JOINING OF DISSIMILAR MATERIAL (SS-Cu) USING DIFFUSION BONDING TECHNOLOGY

A DISSERTATION

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ABSTRACT

Diffusion bonding technologies have been widely used for joining several similar and dissimilar metal systems in which the main mechanism is inter diffusion across the faying surface. Diffusion bonding technology has been extremely helpful where other joining processes cannot be used for some characteristic reasons or materials property. The main reason for extending the technology is the growing necessity of improvement and enhanced performance of the materials.

In this report the attempts are made to study the effects of parameters on the diffusion bonding of the metal system (Stainless steel-Copper). Report begins with the definition of diffusion bonding, the explanation of the process and parameters. After finding the diffusion bonding feasible between stainless steel and copper, research work continued with two different studies (a) studying the effect of change in maximum pressure in constant pressure study (b) studying the effect of change in number of pressure pulses in impulse assisted pressure diffusion bonding.

Preparation of the surface is very critical in case of diffusion bonding. Therefore all the samples were polished in two stages rough polishing and fine polishing as any oxides or impurity present offers hindrance to diffusion across the surface. Process was accomplished in hot vaccum press under protected temperature. Microstructure, metallographic and mechanical properties of the samples was studied to find out the effect of parameters used.

Optimum parameters were found to be 4 MPa, 875˚C, 30 minutes in constant pressure diffusion bonding. Maximum strength of 226.653 MPa was obtained at this set of parameters. In impulse assisted diffusion process, maximum strength (223.093 MPa) was found at 20 pressure pulses keeping all other parameters constant (6 MPa, 875˚C, 30 minutes).

CHAPTER 1 INTRODUCTION

1.1 General

Indian roads have heterogeneous traffic composed of motorised as well as non-motorised vehicles. Car, buses, bikes and rickshaws are different in vehicular characteristics but share the same road as there are no physical lane segregation provided. Thus, a large variety of vehicular interaction has to be dealt in Indian scenario for which the theoretical models are not sufficient to analyse. Therefore, an individual based approach can be consistent with mixed traffic condition on a regional level.

Transportation planners and engineers always focus on the efficient movement of people and goods across the country. However, transportation touches all aspects of city life such as economic development, quality of life, and socialequity, shortage of water, public health and ecological sustainability.

Improving access by building roads and improving transportation not only reduces congestion but it serves as a driver to drive the real estate prices. Good accessibility attracts jobs and residences which in turn bring in economic development.

The focus should be on the larger movement of people and goods with less number of vehicles and resources with improved policies and regulations. Poor planning and lack of resources lead to problems like higher congestion, noise, accidents and traffic jams.

The solutions should take into account the behaviour of individual travellers, and their ability to learn and adapt to changes in the system. The transportation system is used by the travellers for their movement with required goods and they are bound to make their trip choice with the available limited resources. Travellers are more concerned about their benefit than their decision for route choice but their decisions may have impacts on other travellers or on the system. Planners need to consider the entire system and collective impact of the individuals' decisions, like what factors can affects the system as a whole, and how will those users will react to the system.

Recent advances in technology have made it possible to offer more advanced solutions for trip planning than were available even five years ago. Open source mapping, new trip planning tools, and open data sources on roads, ridesharing, and transit make it possible to collect and disseminate information in a much more sophisticated manner. The increasing use of smart phones and tablet devices makes it possible to provide personalized information so that each commuter can obtain real-time information on availability of travel mode alternatives for his individual commute trip. Links to social media all commute to share their commute experiences and to find persons with similar interests with whom they can carpool or vanpool. Supplementary information on supporting programs such as guarantee ride home and tax benefits for car poolers, vanpoolers, and transit riders can provide further incentives for commuters to consider using these modes.

Bengaluru, is the fourth most populous city in India with a population of approximately 8 million (Census of India 2011). It has a vehicular population of over 6 million, with most of those being private vehicles. Over the past five to six years, faced with an ever-increasing vehicular population and limited road space.

The ever-increasing motorisation of cities is unsustainable, and that there needs to be a shift towards sustainable transport systems. Most of the commuters in the city travel to different regions to work.

Most of these trips are made by public transport or driving alone. So, person centric approach need to be focussed to help commuters make well informed trip based choice and better understanding of the reason for their decision is required which can be served by agent based modelling.

Currently available trip planning systems lack one or more features that are critical to helping commuters make fully informed decisions on how to commute based on comparative travel times and costs of different travel modes.

1.2 Background

Increasing urbanization, rising incomes and population growth are primary cause of rapid growth of travel demand in India. The observed trend is that as household income increases people prefer personal transport rather than public transport because of comfort with individual mobility and freedom of choice. During last few decades, ownership of two wheelers and four wheelers has increased sharply in the city which has led to increase in congestion, pollution and increased number of accidents. Despite of several road improvement strategies, congestion is increasing and public transport is unable to pace the travel demand. Bengaluru is undergoing physical growth since 1950s when public sectors has established large scaled units in the city and industrial townships are incorporated Bengaluru urban agglomeration. The physical growth is characterized by urbanization of rural communities and incorporating them into city with more development over the years. In 1990s, Bengaluru has emerged as computer software and information technology hub which has further augmented population growth along with the quality of life provided by city.

Bengaluru has gradually evolved as fifth largest city and is still developing as mega city. Bengaluru has more than 3000 km of surfaced roads. Average road width is less and only around 10% of the roads can be classified as major arterial roads. Ring roads have been developed on the outer and inner edge but narrow roads are still cause of road congestion. Bengaluru metro is expected to be the solution to the city's traffic and road woes. While phase 1 has been completed and is open to public, work for other phases is still under progress. It's ironic that the construction work currently underway is a prime reason for various traffic bottlenecks across the city because pace of construction is not up to the mark as we can see in other metropolitan cities in India.

1.3 Need of the study

Urban mobility encompasses the characteristics of heterogeneous transportation system including numerous agents with different purpose, stakeholders with varied aims and objectives and their strong interaction with the environment in which they live. These agents have varied roles that leads to different interests, often conflicting. As a consequence, they follow their own goals without considering any centralized control that creates both economic and environmental inefficiency: a larger number of vehicles and trips per day compared to the optimal one, higher pollution level and congestion and low average load factor per vehicle. This has led to serious climatic changes and traffic congestion problems which is gradually degrading health of people.

Agent based modelling has proved to be an effective instrument in studying the dynamic behaviour of various agents and complexity of urban transport network. Mobility analysis of urban passengers required to be supported by economic models and tools that can help in creating a knowledge base about freight and flows of people and behavioural issues of the different stakeholders by simulating current and the future scenarios about freight and passenger vehicles, infrastructureand actors' needs, commodity flows. An analytical approach need to be followed to investigate different decision-making processes among different stakeholders to address the organization of urban mobility systematically. This kind of modelling is helpful and interestingas according to the derivate nature of the transport demand, it represents travelling activities as direct consequences of the need of heterogeneous activities performed by individuals.

1.4 Objectives

To identify movement of people on a network at different time of a day for various trip purposes specifically for work trips

To identify the source and the sink of trips by commuter segmentation and understand the demand creation on the urban network from aggregated travel behaviour.

To develop a framework for the application and implementation with the use of existing large scale dynamic Multi-Agent based Transport Simulation System(MATSim).

CHAPTER 2 TRAVEL DEMAND MODELS

2.1 General

Transport planning evaluates the need to develop a plan for an efficient and accessible transport system which will serve desirable human activities. Decision makers are assisted to make the informed traffic planning decisions by performing travel analysis. To do this, travel demand models have been developed to forecast travel behaviour and travel demand for a specific time frame including a set of assumptions. Travel demand models support decision making by forecasting the impacts of transport alternatives available and land use scenarios (Castiglione et al., 2015). The following two approaches can be used for transport demand forecasting:

i. Aggregated models in which travel demand is considered as aggregated transport flow between zones, and
ii. Agent-based models that considers travel demand at the level of individuals throughout the model.

2.2 Four step modelling

4-step' demand modelling was introduced in the 1960s (de Dios Ortúzar and Willumsen, 2011). Four step models are traditional ways of doing regional transport planning. They are originally specified as trip-based models and aim at predicting the number of trips for different travel modes and routes taken between any two origin and destination zones. Data requirement for four step modelling includes household travel survey information, census information, and a representation of the transportation network. The database includes the current (base year) levels of population, economic activity like employment, educational, shopping space and leisure facilities of each zone. The process has four basic phases-

i. Trip generation (Number of trips to be made)
ii. Trip distribution (Deciding where do they trips lead to)
iii. Mode split (Mode of travel from the available choices)
iv. Traffic assignment (Predicting the routes to be allocated to the trips)

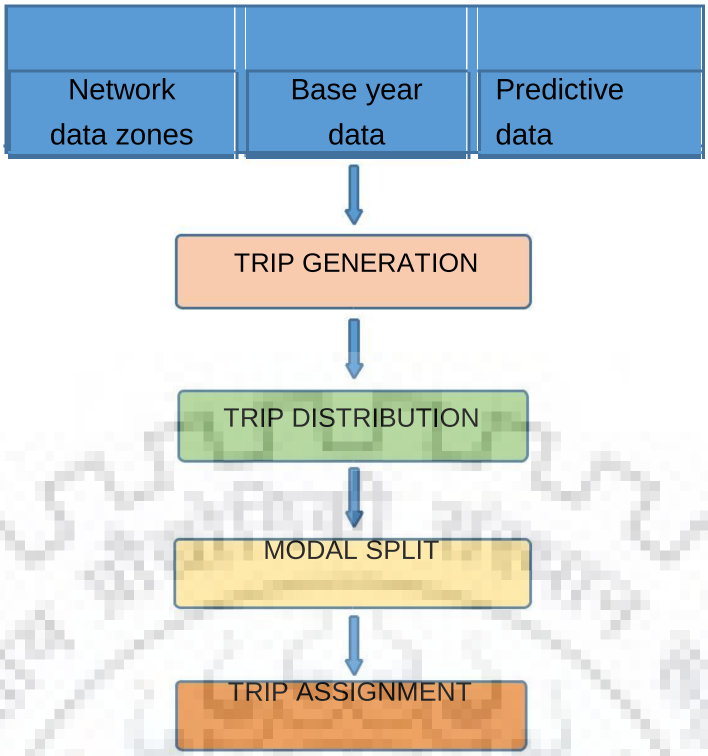

FIGURE 1 GENERAL FORM OF THE FOUR STEP MODELLING (ANDA ET AL. 2016)

The model is started by defining the study area and dividing it into number of traffic analysis zones, including all the traffic network available in the system. Trip generation is the first step in the four step modelling that encompasses the trips origin and destination for a particular traffic analysis zones i.e. the number of trips produced by and attracted to each zone. The second step is trip distribution that connects where trips are produced and where they are attracted to. The trips generated are distributed to the various zone based on choice of destination. This can be done by various models like gravity models and growth factor models by drafting origin-destination matrix (O-D matrix). The third mode choice step determines the travel mode, such as automobile or bus, used for each trip. O-D matrix obtained from second step is divided into number of matrices based on various modes. Depending on the factors affecting the mode choice, the classification of mode is done based on binary or multinomial mode choice models. The fourth assignment step predicts the routes used for each trip. This step determines volume of traffic on the network, trip pattern based on origin and destination and checks congestion on the busiest links. Hence, it allows to model congestion induced traffic delays in each trip (Rieser 2004).

Modelling of demand thus implies a procedure for predicting what travel decisions people would like to make given the generalized travel cost of each alternatives. The base decisions include the choice of destination, the choice of the mode, and the choice of the route. This process helps to understand the effects of future developments in the transport networks on the trips as well as the influence of the choices of the public on the flows in the network.Four step modelling is basically concerned about individual's activity chain process, advanced version of this is Activity based models which have higher fidelity.

