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Congestion Mitigation Measure in Hyderabad – A Midnight Summer Dream?

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Vehicle emission contributes highly to air pollution in Hyderabad, the rapidly growing Indian megacity. One of the main sources of the increased emission load from vehicles is the growing traffic congestion in the city. Evidence from numerous cases around the globe suggests that effective traffic management measures dealing with this problem should necessarily include both supply and demand based approaches. However, the existing traffic measures in Hyderabad only focus on the supply side: strategies that improve the physical aspects of roads by increasing the road capacity either by widening existing roads or by constructing new roads or flyovers. Demand-based approaches i.e. the strategies that aim to alter drivers' behaviour to reduce temporal and spatial increase of vehicle demand are vastly ignored in the city, e.g. road pricing, restrictions on car ownership or staggering working hours. Still, demand-based approaches are not a panacea, as they are not always feasible. Moreover, these strategies require an institutional system able to cope with the increasing vehicle demand. Hence there is a critical need to develop traffic measures that balance both supply and demand strategies complemented with an effective institutional system. This significantly necessitates a better understanding of the traffic congestion in the city.

An extensive macroscopic and microscopic study of traffic congestion in the city is provided in this paper. At the macroscopic level, the general factors causing traffic congestion are discussed mainly under three spectrums: physical, behavioural and institutional. At microscopic level, the existing utilisation of road space by heterogeneous vehicles (physical) pertaining to its distinct driving behaviour (behavioural) that triggers traffic congestion is precisely studied under the effect of exist-

ing traffic rules (institutional). The current practice of congestion mitigation measures around the world is demonstrated and the application possibility of these measures is hypothetically assessed under 'what if' scenarios for Hyderabad. The paper concludes by highlighting the policy-relevant areas in need of further research.

1. Introduction

Climate change and air pollution are closely related and particularly relevant in every urban setting, all around the world. Emitted greenhouse gases such as ozone, particulate matters and carbon dioxide deteriorate the atmosphere. Ozone and particulate matters affect the living organisms and carbon dioxide stays longer in the atmosphere contributing to air pollution. In India, the road transport sector contributes to three-fourths of carbon dioxide in the form of vehicle emission (Ministry of Petroleum and Natural Gas, Government of India, 2002).[1] Although the problem of air pollution due to traffic has been – at least partially – addressed in the great metropolises of the developed world, it emerges as a huge challenge for the future of the emerging megacities of the fast developing countries. For instance, the number of passenger cars in the United States and the European countries is ranging from 260 to 750 passenger cars per 1000 population which is higher than the developing countries like China, India, Indonesia and Peru that has negligible numbers ranging from 50 to 100 passenger cars per 1000 population (Sokhi and Kitwiroon 2011).

On the other hand, a motorised passenger car in Germany contributes 6.27 grams of carbon monoxide per kilometer, which is significantly lower than a car in India that contributes 23.8 grams of carbon monoxide per kilometer (Faiz et al. 1996). One can easily imagine the increased negative impact in Delhi for example, if the numbers of cars per 1000 population reach a comparable state with the number of cars in Berlin without achieving the reduction of emissions per vehicle. In spite of the increased vehicle ownership and subsequent carbon dioxide emissions in the developed cities, their efforts to improve the air quality have already shown results. Many cities have adopted policy measures that include the regulation of Euro standards and cleaner fuels, traffic reduction measures that include priority to public transport especially buses, parking control policy, improving walking and cycling, providing an excellent road infrastructure to facilitate all these measures. Hence, there are lots of lessons to be learned from the experiences of these cities that faced in the past extreme problems of traffic congestion and air pollution due to the increasing car fleet of their citizens and the ways that such problems have been softened. However, policy makers and planners in the developing megacities of the future must avoid transplants of measures from such successful cases as the experience shows that rarely, if ever, a transplanted system will function as intended.

The paper aims to advance the understanding of the traffic congestion problem in Hyderabad, India and explore the applicability of several plausible measures in the particular context. To achieve this aim, the authors build their argument based on some empirical evidence drawn from the Sustainable Hyderabad Project but they mostly rely on secondary sources and a pertinent literature review. Without making any overstatements they argue that under the current circumstances and the recently introduced policies on transport it is quite likely that traffic congestion abatement in Hyderabad will remain a midnight summer dream. Unless a whole range of factors and their attributes contributing directly or indirectly into the problem is taken into account, current solutions tend towards improving physical aspects like improving road capacity will only provide a temporary relief. Noland (2001) argues that road improvements encourage latent demand where it tends to invite more new people to travel. The theory of induced travel demand (Cervero 2003) argues that in the long run, these road based improvements will only increase the number of private vehicles disproportionately to the total length of roads available resulting to similar problems of congestion like before the improvements.

The paper briefly introduces the traffic system of Hyderabad and identifies several key factors that contribute to the problem of traffic congestion. In order to support our argument, amongst the dozens if not hundreds of success stories around the globe we select a handful of promising measures and based on them, we construct five hypothetical scenarios on their application in Hyderabad. We employ the scenarios approach as the core of our paper, so as to allow a reflective thinking based on international experience and local conditions about critical risks and opportunities in the future and to explore ways in which these might unfold. From such perspective, the provided scenarios can be seen as an entry point for policy intervention and as a tool to highlight the critical uncertainties ahead that might affect learning process in the policy formulation. The authors do not claim in any way that this tool constitutes the solution to the problem, or any novel methodology that will eventually lead to ground-breaking findings. There is one key issue though which is not trivial and the scenarios enable us to discuss. As it will be shown in the following, the logic around which the transport system is designed and the traffic congestion abatement measures that are likely to be introduced in Hyderabad are lacking the holistic perspective required to be effective.

The paper is structured as follows: Section 2 identifies the most important factors influencing traffic congestion in Hyderabad and describes their main attributes. Thus the authors construct a two-dimensional picture, at macroscopic and microscopic levels (Fig. 1), of the acute problem of traffic congestion in the Indian megacity. Following, the authors in section 3 discuss some popular congestion abatement measures from around the globe, in an attempt to define their strengths and weaknesses. Section 4 builds upon the described situation in Hyderabad and based on the international experiences briefly presents several plausible "what if" scenarios. The paper concludes by providing in section 5 a series of key research questions with policy relevance and highlighting areas urging further research.

