic management (Khanal and Sarkar, 2016)- At the 8 selected junctions the constables control the traffic by adjusting the traffic signal light. They are authorised to control the traffic only by two methods- firstly by controlling the traffic at the signal and secondly by enforcement of bills/fine for ill behaviour on the road.

Further, as recorded from the interviews- the respondent's main concern was the time schedule which led to peak and non-peak hour traffic in Madhapur. Further, the interviews respondents- the traffic police at each junction also stated their perspective of the purpose and traveling schedule to be concise and peaked at a similar timing.

The visit to Madhapur is mainly due to work and leisure, due to the presence of IT companies, commercial spaces and entertainment sectors (as studied from the land-use map), the vehicles patters mostly observed by the traffic police (at the junctions) were two-wheelers and four-wheelers. Also, obtained from the Preliminary report (LEA Associates south Asia Pvt. Ltd., 2015) stating that count the vehicle usage in Madhapur witnessing the same.

The above graph, it is clearly understood that the usage of two-wheeler and four wheeler is higher followed by the three- Wheeler (Intermediate public transport). These three vehicles dominate the traffic composition in Madhapur, first two being private vehicles. As stated by the Traffic Police Commissioner of Cyberabad and the Deputy Engineer of GHMC- the high usage of private vehicles and "one person one car". From the above literature, the current major issue causing congestion is the ignorance of the prevailing traffic condition. Following it is important to understand the PCU values at each junction in correlation to the vehicles usage. The below table states the PCU values at each junction.

Sl. No	Corridor Name	Morning Peak (PCU's)	Evening Peak (PCU's)	Peak Hour (PCU's)
1	Biodiversity park- Mindspace Jn	3304	**4165**	4165
	Mindspace Jn.- Biodiversity park	4117	**4343**	4343
2	Mindspace Jn.- TCS Jn.	4079	**5515**	5515
	TCS Jn.- Mindscape Jn.	**6377**	5762	6377
3	TCS Jn.-Cyber tower Jn.	2199	**2639**	2639
	Cyber tower Jn.- TCS Jn.	**4995**	2920	4995
4	Cyber tower Jn. – Ayyappa society Jn.	855	**2976**	2976
	Ayyappa society Jn. – Cyber tower Jn.	**4154**	2161	4154
5	Ayyappa society Jn. –Hitech city	1274	**6426**	6426
	Hitech city- Ayyappa society Jn.	**5860**	3349	5860
6	Hitech city- Rajiv Gandhi roundabout	1378	**6676**	6676
	Rajiv Gandhi roundabout – Hitech city	**7988**	3829	7988
7	Rajeev Gandhi roundabout to JNTU Jn.	3193	**3421**	3421
	JNTU Jn. – Rajeev Gandhi	**3457**	2482	3457

Table 29: Morning and Evening PCU

Thus, t**he nature of the traffic is predictable to be passenger movements with a 45.5%-27.5% proportion of private vehicles**. The range of the pedestrian flow is 100-200 pedestrians all along the corridor. The average journey speed of the vehicles are measured to be 42 KMPH. Land-use patterns, most of the commercial and IT companies are concentrated at the main roads (along with the linear stretch). Along with the observed PCU values demanding wider roads. Hence, the traffic management by the service provider is unable to meet the demand of the growing development and is leading to the road traffic congestion in Madhapur.

*5.2.3. What **level of service** effect the traffic congestion in Madhapur zone, Hyderabad city?*

The Municipalities in Hyderabad- GHMC and HMDA, provide supply measures and management of traffic. The performance measures needs to be assessed. It involves to compare the given values to a relative set of standards. The supply measures and management needs to be analysed in order to provide appropriate maintenance completing the third tier of supply-oriented measures. The standards are compared with Indo-Highway Capacity Manual (Central Road research institute-CSIR, December,

2017) which was revised in 2017, the guidelines provide the standards of urban road, bridges etc. In the measure of level of service it is important to identify breaks, glitches in service levels.

There are different classification of vehicles in Hyderabad which operate on the road. There is no restrictions or lane priority given to any vehicles. There is combination of motorized, non-motorized private and public vehicles, and transport vehicles.

According to the standards, the relationship between the volume of traffic which the flow rate with speed and density of vehicle are fundamental in understanding the notion of capacity and level of service. The Preliminary project report (LEA Associates south Asia Pvt. Ltd., 2015) define the following data in the table with the V/C ratio and Level of service of the corridors.