2.3 Activity based Models

Activity based models are more detailed version of four step models as it includes when, how, for how long and with whom activity is being performed and the travel choices made for the trip. The fundamental principle of activity-based models is the understanding that travel is ultimately derived from the need to participate in activities. The aim of activity-based models is to forecast for each individual the number, sequence and type of the activities conducted over a certain time-period subject to a set of spatial, temporal and resources constraints. However, while activity-based models allow to generate spatially and temporally disaggregate description of travel demand, for route choice and traffic simulation this travel demand is often aggregated again to so-called origin-destination-matrices that describe how many trips are conducted between any two OD-pairs. This restriction was formerly due to the lack of simulation models appropriate to simulate traffic for a relevant spatial extent, i.e. entire cities or regions and across an entire day, but still apply nowadays due to the computational requirements of agent-based transport simulation.

Activity based paradigm basically includes five important features: (Chu & Cheng, 2014)

Travel was derived from activity participation.
Activity based approach focused on orders of patterns of activities.
Individual's activity is both planned and implemented in the household perspective.
Activities were spread throughout a 24-hour period in a continuous manner, rather than simple classification of 'peak' and 'off peak' events.
Travel and location choices were restricted in time and space, and by personal constraints.

Various methods used in activity-based travel analysis, including discrete choice models, hazard duration models, structural equation models, and computational process models. Along with the four step model data requirements, activity based models require one more type of input, a 'synthetic population' at the level of individual households and persons that is representative for the actual population of the area of interest. (Anda, Fourie, & Erath, 2016)

2.4 Agent Based Models

Agent based models are innovation in transportation modelling domain. Agent based modelling and simulation has been applied to various spectrums including biology, ecology, computer science, transportation management, business and military etc. ABMS is primarily consists of two methodological classifications:

- Individual-based models that study personal transportation-related activities and behaviour.
- Computational (or system) methods that study a collaborative and reactive transportation system that exhibits intelligence by modelling a collection of autonomous decision making of subsystem entities called agents.

2.4.1 Introduction to ABMS and its applications

ABMS originated from Artificial Intelligence and Computer Science but is now being advanced autonomously in research centres all over the world. The origin of ABMS can be traced back to John von Neumann, who perceived and developed a device later called as cellular automata.

In the mid-1990s, Joshua Epstein and Robert Axtell (Zheng, 2013) developed Sugarscape, an artificially intelligent ABSS, which captures fundamental concepts of social sciences. Sugarscape demonstrated how simple rules could create a complex society in a bottom up manner, as shown in figure 2, and stimulated further growth in agent-based modelling.

FIGURE 2 A BOTTOM UP APPROACH TO AGENT B ASED MODELLING AND SIMULATION (ZHENG 2013)

Agent-based modelling (ABM) is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. Each agent can have its own attributes and its own states, can be designed as driven by rules that are its own. The behaviour of each agent can depend on the behaviour of other agents in its local space.

ABMS is flexible and provides a natural description of a system. ABMS is superior in modelling the following situations:

i. Population is heterogeneous, and each individual possesses dissimilar characteristics.
ii. The interactions between agents are complex, nonlinear, discontinuous, or discrete.
iii. Space is crucial, and agents' positions are not fixed.
iv. Agents exhibit complex behaviour, particularly involving learning, interactions, and adaptation.

In the context of a multi-agent system, simulating means asking each agent repeatedly to execute the rules that define them and based on the iterations aggregated results of agents' behaviour can be determined step by step. It can integrate a wide range of decision dimensions in a co-evolutionary learning loop, but due to its modular framework, it can also be used for traffic simulation only and integrated with other activity-based travel demand models. Thus, through a dynamic chain of loops connecting different levels of abstraction, agent-based simulation enables the behaviour of "low" level entities to be combined to generate the macroscopic regularity that we want to reproduce.

Agent-based simulation thus allows us to go beyond the forms of numerical simulation adopted by Boudon and Granovetter, which in fact used simulation in support of a mathematical model formulated at the aggregate level. To express this difference, researchers suggested thinking of agent-based simulation as a method in which "a single unified model of the population" is replaced with "a population of models each of which is an autonomous decision-maker". This decomposition makes it possible to model mechanisms governing the dynamics of each level of analysis and their relationships. Agents may implement various behaviours apt for the system they represent—for example, producing, consuming, or selling. Repetitive competitive interactions between agents are a feature of agent-based modelling, which relies on the power of computers to explore dynamics out of the reach of pure mathematical methods. At the simplest level, an agent-based model consists of a system of agents and the relationships between them. Even a simple agent-based model can exhibit complex behaviour patterns and provide valuable information about the dynamics of the real-world system that it emulates. Additionally, agents may be capable of evolving, allowing unanticipated behaviours to emerge. Sophisticated ABM sometimes includes neural networks, evolutionary algorithms, or other learning techniques for realistic learning and adaptation.

2.4.2 Agent based modelling platforms

There are various well-known agents based transport modeling software that includes transportation analysis and simulation system (TRANSIMS), (Nagel et al., 1999) Toolbox for multi-agent transport simulation (MATSim), (Balmer et al., 2009) Sacramento based on activity Travel Demand Simulation Model (SACSIM), Activity simulator, greenhouse emissions, Networks and Travel (SIMAGENT), Open Activity-mobility simulator (OpenAMOS), and integrated use of land, transport, Environment (ILUTE). Some software does not classify themselves under ABMS but they have similar structure in the modeling paradigm. Most of these agent-based models are individual models. They have roots in activity-based demand models and are generally characterized by a similar functionality. An agent is a person or traveler in general. These models more combines transportation elements – travel activities and loading platforms in a micro simulation platform.

The structural design followed by agent-based transport systems shown in figure 3:

i. An agent represents an individual or traveler and relates to individual demographic and travel characteristics.
ii. The claims system, or activity travel plan, for each individual agent is based on the demographic characteristics. Action plans are reviewed, improved and finalized so that all plans comply with spatial (facility) and time (schedule) constraints.
iii. The action plans are submitted to a microsite to produce the transport results across the network.
iv. Network performance is a source of feedback on action plan decisions and route choice. Agents review the action travel plan and preferred route decision, so that both decisions are optimized simultaneously.

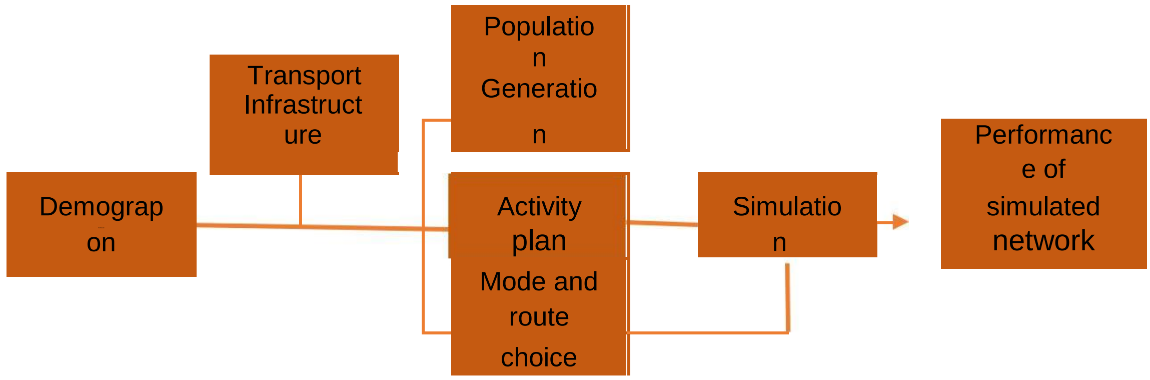

FIGURE 3 MODEL STRUCTURE OF AN AGENT BASED SIMULATION APPROACH

In recent times, an increasing number of modelling toolkits have become available to facilitate agent-based modelling and applications. Each software toolkit has a variety of characteristics, and many efforts have been attempted to review and compare these toolkits. (Zheng, 2013). These toolkits are in general integrated tool suites, designed to simplify the construction of agent-based models and the development of agent applications. There is no universal definition of an agent toolkit.

2.5 Advantages of agent based modelling over traditional modelling

i. Agent based models has the ability to model individual decision making process. It works well with travel behaviour theory as it considers diversity across individuals.

ii. ABM is cost effective and time saving approach because it is always to better to simulate and test the effectiveness of the interventions rather than implementing it without knowing whether the outcome will be success or not. The work is computer based with reduces the research cost incurred by traditional model.

iii. ABM has the canonical approach to modelling emergent phenomena: in ABM, one models and simulates the behaviour of the system's constituent units (the agents) and their interactions, capturing emergence from the bottom up when the simulation is run.

iv. The computational flexibility in the multiple dimensions. It has the ability to change levels of description and aggregation: one can easily play with aggregate agents, subgroups of agents, and single agents, with different levels of description coexisting in a given model.

v. It provides a natural framework for tuning the complexity of the agents like behaviour, degree of rationality, ability to learn and evolve, and rules of interactions

vi. It has larger range of output options, from overall statistics to information about each synthetic traveller in the simulation.

vii. ABM makes the model seem closer to reality. It is more natural to describe how vehicles move in a lane than to come up with the equations that govern the dynamics of the density of vehicles. Here, end user is considered valuable that make it more consistent with the approach.

2.6 Multi Agent Transport Simulation Toolkit MATSim

2.6.1 MATSim Toolkit

MATSim plays a special role and can be considered the currently widely applied model in agent based modelling. It can integrate a wide range of decision dimensions in a co-evolutionary learning loop, but due to its modular framework, it can also be used for traffic simulation only and integrated with other activity-based travel demand models.

In MATSim, a day is simulated multiple times and after each iteration a fraction of the agents is allowed to modify their plans (i.e. mutation/crossover phase). For instance, they can change their departure time, the travel mode of a sub-tour, location of a given type of activity, among others. At the end of each simulated day, the utility of the day is measured for each agent using a scoring function that rewards agents for performing activities, while penalising them for travelling, transferring between transport modes, waiting at transit stops and arriving late for activities, etc. In such way, agents seek to improve their utility over iterations until the system reaches an equilibrium where the generalised utility cannot be longer improved (i.e. a steady state is reached) (Hornie.et.al).

2.6.1.1 Overview

MATSim is an activity-based, extendable, multi-agent simulation framework implemented in Java. It is open-source and can be downloaded from the Internet (github n.d.). The framework is designed for large-scale scenarios, meaning that all models' features are stripped down to efficiently handle the targeted functionality; parallelization has also been very important.
MATSim's approach is iterative: Starting from an initial condition, the system is run over and over again while agents adapt. At the same time, boundary conditions are kept constant. Iterations have always been used in computational implementations of the Nash/Wardrop equilibrium assignment procedure; it has been clear for many years that feedback should consider all other choice dimensions besides route choice as well; and both evolutionary game theory and the science of complex adaptive systems have shown the way to move forward. MATSim develops its iterative approach directly as an extension of the assignment procedure: The route adaptation process is extended towards other choice dimensions, such as time choice, mode choice, location choice, etc.

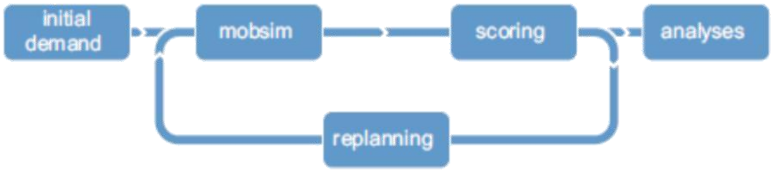

FIGURE 4MATSIM LOOP CYCLE

MATSim is strongly based on events stemming from the mobsim. Every action in the simulation generates an event, which is recorded for analysis. These event records can be aggregated to evaluate any measure at the desired resolution.

