Exploring Transportation Demand Management as a Strategy to Decongest Indian Cities and Improve Mobility

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Abstract: Indian cities are known for their notorious traffic congestion and limited mobility. Increasing per capita income and urbanization are further aggravating the already constrained situation and results in hazards like environmental pollution, accidents and health risks. One of the major reasons for the urban congestion problem is the increasing use of private vehicles. This study addresses the problem of congestion by introducing Transportation Demand Management (TDM) strategies. TDM encourages people to shift from private vehicles to public transport modes like mass transit and buses. In this research the Jaipur Walled City is analysed for the empirical research. The research employs an aggregate Logit modelling for analysing modal choice probability. For the purpose of modelling, data is collected by a mix of primary and secondary surveys. Based on the findings, this research discusses strategic interventions in four sectors – road space redesign, public transit improvements, use of MRTS and parking arrangements.

1. INTRODUCTION

“It’s no secret that the good days of the automobile are over. In 2009, we saw the peak of driving in the world, and it’s on the way down.” - Jan Gehl

Rising traffic congestion is an inescapable condition in all the large and growing metropolitan areas across the world (Downs, 2004). Today’s Indian cities are also experiencing similar threats from excessive congestion and environmental pollution. Excessive travel is not only generating jammed roads, but also causing undue energy usage, unwarranted carbon emissions and frequent road accidents (Pojani & Stead, 2017). In 2015, the World Health Organization (WHO) rated New Delhi, the capital of India, as the world’s most polluted city (Times of India, 2015). With its growing population and rising number of private vehicles, the situation is likely to deteriorate further in the near future. In India, inadequate public transport is failing to meet the mobility needs of urban areas (Airy & Chandiramani, 2016). Mobility creates access to opportunities for advancement of individuals and communities as a whole. Greater mobility does not mean
more traffic (BMZ, 2016), and in fact precisely means the exact opposite. Mobility includes movement of people and vehicles in conjugation with pedestrian and non-motorized transport (NMT).

A conventional supply-based approach to moderate urban traffic congestion problems is proving to be ineffective, as is evident from the current transport condition in Indian cities. Roads and transportation services occupy 21% of land in New Delhi, and yet it experiences acute traffic congestion. Mobility crises begin to build up in cities where a large share of daily trips is made by personal vehicles that occupy more road space but carry fewer people, pollute more and edge out walking, cycling, buses and intermediate public transport (Chakrabarty & Gupta, 2014). The automobile-centric planning that focuses on road widening, construction of additional roadways and flyovers, and foot overbridges and underpasses are only prompting increased use of private vehicles in New Delhi. This is despite the fact that private vehicles fulfil less than only 20% of the transport needs of the city (MoUD, 2015a). This growing dependence on personal vehicles is already showing one of its worst impacts—gridlocked roads and reduced mobility in spite of the additional supply of transit infrastructure (Chakrabarty & Gupta, 2014).

The present approach of supply-based traffic solutions is causing induced demand of transportation due to a phenomenon called the ‘principle of triple convergence’. Downs (1992) in his book mentioned the triple convergence phenomenon, which occurs due to information dissemination. The triple convergence causes more automobile users to use the improved transit facilities during peak hours. The traffic volume continues to rise until vehicles are once again moving at a crawling speed during the peak hour (Downs, 1992). Assuming that people minimize their travel time, three behavioural responses occur immediately following a road improvement. First, drivers who were using other routes switch to those incorporating the newly improved road (i.e., spatial convergence). Second, drivers who were traveling at off-peak periods switch to the peak (i.e., temporal convergence). Finally, public transport users switch to driving their automobiles (i.e., modal convergence). As more and more drivers use the improved road, traffic volumes rise until congestion, once again, manifests itself (Scott, 2003). Even some commuters who use public transportation might start using this route during peak hours. This will continue happening until an equilibrium is achieved. As a result, the traffic flow becomes ‘self-adjusted’, and results in a wider, but equally congested highway (Downs, 1992). The triple convergence is a rough equilibrium reached in peak periods between the best and the alternate routes. It is often used to discount the supply-side approach that favours adding new transit infrastructure like roads, highways, over-bridges, and underpass etc. (Kornhauser & Fehlig, 2003).

It is difficult to build our way out of congestion. Moreover, augmenting physical infrastructure has limitations of time, space, and capital. Hence, the primary necessity is to manage travel demand efficiently rather than augment supply irrationally. Accepting the case of triple divergence, triple divergence strategies include road pricing, and other alternative demand management approaches as the only congestion reduction strategies (Kornhauser & Fehlig, 2003).

Since private vehicles are causing major traffic chaos, both ownership and usage of private vehicles need innovative solutions to address the issues of traffic congestion. Passenger car ownership in India will witness a rise of 775 percent over the next 24 years with the number of vehicles going up from 20 per 1,000 inhabitants to 175 per 1,000 inhabitants (PTI, 2016). The
‘Transportation Demand Management’ (TDM), which consists of a wide range of policies, programs, services and products influencing why, when, where and how people travel, is a viable alternative transportation solution. The Planning Commission (2012) raised concerns over the present state of unsustainable urban transportation and the need to shape travel demands for achieving an efficient, effective, equitable and sustainable transportation system. TDM offers four approaches for managing travel demand – a reduction of travel demand, shift travel demand to non-peak periods, divert travel demand to alternative routes, and shift travel demand toward alternative modes of transport. This study will focus on TDM strategies that can influence travellers to shift away from their private vehicles to instead use sustainable transit and reduce congestion. The objectives of this research are:

a) to understand TDM impact on limiting traffic congestion and enhancing mobility;
b) to assess the implementation of TDM strategies and resolve traffic congestion; and
c) to validate TDM strategies as a relevant solution to decongest Indian cities and improve mobility.

The study is divided into five sections. Section 2 reviews the existing literature and theories of TDM. This section contributes to establishing a theoretical understanding of TDM and its impacts on mitigating traffic congestion. This section also introduces the study area and details the areas of empirical analysis. Section 3 explains the analysis techniques and the data collection methodology. Section 3 connects to Section 4 where the data analysis process and inferences from this analysis are described. Finally, Section 5 concludes with remarks and closing comments.

2. LITERATURE REVIEW

This literature review section starts with the definition, principles, strategies, benefits, and types of TDM to improve mobility and reduce mobility of a city. This section also discusses the use of demand management over the conventional supply-side management of mitigating traffic congestion and improving mobility in Indian cities.

2.1 Definitions

Mobility is a locational advantage that creates safer and attractive cities for the drivers of economic growth (BMZ, 2016). Improving mobility and reduction of congestion through travel demand management strategies occurs by reducing demand caused by single occupancy vehicles in a transportation network. It is also practiced to reduce highway congestion. A regional approach to travel demand management can improve transportation performances by reducing highway congestion and traveller delays, enhancing air quality, and enabling access to jobs, schools, and other opportunities (Rodriguez, 2009). Travel demand management is designed to maximize mobility by increasing the number of persons in a vehicle, and by

1 As per the literature, TDM stands for both Travel Demand Management and Transportation Demand Management. However, for the purpose of this paper, TDM shall refer to Transportation Demand Management.
influencing the time or need of travel (Teets, 1995). Travel demand management alters travel behaviour to increase transport efficiency and achieve specific planning objectives (Litman, 1995). The ‘Institute of Transportation Engineers’, Washington, in its publication on ‘Intelligent Transportation Primer’ defines travel demand management as the application of strategies and policies to reduce travel demand, or to redistribute this demand in space or in time (Nelson, 2000). The demand management strategies can be categorized into two divisions - mandatory and voluntary. The mandatory strategies control demand for road use through a set of rules or disincentives, and the voluntary strategies commence with the people’s preference to choose activities and reduce travel demand. Examples of the voluntary strategies are flexible work arrangements, compressed workweeks, rationing of cars, etc. Rule-based mandatory strategies include most of these voluntary strategies if they are mandated, i.e. flexible work schedule or 4-day work-weeks, license plate rationing, etc. The disincentive-based mandatory strategies include road pricing, variable toll rates, and variable parking rates, etc. (Machemehl et al., 2013). A proactive travel demand strategy enables the urban transportation system to be more efficient, effective, equitable and sustainable (Planning Commission, 2012).