Sl. No	Corridor Name	V/C ratio	Level of Service
1	Biodiversity park- Mindspace Jn	0.87	E
	Mindspace Jn.- Biodiversity park	0.91	E
2	Mindspace Jn.- TCS Jn.	1.53	-
	TCS Jn.- Mindscape Jn.	1.77	-
3	TCS Jn.-Cyber tower Jn.	1.29	F
	Cyber tower Jn.- TCS Jn.	1.39	F
4	Cyber tower Jn. – Ayyappa society Jn.	0.83	-
	Ayyappa society Jn. – Cyber tower Jn.	1.15	-
5	Ayyappa society Jn. –Hitech city	1.78	F
	Hitech city- Ayyappa society Jn.	1.63	F
6	Hitech city- Rajiv Gandhi roundabout	1.85	F
	Rajiv Gandhi roundabout – Hitech city	2.22	F
7	Rajeev Gandhi roundabout to JNTU Jn.	0.98	E
	JNTU Jn. – Rajeev Gandhi	0.99	E

Table 30: Presents the Volume/ Capacity ratio of Traffic volume on road along Bio-Diversity park- JNTU corridor with the level of service (Central Road research institute-CSIR, December, 2017, LEA Associates south Asia Pvt. Ltd., 2013)

LOS E- Traffic Volume=Capacity

LOS F- Traffic Volume > Capacity

The level of service E and F states unstable flow and heavily congested flow of vehicles on the road (Central Road research institute-CSIR, December, 2017). In conclusion, all the junctions are under the category of ‘E’ and ‘F’ with the values ranging from 0.87- 2.22. This indicates the low level of service and maintenance of road infrastructure in Madhapur.

*5.2.4. How does the **road user** effect the traffic congestion in Madhapur zone, Hyderabad city?*

The people in the vehicles are using the road and the infrastructure. The users of the infrastructure is considered in the case as it brings in the factors such as- the number of vehicles generating the trip by in the area. Secondly, the driving habits of the users causes non-recurrent traffic. This is an avoided situation regardless of the location. Hence it considered as the control variable by making it constant

and unchanged throughout the course of the study. In following study it was important to consider due to the reason of trip generation due to the presence of the IT sectors and commercial area.

According to Stoper (2003) people generally travel due to derived demand subscribing to the application of economic theory to travel i.e. People travel to a location to pursue an activity. Further, according to him, as the demand for travel increases, there are more trips generated. With the increase in the trip generation, the number of vehicles on the road increases with overloading the capacity of the existing infrastructure. In the Madhapur area, the main reason of the visit is due to the presence of the IT sector. Employee migrated from adjacent cities in search of work in Hyderabad IT sector. An adverse effect was created on the land-use pattern by a combination of IT parks and housing. Further, inviting the commercial and recreational spaces to grow due to the presence of the large group of people in the area. The trip were generated due to work, leisure, shopping and for entertainment purposes creating the existing infrastructure unbearable to accommodate the growing demand.

As said by the Commissioner that every day they expect around 0.1 Million of people who provide IT services and make the area heavily dense. As a human nature one would prefer to stay in a peaceful environment close to work. Madhapur was a suburban area, it gained its importance after the construction of the IT sector. People working there preferred houses around the area which led the developers to build housing and recreations. The new settlement and recreation area invited other people from the city to visit. Currently it is one of the bustling areas in the city with modern development.

Summary of the Fatality rate from 2016-2018

S.no.	Month	2016	2017	2018
1	January	1	0	2
2	February	1	2	1
3	March	7	7	3
4	April	6	3	2
5	May	7	4	1
6	June	4	1	-
7	July	7	0	-
8	August	1	1	-
9	September	5	0	-
10	October	5	0	-
11	November	6	5	-
12	December	0	4	-

Total	50	27	9

Table 31: **Summary of the fatality rate in Madhapur in the year 2016, 2017 and 2018 (Cyberabad Traffic police, 2018)**

Secondly, the inappropriate driving habits cause an increase in the fatality rate. The table below summarizes the fatality rate of years 2016-2018. As seen from the table the fatal deaths in year 2016 was more compared to 2017, which is due to the construction work of the infrastructure.

The accidents caused on the road leads to non-recurrent movement of traffic congestion which is unexpected, unplanned. (OECD and ECMT, 2007).

Hence, as studied in the following case from the fatality report is understood that the accidents were a minor cause of the non-recurrent jams, further confirmed by the Commissioner of the Traffic police that the major cause of the traffic congestion is the maintenance and lack of adequate measures taken. The existing infrastructure is insufficient to cater the current traffic conditions. According to the standards obtained from the Indo Capacity Manual (Central Road research institute-CSIR, December, 2017), the dimensions and provision differ greatly in value.

Thus, in summary- The anticipation of the space brought in the developers and people eager to explore the development. It has increased and led to an unexpected demand of the infrastructure from the Municipalities. As the demand increased it pressurized the infrastructure and led to several issues such as the road traffic congestion, accidents and ill driving habits among the road users.

5.2.5. Main research question:

What level of supply-oriented measures (supply- strategy, traffic management and level of service) by the Municipalities influence the Road Traffic Congestion in Madhapur zone, Hyderabad city?

The objective of the research is to investigate the effect of supply-oriented measures on the road traffic congestion. The independent variable supply-oriented measures are divided into- Supply strategy, traffic management and level of service. Each of these are studied individually to analyse its effect on the road traffic congestion. From the Land-use pattern 8 main junctions are identified which receives the highest traffic congestion.