2. Factors Triggering Traffic Congestion

Focusing on the seven million inhabitants of the Indian megacity of Hyderabad, we observe an acute problem of air pollution, where vehicle emissions have become an intangible and veritable threat to the citizens, as the number of vehicles and their harmful emissions are rapidly increasing. Before we continue we must stress that air pollution (pertaining to vehicle emission) load, at any given point is generally classified as start and running emission. The start emission is here understood as the pollutants emitted during the start of a vehicle and continues for the first few minutes of driving, until the emissions-control equipment has reached its optimal operating temperature. In running emissions, pollutants are emitted during driving and idling after the vehicle is warmed up. In both types of emissions, the pollutants emitted are carbon monoxide, volatile organic compounds, nitrogen dioxide, particulate matter, carbon dioxide and methane. The estimation of start and running emission emitted for four representative stretches in Hyderabad shows that in all four stretches carbon monoxide contributes more than half of the total start emissions, while carbon dioxide is the highest contributor in total running emissions (Chidambaram 2011).

This recent study (Ibid.) also reveals that the increasing trend of two-wheelers, three-wheelers and passenger cars during the peak hours contributes to substantial amount of air pollutants in both start and running emissions. In other words, the transient driving pattern (i.e. acceleration and deceleration of vehicles) contributes to start and running emissions. This may be due to the occurrence of stop and go condition of vehicles – also called traffic congestion – during peak hours. It is observed that city and traffic congestion go hand in hand. The traffic congestion in a city could be seen in a positive note: The dynamic, affordable, liveable and attractive urban regions will never be free of congestion (Transport Research Center 2007); it is the evidence of social and economic vitality of culturally and economically vibrant cities (Taylor 2002).

Hyderabad is the largest contributor to the state Andhra Pradesh GDP (Gross Domestic Product), state tax and other revenues and also the hub for India's prominent Information Technology sectors and service industries (World Bank 2009). However, there are always consequences associated with traffic congestion in the city. Everyday millions of people in the city, experience the consequences in the form of repeated travel time delays and air pollution. Any minor incident can bring traffic to a standstill for extended periods of time which further leads to economic loss due to uncertainty in travel time, unreliability in services, travel time delay and subsequent queuing of vehicles (Institute for Transportation and Development Policy 2005).[2] This confirms that traffic congestion in the city is a real problem to be addressed. But how the city currently attempts to deal with traffic related problems?

The city development action plan proposed by Greater Hyderabad Metropolitan Corporation states that the city has 16 existing elevated corridors (flyovers) and 15 proposed road widening projects (GHMC 2011).[3] It seems though that such projects only indicate a "road infrastructure fever" that has hit Hyderabad. Urban transport planners base their decisions on the belief that road improvement projects are the effective methods to combat the problem of congestion. Unfortunately all of the evidence points in exactly the opposite direction, which is supported by the fact that the traffic volume is yet exceeding the road capacity on those elevated corridors and results in congestion during rush hours. The reason for this could be a whole range of policy constraints including the lack of policies recommending the restriction in usage of private vehicles; lack of policies promoting an increase of public transport usage; lack of documentation either on the evaluation of existing policies or on their efficiency.

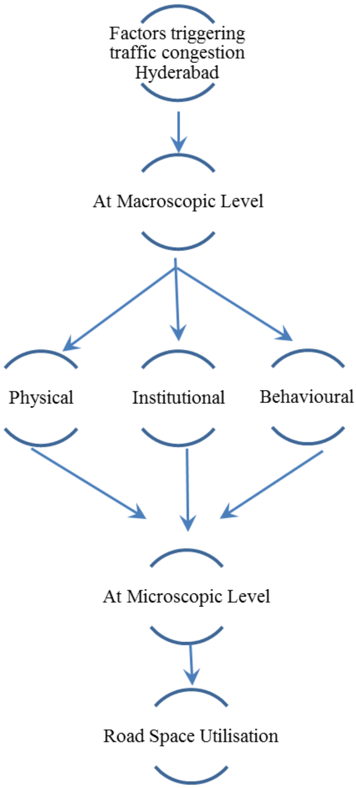

Fig. 1 Factors Triggering Traffic Congestion in Hyderabad
Source: Own

Recently, the Hyderabad Metropolitan Development Authority has initiated the Unified Metropolitan Transport Authority in 2008, for dealing with issues related with traffic and transportation in the city (HMDA 2009).[4] Its function includes managing the implementation of various traffic and transportation measures undertaken by various agencies in the city, ensuring that effective public transport systems are in place for the metropolitan region, and integrating various routes of public transport and issues including combined ticketing and feeder services. Although this is unquestionably a much promising plan, in reality it looks rather a pharaonic work requiring substantial funds subtracted from other measures perhaps more promising and with high degree of uncertainty involved.

It is quite characteristic that currently either most of the routes are not connected with public transport buses or most of the buses are already overcrowded as the service is not frequent. For such a plan, the fleet of the public transport vehicles should be multiplied and the logistical support required will exponentially increase. As the situation now stands, even the simplest of measures to promote public transport (like providing exclusive bus lanes) is impossible due to the inadequate capacity of roads but also highly questionable in terms of drivers' compliance to any restrictions. The authors argue that the very essence of such uncertainty related to most engineering and policy constraints is the failure of the policy makers to understand the indigenous factors triggering or enhancing traffic congestion in the city.

2.1. Macroscopic Factors

Seeking to identify the factors triggering traffic congestion in Hyderabad from a macroscopic perspective, the authors make a sketchy categorisation of physical, institutional and behavioural attributes. This subsection describes the three distinctive groups of factors in an attempt to construct the broader picture of traffic congestion in the city.

2.1.1. Physical Factors

The city has radial and orbital form of road network development (Fig. 2). The river Musi divides the city into two parts: old city and new city. The historic old city is the central core area, with three national highways passing through the city centre. It consists of narrow side roads with mixed traffic and old buildings, which suffers from chronic congestion. Mostly low income and middle-income group people reside in the old city and certain parts of it have now turned into slum settlements.

The recent urban growth expands the new city towards the west and north directions of Hyderabad. The new city hosts many government buildings, software companies, shopping malls and universities. Due to these amenities, there is a sharp increase in land value.

Overall, the old city has suffered a general decline while the new one has emerged as the dominant urban part of Hyderabad in terms of growth and employment. This trend results to an increased average trip length of vehicles. On the one hand, bicycles and walks trips less feasible due to the long distance and on the other, private motorised vehicles trips are increased resulting in unrestrained vehicle demand. The current road building in the city could not keep up with rapid expansion of these private vehicles. Hence there is a mismatch between road supply and vehicle demand (i.e. the number of vehicles) in the city. For instance, the vehicle composition of the city comprises of motorised two wheelers (74.3 per cent), passenger cars (15.6 per cent), three wheelers (3.23 per cent), bus (0.8 per cent), truck (4.1 per cent), pick-up trucks or vans (1.45 per cent) and others (0.52 per cent) (Hyderabad Traffic Police 2011).[5] This shows that private vehicles contribute substantial share to the total vehicle population.