### 2.2 TDM Strategies

TDM strategies vary from pull strategies to push strategies. The pull strategies incentivize or attract travellers to use sustainable modes of transport, and the push strategies discourage them from using the unsustainable modes of transport. Generally, the pull strategies are balanced with the push strategies to achieve an effective travel demand management solution. Many global cities have successfully implemented TDM strategies to mitigate traffic congestion issues. Cities like Barcelona, Seoul, and Singapore have successfully implemented TDM strategies to decongest their urban centres. The city of Barcelona used superblocks as a unit of its TDM strategy. It applies push factors like one-way roads, speed limits and no through-traffic, and pull factors like open areas and underground parking. Seoul city applied push factors, like a congestion impact fee system and parking lot restrictions, and pull factors such as company incentive programs. The island nation-city of Singapore implemented push factors like car taxes, an area licensing scheme, vehicle quota system and weekend car system, and pull factors like a mass rapid transit network (MRTS). Table 1 below shows a cumulative strategy matrix, classifying TDM strategies into nine categories ranging from pull to push measures.

| TDM Category | Examples Of TDM Strategies |
|--------------|-----------------------------|
| Pull 1 Improvement In Alternative Modes | Cycling Improvements, Pedestrian Improvements, Shuttle Service, NMT, Public Bike System, Car Sharing, Transit Improvements, Complete Streets |
| 2 Planning- Integrated Land Use And Transport | New Urbanism, TOD, Car Free Planning, Land Use Density And Clustering, Location Efficient Development |
| 3 Workplace Based Instruments | Alternative Work Schedules, Flex Time, Teleworking, Commuter Financial Incentives |
| 4 Travel Behavior Change Programs | Transit, Walk And Cycling Encouragement |
| 5 Information Programs | Multi Modal Navigation Tools |
2.3 Benefits of TDM

TDM offers certain benefits over conventional supply-based methods of traffic management. The benefits are the following: Firstly, it facilitates efficient land use that encourages transit-oriented development, walkable neighbourhoods, and reduces the travel need and travel distance. Secondly, it helps to reduce congestion by limiting travel demand and distributing it over time, space, or alternative modes of travel. Thirdly, it enhances transportation diversity of travel modes and its connecting networks. This diversification facilitates travellers with a wide array of transport modes, as per their preferences and requirements. Fourthly, it helps to achieve improved traffic safety through the reduction of private vehicles and increased use of public transport and NMTs. Fifthly, it improves user convenience within the transportation system, for people traveling across all modes of transport. The strategy like road space reallocation benefit pedestrian and NMT users often dominated by private vehicles. The transit improvement strategies provide better comfort, convenience, and safety both to the pedestrians and the public transport users. Sixthly, it augments energy conservation through the reduced use of private vehicles. Seventhly, it reduces pollution by encouraging more sustainable modes of transport like walking, NMT, and public transit. The pollution free environment improves people's fitness and health by encouraging them to walk, cycle and use other NMT modes. This also results in enhanced physical activity and improved health. Finally, it helps to achieve consumer cost savings through the consumer’s preferential choice of travel mode, based on their financial capacity. Consumers can also choose their travel time and routes to reduce travel cost. This also contributes to roadway cost savings through reduction or postponement of the need to add new roadways. It also utilizes available transport infrastructure to its maximum capacity and therefore saves on infrastructure development costs.

TDM helps to address transportation problems either by diverting the travel demand over alternative modes of transport, timings or routes, or by reducing the need to travel. It not only eases congestion but also serves various other benefits such as cost savings, revenue generation for the improvement of transport facilities, traffic safety, energy conservation, reduced pollution and promotes fitness among consumers. The benefits of TDM strategies are presented in the following table (Table 2).

| Planning Objective (1) | Expand Road Capacity | Increase Fuel Efficiency | Mobility Management |
|------------------------|----------------------|--------------------------|---------------------|
| User convenience       | ✓                    | -                        | ✓                   |
| Congestion reduction   | ✓                    | ✓                        | ✓                   |
| Roadway cost saving    | ✓                    | ✓                        | ✓                   |
| Consumer cost saving   | ✓                    | ✓                        | ✓                   |
| Transport diversity    | ✓                    | ✓                        | ✓                   |

*Table 2. Benefits of TDM over conventional methods of addressing traffic problems*
| Planning Objective (1)          | Expand Road Capacity | Increase Fuel Efficiency | Mobility Management |
|--------------------------------|----------------------|--------------------------|---------------------|
| Improved traffic safety        | X                    | X                        | ✓                   |
| Energy conservation            | X                    | ✓                        | ✓                   |
| Reduced pollution              | X                    | ✓                        | ✓                   |
| Efficient land use             | X                    | X                        | ✓                   |
| Improved fitness and health    | X                    | X                        | ✓                   |

Source: (Litman, 2016)

In order to establish a case for TDM strategies in Indian cities, this research identifies the city of Jaipur for empirical research. The reasons for selecting Jaipur city for empirical research are several. Firstly, it has a persisting congestion problem that chokes the city. The absolute population and density have resulted in acute congestion, which are further aggravated by other underlying factors such as the concentration of commercial activities, tourism, and a growing city population. Secondly, increasing vehicle ownership and use of private vehicles in the city. Thirdly, poor condition of public transport. Fourthly, the city’s size and its underlying contexts, which represent typical expressions of the existing problems of Indian cities. Fifthly, its proximity and approachability for collecting data and carrying out primary surveys. The details about the study area are presented in the next section.

2.4 Study area

Built in the year 1727, the Walled City is the historic centre of Jaipur. It continues to be a significant part of the city (Jawaid et al., 2017). It is a bustling central business district (CBD) that facilitates more than 60% of the commercial activities of the city (MacDonald, 2015). The built forms are a combination of commercial, residential and heritage structures. Almost 97% of tourists and visitors come for a stopover at the Walled City (Jaipur Smart City Ltd, 2018). The 6.7 sq. km. area of the Walled City was initially designed for a population of 50,000 people. Today, the population of the Walled City is about 400,000 people with an average population density of 58,207 people per sq. km (Jawaid, Pipralia, & Kumar, 2016) (Figure 1).

![Figure 1. The study area of Jaipur Walled City (JDA, 2011)](image)

Being a historic city, the Walled City experiences various transportation related issues. Traffic congestion, pollution, intermixing of the fast- and slow-moving heterogeneous traffic, lack of lane discipline, parking chaos, and uncomfortable street experiences create much of the traffic problem
within the Walled City due to a variety of factors. Being the CBD, the Walled City attracts excessive influx of passenger and commercial vehicles - private, public and intermediate paratransit. A high number of low-floor buses clog the roadways due to their slow pace, big size, and repeated halts. Excessive growth in commercial and retail activities, along with a drastic shift of land use, also augments traffic congestion, delays, and extremely low travel speed within the travel area. Increased socio-economic ability coupled with inadequate public transportation accessibility has resulted in the drastic growth of private vehicle ownership. It not only creates a traffic bottleneck but also creates extreme parking difficulties within the Walled City area. Air and noise pollution, and environmental degradation of the Walled City area are the direct consequence of the traffic congestion.

The wholesale and retail commercial activities within the Walled City premises create an additional demand for warehousing and logistics operations. Goods vehicles like mini trucks and pick-up cars move within the Walled City area during peak hours in the daytime to meet this demand. It causes a major slowdown of traffic and mobility, particularly during loading and unloading activities. Besides, mobility through intermediate public transport (IPT) vehicles causes traffic jams due to their slow speed, eccentric travel patterns, and excessive space requirements per traveller. The absence of appropriate regulations, non-enforcement of traffic rules and missing institutional control over goods vehicles and IPTs are further deteriorating the travel situation.