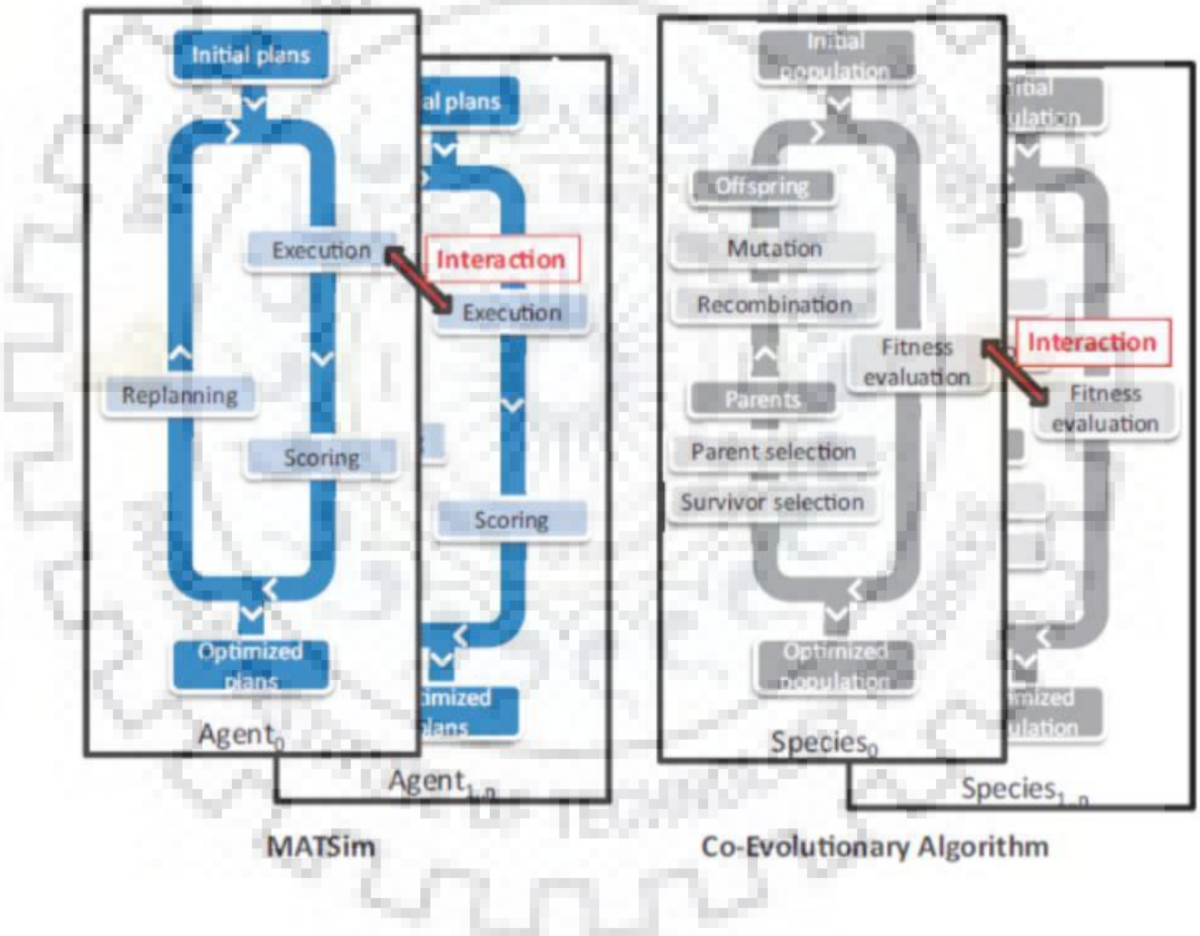

FIGURE 5CO-EVOLUTIONARY ALGORITHM OF MATSIM

2.6.1.2 MATSim co evolutionary algorithm

The MATSim equilibrium is searched for by a co-evolutionary algorithm. These algorithms co-evolve different species subject to interaction (e.g., competition). In MATSim, individuals are represented by their plans, where a person represents a species. With the co-evolutionary algorithm, optimization is performed in terms of agents' plans. It achieves more than the standard traffic flow equilibrium that ignores activities. Eventually, an equilibrium is reached, where the agents cannot further improve their plans unilaterally.

2.6.2 Mobsim

A comprehensive approach to vehicles, in terms of micro-simulation, is to generate a synthetic vehicle fleet. Each leg is supposed to know which vehicle it wants to use. This states that every time the QSim needs a vehicle with a specific ID, it will search for it in the vehicles data container, throwing an exception if it is not found there.

MobSim is needed which can do multiple iterations in reasonable time and also provides good approximation of travel times. Therefore, a queuing model is used, (Simon et al. 1999) gives an algorithm to use it in simulation. This algorithm is applied to Portland city. It was an early application of this model. A vehicle has to stay on the link at least for the travel time calculated from free flow speed. Vehicle can then leave the link if flow capacity allows. It will check for space on the destination link according to that link’s storage capacity and number of vehicles on that link. If space is available, it will be moved up to that link, else spill back will occur. Queue simulation can also add the delays at the nodes i.e. at intersections wherever traffic signal is provided. But in this study all the signals areassumed green and hence there is no delay at nodes.

This model is used in the Java based mobility simulation. Qsim is based on time step approach as it considers state of queue at every time step. There are certain parameters associated with it like flow capacity, storage capacity, these can be set into configuration file.

2.6.3 Input for MATSim

MATSim needs some basic inputs like initial demand, network with given physical constrains in specific format for simulation. All the input files for MATSim are in xml. MATSim needs several files as input, some of them are necessary and some are for extra help in analysis depending on the available data and required results (Horni A et al. 2012).

MATSim needs some basic inputs like initial demand, network with given physical constrains in specific format for simulation. All the input files for MATSim are in xml. MATSim needs several files as input, some of them are necessary and some are for extra help in analysis depending on the available data and required results (Horni A et al. 2012).

i. Network

The transportation system is represented by network of lines; each transit route/ road is represented as a line on a map that is a zone map. The intersection of the transportation lines are nodes. A road is defined by links on its path. A link is identified by the two nodes at the end of each link. MATSim network consists of nodes and links with attributes assigned to them. One link is made by one start and one end node, known as origin and destination. All nodes have given coordinates. Attributes of links are capacity of link, free flow speed on link, length of link, number of lanes, width of link, type of vehicle allowed on the link etc. These are important and necessary attributes to define a network.

An example of network xml file is shown below-


```xml
    <node id="997846407" x="1380694.2730375172" y="-475025.14195315493" >
    </node>
    <node id="997846949" x="1380489.7542431797" y="-475361.121653805" >
    </node>
    <node id="997847035" x="1379924.7975690782" y="-473615.23245069594" >
    </node>
    <node id="999335657" x="1362289.844449141" y="-478132.63840933423" >
    </node>
    <node id="999336877" x="1361853.7264116956" y="-478025.15434769634" >
    </node>
</nodes>

=================================================================== -->

<links capperiod="01:00:00" effectivecellsize="7.5" effectivelanewidth="3.75">
    <link id="1" from="4122318497" to="4122362817" length="64.24239258730445" freespeed="4.166666666666667" capacity="60
        <attributes>
            <attribute name="origid" class="java.lang.String" >410392692</attribute>
            <attribute name="type" class="java.lang.String" >residential</attribute>
        </attributes>
    </link>
    <link id="10" from="292569589" to="2251722075" length="103.85963356471498" freespeed="8.333333333333334" capacity="1
        <attributes>
            <attribute name="origid" class="java.lang.String" >252710683</attribute>
            <attribute name="type" class="java.lang.String" >secondary</attribute>
        </attributes>
    </link>
```


FIGURE 6XML EXAMPLE OF NETWORK

For the nodes it has unique node id and x, y coordinates; for links it has start node id, end node id, length of link, free flow speed, link capacity, number of lanes, directional movement and allowed modes on the link. MATSim takes only one-way links. Therefore, for every direction one separate link is required.

ii. Plan

The travel of a person is marked by attributes like its purpose, destination, duration, mode and other hygiene factors. A MATSim plan file will have daily routines describing travel activities for all the individual travellers named as agents here. It is similar to O-D matrix. This file gives time dependent demand generated from the travel activities of the people based on household survey. Travel activities here refer to what individuals are actually doing (travelling, departing or waiting) based on their purpose of the travel (education, work, home or other).

An example of plan file is shown below-

```
<person id="1">
    <attributes>
        <attribute name="age" class="java.lang.Integer" >40</attribute>
        <attribute name="employed" class="java.lang.Boolean" >true</attribute>
        <attribute name="vehown" class="java.lang.Boolean" >none</attribute>
        <attribute name="gender" class="java.lang.String" >male</attribute>
    </attributes>
    <plan selected="yes">
        <activity type="h" x="1366521.1799840627" y="-478635.5906019467" end_time="07:30:00" >
        </activity>
        <leg mode="pt">
        </leg>
        <activity type="w" x="1374809.5869260351" y="-487144.11648402596" end_time="17:30:00" >
        </activity>
        <leg mode="pt">
        </leg>
        <activity type="h" x="1366521.1799840627" y="-478635.5906019467" >
        </activity>
    </plan>

</person>
```

FIGURE 7 XML EXAMPLE OF PLANS FILE

Important parameters for a plan file are given below-

Id: Each agent needs a unique identifier id.

Activity type: Activity type can be home, work, shopping, etc.

Activity location: Plan needs location of all activities, these locations should be in x, y coordinate system. MATSim needs coordinates in meter for that a coordinate transformer is needed which can convert WGS84 to metric unit. For that a spatial reference system can be used. Same transformation is used to generate network file for MATSim.

Activity time: For all activities at least end time should be given.

Leg: All plans need a travel mode which can be car, public transport, motorbike, walk etc. When MATSim runs, it assigns all the activities on nearest possible links.

iii. Counts

It helps in validating the results of simulation by comparing the traffic counts of simulation to the real world traffic counts. This file is important to compare the results of various simulation scenarios with real traffic counts. It starts with XML preamble. To generate a count file for MATSim, traffic counts at some known locations at one-hour time bin is required. Then MATSim will generate counts comparison of given links for one-hour time bin.

iv. Facility

Facility file is an optional element in MATSim not mandatory but it helps in input component. Agents perform activities at links in a network or alternatively at facilities. Facilities consist of land use details of the area considered under study which can add value to the simulation done based on the requirement. Facilities are always connected to exactly one network link.

Facilities can contain their opening hours. If defined they are taken into account by the corresponding scoring function.

v. Configuration

Controller (called Controller in MATSim) needs one argument and that is the configuration file. This is the main input to be fed in GUI to run the simulation and generate output. This file is needed to configure the MATSim simulation as per the individuals' behaviour or depending on the scenario considered. Configuration file known as config provide functionality to configure a MATSim run. The modules included in config file are described below-

a. Network: This module is mandatory and it has location of input network file. If time dependent network is being used, then location of network change event file will be given in this module. The network used for this study is given in the figure 4 below-

FIGURE 8EXTRACTED NETWORK

b. Plans: This module is also mandatory and it has location of input plan file.
c. Controller: This is also mandatory module. It is responsible for all simulation runs, including the initialization of all required data, iterations, analyses, etc. This module sets the output directory, first and last iterations, mobility simulation used, interval for writing event and plan file etc.
d. Counts: This module is not mandatory but advisable. It sets the input count file which is used for validation of simulation. After simulation it compares the original count vs. MATSim counts.
e. MobSim: As mentioned, MATSim needs a mobility simulation, the chosen MobSim will be put here. Some of available MobSims are mentioned in section. This module sets the flow and storage capacity factor for the simulation. It also sets the main mode (congested mode) of simulation and vehicle behaviour. All the travel modes except main mode are teleported from origin to destination with given speed.
f. Strategy: This module is important because it sets the method for re-planning. It has several planning strategies by which tells how a new plan will be selected. For each strategy name of the strategy and probability for that is given in this module. Some of them are-

    Best Score: This will select the plan having best score from the existing plans of the agent.

    Re-route: It uses the routing algorithm to calculate new least cost route using travel times from the previous iterations.

    Time Allocation Mutator: This strategy mutates the departure time and duration of an activity randomly within a specified given range.

g. PlanCalcScore: This module sets the parameters which affects the agents’ behaviour. All utility parameters responsible for the score calculation are set in this module. Due to performance reasons, the sample population taken for simulation is not 100%. Sample population can be taken for example as 1%, 10% and 25% of entire population.

These are the input files required by MATSim which are run in GUI or in any IDE to obtain the required results. These MATSim files can be generated using any programming language.