To cope up with these increased private vehicles, the GHMC (Greater Hyderabad Municipal Corporation 2011) has increased the area of the road network from 9 per cent in 2005 to 12 per cent in 2011 out of total area (Greater Hyderabad Municipal Corporation 2011).[6] Additionally the vehicles present extremely heterogeneous characteristics. Such characteristics refer to the traffic that comprises of varying vehicle static (dimensions) and dynamic (performance) characteristics (Mallikarjuna and Rao 2006). Also, the geometric design of the existing roads does not support this heterogeneity in vehicles. Concluding we can argue that despite the intense effort of the city planners on developing further the infrastructure in order to deal with traffic problems, the physical factors represent a limiting factor not to be underestimated.

2.1.2. Institutional Factors

North (1990: 3) defines institutions in economics and political science:

Institutions are the rules of the game in a society or, more formal-

> ly, are the humanly devised constraints that shape human interaction. They are made up of formal constraints (e.g., rules, laws, and constitutions), informal constraints (e.g., norms of behaviour, conventions, and self-imposed codes of conduct), and their enforcement characteristics. In consequence, they structure incentives in human exchange, whether political, social, or economic.

In the transportation context, the traffic rules, transport policies, traffic measures, traffic enforcement and the sanction mechanisms, together with the behavioural aspects of driving, form the system of transport institutions. In Hyderabad, this system comprises of ill-timed traffic control systems such as traffic signals and sign. The authors can risk a generalisation here by arguing that the formal constraints in the particular setting are either inadequate or non-existent. If they exist, they are often found out of order or badly placed. Additionally, the present traffic enforcement system is mostly manpower based i.e. traffic police. There is a staff crunch among traffic police wings and equipment. Hence, a single traffic policeman needs to manage thousands of vehicles plying at the same time.

It is worth mentioning that traffic policemen are also vulnerable to rapidly aging problem and health problems due to their constant exposure to vehicle emissions (Suresh et al. 2000). In parallel, existing traffic rules manuals are neither adequately defined to mixed traffic conditions nor up to date to the changing demographics, land use, life style and travel patterns. Hence the traffic rule system follows those outdated manuals which also influence the rules' enforcement. For instance, the sanctions for violations are still negligible, so drivers often prefer paying the fine and keep breaking the traffic rules. Also, the traffic rules are not properly linked to driver training and road education.

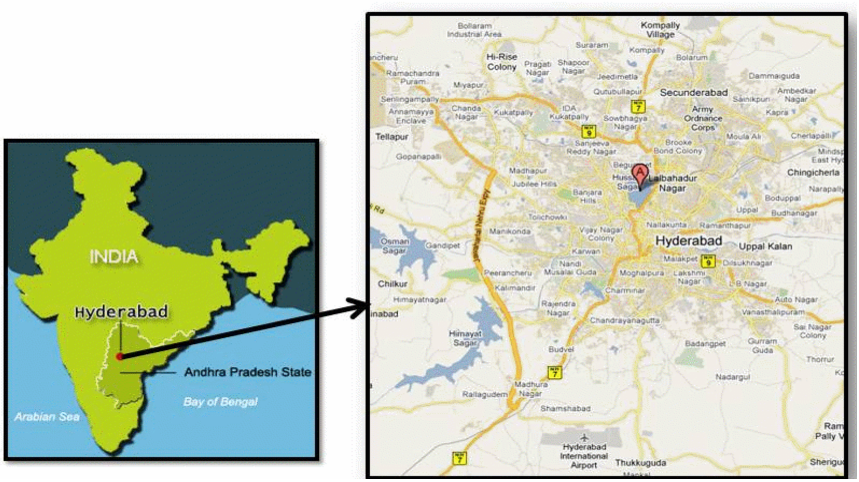

Fig. 2 The Road Network of Hyderabad
Source: Google Maps[7]

Testing procedures are common for all vehicle type drivers irrespective of heterogeneity of traffic situation, there is no ethical training for drivers about how to respect the values of other road users, the duration of license renewal period is high (minimum 20 years) and no physical tests assessing physiological characteristics of the drivers take place. This leads to low moral education and reduced ethical values among road users (Verma et al. 2011). In addition to proper driver training, each individual vehicle driver's personal traits such as age, gender, experience, purpose of driving etc. determine the intensity of aggressiveness: Young adults will be more aggressive than old age drivers (Constantinou et al. 2011), male drivers will be more aggressive than female drivers, novice drivers will be aggressive than experienced drivers, goal oriented drivers will be aggressive than the drivers engaged in pleasure trip.

The encroachments on the side of the roads such as street vendors and pavement dwellers additionally narrow down the available road space and affect the smooth flow of traffic (Singh 2005). Vehicles are illegally parked on the roadside by shop-owners and customers due to the absence of designated parking lots in the city.[8] Additionally, the absence of footpaths in some roads forces pedestrians to share the roads along with motorised mixed traffic.

This often conflicting combination of dysfunctional formal constraints with a series of very complex informal particularities of drivers in Hyderabad creates an explosive mixture of conditions that intensify rather than regulate traffic problems.

2.1.3. Behavioural Factors

Individuals on road include vehicle drivers and pedestrians. Their behaviour is dynamic and hence their on-road behaviour is difficult to predict. All vehicle drivers irrespective of the heterogeneity in size and speed of their vehicle have a common goal on-road i.e. to reach their destination. Though their destination might be different, the available choice with respect to route, vehicle mode and travel time to reach their destination is limited. Hence drivers' decisions could coincide in route or in vehicle mode or in travel time. When they coincide, then all drivers are forced to be in the competitive position to make their driving task possible. This could result in congestion and conflicts.

It is also observed that the institutional constraints have triggered behavioural response from people. For instance, the Hyderabad's public transport network is not rightly balanced throughout the city. This means that individuals have different degrees of access to the network offered by State Government. This has resulted in increased car ownership and motorised two-wheelers mostly among middle-income and high-income groups.

The remaining groups, who could not afford to buy neither a car nor a two-wheeler, depend solely on public transport, although it is ill managed and unreliable. As the vehicle occupancy[9] of cars and two-wheelers is much less than that of public bus, the increase in private vehicles demands for more road space. This has also increased a tendency of aggressive driving[10] among motorised vehicles that adds complexity to increased congestion.