Among the 8 junctions, there has been few areas which witnessed change in the infrastructure in the past 5-6 years. Out of the 8 junctions from the Passenger car unit values, are exceeding the capacity of the road. The main research question summaries the sub-research question and explains the individually the effect of supply- oriented measures on the road traffic congestion.

1. **<u>Bio-Diversity Junction</u>**

   Supply strategy

   i) The area has received flyover, and road expansion. But the flyover carries the north traffic (Mehdipatnam) to the Gachibowli. This has no effect on the traffic moving towards Madhapur, hence the traffic from Gachibowli and Mehdipatnam enters the Madhapur area directly from the Bio-Diversity junction.

   Traffic Management

   i) The junction has 3-Arms, operated by two traffic police constable and is signalized.
   ii) The junction at the peak hour receives 14,001 PCU/Hr. of which the 36% of traffic is from Gachibowli and 55% of the traffic is from the north traffic (Mehdipatnam area). The following junction receives 51.4% of motorised two wheeler with capacity of 1-2 people.

   Level of service

   i) The PCU values recorded explains that the junction is witnessing its exhaustion with volume/ capacity- 0.87 and 0.91 and Level of service- ‘E’ stating the road to be congested.

Effect on the Road Traffic congestion

Biodiversity junction carries traffic for 240 minutes at peak hour. The movement of traffic is slow and takes more than 6 minutes to reach the next junction. The over bridge carries traffic from north to south of other area, but the traffic entering from the north and south to Madhapur clogs at the entry junction. In summary, there is high number of usage of private vehicle and the Volume/ Capacity states the level of service E which explains the traffic free flow of 40-22 percentage.

2. **Mindspace Junction**

Supply strategy

i) After the construction of the IKEA store at the junction the traffic volume has increased (Sharad Mohindru Associates, 2017). The underpass has been constructed in the year 2018. There is no data recorded of the PCU at the junction

Traffic Management

i) The junction has 4- Arms, operated by two traffic police constable and is signalized. The junction at the peak hour receives 14,393 PCU/Hr. of which 50% comes from the three lanes from Madhapur and from which 86% go straight to Bio-diversity Park.
ii) Even this junction receives its most prevailing traffic from the motorised two wheeler which is 44.3%, followed by 40.6% of four wheelers- cars/Jeeps.

Level of service

i) There is no data recorded of the PCU at the junction. Hence, there cannot be any conclusion made for this particular junction.

Effect on the road traffic congestion

There is no recorded PCU value and volume/ capacity ratio of the following junction, as the infrastructure was added in action in the year 2018. But as recorded from the traffic constable at the junction he mentioned the following points. Firstly, there is a huge hassle for half the traffic who intends to take right or left from the junction. They are forced to go forward and perform 'U' turns. Secondly, the traffic currently is jammed at the junction for 120 minutes and it takes more than 4 minutes to travel to the next junction. Although the direct effect is not justified due to the lack of the PCU and Volume/capacity data.

3. **TCS Junction**

Supply strategy

i) There were no changes in the infrastructure in the last 5-6 years.

Traffic Management

i) The junction has 3-Arms, operated by two traffic police constable and is signalized. The junction at the peak hour receives 15,510 PCU/Hr. of which 58% is from Mindscape junction of which 68% goes straight to Hitech city Junction.
ii) The junction receives its most prevailing traffic from motorised two-wheeler which is 49% followed by four wheeler at 36%.

Level of service

i) The PCU value the road capacity is less making the ratio of volume/Capacity at 1.29 and 1.39 and Level of service at 'F' stating the traffic in the corridor is heavily congested and requires measures to be taken.

Effect on the road traffic congestion

The junction is placed between Mind space and cyber tower junction, both the junction receive heavy traffic from other areas. The minimum congested rush hour at this junction is 240 minutes. It takes minimum 3-4 minutes to go to next junction. There has been no changes seen. The junction has volume/ Capacity ratio of 1.29 and 1.39 making this junction at level of service F which states <22 percentage of free flow of traffic.

4. **Cyber Tower Junction**

Supply strategy

i) Existing over bridge and no recent initiative of building or expansion infrastructure was taken recently.

Traffic management

i) The presence of the Cyber tower at the junction makes this junction the most important junction in the corridor, plus it is the midpoint and connects to different area. The junction has 4- Arms, operated by four traffic police constable and is signalised.
ii) The junction receives a Peak Hour PCU of 12,629 per hour of which 31% of the traffic is from the Jubliee check post (west side of the city) and 58% from Kondapur (south side).
iii) The junction mostly receives 52.8% of motorised two wheelers and 26.6 % of four wheelers- cars/Jeeps.

Level of Service

i) With the existence of the bridge connecting the TCS junction traffic to Ayyappa society the junction still remains at the ratio of volume/Capacity at 0.83 and 1.15 which is a combination of level of service of 'E' and 'F', the junction is at the verge of exhausting its capacity and requires immediate mitigation methods in order to avoid heavy ques.