High parking demand, especially for cars, is another major traffic problem. In addition to the designated off-street parking locations, a continuous bay parking strip along all the major roads of the Walled City slows down traffic and reduces mobility. The gap between supply and demand for parking spaces increases the on-street parking load that leads to confusion and chaos. Cars can be seen to cruise along the primary roads in the search of parking spaces. It is observed that some people do not even park their vehicle and continue cruising while their co-passengers indulge in shopping. Some people park their vehicles in unauthorized spaces such as on the secondary and tertiary streets. This encroachment creates havoc not only for the residents of these areas but also for those who visit these places for work or business. Similarly, the shaded walkways, which are meant for the pedestrians, are encroached by the extension of shops and vendors (Figure 2 and Figure 3).

The Walled City area is already saturated with land constraints and restricted land use regulations. Therefore, augmenting transit infrastructure like roads, parking spaces and transit amenities are difficult. The state government is constructing an underground MRTS corridor that penetrates the Walled City and connects with the greater Jaipur city region. Once completed, the MRTS corridor is expected to reduce the traffic congestion of the Walled City. However, its true effect on congestion reduction can only be realised once it starts operation. Accessibility of the MRTS corridor and its limited reach only to certain parts of the city may reduce its effectiveness. Congestion due to goods vehicle may continue to be a

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\[1\] In developed countries Intermediate public transport (IPT) is often used as a demand responsive system such as shared-ride taxis and dial-a-ride services. For developing countries, IPT is referred to as a variety of transport modes fulfilling the gap between public transport and private vehicles Ghosh, & Kalra (2016). "Institutional and Financial Strengthening of Intermediate Public Transport Services in Indian Cities". Transportation Research Procedia, 14, 263-272. Examples of IPT in developing countries are auto rickshaw, e-rickshaw, etc.
persisting problem. TDM strategies may become an effective tool for mitigating congestion problems in a constrained environment like the Jaipur Walled City. The present study specifically focuses on TDM strategies, which can mitigate congestion and encourage a modal shift from the private mode of transit (cars and two-wheelers) to the public mode of transit (MRTS and city buses).

![Figure 2. Encroached walkway in the Walled City area (Source: Authors)](image)

Figure 2. Congestion and mix of traffic-stalling traffic and pedestrian movement (Source: Authors)

3. COLLECTION STRATEGY AND MODELLING

The purposes of modelling travel demand are to simulate situations that enhance mobility and reduce congestion. Congestion measurement entails quantifying both the adequacy and quality of transportation systems (Chakrabarty & Gupta, 2014). Modelling of demand implies a procedure
for predicting what travel decisions people would like to make given the
generalised travel cost of each of the alternatives (Mathew & Rao, 2006).
Traditionally, an approach known as the “four-step process” has been used
for regional transportation modelling. As its name implies, this process has
four basic phases: trip generation (the number of trips to be made), trip
distribution (where those trips go), mode choice (how the trips will be
divided among the available modes of travel), and trip assignment
(predicting the route trips will take). In order to achieve the objectives of the
transportation demand management, the research uses two analysis models –
a travel demand model and modal split model. The travel demand model
starts with defining the study area and dividing them into a number of zones
and considering the entire transport network in the system. The database
also includes the current (base year) levels of population, economic activity
like employment, shopping space, and educational and leisure facilities of
each zone (Mathew & Rao, 2006). It informs the travel-related information
within the Walled City area, the transportation trends of the city, including
origins and destinations, traffic volume, different travel modes, and traffic
routes, etc. The modal split model predicts the percentage of trips for each
of the available modes of travel. This research develops a traditional
aggregate model for comprehending the transportation pattern of the study
area. The analysis requires a wide array of data. The following section
further explains the data requirements and the data collection strategy.

3.1 Data sources

The relevant data and potential sources are classified into two categories,
primary sources and secondary sources. The secondary data such as books,
articles, journals, theses, newspapers and public data are collected from the
relevant sources. The data gaps are identified during the collection of
secondary data. The remaining identified data was collected from primary
sources. The secondary study consists of a literature review on
transportation demand management. This paper develops a theoretical
understanding and knowledge through various case studies. Exploration of
the secondary data also provides the necessary information regarding the
data gap and further data requirements. The primary survey also allows the
necessary customization of the survey format and necessary checks on data
quality. Collecting data from primary sources includes both on-site and off-
site modes. The on-site data was collected by visual survey, questionnaire
survey, rapid appraisal, and observation. The data thus collected was
compiled after verification and validation from the web sources and
previous literature. The off-site data was collected from various government
and non-government organizations. The purposes of data collection through
the primary survey were:
- to understand the mobility culture, mode choices and related human
  behaviour;
- to find various choices or behavioural traits that lead to the congestion
  problem;
- to find the variables (e.g. age, gender, health, and climate.) which lead to
  the mode choices;
- to assess the willingness to pay for augmented facilities; and
- to anticipate the expected response of masses, as a reaction to the
  implementation of various TDM strategies.
The data collected through observation includes traffic volume counts, pedestrian counts, semi-public vehicle counts for occupancy, potential mobility conflicts, congestion-related conflicts and their causes, speed and delay survey, road network inventory, street sections, land use data, available parking inventory, goods vehicles, and visitor and tourism networks.

Three types of interrogative surveys are conducted – household survey, survey at commercial enterprises and business establishments, and visitors’ survey.

a) Household survey

For surveying, households were selected by stratified random sampling. The household survey was focused on variables such as residential location, economic status, housing condition, family composition, vehicle ownership, types of daily activities involving travel, modal choices, travel behaviour, health and social indicators.

b) Surveys at commercial enterprises and business establishments

The commercial enterprises and business establishments, including small traders and street vendors within the Walled City area, produce a bulk of the travel need. People working as traders are surveyed at their workplaces. The traders are identified through stratified random sampling. The survey topics focus on the shop-work location, business type, resultant logistic activities, vehicle ownership, travel behaviour and modal choices, etc.

c) Visitor surveys

The Walled City’s visitors consist of the third group of respondents. The respondents include local shoppers, wholesale buyers, and national and foreign tourists. These responses are collected at random locations and places with high footfall. The choices of respondents ensure a balanced geographical distribution of respondents across the city. The survey questions include their place of origin, duration, and interval of travel to the Walled City, frequently visited places, modal choice, travel behaviour, vehicle ownership and parking preferences.

Respondents are surveyed by a set of pre-designed questions. Most of these interviews are conducted in person without any prior appointment. The responses are based on their convenience, memory, and ability to recall past incidents. Some of the responses are collected online through e-mails, the cloud system, and other relevant technologies. The web-based survey form (i.e. Google forms) is used to record some of the respondent’s responses.

3.2 Sampling Methodology

The Walled City is classified in 9 Chowkris (or Districts). Each Chowkri is considered as a stratum for stratified random sampling. Samples at each Chowkri are roughly proportionate to the population of that Chowkri. About 0.01% of the population, approximately 400 samples, are collected from the Walled City area. The types of sampling are further explained in the next sections.

Chowkri is a neighbourhood or community surrounded by major roads.
3.2.1 Rapid appraisals

Rapid appraisal is an efficient and accurate tool to comprehend an urban problem quickly. Rapid appraisals are conducted with various user groups such as cab drivers, traffic police, e-rickshaw drivers, auto drivers, shoppers, residents, and workers. Rapid appraisals are intuitive without any specific questionnaire format. The focus of these appraisals is to identify the problem areas and past incidents of failures and successes of traffic congestion reduction strategies.