2.6.4 Controller

It is the main processor for the MATSim simulation. Each iteration has three steps, they are execution, scoring and re-planning. These steps are iterative till the steady state condition is reached. They are described as:

1. Execution- Execution of agent's plan is done by predefined traffic mobility simulation. In this study simulation implements using queue model. Several MobSims have been developed till now, they are Queue Simulation QSim, DEQSim (Discrete event Queue Simulation) and JDEQSim (Java Discrete Event Queue Simulation). DEQSim is used previously as event based simulation model in which programming was done in C++ but it was not compatible with major scenarios and it is further advanced in Java version.
2. Scoring- Scoring: In this step the score of selected plan of an individual is determined. To calculate the score of a plan.
3. Re-planning- Re-planning takes place depending on the strategies and their probabilities. Several strategies can be used some of them are:
   - Time choice
   - Route Choice
   - Mode choice
   - Destination choice

   More than one strategy can be used. A weight of each strategy is also assigned and hence depending on the probabilities re-planning takes place.

2.6.5 Output from MATSim

MATSim generates several output files after the simulation is done. These files are used for analyses, validation of simulation, calibration and visualization. The modules included in the generated output events during Mobsim cycle are described below-

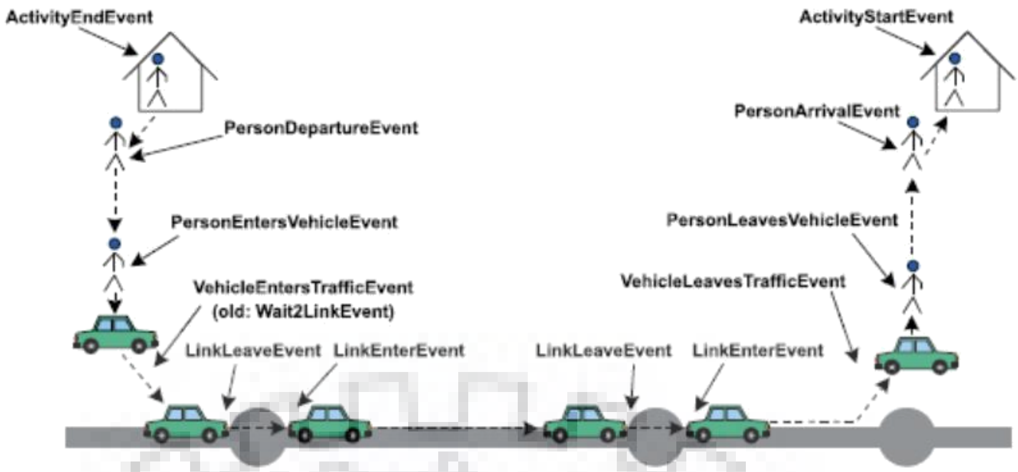

FIGURE 9 MOBSIM EVENTS

Events: Events are used to write all changes in the state of an agent or an object. These events are generated for all agents. Whenever an event occurs, its time is recorded. Apart from the time of event other information like type of event, agent id, id of link if agent enters link or agent leaves link, travel mode etc. For example, agent departure event, agent wait to link event, activity start event, activity end event, vehicle enter event, link enter event, link leave event etc. Stored attributes depend on the type of event. MATSim creates one event file per iteration. After every iteration or maybe after 10 iterations this file can be dumped: as per user defined number of iterations, events file can be written. This file contains all information about all the agents' plans as shown in fig 6.


```
<event time="21600.0" type="actend" person="11" link="338313" actType="h"  />
<event time="21600.0" type="departure" person="11" link="338313" legMode="pt"  />
<event time="23763.0" type="travelled" person="11" distance="16151.606654124662"  />
<event time="23763.0" type="arrival" person="11" link="46237" legMode="pt"  />
<event time="23763.0" type="actstart" person="11" link="46237" actType="o"  />
<event time="25200.0" type="actend" person="7" link="356839" actType="h"  />
<event time="25200.0" type="departure" person="7" link="356839" legMode="pt"  />
<event time="25200.0" type="actend" person="21" link="216963" actType="h"  />
<event time="25200.0" type="departure" person="21" link="216963" legMode="pt"  />
<event time="26381.0" type="travelled" person="7" distance="7338.168736591574"  />
<event time="26381.0" type="arrival" person="7" link="46237" legMode="pt"  />
<event time="26381.0" type="actstart" person="7" link="46237" actType="w"  />
<event time="27000.0" type="actend" person="35" link="264655" actType="h"  />
<event time="27000.0" type="departure" person="35" link="264655" legMode="pt"  />
<event time="27000.0" type="actend" person="1" link="47511" actType="h"  />
<event time="27000.0" type="departure" person="1" link="47511" legMode="pt"  />
<event time="28569.0" type="travelled" person="21" distance="26171.26942844256З"  />
<event time="28569.0" type="arrival" person="21" link="30818" legMode="pt"  />
<event time="28569.0" type="actstart" person="21" link="30818" actType="w"  />
<event time="28800.0" type="actend" person="99" link="47511" actType="h"  />
<event time="28800.0" type="departure" person="99" link="47511" legMode="pt"  />
<event time="28800.0" type="actend" person="94" link="350986" actType="h"  />
<event time="28800.0" type="departure" person="94" link="350986" legMode="motorbike"  />
<event time="28800.0" type="PersonEntersVehicle" person="94" vehicle="94_motorbike"  />
<event time="28800.0" type="actend" person="93" link="264655" actType="h"  />
```


FIGURE 10XML EXAMPLE OF OUTPUT EVENTS FILE

Log file: During each run, a log file is created in MATSim. This file contains several information, which is needed later for analyses. This file will store information of computer on which simulation is run, memory assigned for simulation, start and end of default event handlers, start of iteration, end of iteration, dumping of data etc. This file is helpful when a run has crashed for some unknown reason. Similarly, all warnings and errors are also written in log warning file, which may be useful for debugging.

Visualizer: This is the important output in which one can visualize all the events. As events file have information for all agents at every time step, therefore sometimes event file has millions of events. Then it became very difficult to analyse such results. MATSim provides a tool to visualize movement of agents on the links. Visualizer provides flexibility to look on any agent among all the agents. Timing of activities and location of agents can be visualised. By visualizing events, analysis of results becomes very easy and time saving when one needs a quick look on simulation results.

Plots and text files: MATSim generates several plots and text files during a simulation run, which can be used to analyse the results. For example, score statistics, averaged travelled distance, and leg histogram for all modes which are created after every run. Apart from these MATSim also writes some text files, like link statistics, trip durations, score statistics, travel distance etc.

Counts: If a count file is inserted into MATSim as input then it will generate comparison graphs. These graphs are comparison of real traffic count and simulation count, if real count is not available or otherwise it can also compare simulation count and count from output of some other software. MATSim can also generate Google Earth format (. kmz) file.

CHAPTER 3STATE-OF-THE-ART TRAFFIC SIMULATION MODELLIING

3.1 Transport Planning Process

Urban Transportation Planning Process (UTPP) is a multistage process that includes transportation models such as trip generation, trip distribution, mode choice and trip assignment.The goal of urban transportation planning is to develop a plan for an efficient, balanced transportation system for an urban area, one which will promote a desirable pattern of human activities. Transport planning is defined in the following levels-

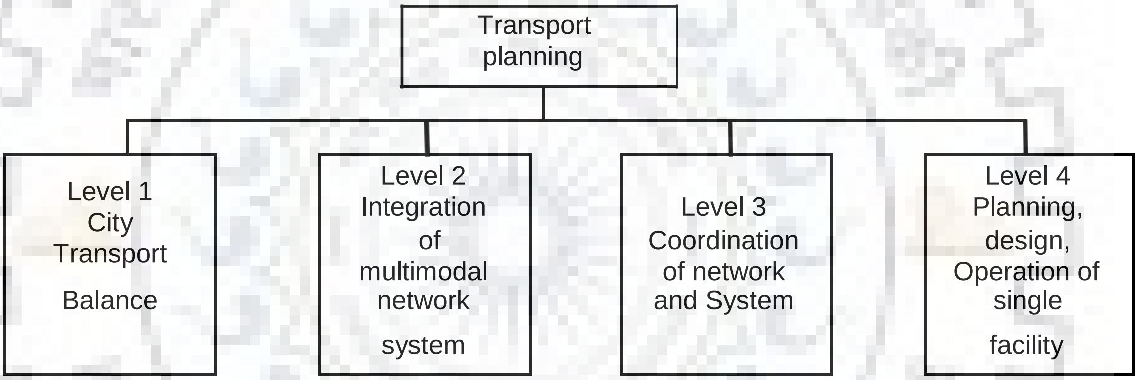

FIGURE 11 TRANSPORT PLANNING PROCESS (REISER 2004)

In the Planning process, level 1 encompasses parameters like economy, housing, social conditions, transport and environmental conditions at city level. Transit, pedestrians and other users are part of level 2. Level 3 coordinate the urban streets and road network. At the concluding stage of planning process, the policies and interventions are suggested for the intersections, road networks, plaza etc. depending on the challenges faced based on traffic conditions.

"A model is defined as a simplified representation of part of the real world which concentrates on certain elements considered important for the analysis from a particular point of view".Demographically disaggregate approaches to travel demand modelling were attempted with the development of logit and other discrete choice techniques as a derivative of the utility model. By inclusion of variables other than travel time in determining the probability of making a trip, it is expected to have a better prediction of travel behaviour. The singly constrained gravity model and logit model have been shown by to be of essentially the same form. The application of these models differs in concept in that the gravity model uses impedance of travel time, perhaps stratified by socioeconomic variables, in determining the probability of trip making, while a discrete choice approach brings those variables inside the utility or impedance function.

3.2 Micro Simulations in urban public transport

Micro simulation is becoming more and more important in traffic simulation, traffic analysis and traffic forecast. It is not a vehicle which produces traffic, it is the person who drives it. Persons do not just produce traffic, instead each of them tries to execute his day (week, life) in a profitable way. They go to work to gain money, they go hiking for their health and pleasure, they visit their relatives for pleasure or because they feel obliged to do so, they shop to cook a nice dinner at home, and so on. Since not all of this can be done at the same location they have to travel, which produces the traffic. To plan a day efficiently, a lot of decisions are made by each person:

- Which route should I take to get to work? Route choice decision
- Which mode should I use to go to the lake? Mode choice decision
- Should I drink another coffee before going home? Activity duration choice decision
- Should I go shopping near my home or at the work place? Location choice decision
- When should I go for sports today? Activity starting time choice decision
- Should I go swimming before or after work? Activity chain choice decision

There are many more decisions to make, some of them are planned hours (days, months) in advance and others are made as a spontaneous reaction to specific situations. Many decisions induce other decisions shows the importance of describing plans for each individual in a simulation model, because it is the plan and the decisions made by the person who adhere to this plan that produces the traffic. (Rieser, 2004)

The report is organized as: the case study to which the approaches are applied is discussed in the beginning including the description of the OD-matrices and how the matrices have been generated. This is followed by a detailed description of the "activity chain generation process". To assess the quality of the results we compare VISUM and MATSim results employing OD-matrices and daily activity chains respectively.

Finally, conclusions and recommendations for future research are outlined. Converting demand or OD-matrices to day plans offers new possibilities to get input data for agent based micro-simulations. The described processes show a prominent approach to reconstruct day plans from OD-matrices. Moreover, since the behaviour of individuals is not easy to determine without expensive surveys, day plan reconstruction is an alternative. The experience gained from this project shows that by using OD-matrices, many behavioural data gets lost which is necessary for micro-simulations like MATSim.

The purpose of this paper is to present a formal approach to multi-agent systems that fits in with simulation of urban public transport networks. The system is viewed as an organization which federates a set of interacting agents. Each agent defines an abstract characterization of the behaviour of an active entity in the organization. This work also illustrates an approach to elaborate, from a specification written with Object-Z and Statecharts, an operational Statechart model which can be easily simulated. The approach is tested this aon many others aspects of the transportation domain. The conclusion is writing some rules in order to formalize the step from formal specification to simulation.

In contrast to Bouman (2012), the interaction with private vehicles was accounted by introducing a stochastic model of the speed of buses between public transport stops and bus dwell time behaviour at stops. This allows not only to improve the simulation time substantially, but also to predict the operational stability of alternative public transport schedules, making simulations of system-wide network redesigns possible. For this purpose, they adapted three inputs to the MATSim environment. Firstly, a reconstruction of bus trajectories from smart card data was developed. Given all boarding and alighting transactions of bus users, the position in space and time of the corresponding buses was estimated. They imputed the time it takes for a bus to travel between bus stops locations by grouping its transactions at each stop into sets that represent bus dwell operations. Then, from the reconstructed bus trajectories they determined the number of services and the time when the services start for every bus line in Singapore. For the particular case of train services, they took the start times from the Google Transit Feed Specification (GTFS) since especially during peak hour train trajectories cannot reliably inferred from public transport smart card data.