Effect on the road traffic congestion

As said by the traffic constable, this area is one of the most important junction. It receives traffic from extreme south and north of the city. The junction has long wait hours- 240 minutes minimum during peak hours. It takes 4-5 minutes to reach the other junction. The level of service from the volume/ capacity ratio of 0.83 and 1.15 is E and F indicating the traffic movement to have a free low between 40-22 percentage or lesser.

5. **Ayyappa Society Junction**

Supply strategy

i) There has been a new construction of underpass in the year 2017, the constable at the junction confirmed that the flow of traffic and congestion remains unchanged. This may be because the underpass holds one way traffic which moves the vehicles from the perpendicular direction of the corridor.

Traffic management

i) The junction has 4-Arms, operated by two traffic police constable and is signalized. The junction at the peak hour receives 8,656 PCU/Hr. of which 32% of traffic comes from the two arm Ayyappa society of which 54% goes towards kondapur.
ii) The most prevalent mode of traffic at this junction is motorised two wheeler with 49.7% followed by 32.9% of cars/jeep.

Level of Service

i) As the underpass was recently built, there is no data available regarding the PCU value. Hence, no conclusions can be drawn for this particular junction.

Effect on the road traffic congestion

The underpass built at the junction carries traffic perpendicularly one way. This makes it traffic flowing from Cyber tower junction to Rajiv Roundabout to flow without hassle. But the constable said that the new underpass has no effect on the traffic flow and it still remains

congested. The minimum congested time at the junction is 120 minutes. Although the direct effect is not justified due to the lack of the PCU and capacity/Volume data.

6. **Rajiv Roundabout Junction**

Supply strategy

i) There has no changes witnessed at the junction.

Traffic management

i) The junction has 5-Arms, operated by 3-4 traffic police constable and is signalised. The junction at the peak hour receives 11,791 PCU/Hr. of which 66% of traffic comes from 3 lanes of JNTU and 94% of the traffic goes to Madhapur. The most prevalent mode of traffic is motorised two wheeler which is 57.5% followed by 29.9% of four- wheeler

Level of Service

i) Hence the volume/ Capacity ratio of the corridor is 1.85 and 2.22 marking the highest ratio in the corridor, representing heavy traffic jams and congestion with Level of service at 'F'.

Effect on the road traffic congestion

There has no changes at the junction, the traffic gets jammed for minimum 240 minutes during the peak hours. Plus the heavy usage of private vehicles increases in the PCU values and the volume of vehicles on the road. Capacity/volume ratio is 1.85 and 2.22 making the free flow > 22 percent and causing heavy congestion.

7. **JNTU junction**

Supply strategy

i) The area has not witnessed any changes since 5-6 years.

Traffic management

i) The junction has 3- Arms, operated by 2 traffic police constable and is signalised. The junction at the peak hour receives 15,899 PCU/Hr. of which 49% comes from Miyapur (South west) goes towards Kukatpally. The most prevailing traffic composition at the junction is motorized two wheeler with 57% followed by intermediate public transport by 20.1%.

Level of Service

i) Hence the volume/ Capacity ratio of the corridor is 0.95 and 0.96 making it close to level of service 'F' and worsening the situation. The entire traffic flowing from Rajiv Roundabout junction flows from JNTU junction to exit the Madhapur area.

Effect on the road traffic congestion

The presence of University at the junction makes it more crowded, the multitude is a combination of vehicles and pedestrians. There has been no changes at the junction to improve the condition. The volume/ capacity values is ranging from 0/95 to 0.96 which states the level of service at F indicating the traffic free flow is less than 22 percent. The minimum congested time at the junction is 240 minutes and takes about 5 minutes to reach the next junction.

The traffic at the 8 junctions has seen the higher congestion level which represents the traffic volumes close to the capacity level with reduced speed. It also indicates the level of comfort and convenience is extremely poor and frustration among the drivers is generally high. Any unexpected reason of congestion such as fatal and non-fatal accidents can cause a breakdown flow with huge queues.

Hence, it is clearly understood that out of 8 junctions which are representing the main area of traffic congestion in Madhapur, 4 junctions have reached their capacity and other 4 junctions are on the verge of reaching their capacity. But in both cases the supply oriented measures has not made a difference in half of the junctions. Lastly, the flow of traffic is <22 percentage of free flow speed. Hence, as per the

current situation, the supply- oriented measures are affecting 50% of the junctions which are facing severe road traffic congestion.

5.3. Future research

The following study adds knowledge to the existing studies on Congestion Management. It presents a specific case in the City of Hyderabad which is one of the prominent IT zones. As mentioned in the official website of GHMC (Greater Hyderabad Municipal Corporation, 2018), there is a requirement for detail study regarding the supplied infrastructure. The study can be used for the policymakers to mitigate the congestion and acquire in-depth knowledge. This implies that the spatially related indicators, level of service (benchmarking) are a highly provable method to assess the traffic congestion aiming to complement the multi-criteria assessment that is mostly based on the derived values. Through the empirical study, these indicators are valid and reliable in accessing and understanding the reason behind the congestion.