3.2.2 Personal interviews

Personal interviews with government officials on traffic regulation and control, regional and city level transportation and town planning schemes provide good insights into problems. The interviews were also helpful in directing research towards plausible strategic interventions. Following the personal interview, the administrative and spatial data were collected from the various government, non-government, and private organizations. The data inventory is presented in the table below (Table 3)

| Organization                          | Data                                                                 |
|---------------------------------------|----------------------------------------------------------------------|
| Jaipur Municipal Corporation          | Ward map and ward-wise population data                               |
| Jaipur Development Authority          | Comprehensive mobility plan for Jaipur                               |
| Jaipur Smart City Ltd.                | Classified traffic volume counts, modal share data                   |
| Jaipur City Transport Services Ltd.   | Jaipur city bus routes                                               |
| Traffic Police Office                 | Recorded traffic problems in Walled City area, inventory of lands for future parking development |
| Regional Transport Office             | Vehicle growth data of the past decade                               |
| Rajasthan Directorate of Local Bodies, Jaipur | GIS database for Jaipur City                                         |
| Town Planning Department, Jaipur      | Jaipur Master Plan 2025                                              |
| Uber, Jaipur                          | Origin-Destination Data                                              |

3.3 Travel demand modelling

The Jaipur municipal area is divided into seven zones, namely Vidyadhar Nagar, Civil Lines, Sanganer, Mansarovar, Moti Dungri, Walled City and Amber zone. The ward-wise population data was available from the Jaipur Municipal Corporation. Each zone that generates trips to the Walled City is represented as a unit in the map (Figure 4). The Walled City is labelled as Zone 6 in the map.

After the demarcation of the traffic analysis zone (TAZ), the following actions are taken for travel demand modelling.

Step I: Modes of Transport

Four major modes with two each from private and public transit are considered – car and two-wheeler (private), MRTS and city bus (public) for the modelling purpose.

Step II: Trip Generation

Trip generation models are used to predict the trip ends generated by a household or a zone, usually on a daily or a peak-period basis. For the current research, the trip generation per day is calculated at each TAZ, based on its respective population size. The URDPFI4, India suggests that the total

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4 The Ministry of Urban Development (India) publish the Urban and Regional Development Plans' Formulation and Implementation (URDPFI) Guidelines The guideline refers to
The number of trips generated in an area is 1.1 times the population of that area (MoUD, 2015b). The research assumes a trip generation index from the URDPFI guidelines. Table 4 below shows the accumulated trips from each TAZ.

Figure 3. Traffic analysis zone

| Zone No. | TAZ Zones          | Population (2011 Census) | Person Trip Generation per day (1.1 * Pop.) |
|----------|--------------------|--------------------------|--------------------------------------------|
| 1        | Vidyadhar Nagar    | 726,309                  | 798,939                                    |
| 2        | Civil Lines        | 547,064                  | 601,770                                    |
| 3        | Sanganer           | 424,564                  | 467,020                                    |
| 4        | Mansarover         | 352,980                  | 388,278                                    |
| 5        | Moti Dungri        | 389,708                  | 428,678                                    |
| 6        | Walled City        | 314,733                  | 346,206                                    |
| 7        | Amber              | 290,827                  | 319,909                                    |
| Total    |                    | 3,046,185                | 3,350,800                                  |

The Jaipur Comprehensive Mobility Plan records 3.4 million trips in Jaipur city (Smith, 2010). The calculated figure validates the findings from the existing mobility plan.

Step III: Trip Distribution

The productions and attractions of trips of each zone are referred to as $T_{ij}$, where $i$ refers to the trip origin and $j$ refers to the trip destination. Each TAZ is considered as $i$, and the Walled City area is considered as $j$. In order to calculate the origin of a trip, the study conducted an origin and

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various aspects of planning by the state governments, development authorities, private sector enterprises, and planning organizations.
destination survey or O-D survey. The survey collected 400 samples during the peak hours on weekdays. Table 5 below shows the percentage of trips originating from each TAZ and its corresponding trip numbers.

| Zone No. | TAZ Names          | Percentage of trip share from O-D survey | Daily person trips from each zone destined to Walled City |
|----------|--------------------|------------------------------------------|----------------------------------------------------------|
| 1.       | Vidyadhar Nagar    | 8%                                       | 63,915                                                   |
| 2.       | Civil Lines        | 33.8%                                    | 203,398                                                  |
| 3.       | Sanganer           | 9.6%                                     | 44,834                                                   |
| 4.       | Mansarover         | 22.5%                                    | 87,363                                                   |
| 5.       | Moti Dungri        | 20.9%                                    | 89,594                                                   |
| 6.       | Walled City        | 3%                                       | 10,386                                                   |
| 7.       | Amber              | 1.6%                                     | 5,119                                                    |
|          | Total              | 100%                                     | 504,609                                                  |

Step IV: Modal Choice Probability

The modal split models predict the percentage of trips of each mode by a trip maker. The measure involves preparing a model for modal choice probability based on the trip generation, trip distribution and other data sets such as travel costs, travel times, and distances, etc. The Logit model is used for modelling the probability. The analysis is presented in Annexure 1.

Logit model uses formula:

\[
P_{i} = \frac{e^{u_{i}}}{\sum_{i=1}^{k} e^{u_{i}}} \]

[1]

Where,
- \( P_{i} \) = the probability of a traveller choosing mode \( i \),
- \( u_{i} \) = a linear function of the attributes of mode \( i \) that describe its attractiveness. It is also known as the utility of mode \( i \); and
- \( \sum_{i=1}^{k} e^{u_{i}} \) = the summation of the linear functions of the attributes of all the alternatives, \( k \), for which a choice is available.

The utility function is calculated based on the following equation:

\[
u_{i} = a_{i} + b_{i} \times IVTT_{i} + c_{i} \times OVTT_{i} + d_{i} \times COST_{i}
\]

[2]

Where,
- \( IVTT_{i} \) = the ‘in-vehicle travel times’ for mode \( i \);
- \( OVTT_{i} \) = set of variables measuring the ‘out-of-vehicle travel times’ (OVTT) for mode \( i \)—walk, wait, and transfer times—may all be kept separate or combined, depending on the calibrated structure of the model;
- \( COST_{i} \) = the cost of mode \( i \);
- \( a_{i} \) = mode-specific coefficient (constant) to account for mode bias not measurable with the level of service variables;
- \( b_{i} \) = coefficient for the \( IVTT \) variables of mode \( i \) (-0.015, -0.018 and -0.02);
- \( c_{i} \) = a set of coefficients for \( OVTT \) variables of mode \( i \) (2-3 times \( b_{i} \)); and
- \( d_{i} \) = coefficient for \( COST \) variable of mode \( i \).
4. MODELLING FINDINGS

The constants and variables are measured from the primary sample survey results (Refer to Annexure 3, Annexure 4, and Annexure 5 for survey pro forma). The mode specific (e.g. car, 2-wheelers, MRTS, and city bus) independent variables such as in-vehicle travel times (IVTTi), out-of-vehicle travel times (OVTTi), and cost of mode (COSTi) of each mode from each TAZ are collected from the primary survey. Respondents travelling by four identified modes (car, 2-wheeler, MRTS and city bus) from each TAZ informed about the independent variables IVTT, COST and OVTT. Annexure 1 and Annexure 2 provide the mean from the survey findings. The respondents of each mode from each TAZ mentioned their mode preferences during the survey. The constants (ai, bi, ci, and di) are calculated as the mean of their preferences. The probability of using a mode (among the four modes) from each TAZ is identified through the probability function of the Logit model. The probability modelling for an existing trip condition is presented in Annexure 1). Annexure 2 records a probability modelling condition when TDM strategies are implemented.

The modelling reveals that:
- 29% of trips are expected to be conducted by car;
- 42% of trips are expected to be accomplished by two-wheelers;
- 23% of trips are expected to be achieved by metro; and
- 6% of trips are expected to be executed by city bus.