Secondly, they needed to generate activity plans for each agent in the simulation. To that end, they established a 25 min threshold to identify the final alighting location of each multistage trip to not split journeys at transfer points. Since smart card records only document boarding times but not when a person actually arrived at the bus stop: given that average headway for most bus services is 10 minutes or shorter, they assumed a uniform arrival time distributions and randomly drew the actual arriving time from the bus stop with the only parameter being the corresponding headway between consecutive services of the specified line.

Only public transport vehicles were simulated, a simplified network offered the opportunity to lower the computational demands of the simulation substantially. Instead of the MATSim queue model, a stochastic travel time model was introduced to model travel times between two simultaneous stops. The model is fit based on a multinomial regression model taking assuming that stop-to-stop follow a normal distribution. As shown by Sarlas and Axhausen (2015) the parameters that determine the speed of vehicles in a network link were related to the level of demand on the link and to the topographical information contained in the network description. The model is included to account for dwell time variability in the simulation.

3.3 Choice modelling and Traffic Assignment Models

The traffic assignment problem, whether macroscopic or microscopic, static or dynamic, trip based or agent-based, is to identify a situation where travel demand and travel supply (network conditions) are consistent with each other. Travel demand results from a demand model that reacts to conditions in the network; these are the output of a supply model (network loading model) using travel demand as its input. A solution of the traffic assignment problem describes an equilibrium between travel demand and travel supply.

Possibly, the most intuitive mathematical formulation of this problem is defined by a fixed Point: Find a demand pattern generating network conditions that, in turn, cause the same demand pattern to re-appear. This formulation is operationally important because it motivates a straightforward way of calculating an equilibrium by alternately evaluating the demand model and the supply model. If these iterations stabilize, a fixed point is attained that solves the traffic assignment problem.

MATSim is taken out from the static and macroscopic assignment of route flows and incrementally enriches this formulation into a dynamic and fully disaggregate agent-based assignment problem.

3.3.1 Statistical traffic assignment

In a statistical traffic assignment, a user equilibrium (UE) postulates that "the flow r_k^{od} on a route k with sets of route k^{od} and density q, zero for every route kof non-minimal cost" (Wardrop, 1952):

$$\mathbf{c(k) = min\ c(s),\ r_k^{od} \geq 0} \quad (1)$$

$$\mathbf{c(k) > min\ c(s),\ r_k^{od} = 0} \quad (2)$$

where

c(k) is the cost (typically delay) on route k and € k^{od}

$q = k^{od} * r_{k^{od}}$

Alternative, frequently-used approach is to distribute the demand on the routes such that an SUE is achieved, where users will be having different perceptions of route cost and each user takes theroute of perceived minimal cost. Mathematically, this means that the route flows fulfil distribution described as

$$\mathbf{r_k^{od} = p_k^{od}\ (c(x(\{r_k^{od}\})))\ q} \ (3)$$

where the route splits $p_k^{od}$is a function of the network costs c(k), which depend on the networkconditions k, which, further depend on all route flows r_k^{od}.

In either case, the model needs to be solved iteratively, which typically involves the following steps (Sheffi, 1985):

i. **Initial conditions:** Compute some initial routes (e.g., best path on empty network for everyO-D pair).

ii. **Iterations:** Repeat the following many times.

  Network loading: Load the demand on the network along its routes and obtain networkdelays (congestion).

  Choice set generation: Compute new routes based on the network delays.

  Choice: Distribute the demand between the routes based on the network delays.

Choice set generation: Mostly, the new routes are best paths calculated based on the last iteration ("bestresponse" or "best reply" choice set generation). A priori enumeration of all possible routes is computationally unfeasible that is why the routes are generated within the iterations.

Choice: Demand is usually shifted among the routes to improve consistency with the route choice model, assuming constant network delays: In a UE, the flow on the best routes is increased at the cost of the other route flows (“best reply” or “best response” choice), whereas for an SUE, flows are shifted towards the desired route choice distribution which is often a version of multinomial logit model.

For stability reasons, this shift is typically observed in a gradual way that dampens the dynamics of iteration. The iterationsare repeated until some stopping criteria is fulfilled, indicating a fixed point is attained. In the best reply situation, the fixed point implies that no shift between routes is taking place, i.e., the best reply to the previous iteration is either the same, or at least of the same performance, as that was used in the previous iteration.

3.3.2 Dynamic traffic assignment

The network and demand conditions are same as discussed above including a change in choice for individual travellers while iterating i.e.;

Choice: Assign every traveller to a route (which can be the previously chosen one) based on network delays(Agarwal et al. 2017).

In dynamic traffic assignment, if the new routes are best paths based on the last iteration and demand is shifted towards these new routes and the iterations reach a fixed point, this is then a dynamic UE. The SUE interpretation is carried over in a same manner.Destination choice and elasticity in demand applies to the dynamic case as well. The sole consideration of route choice does not constitute a limitation because departure time choice can be translated into route choice in a time-expanded version of the original network(Horni et al. n.d.)

In the static case, for every O-D pair, one needs to assume a steady flow oftravellers onto the network at the origin, corresponding to that O-D flow. In the dynamic case, one needs to generate the appropriate number of travellers for every time slot and every O-D pair and distribute them across the network. There onwards, the origin, destination and departure time is fixed for every simulated traveller to find an appropriate path. Arguably, this re-interpretation is behaviourally more plausible in the dynamic case.

In a trip-based context, there are two major considerations to go from continuous flows to individual travellers:

i. Dynamics of traffic flow in complex network infrastructure are difficult to model as continuous flows, but are relatively simple to simulate at the individual vehicle level. Disaggregating an O-D matrix into individual trip makers allows the assignment of one vehicle to every trip-maker in the microscopic traffic flow simulation.

ii. Demand heterogeneity through a large numberof commodity flows is computationally insufficient to capture, but the sampling of trip-makers with varied characteristics is significantlystraightforward. For example, every vehicle can be given an individual route to its individual destination. For a finite population of heterogeneous travellers, each traveller constitutes an integer commodity and the choicestep thus must be changed from "gradually shift the route flows towards something consistent with the behavioural model" into "for a fraction of travellers, assign a single behaviourally plausible route to each of these travellers".

For a **particle SUE**, the limit assumption of the macroscopic model is discarded and the choice fractions p_k^{od} described in equation 3 are now interpreted as individual-level choice probabilities P_n.

$$P_n = f(k, E(c,r,x))$$

where

k is a binary variable that indicates if traveller n takes route k.

E denoted the expectation.

A particle SUE is defined as a system state where travellers chooseroutes from a stationarychoice distribution and the resulting distribution of traffic conditions re-generates thatchoice distribution. An operational particle SUEspecification results if one assumes that random fluctuations are filtered out bytravellers from what they observe and make their decisions only on average route costs.

This approach incorporates some generality; it can be shown that choice distributions basedon expected network conditions coincide, up to first order, with the stationary choice distributions based on fluctuating network conditions (Flotterod et al., 2011).

This widens the behavioural modelling scope ; all choice dimensions of an all-day travel plan can now be jointly equilibrated. This increases the degrees of freedom that need to be modelled but also carries a set of natural constraints along, which again reduce the solution space. The disaggregate counter piece of an SUE implies that every agent considers a whole choice set of (possibly suboptimal) plans and selects one of these plans probabilistically, which can lead to huge data structures.

3.4 Case study

The work of Fourie et al. (2016) shows one of the possible integrations of big data algorithms within an agent-based transport modelling framework. They enhanced the simulation results of a complex model by introducing what is called in the computer science literature as a machine learning surrogate. They substitute a compartment of the whole model with the behaviour obtained from the statistics of the smart card data. The results not only represent a more accurate representation of the real world, but also an improvement of the overall computation time. However, still several limitations have to be addressed such as implementing the passing behaviour in the queue simulation, the reconstruction of train trajectories, a better representation of walking, waiting and transfer activities to better represent route and mode choice preferences. In addition, public transport smart card data obviously do not contain any information of motorised travel demand and active mobility. To tackle the aforementioned problems, additional datasets can be included.

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CHAPTER 4 SCENARIO ANALYSIS

4.1 Study area

Bangalore, officially the Bengaluru is spread over around 8000 sq. km area with a population of 8,443,675 (2011 census). It is ranked as the third biggest city in the nation in terms of population and fifth most populous urban agglomeration in the country. Bengaluru is India's leading Information Technology exporter and is referred to as the "Silicon Valley of India".

Bengaluru has further subdivisions as urban, rural and Ramnagara district. The study area is taken as Bengaluru urban which is surrounded by the Bengaluru Rural district on the east and north,and the Krishnagiri district of Tamil Nadu on the south and the Ramanagara district on the west. Bengaluru Urban has five taluks: Yelahanka, Bengaluru North, Bengaluru East, Bengaluru South and Anekal. The city of Bengaluru is situated in Bengaluru urban district. (Wikipedia) Due to growing opportunities and development, the population density of Bengaluru has increased 47% in just ten years that is attracting more people across the country towards Bengaluru. In 2011, there were 4,378 people per square kilometre, up from 2,985 ten years before. The total number of vehicles as on date are 44 lakh vehicles, with a road length of 11,000 kilometres (6,835 miles) that comprises of privately owned vehicles as well. Buses operated by Bengaluru Metropolitan Transport Corporation (BMTC), autos and car-pooling by Ola and Uber are an important and reliable means of public transport available in the city. BMTC runs air-conditioned luxury buses on major routes, and also operates shuttle services from various parts of the city to Kempegowda International Airport. Auto-rickshaws yellow – black or yellow-green and green auto-rickshaws, referred to as *autos*, are a popular form of transport. They are metered and can accommodate up to three passengers.

4.2 Pilot study

A household survey was conducted for collecting data for one day. The process was initiated by deciding the parameters affecting individual choice of transport mode based on which the questionnaire is prepared. Based on the historical data, the wards having highest density in Bengaluru are chosen which were further divided into four zones of Bengaluru i.e. north, south, east and west. Then the sample size for data collection is taken as 87 data points per zone as shown in figure 12.

Segment	Area	
HBE	Nagarbhavi	
	Jayanagar	
	Banashankari	
	Rajaji Nagar	
	Peenya	
HBW	Bannerghatta road	Bomma Sandra
	Whitefield	Peenya
	Electronic city	MG road
	CV Raman nagar	Marathahalli
HBO	KR Market	Banashankari
	Sampangi Rama Nagar	MG road
	Malleshwaram	
	Sheshadripuram	

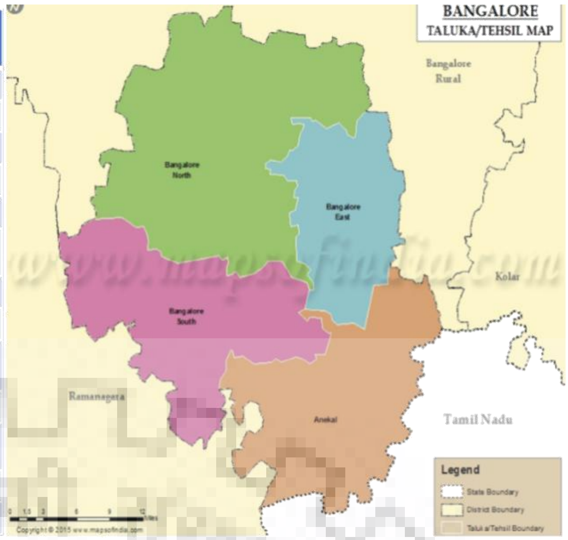


FIGURE 12AREA COVERED IN BENGALURU

Then the collected data is filtered according to the attributes chosen for the study that includes age, gender, vehicle ownership and employment. Various modes of travel are available in Bengaluru. In our study we have considered car, bike and public transport. To create a digital MATSim network for the study scenario, input. osm file are taken from bbbike.org in the form of xml file and then transformed into network.xml file. These files contain node ids, coordinates, length of link, width of link etc. To transform coordinate system of nodes from WGS84 to metric unit spatial reference EPSG 24375 is used. Then plans of agents are generated in xml format by automating them through java codes based on utility equations. Part of data in household survey was unavailable like actual duration of starting and ending of activities by each agent, for such cases the required data is randomised.