From the above mentioned general or macroscopic, as we named them, factors, it is observed that the city lacks in traffic regulations and accurate enforcement mechanisms, ignores the travel behavioural interventions from the behavioural perspective and focuses only on improving physical interventions like increasing the road capacity from the physical perspective. Building more roads does not necessarily ease the traffic congestion. Indeed, building more roads has only exacerbated the traffic congestion. There is a lack in deeper understanding of the traffic congestion problem. Under the microscopic lens as we will discuss in the next subsection, it is observed that the practices and interactions of each individual drivers and the heterogeneity in their behaviour and in their vehicles adds complexity to the limited road space. In addition to this, there is a lack of enforcement to regulate the road space usage. Thereby one of the direct implications of the overall situation is the fact that the available road space is not effectively utilised among vehicle drivers. This urges for a deeper analysis of the problem of disproportionate road usage in the city that is discussed in the following section.

2.2. Microscopic Factors

Given the macroscopic image constructed by the authors in the previous chapter, we judged that a deeper, more thorough look at the fine details that compose this picture, what we named microscopic factors, is particularly relevant so as to allow us deriving to an accurate description of the traffic congestion problem. Consequently we are very interested in road space utilisation with respect to different vehicle types. The vehicle numbers are disproportionately increasing in respect to road capacity. This creates a high demand for road space among the vehicles especially during peak hours, emulating a situation similar to rivalry for a common pool resource. This heterogeneity among vehicle drivers also amounts to additional complexity on this road space demand. The heterogeneity includes drivers' personal traits, their vehicle types with respect to size and speed, their purpose of travel: work, leisure (shopping or entertainment or education); and their priority among transport attributes: time, route, vehicle mode with respect to cost, comfort and value.

For instance, a bus driver will most probably have different purpose of travel and different priority when compared to a truck driver. When hundreds of vehicle drivers travel together, there could be high probability of coincidence in their priority. For instance, irrespective of the purpose, most of the vehicle drivers will have time of travel as their main priority when they travel. When increasing number of people make similar decisions in their travel time, it may result in stagnation of vehicles at particular time, as the road space is limited. This could be clearly seen from a real case in Hyderabad. The main roads in the city are congested during morning and evening peak hours and are not congested during the rest of the day (Chidambaram and Zikos 2011). Long queuing of vehicles during the peak hours is not a problem per se, at least as long as the vehicles move. The real problem lays when the traffic comes to a standstill, which is often the case.

There might be numerous reasons for traffic standstill. One of the most interesting and common reasons observed is that two-wheelers and three-wheelers in India often perform lane splitting[11] between cars and buses. Although two-wheelers and three-wheelers could jump the queue, cars, large commercial vehicles and buses are stuck in the queue as their movement is further affected due to space encroachment of small vehicles. This results in huge travel time loss for bigger vehicles. Every day, the growing intensity of vehicular traffic in the city is reflected by the additional travel time delay. The authors suggest that this situation could be improved by a lane driving system applied in the city if properly enforced and internalised in the drivers' behaviour. Although lane markings exist on the road, during rush hours lane discipline is not respected[12] as stated in the traffic rules manual.

Current research work justifies the lack of lane discipline in India. Mallikarjuna and Rao (2006) justify that the standard width of road (3.5 m) is considerably larger than the width of motorised two wheelers and three wheelers (0.8 m and 1.4 m) and hence such vehicles do not feel restricted by the lane discipline rules in India. Tiwari (2002) argues that particularly the left lane in India is only partially used by motorised vehicles due to less enforcement. He also observes that there is no segregation of vehicles on road based on performance characteristics. Gokhale (2011) further concludes that Indian traffic system is mostly of non-homogeneous nature in which mixed fleets with all types of vehicles ply together without any strict-lane discipline.

Dhar (2008) perceives the difference between Indian street traffic scenario and developed countries: The road conditions are more varied, the traffic is unstructured, lack of lane discipline and numerous types of vehicles. Gowri et al. (2009) argue that in homogeneous traffic, the physical dimensions do not vary much and so vehicles could follow lane discipline but in India due to highly varying physical dimensions and speeds, vehicles could not follow lane discipline as any lateral position on the available road space is occupied by small sized vehicles (motorised two-wheelers and three-wheelers). Kumar et al. (2011) find that it is difficult to measure the traffic parameters on an urban arterial, especially under heterogeneous traffic conditions, as there is lack of lane discipline and because of complex interactions among different vehicle types. Mathew and Radhakrishnan (2010) suggest the need for model that accounts side-by-side stacking of vehicles across the road width occurring in the absence of lane discipline.

In the above short review, we distinguished the problem of lack of lane discipline in India and we approached it through various factors: heterogeneous vehicle types, standard road lane width, no lane segregation, unstructured traffic, lateral movement of small vehicles etc. Among the above mentioned factors, the most important but undisclosed factor is the driver behaviour influenced by the rules-in-use, which plays a main role in decision making whether to follow or not to follow lanes. There is also lack of awareness among drivers about the advantages of lane discipline. Enforcement of lane discipline will only work, either if drivers are well aware of their position on road (relying on a rational choice made by drivers with perfect information) or if a monitoring and sanctioning mechanism is set in a way that no rule breaking is possible (a perfect monitoring situation, not observed anywhere in the world). A more reasonable argument would be a fine balance between multitudes of factors. In such case, the effective utilisation of road space will succeed and sustain, if both enforcement of lane discipline and awareness among people about lane discipline is reached. This might convert the standstill of vehicular traffic in to a smooth flow of traffic.

But is there evidence of such a functional equilibrium? Many anti-congestion measures are practically being adopted across the world to ensure the smooth flow of traffic. Despite their success in the particular context where they are applied, they do not necessarily provide sufficient platform for behavioural response from people beforehand, at least per se. The pros and cons of some of the commonly applied measure are briefly discussed in the next section.

3. Congestion Abatement Measures

There are too many congestion abatement measures implemented around the world and it falls outside the scope of the current paper listing them all. However, taking as a starting point their common purpose, to improve the effectiveness of a transport system to avoid excessive congestion in the city, we present some of the potential demand based congestion mitigation measures (Table 1) that mainly aim to restrict the passenger car usage and enhance the mobility of people and also consider them as potential candidates for hypothetical application in Hyderabad. The description, application and the pros and cons of each of these measures are discussed briefly:

3.1. Traffic Calming Measure

3.1.1. Description

In 1985, the traffic calming measure was introduced (Hass-Klau 1985). The measure aims to slow or reduce motor-vehicle traffic to improve the living conditions as well as to ensure safety for non-motorised vehicles. The measure intends to improve 3 E's: engineering, education, and enforcement. Engineering measure aims at improving the physical aspects of road such that the speed of the traffic is greatly reduced. Some of engineering based measure is speed bumps, speed humps, living street and pedestrian refuges. Education measure aims in creating awareness among people about safe driving. Enforcement measure includes limiting the speed by providing speed limit sign. Some of the measures that include both education and enforcement are vehicle activated sign; publicity campaign and speed limit warning signs.