The model is calibrated by comparing its outcomes with the actual modal split recorded by the survey sample. The actual modal split is 32%, 41%, 21% and 6% for the car, two-wheeler, MRTS, and bus respectively.

4.1 Results of modelling and suggested strategies

The major findings from the analysis are: Firstly, a skewed preference of the private vehicles (71%) against the public modes of transportation (29%). Secondly, an extremely low bus ridership, which indicates the city’s need for a review of its bus service strategies. Thirdly, a relatively high car ridership that indicates the need to promote the alternative modes of transportation like public transit, NMTs, etc. Fourthly, an exceptionally high two-wheeler ridership that creates major congestion and parking woes. The present mobility plan of Jaipur predicts a further increase in the numbers of two-wheelers in the near future. Unless addressed soon, the growing number of two-wheelers may further congest the Walled City area. Fourthly, a possibility to alter the modal choices by one or a combination of the following strategies, such as change in the attractiveness of the modes of transport, change in travel time for a mode of transport, and change in travel cost for a mode of transport. Fifthly, extreme parking problems within the Walled City that create further congestion, pollution and delays in traffic movement.

A wide range of TDM policies and strategies are available for managing travel demand. In the current research, some of the TDM strategies that are known to influence modal shift are suggested and validated. These strategies are discussed below about the findings above (Table 6). The strategies combine both the push and pull factors mentioned in Table 1.
Table 6. Findings and Suggested Strategies

| Problem findings | Suggested strategies |
|------------------|----------------------|
| A skewed preference for private vehicles (71%) over the public modes of transportation (29%); | Road space reallocation is a highly efficient ‘pull’ measure which encourages people to walk or travel by NMT, bus, or MRTS. These alternative modes of transport are encouraged with a reduction of driving speed and increment of the ‘Right of Way’ (ROW). It is also a ‘push’ measure since it takes away some road space from private motor vehicles and reallocates space to pedestrians, NMTs and High Occupancy Vehicles (HOVs). |
| An extremely low bus ridership, which indicates the city’s need to review its bus service strategies; | Public transit improvement is a ‘pull’ measure which promotes public transit and attracts users by increasing frequency, speed, safety, availability, information systems, user comfort and convenience, etc. Within the Walled City, the public bus infrastructure needs significant improvement to attract more passengers. |
| A relatively high car ridership that indicates the need to promote alternative modes of transportation, like public transit, and NMTs. An exceptionally high two-wheeler ridership that creates significant congestion and parking woes. The present mobility plan of Jaipur predicts a further increase in the number of two-wheelers soon. The growing number of two-wheelers may further congest the Walled City area unless addressed soon. Extreme parking problems within the Walled City that creates further congestion, pollution and delay in traffic movement. | MRTS encouragement combined with last mile connectivity increase use of MRTS which can attract more people to use public transit. Currently, the MRTS corridors are constrained with a limited network and shortage of last mile connectivity. Use of feeder services for last mile connectivity ensures utilization of MRTS facilities. |
| Visitor parking outside the Walled City is a ‘push’-cum-‘pull’ measure of demand management. A cheaper parking facility outside the Walled City area would encourage people to avoid on-street parking within the Walled City area. It would encourage people to park outside and use alternative modes of travel like NMT, walk, bus, MRTS, and IPT. As a result, the Walled City area would experience a reduction in congestion and traffic. |

The suggested TDM strategies, if applied cumulatively, could bring about a modal shift by increasing the overall attractiveness of public transport and by increasing the travel time and cost of using private vehicles. One needs to recognize that for a given problem identified from the analysis, multiple strategies may be required to be implemented. The results are modelled by using the Logit model presented earlier. The calculations are given in Annexure 2. The list of strategies and their anticipated effects are presented in the table below (Table 7).

Table 7. List of strategies and their anticipated effects
| Zone No. | Strategy                                      | Effect                                                                 |
|---------|----------------------------------------------|------------------------------------------------------------------------|
| 1       | Parking pricing                              | Higher cost of using private vehicles                                  |
| 2       | Outside visitor parking                      | Increased OVTT for using cars                                          |
| 3       | Road space reallocation                      | Decreased in-vehicle travel time for bus, walk, NMT                   |
| 4       | Public transit improvement                   | Increased attractiveness for buses, reduced IVTT for using the bus     |
| 5       | MRTS encouragement                           | Decreased OVTT for metro due to feeder services                       |

In forthcoming research, the model would be applied in multiple cities for a comparative analysis. This will help to check the consistency and applicability of the model.

5. CONCLUSION

The study was conducted due to the motivation for exploring TDM as a viable means to address the urban congestion problem in Indian cities. The research explores TDM definitions, theory, strategies, advantages and case studies through literature review. Jaipur’s Walled City area was considered as the study area for the empirical analysis. The transportation system of the study area was studied by collecting on-site and off-site primary and secondary data. The secondary data was collected through web sources, rapid appraisals, interviews, and administrative data. The primary data was collected through surveys and observation. All the data collected was compiled to develop a traditional travel demand aggregate model of the study area. The Logit model was used to visualize the modal choice probability of the study area. The relevant findings from the empirical analysis lead towards developing the strategic intervention for the study area.

The findings and strategic interventions can be generalised to compare the traffic situations among the relevant developing countries in the world, experiencing rapid urbanization and congestion. TDM offers a viable alternative solution to address transportation problems, as compared to the traditional supply-based strategies. Continuous supply-based approaches will not help to curb transportation problems. This paper cites the "principle of triple convergence" to argue the unsustainable method of supply-based transport solutions. TDM strategies like parking pricing, parking restrictions, road space reallocation and improvement of alternatives can be viable means of addressing congestion in urban India. The management of parking demand also curbs automobile use, which results in lower usage of fuel and prevents water resources and runoff from being polluted (Liu, Pai, & Lin, 2018), bringing about a favourable modal shift and cost-effectiveness. The modal shift can generate a significant improvement of mobility and a reduction in congestion. It is, therefore, imperative to design new patterns of urban mobility in both expanding and mature cities, in order to cope simultaneously with economic development, social inclusion and global and local environmental protection (Portugal-Pereira et al., 2013).