All the trips are classified into 3 categories on the basis of trip purpose which are Home-Based-Work (HBW), Home-Based-Educational (HBE) and Home-Based-Other (HBO). The duration for h-w-h trips is taken between 8:00 am to 8:00 pm, assuming each agent is working for 8 hours. For h-o-h trips, time is randomised between 1:00 pm to 4:00 pm and 6:00pm to 12:00 am. For h-e-h trips, time is taken between 8:00 am to 6:00pm, assuming duration as 7 hours a day. Generated files are clubbed in a config file and the framework for the scenario generation has been prepared and simulated. Figure 13shows different simulated modes on network during evening.

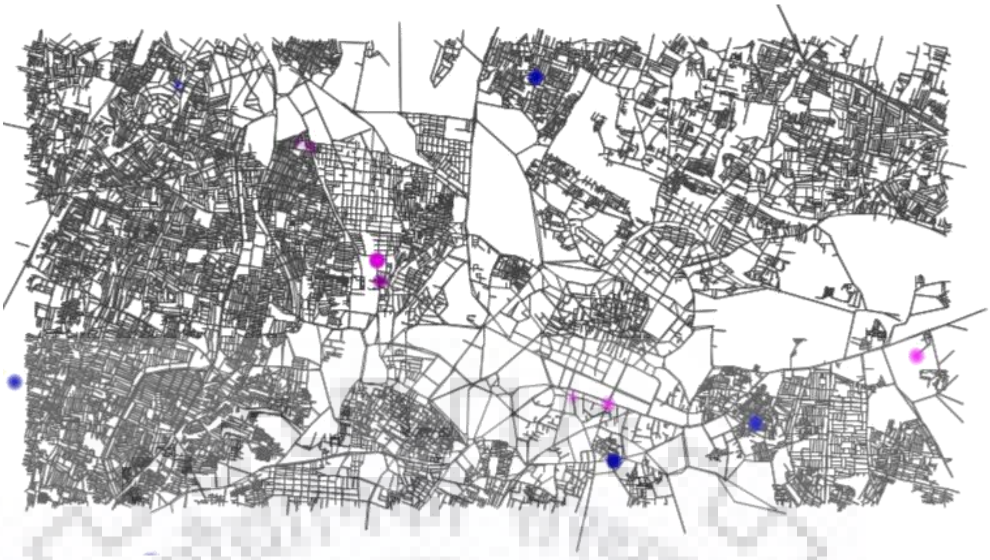


FIGURE 13 SIMULATED NETWORK OF BENGALURU

The generated output has given an impression of the mode utility which is described in figure 14 below.Work and education trips contribute more than 70 % of total trips in a day.

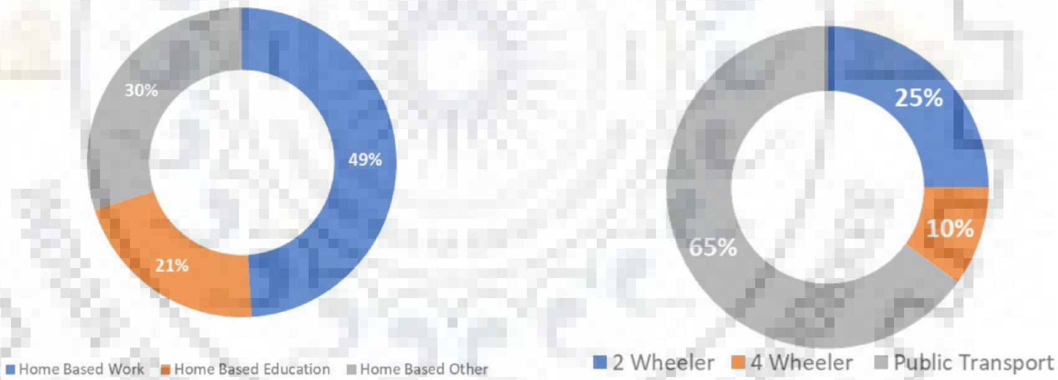


FIGURE 14TRIP GENERATION WISE AND MODE WISE TRIP DISTRIBUTION

4.3 Modelling the study scenario

The framework developed from pilot study become the basis of further work done and the modelling has been done for a smaller region in Bengaluru. The chosen locations are three wards in Bengaluru south described as below-

TABLE 1 DETAILS OF WARD

Ward Number	Ward Name	BBMP Zone Name	BBMP Division	BBMP Sub Division
147	Adugodi	South	BTM Layout	Koramangala
151	Koramangala	South	BTM Layout	Koramangala
173	HSR Layout	Bommanahalli	Bommanahalli	Bommanahalli

Adugodi is located along Hosur road and it serves as economical residential location to most of the students and employees. Koramangala is situated in the south-eastern part of the city, it is a highly sought residential locality with a mix of luxury apartments, commercial structures, and posh bungalows and wide, tree-lined boulevards. Post-independence, its location between Bengaluru and Electronic City attracted migrants from across the country during Bengaluru's tech boom of the late 1990s. Consequently, it has gradually developed into a commercial hub. HSR Layout has emerged as a leading residential area due to its proximity to IT Parks in Bengaluru. It is also a gateway to Electronic City, a major IT hub of the city.Detailed methodology of the work done is described in the flow chart below-

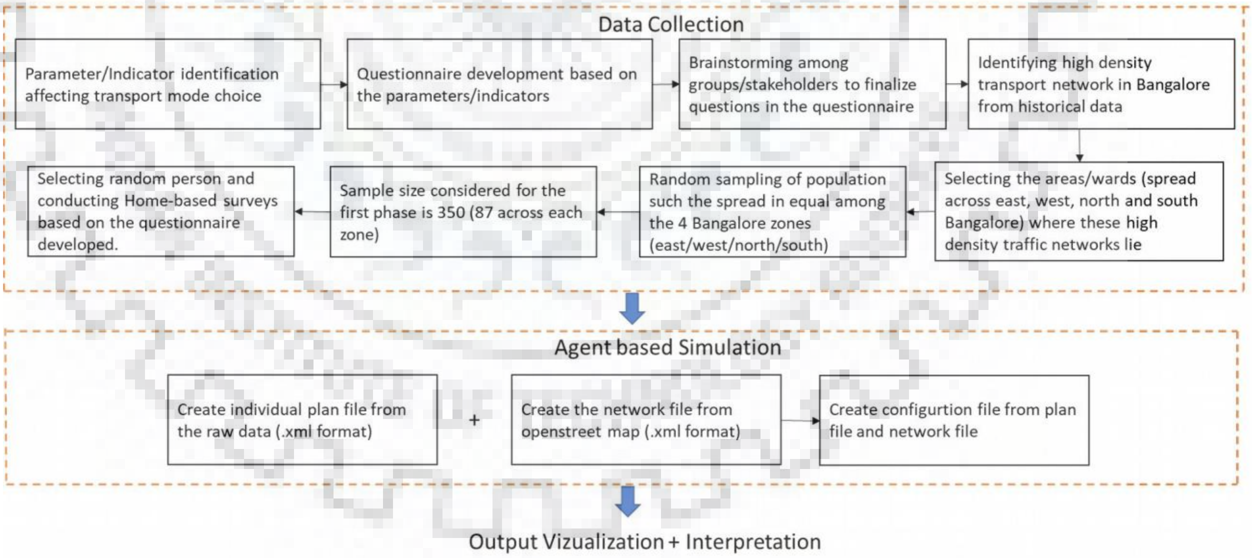


FIGURE 15METHODOLOGY OF WORK DONE

4.3.1 Data collection

Adugodi ward is taken as the location for data collection due to its close proximity to other two chosen locations. Adugodi ward is divided into 8 dominant locations considering presence of either public amenity so that survey could be carried out. The description of the locations is described below :(refer Figure 16)

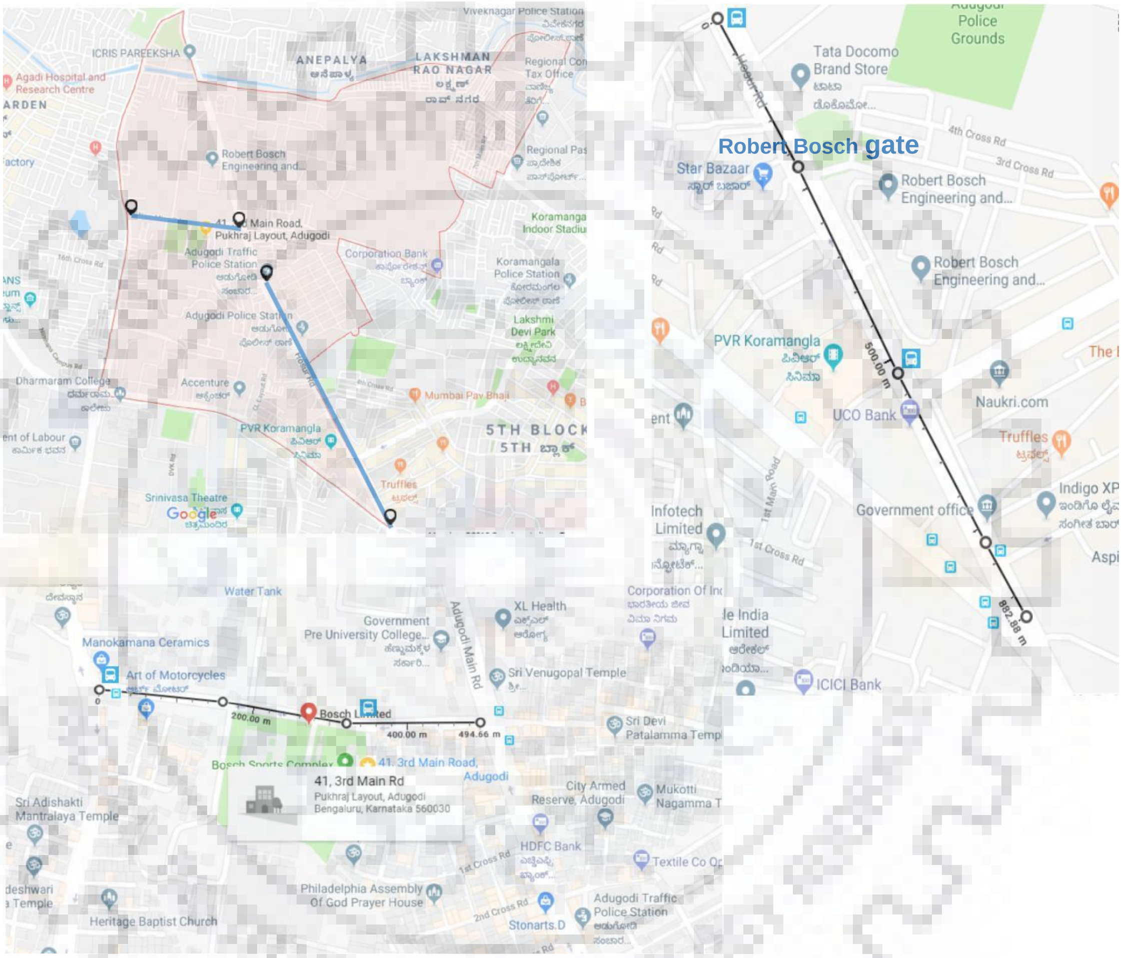


FIGURE 16 LOCATIONS FOR DATA COLLECTION

1. This is Adugodi police quarters bus station marking beginning of the stretch with coordinates

   12.9392665, 7.6087206.

1. This is Public toilet near RBEI Koramangala with coordinates 12.936533, 77.6113385
2. This is bus stop opposite to Forum mall with coordinates 12.9348152, 77.61638
3. This is check post at the Hosur road intersection with coordinates 12.931942, 77.6120838
4. This is Pukhraj layout bus stop marking starting of the stretch with coordinates

12.9443645, 77.6030953.