However, in order to assess different perspective, such as-

1. The perception of people using the infrastructure, their modal choices and satisfaction levels of the existing infrastructure. The research can be carried forward adding to the perception of the people where the service provider can understand the user point of view regarding the provision. A survey needs to be conducted to get a review regarding the user perception.

2. Effect of weather conditions on the non-recurrent traffic congestion- The data requires to be gathered over the years, and require assessment of multiple indicators in two fields such as the storm water drainage pipelines, gutter systems and orientation of the road. In the context of India, where it is receiving major changes due to climate change which is hampering the infrastructure and leading to unexpected stop or delay of mobility. For example, in Hyderabad due to the poor drainage infrastructure the road gets clogged and makes it very difficult for the vehicles to cross. As the following study provides a prototype details regarding the recurrent congestion and further the non-recurrent congestion due to weather condition can be added to improve the quality and durability of the infrastructure to adopt and sustain to shocks making it resilient.

5.4. Recommendations

The analysis of the road infrastructure and from the understanding of the level of service provided by the service provider- GHMC and HMDA, there is a need to improve the existing infrastructure. The following recommendations are given in order to initiate the improvement process and easing the traffic congestion in the city. The following recommendation is for commercial zones with a high number of activities.

1. Recommendation 1: Requirement of High level of coordination among the service providers

The service provider GHMC and HDMA require a **high level of coordination** and involvement of different actors. This will lead to a new process of decision making as it involves the all the stakeholders and actors. The decision taken can be holistic and can avoid the inadequacy.

2. Recommendation 2: Strategies and policies

There is a need to implement policies and strategies to avoid exhaustion of space to provide infrastructure. The following section recommends two strategies congestion charges and High vehicle occupancy lanes in order to reduce congestion which is required as per the findings from the field visit.

Implementation of congestion charge

There is a need to implement a **congestion charge** in the city of Hyderabad. As the city is witnessing change and development in the infrastructure in the IT sector, it is important to implement the congestion charge in order to leapfrog. Further, this policy is required in order to avoid the exhaustion of space for further expansion of the road or bridge. As seen in the findings of the research most of the junction require 8-10 lanes according to the standards, but the municipality is unable to provide mainly due to low budget and lack of space due to existing commercial space at the edge. This will lead to demolishing of the commercial complexes to add extra infrastructure causing a huge economic damage. Hence, it is highly required to develop policies to overcome the congestion. The congestion charge is a fee which is charged depending on the condition of the traffic or based on the peak hours/fixed schedule (Litman 2002; VTPI 2010).

Implementation of High vehicle occupancy lanes

As observed from the finding- high usage of private vehicles. There is need to implement policy to avoid people to use low occupied vehicles and promote sharing of vehicles. High occupancy lanes provides the vehicles with higher number of people to form a separate lane. This segregates the traffic and promotes people to travel together of their destination is same. As the constable at the junction specified the timing of the offices being the same. The employee can cooperate and arrange for single mode of travel. This will lessen the number of vehicles on the road.

Further **promoting the use of public transport or joint transportation** in the IT sectors is highly recommended in order to limit the number of vehicles on the road. Along with changing the time schedule of the company, in order to channelize the flow of the vehicles timely.

3. Recommendation 3: Effective land-use planning

An effective land-use planning is required to avoid overcrowding of commercial spaces at the major junctions. The placement of the leisure spaces and shopping zones. Additionally, the existing commercial spaces require parking provision to accommodate the vehicles of the user. This will avoid non-recurrent traffic and allow free movement of traffic without blockage.