3.1.2. Application

The living street signage is adopted and regulated in some European countries namely Germany, Austria, Spain, France, Netherland and Poland. The street space is designed to be shared only by pedestrians, children, bicyclists, and low-speed motor vehicles. The car drivers are given least importance in this type of streets. The maximum speed of vehicle is 20 km/h. This street is structured such that social and recreational functions are encouraged. The traffic calming measure has been applied in Hilden in Germany, Graz in Austria and London in United Kingdom. In the following we briefly present the case of traffic calming in Hilden, Germany.

The city of Hilden is 13 km from the centre of Dusseldorf. The city covers 26 sqkm. It is surrounded by motorways and has train connections to Dusseldorf. Traffic calming measure was adopted in Hilden in 1992 (King 2004).[13] The two objectives of the traffic calming measure in Hilden is to ensure safety for pedestrians, who are the most endangered road user and to reduce the speed difference between the means of transport to create a liveable environment. They consist of following mechanisms: All residential areas are converted into 30 km/h, several street alterations includes: speed bumps, pedestrian crossings, trees in the middle of intersections, narrow street to discourage increase in speed of vehicles, awareness to Hilden residents about traffic calming measure is ensured by communication and realisation process e.g. 20,000 brochures were distributed to all Hilden households, regular inclusion of the local police to monitor the speed level on city street and ensuring bicycle promotion by providing bicycle infrastructure and reducing parking space for cars. As a result, extensive traffic calming in the city copes with the demands of integrated transport planning.

3.1.3. Pros and Cons

The traffic calming measures like providing dedicated bicycle lanes and reducing motorised traffic lanes, priority to public transport encompasses an effective urban transport system. It increases the usage of bicycle and public transport without having real disadvantages for car traffic. It is also effective in reducing vehicle speed by speed humps, rumble strips, roundabouts and mini-circles.

The traffic calming measure is however an expensive measure which is normally applied with the combination of engineering, enforcement and educational measures. This requires sufficient funding mainly to provide infrastructure, install traffic control devices and employ traffic personnel. It generally produces best results in well-planned cities or urban agglomerations of relatively small size like in the case of Hilden.

3.2. Carpooling

3.2.1. Description

Carpooling is a strategy now being implemented across various countries to reduce congestion. It is the grouping of travellers sharing a single car, so that more than one person travels in a car. The common trips are ensured either by car or van. This could be arranged in two ways. The first one is mostly carried out by strangers where the announcement of carpooling is made by a driver through public websites or closed website schemes and passengers respond to his/her announcement by confirming it. This is arranged such that the one person drives all the time, while the others join him/her by paying travel cost. The second one is commonly performed by office colleagues or friends who have common destinations. This is arranged such that everyone involves in alternate driving and so they do not exchange money.

3.2.2. Application

Roughly, there are about 1000 car sharing cities around the world.[14] Though car sharing system is common in United States, United Kingdom and other countries in continental Europe, it is also getting popular in China. Beijing and Shanghai are the examples. China is well developed prior to motorization period. Industrial collaboration with developed countries laid the city to be the automobile-manufacturing centre of the world. China's economic growth has been reflected by increased private vehicle ownership and accelerated urbanization (Shaheen and Martin 2007).

The increased negative impacts of car use on urban air quality and energy security forced the Chinese Government to relook into their earlier policies. This led to the encouragement of public transportation, providing alternative fuels, and implementing travel demand management tools such as car sharing. The rate of private vehicle ownership in Beijing is 11 per cent with 1.8 million private vehicles spread among 15.8 million people (Beijing Municipal Bureau of Statistics 2007). Shanghai is the developing megacity with 17 million people. Vehicle ownerships in Beijing and Shanghai are 212 and 77 vehicles per 1000 capita in 2009 (Hao et al. 2011: 1016). There is a considerable growth in motorization and demand for auto ownership. The traditional car sharing system is a new concept in China. Hence, there exist only two car sharing operators in China namely EdoAuto and Dazhong. EdoAuto is located in the suburban regions of Beijing. Their operation resembles the traditional neighbourhood car sharing model. It has 60 members and six vehicles. The EdoAuto network is about 20 km away from the centre of Beijing. It is a private company that does not have direct relation with Government.

On the other hand, the Dazhong system in Shanghai offers services with support from Government. They are also called as taxi-sharing, in which the driver is supplied by the company. People should make online reservations when they like to make trip. They could be shared by strangers. In the early period, the entry of Dazhong into car sharing market was experimented with only four vehicles. But now the company has almost 20,000 vehicles operating in Shanghai, which also incorporates bus transit and real estate development. A recent survey was conducted in Beijing (2006) and Shanghai (2008) about car sharing familiarity. 38 per cent (i.e. 317 out of 800) were familiarised with car sharing system in Beijing and 53 per cent (i.e. 144 out of 271) were familiarised with car sharing system in Shanghai. As China has its unique features: Large country with an emerging economy, findings suggested that car sharing, a new concept could be different from traditional one applied in Europe and North America. However the main aim of car-sharing would be same as motorized countries: To reduce vehicle ownership, to discourage the demand for parking spaces and act as a strict metering of costs that provides an incentive for people to drive less, thereby increasing mobility.

3.2.3. Pros and Cons

On the one hand, carpooling may cut down the travel cost for passengers as they share the ride with group of people and on the other hand, the drivers can split the travel cost (fuel, parking and maintenance cost) with the passengers. In many motorized countries, the carpoolers can avail the facility of reserved lanes. Also carpools decongest the roads and help in reducing carbon dioxide emissions thereby reducing global warming. Though carpooling does not require large scale infrastructure, the carpooling signs and assigned location are more significant for a driver to pick and drop passengers. The carpooling becomes a burden to driver in case of special events like accident, vehicle repair, snow or flood. The carpooling will be burden to passengers when the driver is not reliable or not punctual. In general carpooling requires a relatively high level of self-organisation and trust between citizens thus it is not universally applicable.