Along with short-term measures that regulate the use of vehicles, TDM strategies are also important to influence a long-term measure like limiting vehicle ownership. India may also take a cue from the West and leapfrog to an era of ‘peak-car’ usage and surpass its ill effects (Newman & Kenworthy, 2011). Since India is at an early stage of motor vehicle proliferation, there is a hope for sustainable transit in the future, if timely steps are taken in the right direction.
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| CAR | n | b | c | d | IVTT (min) | OVT (min) | COST (Rs.) | DRIVING COST (Rs. Per Km) | Distance (Km) | Fuel cost per km (Rs.) | Parking Cost (2 hrs) | Ui | eui | PROBABILITY | Total Number of trips from i to j | Trips by Car from i to j |
|-----|---|---|---|---|------------|-----------|-----------|---------------------------|---------------|------------------------|---------------------|----|-----|-------------|-----------------------------|------------------|
| 1   | Vidhyadhar Nager Zone | 6.3 | -0.018 | -0.054 | -0.05 | 25 | 18 | 95.3 | 55.3 | 7.9 | 7 | 40 | 0.113 | 1.12 | 0.33 | 20400 | 12714 |
| 2   | Civil Lines Zone | 6.3 | -0.018 | -0.054 | -0.05 | 21 | 18 | 91.1 | 51.1 | 7.3 | 7 | 40 | 0.295 | 1.48 | 0.36 | 162240 | 57816 |
| 3   | Sangamner Zone | 6.3 | -0.018 | -0.054 | -0.05 | 21 | 18 | 195 | 119 | 7 | 7 | 40 | -3.614 | 1.03 | 0.05 | 46080 | 2458 |
| 4   | Manavar Zone | 6.3 | -0.018 | -0.054 | -0.05 | 23 | 18 | 133.8 | 92.8 | 12.4 | 7 | 40 | -1.956 | 0.14 | 0.12 | 108000 | 12699 |
| 5   | Moti Dungri Zone | 6.3 | -0.018 | -0.054 | -0.05 | 20 | 18 | 89 | 49 | 7 | 7 | 40 | 0.518 | 1.68 | 0.38 | 100320 | 38267 |
| 6   | Walled City Zone | 6.3 | -0.018 | -0.054 | -0.05 | 10 | 18 | 54 | 34 | 2 | 7 | 40 | 2.448 | 11.57 | 0.62 | 14400 | 8930 |
| 7   | Ambir Zone | 6.3 | -0.018 | -0.054 | -0.05 | 21 | 18 | 96 | 56 | 8 | 7 | 40 | 0.15 | 1.16 | 0.42 | 7680 | 3195 |
| 2 WHEELER | n | b | c | d | IVTT (min) | OVT (min) | COST (Rs.) | DRIVING COST (Rs. Per Km) | Distance (Km) | Fuel cost per km (Rs.) | Parking Cost (2 hrs) | Ui | eui | PROBABILITY | Total Number of trips from i to j | Trips by Two Wheeler from i to j |
| 1   | Vidhyadhar Nager Zone | 2.5 | -0.015 | -0.03 | -0.04 | 21 | 6 | 41.6 | 31.6 | 7.9 | 4 | 10 | 0.341 | 1.41 | 0.42 | 38600 | 15969 |
| 2   | Civil Lines Zone | 2.5 | -0.015 | -0.03 | -0.04 | 17 | 6 | 39.2 | 29.2 | 7.3 | 4 | 10 | 0.497 | 1.64 | 0.39 | 162240 | 64024 |
| 3   | Sangamner Zone | 2.5 | -0.015 | -0.03 | -0.04 | 36 | 6 | 78 | 68 | 17 | 4 | 10 | -1.34 | 0.26 | 0.42 | 46080 | 19534 |
| 4   | Manavar Zone | 2.5 | -0.015 | -0.03 | -0.04 | 28 | 6 | 63.6 | 53.6 | 13.4 | 4 | 10 | -0.644 | 0.53 | 0.44 | 108000 | 47123 |
| 5   | Moti Dungri Zone | 2.5 | -0.015 | -0.03 | -0.04 | 18 | 6 | 38 | 38 | 7 | 4 | 10 | 0.53 | 1.70 | 0.39 | 100320 | 38759 |
| 6   | Walled City Zone | 2.5 | -0.015 | -0.03 | -0.04 | 9 | 6 | 18 | 8 | 2 | 4 | 10 | 1.465 | 4.33 | 0.23 | 14400 | 3341 |
| 7   | Ambir Zone | 2.5 | -0.015 | -0.03 | -0.04 | 18 | 6 | 42 | 22 | 8 | 4 | 10 | 0.27 | 1.45 | 0.52 | 7680 | 3981 |

Average Probability: 0.29

Average Probability: 0.42
### MRTS

|   | MRTS                      | a    | b    | c    | d    | IVTT (min) | OVT T (min) | COST (Rs.) | Ui   | cwi | Probability |
|---|---------------------------|------|------|------|------|------------|-------------|------------|------|-----|-------------|
| 1 | Vidyadhar Nagar Zone      | 1.5  | -0.018 | -0.036 | -0.03 | 24         | 30          | 20         | -0.612 | 0.54 | 0.16        |
| 2 | Civil Lines Zone          | 1.5  | -0.018 | -0.036 | -0.03 | 20         | 20          | 18         | -0.12  | 0.89 | 0.21        |
| 3 | Swagener Zone             | 1.5  | -0.018 | -0.036 | -0.03 | 48         | 20          | 36         | -1.164 | 0.31 | 0.51        |
| 4 | Mansarovar Zone           | 1.5  | -0.018 | -0.036 | -0.03 | 40         | 20          | 30         | -0.84  | 0.43 | 0.36        |
| 5 | Moti Dungri Zone          | 1.5  | -0.018 | -0.036 | -0.03 | 25         | 20          | 22         | -0.33  | 0.72 | 0.16        |
| 6 | Walled City Zone          | 1.5  | -0.018 | -0.036 | -0.03 | 5          | 20          | 5          | 0.54   | 1.72 | 0.09        |
| 7 | Amber Zone                | 1.5  | -0.018 | -0.036 | -0.03 | NA         |             |            | 0      |      |             |

**Total Number of trips from i to j:**

- **Vidyadhar Nagar Zone:** 38400
- **Civil Lines Zone:** 162240
- **Swagener Zone:** 46080
- **Mansarovar Zone:** 108000
- **Moti Dungri Zone:** 14400
- **Walled City Zone:** 14400
- **Amber Zone:** 7680

**Trips by Metro from i to j:**

- **Vidyadhar Nagar Zone:** 6157
- **Civil Lines Zone:** 34545
- **Swagener Zone:** 23317
- **Mansarovar Zone:** 38734
- **Moti Dungri Zone:** 2352
- **Walled City Zone:** 1325
- **Amber Zone:** 0

**Average Probability:** 0.23

**TOTAL:** 106431

### CITY BUS

|   | CITY BUS                  | a    | b    | c    | d    | IVTT (min) | OVT T (min) | COST (Rs.) | Ui   | cwi | Probability |
|---|---------------------------|------|------|------|------|------------|-------------|------------|------|-----|-------------|
| 1 | Vidyadhar Nagar Zone      | 0.8  | -0.02 | -0.055 | -0.03 | 27         | 16          | 18         | -1.16 | 0.31 | 0.09        |
| 2 | Civil Lines Zone          | 0.8  | -0.02 | -0.055 | -0.03 | 20         | 33          | 16         | -1.895 | 0.15 | 0.04        |
| 3 | Swagener Zone             | 0.8  | -0.02 | -0.055 | -0.03 | 60         | 60          | 25         | -2.25  | 0.11 | 0.09        |
| 4 | Mansarovar Zone           | 0.8  | -0.02 | -0.055 | -0.03 | 60         | 20          | 25         | -1.19  | 0.30 | 0.07        |
| 5 | Moti Dungri Zone          | 0.8  | -0.02 | -0.055 | -0.03 | 32         | 18          | 12         | -1.016 | 0.104 | 0.06       |
| 6 | Walled City Zone          | 0.8  | -0.02 | -0.055 | -0.03 | 3           | 10          | 5          | 0.04   | 1.04 | 0.06       |
| 7 | Amber Zone                | 0.8  | -0.02 | -0.055 | -0.03 | 28         | 27          | 15         | -1.695 | 0.18 | 0.07       |

**Total Number of trips from i to j:**

- **Vidyadhar Nagar Zone:** 38400
- **Civil Lines Zone:** 162240
- **Swagener Zone:** 46080
- **Mansarovar Zone:** 108000
- **Moti Dungri Zone:** 100320
- **Walled City Zone:** 14400
- **Amber Zone:** 7680

**Trips by City bus from i to j:**

- **Vidyadhar Nagar Zone:** 3560
- **Civil Lines Zone:** 5855
- **Swagener Zone:** 751
- **Mansarovar Zone:** 9455
- **Moti Dungri Zone:** 6935
- **Walled City Zone:** 804
- **Amber Zone:** 505