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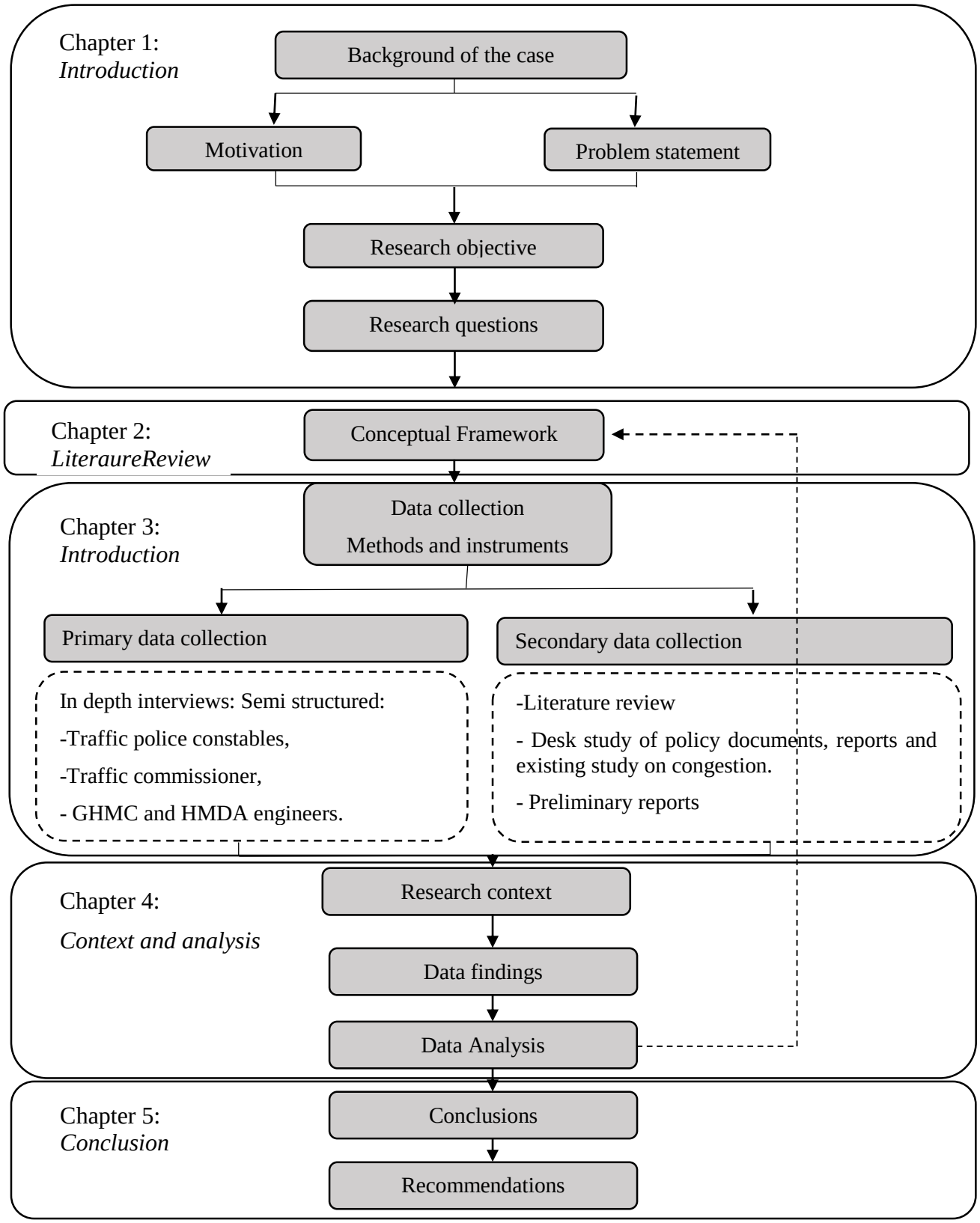
Annexe 1

Thesis Structure:

With the aim of understand the general structure and overview of what the process is, the thesis arrangement is presented below.



Annexe 2

Questionnaire for GHMC and HMDA-

Name of the interviewed person-

Position-

Introduction

The interview is conducted to answers the sub-research questions 1 & 3. The head of Planning Department and co-workers will be interviewed to understand the level of infrastructure provision.

The Indicators which will be answered are- Percentage of fulfilment of the infrastructure provision by HMDA and GHMC, Level of lane proximity given to public transport, Roadway saturation Index, Level of integration of all the service providers. Also to compliment the data collected from the secondary sources.

Questionnaire

Questionnaire to the Head of the Planning Department of HMDA and GHMC

1. How important is Madhapur area to the city in terms of location and land use?
2. Is traffic congestion a major issue in the area?
3. What are the supply oriented measures taken in past 5-10 years to ease the traffic?
4. How is the plan prepared for expansion/construction of the infrastructure and who all are involved in preparing the plan?
5. Which infrastructure needs an upgrade or requires more consideration?
6. What is the scope of the roadways expansion, has the roadway reached its capacity yet?
7. For the Public transport, is there any special provision of lane provided example BRT? If no then Why? If yes, then is it helping to ease the traffic flow?
8. Are there any special measures taken to ease the Traffic congestion in Madhapur zone?
9. Are there any difficulties faced during the provision of the infrastructure?
10. What level of coordination is there between Traffic police department of Hyderabad and GHMC + HMDA?

Questionnaire to the in-charge of the maintenance (2 people)

1. How old is the infrastructure?
2. How regularly the maintenance work is done (weekly/ monthly/ yearly)?
3. When the infrastructure reaches its saturation point (where the cost of maintenance is equal to building a new infrastructure) what measures are taken?
4. When is the maintenance work done? During day time or night time?
   [In order to understand if there is any blockage or delay caused by the maintenance team]
5. How are the encroachment on the footpath resolved?

Questionnaire to the in-charge of particular project (Road expansion, over bridges, Underbridges, footpath etc.) [Depending on the main projects]

1. How is the infrastructure helping in easing the traffic in Madhapur?
2. What is the capacity of the Infrastructure?
3. Is there any provision for future expansion of the infrastructure?

Questionnaire to the in-charge of Public transport facilities

1. What is the level of provision of the buses in the Madhapur?

2. What is the frequency of the buses at a particular junction?
3. How accessible is the bus-stop according to the land-use pattern?
4. What is the level of bus arrival and departure information given to the user?
5. How many buses are allotted in the same direction on a particular route?