5. This is Bosch Link road gate with coordinates 12.944358, 77.6040345.
6. This is Mico bus stop outside Bosch Sports Complex with coordinates 12.9441918, 77.6052534.
7. This is end of the junction opposite to the Bosch power tools with coordinates 12.9439856, 77.6072324.

A household survey was conducted for collecting household diaries including demographic factors of individuals like age, gender, household size, family income etc., vehicle ownership of individuals and trip characteristics including origin and destination ward details, mode of travel, average travel time etc. This survey is based on questionnaire prepared with some modifications in the previous one which are described below-(refer Appendix 1.1)

- Actual trip starting time and origin time is included in the questionnaire to avoid random assumption of the activity duration.
- Data points like travel time and travel distance is taken more precisely in exact hours and kilometres respectively then in an interval.
- Mode of payment for the trip is eliminated from the survey.

4.3.2 Trip characteristics

4.3.2.1. Trip purpose

The trips are work based comprising of home-based-office and home-based-business trips. Home based office trips are in majority and are spread over morning peak and evening peak hours of the day. Home based business trips are less and are mainly occurring between late mornings to early evening. Most of these trips have their origin or destination in ward number 151 and ward number 173. Ward number 173 comprises of most number of trips as shown in graph below-

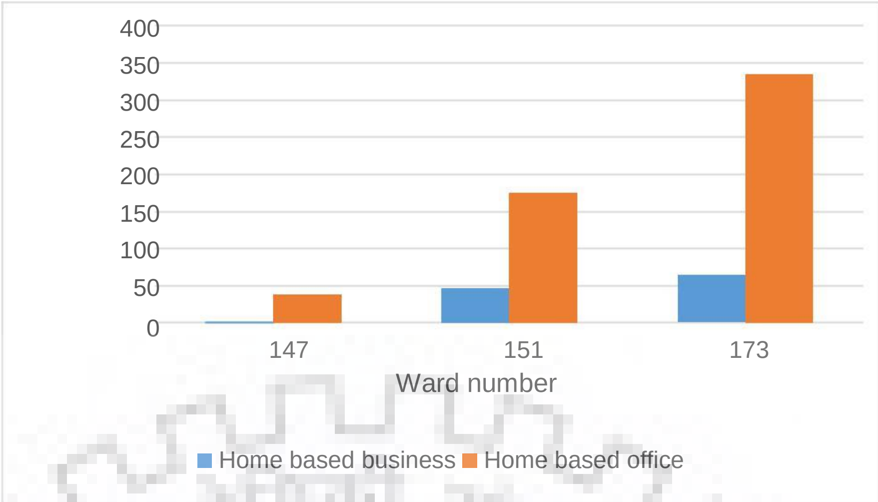


FIGURE 17 WARD WISE DISTRIBUTION

4.3.2.2. Modal share

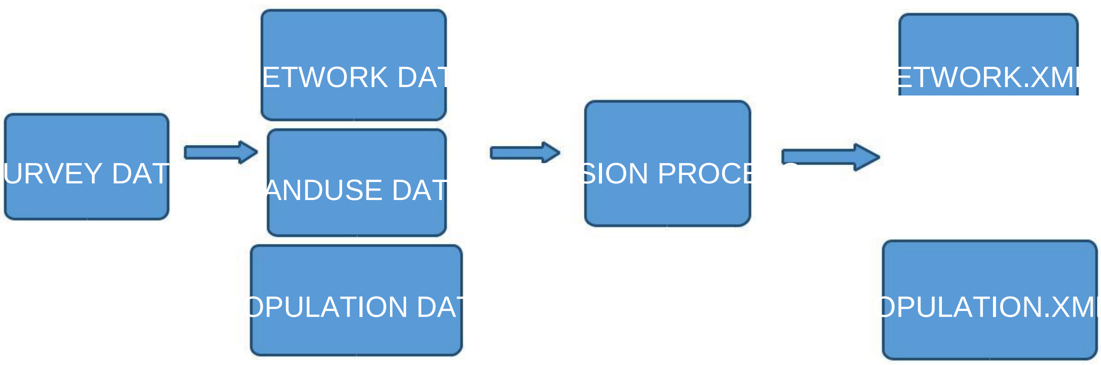
Different modes of commute are being used by people in Bengaluru like car,intercity buses, car pool, auto-rickshaws etc. Auto rickshaws are main mode of local public transport in Bengaluruwhich are in competition with car pools and two wheelers. Bengaluru Metropolitan Transport Corporation (BMTC) runs buses for intercity commute along with various private operators. Various modes from household diaries are classified as car, motorbike and public transport for the study. Auto-rickshaws, Buses, car pool are categorised into public transport. The chart below shoes various mode share distribution for respective trip purpose.

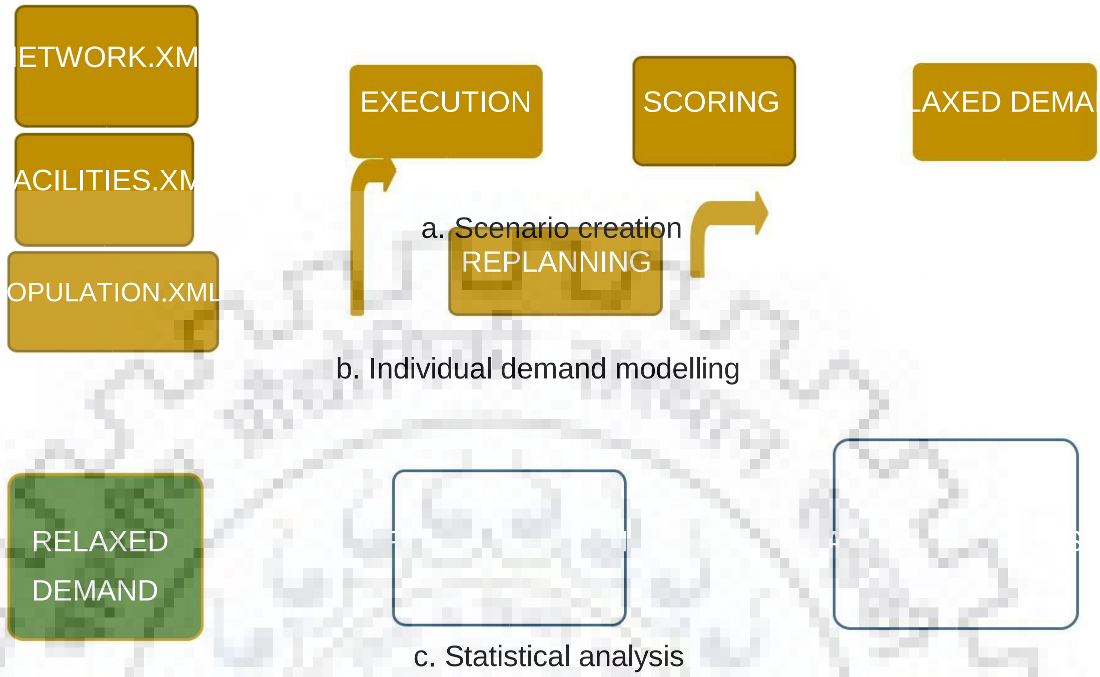
4.3.2.3. Average daily distance and time travelled

According to the household diaries, minimum time taken by commuters for their daily work based activity is 1 hours which extends up to 5 to 6 hours for many commuters. Similarly, people travel for 50-70 km daily for their work. The average travel time calculated is 2.5 hours.

4.3.3 Scenario Generation

The household diaries are converted to commuter's activity plans and the process is described in the flow chart below-





4.3.3.1 Bengaluru network

Bengaluru is divided into 98 wards by Bruhat Bengaluru Mahanagara Palike (BBMP), same division is adopted as shown in the figure below:

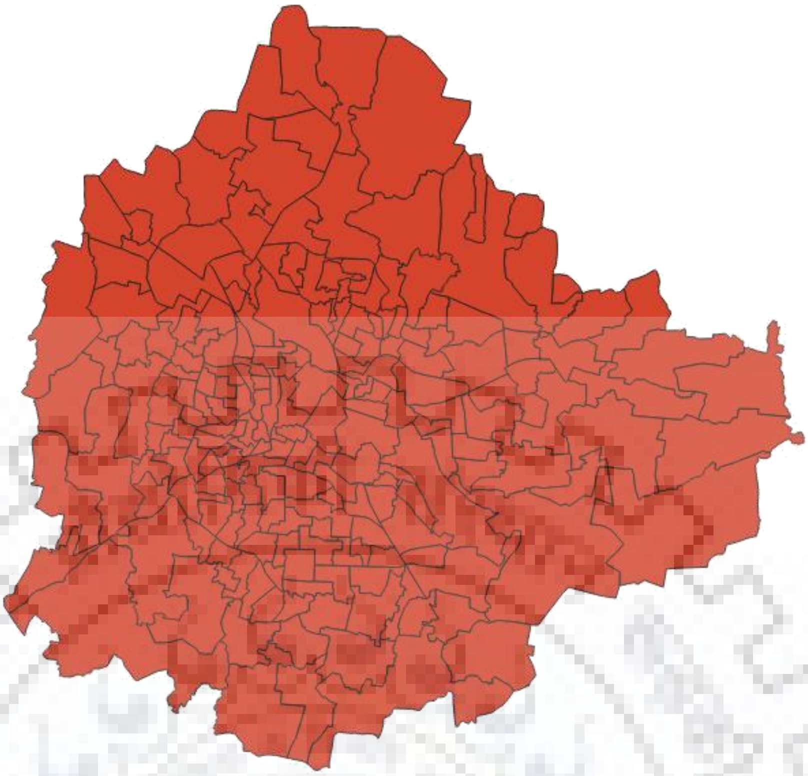


FIGURE 18 WARD MAP OF BENGALURU

To create a digital MATSim network,different sources have been tried to extract network shape file like open street map (osm) and GIS maps. But osm has not enabled extracting map for large area consisting of number of links and nodes and GIS maps need lots of time to create as it is to be created manually. Finally,shape file from bbbike.org maps is taken as input file and then java codes are used to convert the extracted network to the desired xml format as shown in figure 20.

FIGURE 19 EXTRACTED NETWORK

The coordinate system is changed from WGS84 to metric unit spatial reference EPSG 24375(Kalianpur 1937 /India zone IIb). These network file contain information like node ids, coordinates, length of link, and width of link and so on. (refer Appendix 1.2)

4.3.3.2 Initial plans and sample size of synthetic population

Generation of plans file is the first step in agent based modelling simulation. The file contains starting and end ward number of the agent performing activity, starting time and end time of the activity, mode of travel used, trip purpose, age and gender. (refer Appendix 1.2)

A typical MATSim population should have 10 % plans of total populations to reduce artefacts. Hence each agent will represent 10 similar agents. The number of records in typical travel diary surveys is usually much smaller. Thus, the survey population needs to be expanded. "As long as schedule-based transit assignment is not used, decent results can already be obtained from 1% population samples". Here, approximately 2% sample size is used to represent the traffic scenario of the considered population.

4.3.3.3 Modes

MATSim has car, motorbike and truck as main modes in its Qsim config. It has capabilities of multimodal extension too. In this scenario, car and motorbike are leg modes that corresponds to the main mode that means the entered vehicle will be created for the chosen leg and it can enter the network. Pt i.e. public transport is not registered as main mode in Qsim so it is teleported by providing a separate vehicle file.The vehicle file has name of the vehicle, speed and passenger car equivalent. Teleportation means "if the router encounters a leg with mode pt, it generates a "teleportation" route whose travel distance is the same as, and travel time is twice that of, a free speed car route."

This models public transit, assuming it travels along roughly the same routes as a car trip, but takes twice as long with teleported mode speed. Its travel distance is 1.3 times that of beeline factor.

4.3.4Configuring scenario

4.3.4.1 PCU calculation

Passenger car equivalent (PCU) is calculated as the ratio of effective area occupied by vehicle to area occupied by a passenger car taken based on Mallikarjuna and Rao approach for heterogeneous traffic using area occupancy and speed of vehicle entity(Mallikarjuna & Rao, 2006).The dimensions of the vehicle taken are mentioned in the table 2. All the other factors are assumed to be same for all vehicles.