3.3. Congestion Pricing

3.3.1. Description

The traffic congestion is a negative externality created in urban areas especially during rush hours. Congestion pricing is a measure to surcharge users of a transport network in periods of peak demand to reduce traffic congestion. It originates from market economics theory. The theory states that users will be forced to pay for the negative externalities they create, making them conscious of the costs they impose upon each other when consuming during the peak demand, and more aware of their impact on the environment. The scientific contribution of both Vickrey (1955) and Walters (1961) on congestion pricing theory overcomes the practical barriers to implement in the form of road pricing. The pricing mechanism includes the congestion costs. The optimal congestion cost is the point where marginal external cost is equal to the marginal social benefits. The marginal external cost is the increasing function to the number of people using the same road whereas marginal social benefit is the decreasing function to the number of people using the same road.

Table 1. Potential Congestion Mitigation Measures – An Overview

No.	Congestion Mitigation Measures	Mechanism	Countries/Cities
1	**Traffic Calming** This measure is intended to slow or reduce motor-vehicle traffic in order to improve the living conditions for residents as well as to improve safety for pedestrians and cyclists	EEE measure: Engineering measure – Speed humps, Enforcement measure – Vehicle activated signs for speed limit, Education measure – Awareness among school children and students	Germany, Austria, Spain, France, The Netherlands, Poland
2	**Carpooling** It is the grouping of travellers sharing a single car, so that more than one person travels in a car	Car sharing between strangers or office colleagues or friends through website or newspaper advertisements or through other media	United States, United Kingdom, Germany, China
3	**Congestion Pricing** It is system of surcharging users of a transport network in periods of peak demand to reduce traffic congestion	Pricing mechanism to charge the users for the negative externalities generated by the peak demand in excess of available supply	Singapore, Hong Kong, United Kingdom, Sweden
4	**Staggering of working hours** It is the process of adjustment in arrival and departure time of employees	Flex-time, Compressed work week Staggered shifts	France, New York
5	**Lane Differentiation** It is the measure to make better use of existing infrastructure and to limit the impacts of congestion public transport.	High Occupancy Vehicle (HOV) Lanes, High Occupancy Toll (HOT) lanes, Lanes differentiated based on performance characteristics	United States, Netherlands, Australia, India

3.3.2. Application

Congestion pricing was first practically applied in Singapore in 1975. Later it was implemented in France in 1992 and in California in 1995. Congestion pricing policy was included in three countries: in Singapore as area License Scheme, in Hong Kong as electronic road pricing trial and in England as Congestion-Specific Charging for Cambridge (Gillen 2008). Congestion pricing is basically applied in two forms: road pricing and parking pricing. Road pricing involves cordoning off a section of the centre city and imposing a fee on all vehicles that enter it and parking pricing includes the costs of on-street and perhaps off-street parking of vehicles (Larson and Sasanuma 2010). Road pricing was adopted in London, Singapore and Sweden and parking pricing was adopted in Tokyo.

3.3.3. Pros and Cons

It is suggested that congestion will be noticeably reduced by charging the people for creating the problem (very much in line with the "polluter pays" principle in the environmental law). The profit from congestion charging could be used for enhancing public transport infrastructure and this in turn results in modal shift from passenger car to bus. This reduction of traffic will ensure the smooth flow of traffic in the city and consequently improve the air quality. During the initial period, the public acceptance of congestion charging in a city may be difficult as it require sufficient time for people to get rid of the feeling that they are fooled as they have to pay and drive. Moreover, the congestion charging like many other pricing schemes creates an inequality among rich and poor, as the most privileged members of a society can keep using the car while the underprivileged ones who cannot afford the charge are forced to use other means of transport.

3.4. Staggering Working Hours or Flex-time (F-T) Work Hours

3.4.1. Description

Every city has a typical traffic situation where a number of people want to arrive at the same place at the same time. This leads to increase in concentration of arrivals that reduces travel speeds; increases congestion levels and reduces road capacity. The Flex-time work hours was introduced in 1960 and later modified by Vickrey (1969) and Henderson (1974). The basic idea is to have differing work schedules or flexible starting and quitting times. Hence the desired arrival times and arrivals would be distributed and reduce the concentration of vehicle arrivals. The flexitime concept could be adopted in workplaces, schools and colleges. It could make ridesharing and transit use more feasible. There is also another concept called Compressed Workweek (CWW). In this, the employees work fewer but longer days and take one or two days off, such as four ten-hour days each week, or nine-hour days with one day off every two weeks. Flex-time and CWW assist employees to meet other household activities. This reduces their commuting time and stress.

3.4.2. Application

In 1955, Flex-time was first adopted in Metz in France among workers and school children. A public campaign was made to inform workers and school children about their flexibility in departure and arrival time. In response to the public campaign, children started 15 minutes earlier to school and return home 15 minutes earlier than before and factory, shop and office workers started 15 minutes later to work and arrive 15 minutes later to home. As a result, the transport corporation benefits from the reduced congestion cost and hence they did not raise fares (Maric 1977). The staggering of working hour programme was implemented in 1970 in Manhattan, New York (Kuzmya 2010). The main aim is to effectively spread demand for public transport facilities in Lower Manhattan. The new road facility was packed with this increase of private cars. This necessitates the adoption of flexitime concept in order to use the existing infrastructure more efficiently. The employees were given a choice of staggered start times from 8.30 am to 9.30 am with finish times between 4.30 and 5.30 am. The chosen start time is the daily start time. They could re-negotiate the chosen start time if required. For instance, if an employee wishes to start by 8.45 am then he/she should agree to return by 4.45 am. As a result, the substantial and continuing reduction in congestion in the peak period has been observed.

3.4.3. Pros and Cons

The congestion associated with simultaneous arrival and departure of workers at the workplace is greatly reduced due to staggering of working hours. The workers could carry out their personal or family obligations without work pressure. The travel time saving could be enjoyed by the workers with increased speed of vehicles.

The regular departure and arrival time is only staggered to different time and hence there might be the case that the congestion is not completely reduced. The success of this measure highly involves the travel time preferences of people such that working time is not again concentrated but staggered between them. In addition to this, there are some administrative inconveniences involved in record keeping system of employees.

3.5. Lane differentiation

3.5.1. Description

Lane differentiation is the process of directing the different classes of road users to their respective lanes on road. This could be achieved through pricing or regulation mechanism (Harvey 2005: 1). Each road user is informed about their right of way to travel in their respective lanes. The information is made either by display messages or by lane markings on road. Lane differentiation is applied in three different forms: High Occupancy Vehicle (HOV) lane, High Occupancy Toll (HOT) lane and Bus only lane. HOV lane is also known as carpool lane. This lane is particularly reserved for vehicles having maximum occupancy. HOT lane is road pricing scheme that allows single-occupant vehicle to use the HOV lane by paying congestion cost. Both HOV and HOT could exist as separate roads or combined form in a single road. Bus only lane is the lane exclusively reserved only for public transport bus. It is designed to avoid the congestion externality on public bus created by private vehicles during peak hours. In different from these three forms, a simplified form of lane differentiation called lane driving is also applied. Lane driving is a concept of differentiating vehicle based on size and speed by demarcating lanes. The practical application of all the above forms is discussed in the following section.