Questionnaire for Traffic Police Department-

Name of the interviewed person-

Position-

Introduction

The following interview is conducted to answer the sub-research question 2 and 3. The Traffic Police Department are responsible for easing the traffic and maintaining the flow, they can provide their knowledge gained by experiencing the scenario during the time work.

The indicators answered by the interview are (the following indexes will be calculated by picking the combination of 6 junctions) - Average commute travel time, congested time Index, Travel time rate, travel time in congestion Index, Congested Lanes in Km, Number of traffic police per Junction, Average speed to actual speed, Level of Integration of Traffic Police department with HMDA and GHMC, Level of Public transport Information provided to the users, Level of Safety and signalized interaction for crossing, fatality rate, fatality rate for Pedestrian and NMT.

Questionnaire for the Traffic Police at 6 major junctions

1. Which Junction in Madhapur are you placed? Is this your routine place of duty or it chances on weakly/ monthly basis? [This question will provide me the experience of the traffic police at the particular junction]
2. What is the timing for the major traffic congestion at the junction? Peak and non-peak hours?
3. How long (time) does the congested rush hour last?
4. How many Km does the congestion last in peak period and non-peak period?
5. What measures are taken on the spot to ease the traffic congestion?
6. How often a traffic congestion is reported to the department for help?
7. Is the information passed of the congested lane to update the road users to shift or reroute?

Questionnaire for the Head of Head of Police Department

1. How important is Madhapur area to the city in terms of location and land use?
2. What Policies are adopted to avoid the severe cases of traffic congestion?
3. How many Traffic police are to be allotted at a particular junction and how is it decided?
4. Is there any lane priority given to the Public transport Example BRT?
5. What is the fatality rate for vehicle user, NMT and Pedestrian?
6. What is the level of safety in the Madhapur zone and how efficiently are the interaction for crossing signalized to assure full safety of the pedestrian?
7. What measures are taken to provide Information regarding the traffic congestion?
8. What measures are taken on the spot to ease the traffic flow?
9. What level of coordination is there between Traffic police department of Hyderabad and GHMC + HMDA?

Questionnaire for Professor from National Institute of Technology

Name of the interviewed person-

Position-

Introduction

The interview is conducted in order to compliment the data collected. The sub-questions 1 2 and 3 can be answered by the interview. The indicators covered are- percentage of fulfilment of infrastructure by HMDA and GHMC, level of Integration of Traffic Police Department and HMDA + GHMC. As the Professor has done an research on the Public transport in Hyderabad he will be able to provide clear explanation regarding- Level of Lane priority given to the public transport, Frequency and accessibility to the nearest bus-stops, Time frequency of the bus moving in the same direction on a particular route.

Questionnaire

1. According to you is the infrastructure provision adequately done to accommodate the traffic?
2. How is the coordination between GHMC, HMDA and traffic Police? Do they approach Academician for help in designing/ consultation?
3. In the research conducted of the Public transport in Hyderabad,
   (a) Was there any provision for special lane for the Buses example, BRT?
   (b) What is the frequency of the buses?
   (c) What is the frequency of the bus-stop compared to the land-use maps?
   (d) How many buses are allotted to move in the same direction on a particular route?

Annex 3

Morphological Development of the Madhapur area. Highlighting the main area of study by dotted black lines and showcasing the development in the area.