**Average Probability:** 0.06

**TOTAL:** 27865
### ANNEXURE 2

#### CAR

| Zone                     | a     | b     | c     | d     | IVT (min) | OVT (min) | COST (Rs.) | DRIVING COST (Rs. Per Km) | Distance (Km) | Fuel Cost per Km (Rs.) | Parking Cost (2 hrs) | Uji    | eu     | PROBABILITY | Total Number of trips from i to j | Trips by Car from i to j |
|--------------------------|-------|-------|-------|-------|-----------|-----------|-------------|--------------------------|----------------|------------------------|-----------------------|--------|--------|-------------|----------------------------------|------------------------|
| Vidya Nagar Zone         | 0.3   | -0.018| -0.054| -0.05 | 25        | 25        | 115.3       | 55.3                     | 7.9            | 7                      | 60                   | -1.265 | 0.28   | 0.08        | 39400                            | 2902                   |
| Civil Lines Zone         | 0.3   | -0.018| -0.054| -0.05 | 21        | 25        | 111.1       | 51.1                     | 7.3            | 7                      | 60                   | -0.983 | 0.37   | 0.11        | 162240                           | 17553                  |
| Sanganer Zone            | 0.3   | -0.018| -0.054| -0.05 | 44        | 25        | 17.9        | 119                     | 17             | 7                      | 60                   | -4.792 | 0.01   | 0.03        | 46600                            | 597                    |
| Mansarovar Zone          | 0.3   | -0.018| -0.054| -0.05 | 33        | 25        | 153.8       | 93.8                     | 13.4           | 7                      | 60                   | -3.334 | 0.04   | 0.02        | 160000                           | 2668                   |
| Moti Durgi Zone          | 0.3   | -0.018| -0.054| -0.05 | 20        | 25        | 109         | 49                      | 7              | 7                      | 60                   | -0.86  | 0.42   | 0.11        | 160320                           | 10501                  |
| Walled City Zone         | 0.3   | -0.018| -0.054| -0.05 | 10        | 25        | 74          | 14                      | 2              | 7                      | 60                   | 1.07   | 2.92   | 0.22        | 14400                            | 3214                   |
| Amber Zone               | 0.3   | -0.018| -0.054| -0.05 | 21        | 25        | 116         | 56                      | 8              | 7                      | 60                   | -1.228 | 0.29   | 0.13        | 7680                            | 986                    |

**Average Probability** 0.08

#### 2 WHEELER

| Zone                     | a     | b     | c     | d     | IVT (min) | OVT (min) | COST (Rs.) | DRIVING COST (Rs. Per Km) | Distance (Km) | Fuel Cost per Km (Rs.) | Parking Cost (2 hrs) | Uji    | eu     | PROBABILITY | Total Number of trips from i to j | Trips by Two Wheeler from i to j |
|--------------------------|-------|-------|-------|-------|-----------|-----------|-------------|--------------------------|----------------|------------------------|-----------------------|--------|--------|-------------|----------------------------------|------------------------|
| Vidya Nagar Zone         | 2.5   | -0.015| -0.03 | -0.04 | 21        | 6         | 46.6        | 31.6                     | 7.9            | 4                      | 15                   | 0.141  | 1.15   | 0.31        | 36400                            | 11840                  |
| Civil Lines Zone         | 2.5   | -0.015| -0.03 | -0.04 | 17        | 6         | 44.2        | 29.2                     | 7.3            | 4                      | 15                   | 0.297  | 1.15   | 0.39        | 162240                           | 63493                  |
| Sanganer Zone            | 2.5   | -0.015| -0.03 | -0.04 | 84        | 6         | 83          | 68                      | 17             | 4                      | 15                   | -1.54  | 0.21   | 0.33        | 40680                            | 19425                  |
| Mansarovar Zone          | 2.5   | -0.015| -0.03 | -0.04 | 28        | 6         | 68.6        | 53.6                     | 13.4           | 4                      | 15                   | -0.844 | 0.43   | 0.30        | 160000                           | 32178                  |
| Moti Durgi Zone          | 2.5   | -0.015| -0.03 | -0.04 | 18        | 6         | 43          | 28                      | 7              | 4                      | 15                   | 0.33   | 1.39   | 0.35        | 160320                           | 34845                  |
| Walled City Zone         | 2.5   | -0.015| -0.03 | -0.04 | 9         | 6         | 23          | 8                       | 2              | 4                      | 15                   | 1.265  | 3.54   | 0.27        | 14400                            | 3906                   |
| Amber Zone               | 2.5   | -0.015| -0.03 | -0.04 | 18        | 6         | 47          | 32                      | 8              | 4                      | 15                   | 0.17   | 1.19   | 0.52        | 7680                             | 3991                   |

**Average Probability** 0.36

**TOTAL** 165678
| MRTS       | a  | b     | c      | d      | IVTT (min) | OVT (min) | COST (Rs.) | Ui  | exi | Probability | Total Person Trips | Trips by Metro from i to j |
|------------|----|-------|--------|--------|------------|-----------|------------|-----|-----|-------------|---------------------|----------------------------|
| 1 Vidya dhar Nagar Zone | 1.5 | -0.018 | -0.036 | -0.03 | 24         | 15        | 20         | -0.072 | 0.93 | 0.25        | 38400               | 9568                       |
| 2 Civil Lines Zone       | 1.5 | -0.018 | -0.036 | -0.03 | 20         | 15        | 18         | 0.06   | 1.06 | 0.31        | 162240              | 50095                      |
| 3 Sanganer Zone          | 1.5 | -0.018 | -0.036 | -0.03 | 48         | 15        | 36         | -0.984 | 0.37 | 0.58        | 46080               | 26897                      |
| 4 Mansarover Zone        | 1.5 | -0.018 | -0.036 | -0.03 | 40         | 15        | 30         | -0.66  | 0.52 | 0.36        | 108000              | 38678                      |
| 5 Moti Dungri Zone       | 1.5 | -0.018 | -0.036 | -0.03 | 25         | 15        | 22         | -0.15  | 0.86 | 0.21        | 14400               | 3095                       |
| 6 Walled City Zone       | 1.5 | -0.018 | -0.036 | -0.03 | 5          | 15        | 5          | 0.72   | 2.05 | 0.16        | 14400               | 2265                       |
| 7 Amber Zone             | 1.5 | -0.018 | -0.036 | -0.03 | NA         |           |            |        |     |             | 7680                | 0                          |
| **TOTAL**               |    |       |        |        |            |           |            |       |     |             |                     |                            |
| **Average Probability** |    |       |        |        |            |           |            |       |     |             | 0.28                | 130598                     |

| CITY BUS                  | a  | b     | c      | d      | IVTT (min) | OVT (min) | COST (Rs.) | Ui  | exi | Probability | Total Person Trips | Trips by City bus from i to j |
|---------------------------|----|-------|--------|--------|------------|-----------|------------|-----|-----|-------------|---------------------|----------------------------|
| 1 Vidya dhar Nagar Zone   | 2  | -0.02 | -0.055 | -0.03 | 27         | 11        | 18         | 0.315 | 1.37 | 0.37        | 38400               | 14090                      |
| 2 Civil Lines Zone        | 2  | -0.02 | -0.055 | -0.03 | 20         | 28        | 16         | -0.42  | 0.66 | 0.19        | 162240              | 30958                      |
| 3 Sanganer Zone           | 2  | -0.02 | -0.055 | -0.03 | 60         | 55        | 30         | -3.125 | 0.04 | 0.07        | 46080               | 3161                       |
| 4 Mansarover Zone         | 2  | -0.02 | -0.055 | -0.03 | 60         | 15        | 25         | -0.775 | 0.46 | 0.32        | 108000              | 34476                      |
| 5 Moti Dungri Zone        | 2  | -0.02 | -0.055 | -0.03 | 32         | 13        | 12         | 0.285  | 1.33 | 0.33        | 100320              | 33312                      |
| 6 Walled City Zone        | 2  | -0.02 | -0.055 | -0.03 | 5          | 5         | 5          | 1.515  | 4.55 | 0.35        | 14400               | 5015                       |
| 7 Amber Zone              | 2  | -0.02 | -0.055 | -0.03 | 28         | 22        | 15         | -0.22  | 0.80 | 0.35        | 7680                | 2702                       |
| **TOTAL**                 |    |       |        |        |            |           |            |       |     |             |                     |                            |
| **Average Probability**  |    |       |        |        |            |           |            |       |     |             | 0.27                | 123756                     |
ANNEXURE 3