3.5.2. Application

HOV and HOT lanes are common in United States and Netherlands. A proposal for HOV lanes was made in 1977 and later updated in 1981 in Washington DC. The final proposal was published in 2003. HOV projects are mainly focused on three main objectives: to increase the average number of persons per vehicle, to preserve the mobility of the vehicles and to enhance the bus transit operations (Turnbull et al. 2006). In Northern Virginia, HOV is applied in three routes during weekdays: from Capital Beltway to Theodore Roosevelt Bridge in Interstate 495, Route 234 in Manassas to Capital Beltway (I-495) and from Route 28 to the main toll plaza. The vehicles are moving in two directions in all these routes: eastbound (vehicles moving towards east) and westbound (vehicles moving towards west). In first two routes, the HOV lanes are applied in both the available lanes. In both the routes, eastbound vehicles could avail the HOV facility in the morning (6.30 am-9.00 am) and westbound vehicles could use HOV facility in the evening (4.00 am-6.30 am). In the third route, the HOV is applied in the form of HOT. The far left lane is reserved for HOT where eastbound vehicles are allowed in the morning and westbound vehicles are allowed in the evening. The clean fuel vehicles (hybrid and compressed natural gas) are exempted by allowing single-passenger vehicles. It is observed from findings that the HOV lane has created significant increase of Hybrid vehicles, there is a potential time saving realised on this HOV lane and the environmental consciousness is increased among people. However, the HOV lanes are also criticised for its inequality among the usage of private and public vehicles: increased usage of carpooling and decreased usage of public transport bus.

3.5.3. Pros and Cons

Both the HOV and HOT lanes encourage carpooling. This may inherit the benefits from carpooling measure like decongestion and travel cost cutting for carpoolers, etc. Bus lanes may reduce the congestion externality created by private vehicles and help in saving travel time. This may influence people to shift from their private modes to public modes. The construction of HOV or HOT or Bus lanes requires more road space and involves high costs. Sufficient awareness has to be made among vehicle users to rightly use the lane. The role of institution also plays a significant role to enforce the restriction of other vehicles.

From the above review, it is observed that each measure has its own advantages and disadvantages. There is a need to understand their constraints in order to gain potential benefits from preventive measure of these strategies. This necessitates the critical assessment of each measure. The traffic measures are traditionally evaluated using economic approaches that involve net present value of cost and benefits of the measure. The measure is implemented if their net present value of cost is less than net present value of benefits. Though this way of economic evaluation of measure is required for implementation feasibility, the longevity of this measure is determined mostly by behavioural interventions of people and institution of traffic control system. The following section provides a hypothetical assessment of the above measures pertaining to the physical infrastructure, behavioural and institutional parameters.

4. Hypothetical Approach: Scenario Analysis of Potential Congestion Abatement Measures in Hyderabad

Although the authors argue that measures and policies transplanted from one context to another are doomed to fail, they found challenging the idea of constructing several scenarios based on the measures discussed above and their hypothetical implementation in Hyderabad. Aim of this exercise was not to highlight the rather self-evident importance of local conditions, norms, traditions and institutions to the success of any policies implemented, but to facilitate the identification or perhaps even reveal those determining conditions of success or failure and thus show the way for future research with policy relevance. With this purpose in mind, the above mentioned strategies, namely traffic calming, carpooling, congestion pricing, flexitime and lane differentiation are hypothetically implemented in Hyderabad. The plausibility of each measure and the suitability to the city conditions is briefly discussed in the following scenarios, with the main burden on lane differentiation as this particular measure has been judged as the most promising.

Scenario 1: Can we Calm the Traffic in Hyderabad?

The implementation of traffic calming measures may convert congested streets in to liveable street. Nevertheless they require three important aspects to be improved: engineering, enforcement and education.

These three aspects are interdependent with each other. Hence lack of improving one aspect may affect the other two aspects. This involves higher cost for its implementation and maintenance in the city. Thus, in reality it might not be feasible to encompass the whole Hyderabad city with seven million inhabitants.

For instance, if bicycle lanes are provided with sufficient information signs for bicycle riders to use the lane but if enforcement is weak to restrict the motorised two wheelers on bicycle lanes, then the bicycle lanes will function as two wheeler lane and discourage bicycle riders by allowing them not to use the lane. In this way, the whole idea of encouraging bicycle riders through traffic calming could not be effective when adopted in the city. The peripheral growth in the city also makes bicycle less feasible as the distance that needs to be covered is considerable especially given the varying climatic conditions (heat waves, monsoons etc).

Scenario 2: Carpooling in Hyderabad?

In particular, it highly attracts the middle-aged group of people that mostly consist of the working and students section. There are two methods discussed in section 3.2. In the first method of driving among strangers, the reliability and the safety are the main concerns in Hyderabad as interviews by the authors reveal. For instance, if the driver is late or one of the passengers is late, then everyone needs to wait which involves considerable time cost for all passengers. There is also risk of cancelling the trip by the driver due to unavoidable circumstances such as accident or problem with vehicle, increasing the uncertainty of the whole scheme. In the second method of driving among colleagues or friends, it is arranged in a way that everyone participating in the scheme necessarily should own a car. But owing a car is often a good incentive to use it alone. As there is interdependence prevailing among participants, for example one has to necessarily leave for work immediately when the driver picks him up, an extremely high level of self organisation and punctuality is required, conditions which are not always the case amongst employees in Hyderabad.

Scenario 3: Pay or Stay

The success of congestion pricing measures greatly depends on congestion toll. If the congestion toll is too high, then drivers may be induced to change their route or mode or time. If it is low, then drivers are encouraged to use their private vehicles to make use of the low tolls. This necessitates the importance of optimum toll to be designed in accounting the variation in demand. The creation of optimal toll is practically not feasible in the city unless it account the behavioural response of drivers beforehand. Since the city consist of highly diverse groups of people (high, middle and low income groups), the measure may increase the inequality among the low income groups of people as the congestion charge takes a higher percentage of their income in tax. In a context where fighting against poverty constitutes a high priority in the field of regional and national politics, such schemes may be simply impossible from the political perspective. Even if implemented they may create social unrest due to the injustice they embed.