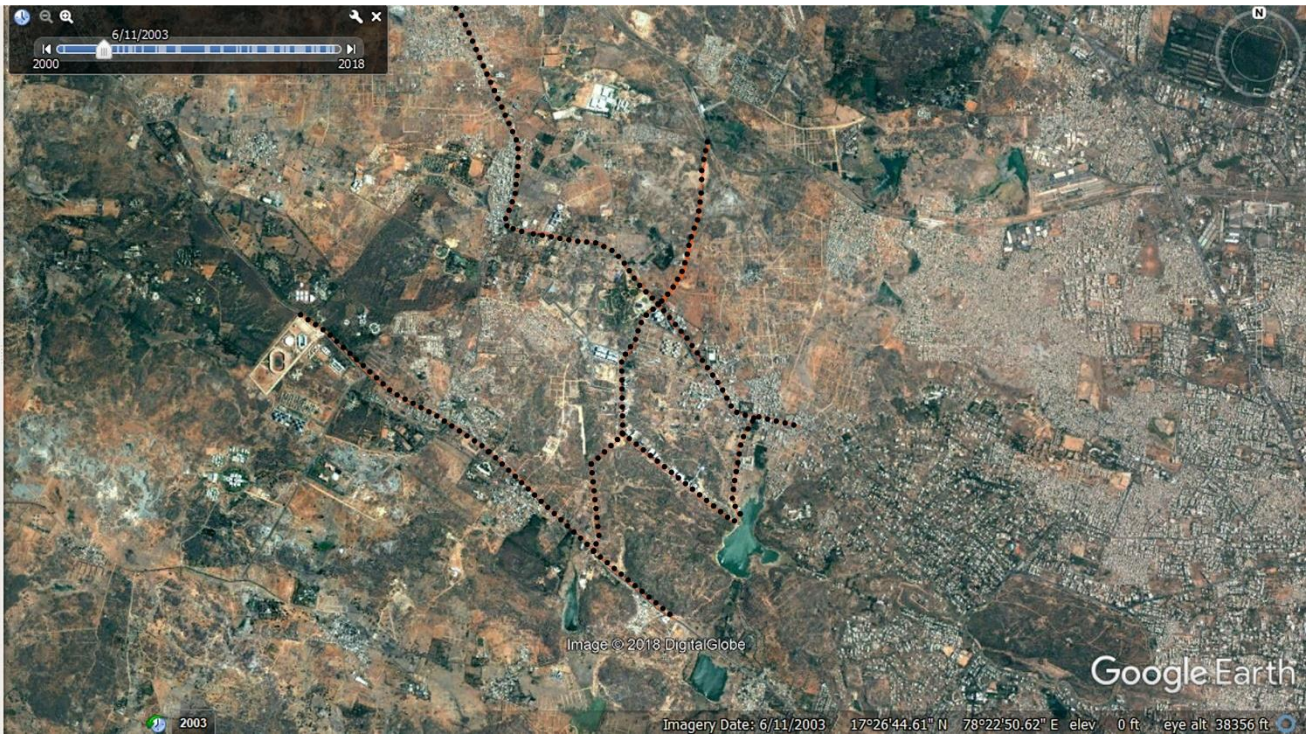


Figure 26: Madhapur area in 2003

Figure 27: Madhapur 2006

Figure 28: Madhapur 2009

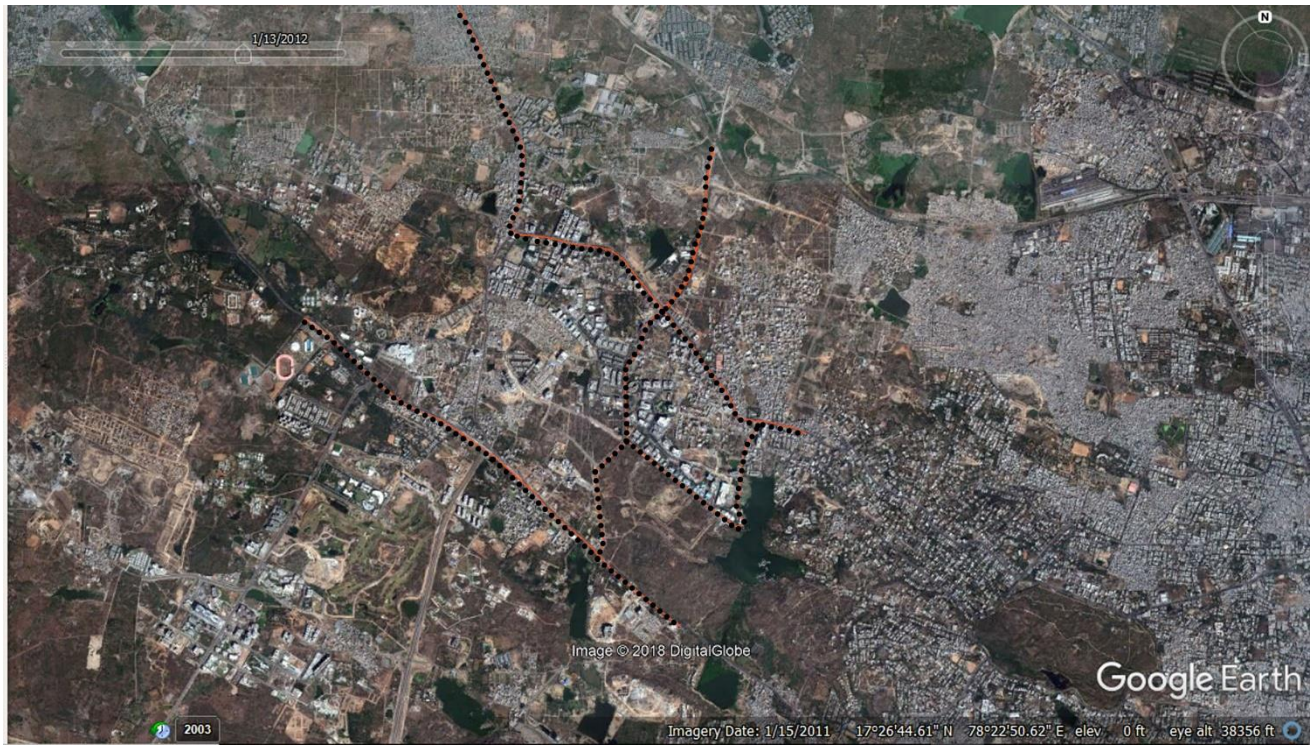


Figure 29: Madhapur 2012

Figure 30: Madhapur 2015

Figure 31: Madhapur 2018

Annex 3: IHS copyright form

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