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

HH SURVEY SCHEDULE FOR RESIDENTS OF WALLED CITY AREA

H. No. and Location (Chopar, Bazaar or Chowki): __________

Street (Level in Hierarchy): □ Primary □ Secondary □ Tertiary

On which floor of the building is the house? □ Ground □ First □ Second

House Ownership: □ Ancestral □ Rented □ Own

Assets Owned: □ Air Conditioner □ Geysers □ Computer/Laptop

How many members are: Working _______ Students _______ Others _______ Total _______

Details of Daily activities (e.g., work, school, college etc.):

| Location (Or distance) | Activity 1 (Member A) | Activity 2 (Member B) | Activity 3 (Member C) | Activity 4 (Member D) |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| Work type (Office/Shop) |                        |                        |                        |                        |
| Designation (Or Role)  |                        |                        |                        |                        |
| Timings                |                        |                        |                        |                        |
| Mode of Transport      |                        |                        |                        |                        |
| Parking (If driving)   |                        |                        |                        |                        |
| Frequency (Weekly)     |                        |                        |                        |                        |
| Age/Health             |                        |                        |                        |                        |
| Gender                 |                        |                        |                        |                        |

VEHICLE OWNERSHIP AND USE

Ownership: Cycles _______ 2-wheelers _______ 4-Wheelers _______ Others _______

Parked Private Vehicles

Allocated Location: __________ Actual Location: __________

Used/preferring Mode of Transport Within the Walled City:

□ Prefer to walk □ Bicycle □ 2-Wheeler □ 4-Wheeler □ Cab
□ Cycle Rickshaw □ E-Rickshaw □ Auto-Rickshaw □ City Bus □ Metro

Reason: __________

Used/preferring Mode of Transport to go Outside the Walled City:

□ Prefer to walk □ Bicycle □ 2-Wheeler □ 4-Wheeler □ Cab
□ Cycle Rickshaw □ E-Rickshaw □ Auto-Rickshaw □ City Bus □ Metro

Reason: __________

As a responsible citizen of Jaipur, do you think there should be:

- Restriction to limit car and motor vehicles usage? □ Yes □ No
- Timing restrictions on goods vehicles? □ Yes □ No
- Promotion of E-Vehicles and pedestrianization? □ Yes □ No
- Restriction on random vehicle parking? □ Yes □ No
- Removal of encroachments on walkways and roadsides? □ Yes □ No

Note: The purpose of this survey is purely academic; the data collected hereby will not be used for any other purpose.
ANNEXURE 4

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

SURVEY SCHEDULE FOR BUSINESSES/SHOPS

Shop No. and Location (Market):

Street: □ Primary □ Secondary □ Tertiary

Deals in (Eg.: Clothes, Footwear, Gemstones etc.):

| Business type: | □ Retail | □ Wholesale | □ Other |
|---------------|---------|-------------|---------|
| Business Ownership: | □ Owner | □ Rent/Lease | □ Other |

BUSINESS OWNER(S):

Residence Location:

Modes of Transport for daily travel:

Allotted and actual Parking Location:

Daily trips to-and-from residence:

Other daily work-based trips:

Timings (Forward and return journey):

Health indicators:

EMPLOYEES:

No. of employees:

| Residence location | Mode of transport | Parking Location | Daily No. of trips | Work Timings | Female/Unhealthy? |
|--------------------|-------------------|------------------|--------------------|--------------|------------------|
| 1.                  |                   |                  |                    |              |                  |
| 2.                  |                   |                  |                    |              |                  |
| 3.                  |                   |                  |                    |              |                  |
| 4.                  |                   |                  |                    |              |                  |
GOODS SUPPLY (LOGISTICS):

Logistic exchange happens to/from which places?

- Within Jaipur:

- Outside Jaipur:

Timings of loading/unloading (if any):

Days of loading/unloading (if fixed):

Types of vehicles used for logistics:

- Hand cart
- Cycle cart
- Horse Cart
- Small Trucks
- Light Trucks

Typical duration of loading and unloading halt:

- <30 Min.
- 30 Min-1 Hr.
- 1-2 Hrs.
- 2-4 Hrs.
- >4 Hrs.

Where is the loading/unloading done:

Place for unbundling goods from larger trucks into smaller and vice-versa:

Personal Observation (Related to resultant traffic problems, if any)

As a responsible citizen of Jaipur, do you think there should be:

- Restriction to limit car and motor vehicles usage?
  - Yes
  - No

- Timing restrictions on goods vehicles?
  - Yes
  - No

- Promotion of E-Vehicles and pedestrianization?
  - Yes
  - No

- Restriction on random vehicle parking?
  - Yes
  - No

- Removal of encroachments on walkways and roadsides?
  - Yes
  - No

If pricing be implemented for management of traffic in the walled city, will you be willing to either restrict freight activity within lean hours (9pm to 8 am) or pay tax for freight activities outside lean hours?

- Yes
- No
- Maybe

Note: The purpose of this survey is purely academic; the data collected hereby will not be used for any other purpose.
ANNEXURE 5

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

SURVEY SCHEDULE FOR VISITORS IN WALLED CITY AREA

Origin (local work/residence/accommodation etc.) ________________________________

Destination(s) (Chopar, Market or Chowki): ________________________________

Frequently visited places in W.C.A.: _______________________________________

Purpose(s) of visiting the walled city (usually):
☐ Shopping ☐ Business ☐ Site-Seeing/Travel ☐ Other________________________

Frequency of visiting the Walled City:
☐ Daily ☐ Twice a week ☐ Once a Week ☐ Once a Month ☐ Rarely
☐ One-Time Visit ☐ Other: _______________________________________________

What time of the day do you generally visit the W.C.A. and time spent here?
☐ Morning ☐ Early Noon ☐ Evening ☐ Night Reason __________________________
☐ <1 Hr. ☐ 1-2 Hrs. ☐ 2-4 Hrs. ☐ >4 Hrs.

Visit group: ☐ Solo visit ☐ Family ☐ Neighbors ☐ Acquaintances from far-off

Mode(s) of Transportation used for traversing to and from the Walled city (summer/rain/winter):
☐ Walk ☐ Bicycle ☐ 2-Wheeler ☐ 4-Wheeler ☐ Cab
☐ Cycle Rickshaw ☐ E-Rickshaw ☐ Auto-Rickshaw ☐ City Bus ☐ Metro
☐ Other_________________________________________________________________

If personal vehicle used:

1. Parking Location
2. Parking Duration
3. Parking Cost
4. Reason of not using public transportation or IPT options-
   ☐ Non Availability ☐ Inconvenience ☐ Expensive as compared to private vehicle
   ☐ Bad Condition ☐ Lack of safety ☐ Wastage of time (in waiting/traveling)
   ☐ Others: ____________________________________________________________
If public vehicle used, reason for this choice:

- ☐ Inexpensive
- ☐ Don’t have vehicle (tourist)
- ☐ Don’t have license
- ☐ Can’t drive
- ☐ Others

Gender, Age, Health Indicators:

As a responsible citizen of Jaipur, do you think there should be:

- Restriction to limit car and motor vehicles usage? ☐ Yes ☐ No
- Timing restrictions on goods vehicles? ☐ Yes ☐ No
- Promotion of E-Vehicles and pedestrianization? ☐ Yes ☐ No
- Restriction on random vehicle parking? ☐ Yes ☐ No
- Removal of encroachments on walkways and roadsides? ☐ Yes ☐ No

If pricing be implemented for management of traffic in the walled city, will you be willing to pay extra (about two to three times) for parking during peak hours?

- ☐ Yes
- ☐ No
- ☐ Maybe

Note: The purpose of this survey is purely academic; the data collected hereby will not be used for any other purpose.