Scenario 4: Introduction of Flexitime Concept in Hyderabad
This flexitime concept is generally targeting certain working groups. The balance of flexibility and schedule of priority are the two main indicators to avoid conflicts in time. This necessitates the creation of awareness among people in regard to flexitime on one hand and receiving the response in the form of public acceptance from them on the other hand. If this is not achieved, then the application of flexitime will only shift the congestion from a certain rush hour to another rush hour in the city. Also the transaction costs involved in such a scheme may be so high in a chaotic situation like in Hyderabad that the implementation of flexitime might be impossible purely from the economic perspective.

Scenario 5: Lane Differentiation instead of Lane Splitting
There are three main concerns associated with both HOV and HOT lanes when adopted in the city. First, the sufficient road space is required to provide the infrastructure for HOV and HOT lanes exclusive for carpools or bus. Second, the current traffic enforcement system in the city includes no advanced technology to count the number of vehicle heads inside the passenger car. This may increase the rate of violation. Third, the congestion management by these lanes may not be sustainable over the long period, as the congestion varies with respect to time and location in the city. Hence the implementation of HOV or HOT or Bus lanes may not be practically feasible.

However when compared to other mitigation measures discussed above, this measure could be fairly suitable for countries having heterogeneous vehicles. When this measure is applied, the lane discipline among vehicle drivers can be improved, as each one aware of their own lanes. In developing countries like India, lane differentiation can be applied in simpler form such that the existing road space is effectively utilised by heterogeneous vehicles. Recently, Chandigarh has adopted this simplified form. It is called lane driving system. The existing road with some improvements in segregation is made. The single unit of road is divided into three lanes: right, middle and left lane. The right lane is allocated for fast vehicles, the middle lane is for the heavy vehicles such as buses and trucks and the farthest left lane is for small vehicles and slow vehicles.[15]

On the one hand the system really helps to regulate the flow of traffic but on the other hand people are not well informed about the system. The lessons learnt from Chandigarh is that sufficient awareness should be made by traffic personnel by conducting lane driving campaign otherwise there are chances of violation of the differentiation of lanes. For instance: In Chandigarh, the lane demarcations are indicated by road lane markings on left, middle and right lane rather than displaying lane demarcation message sign board and two wheeler or car or bus drivers could not see the lane markings on road when they travel at certain speed and hence they are unaware of their respective lanes.

The SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis (Fig. 3) has been carried out for the lane driving system measure. The strength and weakness are the internal factors within the measure while the opportunities and threats are the external factors of the measure concerning environment.

Strengths (+)

- Effective road space utilisation between heterogeneous vehicles
- Reserved lanes for Bus could be made
- Lane splitting is avoided by small size vehicles
- Safer roads
- Increased vehicle speed and reduced travel time

Weaknesses (-)

- Limited road infrastructure for lane differentiation
- No awareness among vehicle drivers about its usage as it is totally new concept
- Inadequate traffic control systems to sanction violation of drivers between lanes
- Incomplete monitoring or feedback mechanism regarding the behavioural response from people to influence change

Opportunities (+)

- Equitable allocation of road space policy could be adopted
- 'Stick to lanes' traffic rule could be enforced
- Conflict points may be reduced among vehicles
- Smooth flow of traffic is ensured
- Lane discipline can be improved among vehicle drivers
- Feedback mechanisms could be developed to assess and improve the utility of the measure

Threats (-)

- Resources Required (Skilled man power, time and money)
- Political will and Stakeholder support (to implement)
- Uncertainties involved (travel time delay or accidents may occur during construction phase, people may or may not protest, implementation cost may exceed)

Fig. 3 SWOT analysis for Lane Differentiation Congestion Mitigation Measure
Source: Own

The strength of the measure is analysed in terms of benefit of the measure to the vehicle drivers in terms of reduced congestion. The weaknesses are the constraints of the measure like weak limited road space, institutions, and absence of feedback mechanism to assess the behavioural response. The opportunities are the improvement of the transport environment like policies, traffic rules, and smooth flow of traffic by using this measure. There will be risks or threats associated like resource requirement, political will or uncertainties such as accident or protest against this measure. Thereby adopting lane driving system in India by overcoming their weakness by strength and threats by opportunities necessitates broader scope in future.

5. Conclusions

Initially, the paper presents an overview of the traffic congestion under macroscopic and microscopic level in Hyderabad. The microscopic analysis of congestion shed light on disproportionate road space utilisation. This is followed by the state of art review of potential demand based congestion mitigation measures including case study application around the world. The merits and demerits of each measure has directed to the scenario analysis under hypothetical application in Hyderabad. Out of the five measures, it is observed that lane differentiation measure is the most promising measure to be considered in order to address Indian heterogeneity in vehicles in a simplified lane driving system. This has directed to SWOT analysis of lane driving system to identify the focus of improvement and open areas for further research.

As an overall, it is observed that the longevity of the traffic measures is underpinned by the greater acceptance by the local community of the city. In other words, the traffic management measures are city specific that depends on the indigenous factors of the city. The indigenous factors include the physical structure of road network, intensity of development, traffic characteristics, enforcement measures and socio-economic details of community: household numbers, their occupation, their income, their vehicle mode, their origin and destination. Hence the traffic measures which are successful in one city could not be appropriate or successful in another context. It is also observed that in Hyderabad, the traditional system in addressing the congestion is the supply based traffic measure.

This means that plans mainly focus on physical interventions like increasing the road capacity and neglect the importance of effective traffic regulation, i.e. the rules and traffic policies in managing private car usage. This may in turn increase the vehicle demand exponentially with respect to road capacity and result in more traffic congestion. This congestion becomes severe when these supply-based measures are directly implemented in practice without providing the opportunity to the actual road users offering feedback beforehand. As a consequence, both road capacity and introduction of traffic rules could suffer from behavioural response of people after it is practically implemented and thus too late to be changed. This involves a huge cost for the government after implementation: To reconstruct or construct the new infrastructure, to deploy the traffic control mechanisms and to provide information to people in the real world and not in the fiction of planners.

Hence there is a straightforward conclusion, still very elusive to the policy making arena: Traffic and transport create a very complex system , which consists not only of traffic regulations but a whole array of institutional constraints, in addition to the physical constraints and to crucial behavioural aspects of the road users. These form the trinity that determines the performance of any traffic measure in the long run. As long as Hyderabad transport planners and policy makers are not to take these equally important parameters into account in the process of long-term planning, traffic congestion abatement measures are to remain an elusive Indian midsummer night's dream.

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10 Aggressive driving can be defined as any form of behaviour that is intended to injure someone physically or psychologically.

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