TABLE 2 PCU CALCULATION

Vehicle type	Length	Width	Effective width	Area	PCU calculation	PCU taken
Car	4.8	1.8	2.8	13.44	1	1
Motorbike	2.2	0.75	1.55	3.41	0.254	0.25
Public transport	12.19	2.59	3.5	42.665	3.17	3

4.3.4.2 Replanning strategies

Replanning strategies are involved in people's choice making based on an implicit choice set. Here, 10% of the agents reroute their current route (module Re-route). The remaining 90% select their highest score plan for re-execution in the current iteration (module Best Score). The maximum number of plans configured as five, the plan with lowest memory will be removed if the memory is full. For some agents, a plan is copied, modified and then selected for the next iteration. All other agents choose between their plans.

4.3.4.3 Scoring parameters

In this step scoring is done to select agent's plan and the score is generated for every step of iteration based on learning rate. This scoring is done based on Utility. Utility is sum of all the activities (perform, wait, travel and departure).

$$U_t = U_{perform} + U_{wait} + U_{travel} + U_{late\ arrival\ /\ early\ departure}$$

This utility function is combination of activity duration and β function.

$U_{travel} = \beta_{travel} *$ activity duration

$U_{perform} = \beta_{perform} *$ activity duration

$U_{wait} = \beta_{wait} *$ activity duration

$$S_i = \alpha * S + (1 - \alpha) * S_{i-1}$$

where

β_{travel} = marginal utility lost during travelling leg mode measured in utility per hour (1/h)

$\beta_{perform}$ = marginal utility gained during performing activity measured in utility per hour (1/h)

β_{wait}= marginal utility lost for arriving late than late arrival time.

S_i = Score of a plan for current iteration

α = Learning rate

S = selected plan for previous iteration Current score calculated from utility function

S_{i-1} = Score of α

The selection probability corresponds to the logit function is-

$$P_i = \exp(\beta S_i) / \sum_j \exp(\beta S_j)$$

where

S_i denotes the utility of plan i

β is a marginal utility

S_j denotes the utility of plan j

The scoring parameters used are described below-

Alternative specific constants = Zero for all modes

Marginal utility of departing early = 0.0

Marginal utility of arriving late = -18.0 utils/hr

Marginal utility for performing activity = +6.0 utils/hr

Marginal utility for travelling= -6.0 utils/hr for all modes

Marginal utility for waiting = -2.0 utils/hr

Marginal utility for waitingPt = -6.0 utils/hr

Learning rate = 1.0

Other important configuration parameters are-

Duration for home activity = 12 hours

Duration for business activity = 3 hours

Duration for office activity = 8 hours

With the use of the above values the input files are generated by automating the above mentioned parameters using java codes. The generated input files are then run animatism GUI to obtain the relaxed demand. The relaxed demand comprising of optimal plans of the users based on best score obtained after 100 iterations.This is further visualised using Simunto Via and desired output are obtained. The simulated output generated consists of images of the agents moving on the network representing agents starting or finishing from home by blue colour, office by yellow colour and green by business colour.(Refer Appendix 1.2)

CHAPTER 5 RESULTS AND DISCUSSIONS

5.1 Characteristics of travel survey data

The percentage distribution of trips generation for various categories is shown in the following table-

Activity Chain	**Occurrences**	**Share (%)**
home-office-home	540	82.949
home-business-home	111	17.05

The movement of the agents on the network is visualised at different point of time (see Appendix). The green rectangles represent cars and motorbikes and dots represents agents using public transport. During the course of time the vehicles were turning red and yellow in colour because speed is getting slowed down due to congestion. The graph shown below shows the probabilistic distribution of various modes chosen over 100 iterations (refer Appendix 1.2 for graph obtained from simulation). It can be observed that public transport and motorbikes trips form a significant proportion of the total trips with 0.41 and 0.32 probability of being chosen respectively.

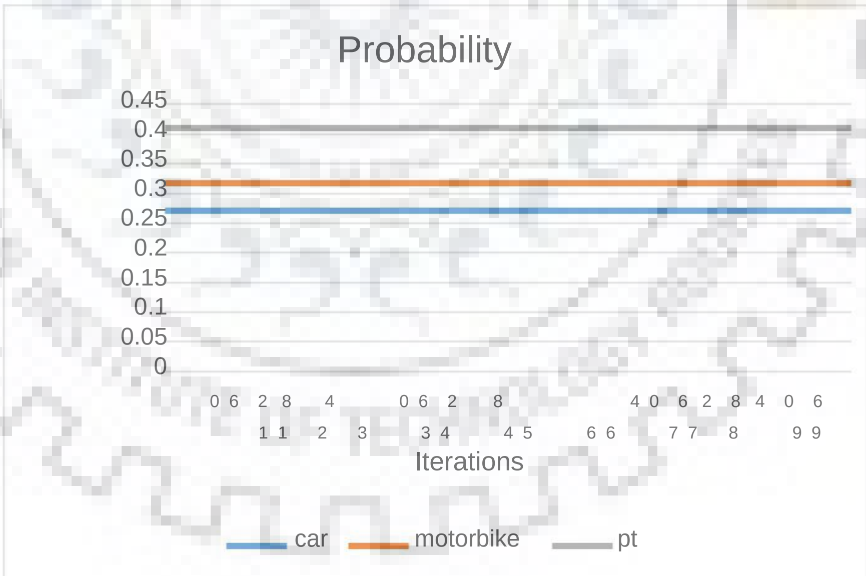


FIGURE 20MODAL DISTRIBUTION

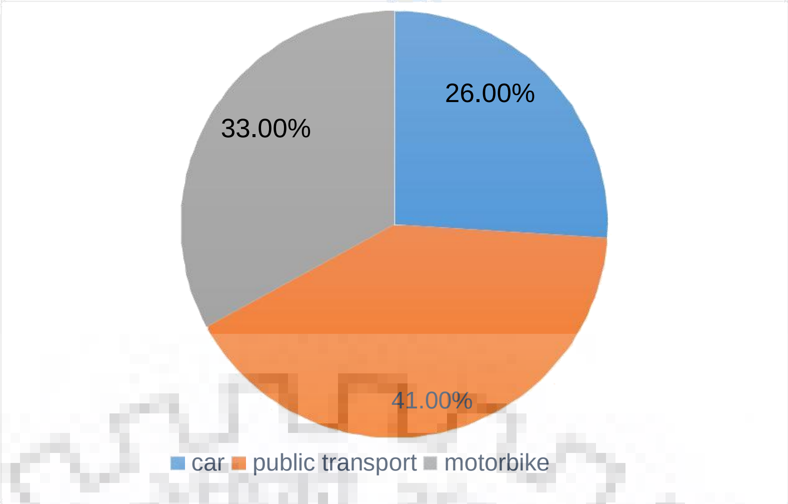


FIGURE 21PIE CHART REPRESENTATION OF MODAL DISTRIBUTION

The distribution shown below in figure shows the variation between people spread over the physical network during a day at different point of time. This is giving us the idea of the density of population in the three wards between 5:00 am to 1:00 am.

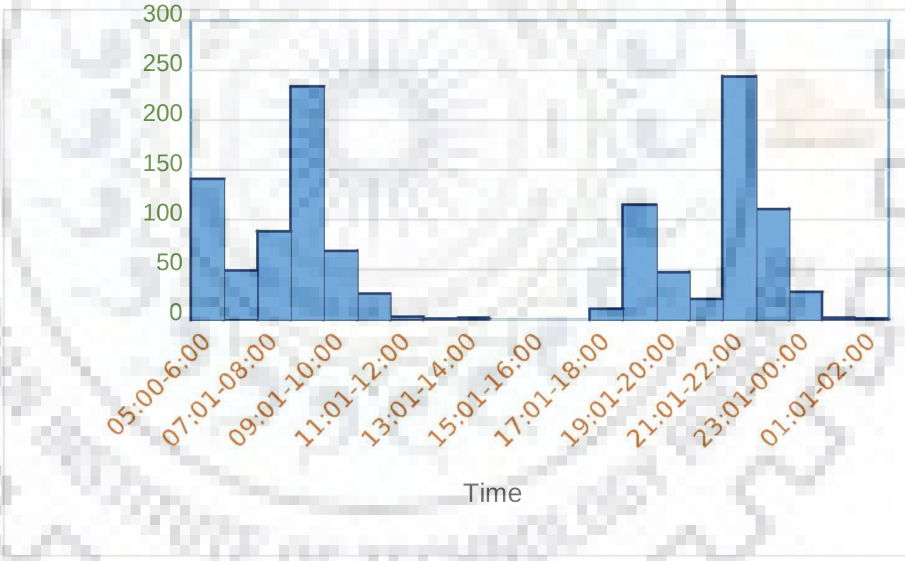


FIGURE 22 FREQUENCY DISTRIBUTION FOR PERSONS

5.2 Results

MATSimusually works for homogeneous traffic like car only. But now with the advancement in modules, it has been compatible with the heterogeneous condition like inclusion of public transit with transit schedules and teleported vehicles. The results obtained from generated scenario of Bengaluru are plausible results and there is possibility of advancement by development of more detailed modules in MATSim. MATSim produces many files as output as mentioned in section 2.5.5 and some can be generated from event handler to analyse the results. Event handlers have all details for congested modes and teleported mode as well.

Using event files only all the analysis results are generated. Score statistics, leg travel distance, leg histograms plots are drawn between utilities vs. iterations, average distance vs. iterations and number of vehicles vs. time of day respectively. MATSim outputs also have a movie file, which shows the movement of all agents on links.

5.2.1 Calculated score and leg distance distribution

The score is calculated to allocate best plans to the agents based on their choices so that optimal path can be provided.The iterative process has to be repeated until the average population score stabilizes. The score development curve is observed in the form of an evolutionary optimization progress.

FIGURE 23 SCORE STATISTICS

Here a line is appearing with all the best, worst and executed scores being overlapped which can be more minutely by zoom in image showing score variation for all the plans as shown in graph below. All the plans with highest score are taken as best plans and allocated to the agents.

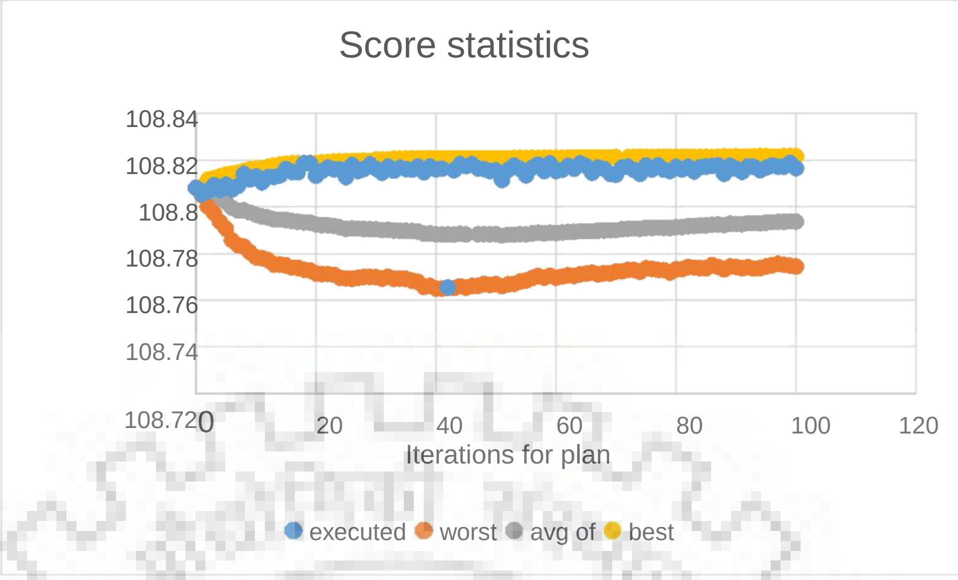


FIGURE 24DEFINED SCORE STATISTICS

Orange, yellow, grey and blue curves in score statistics and in leg travel distance plot are showing values corresponding to worst plan, best plan, average of plans and executed plan respectively. The graph below shows the average distance travelled by distributed as average of leg distance per plan.

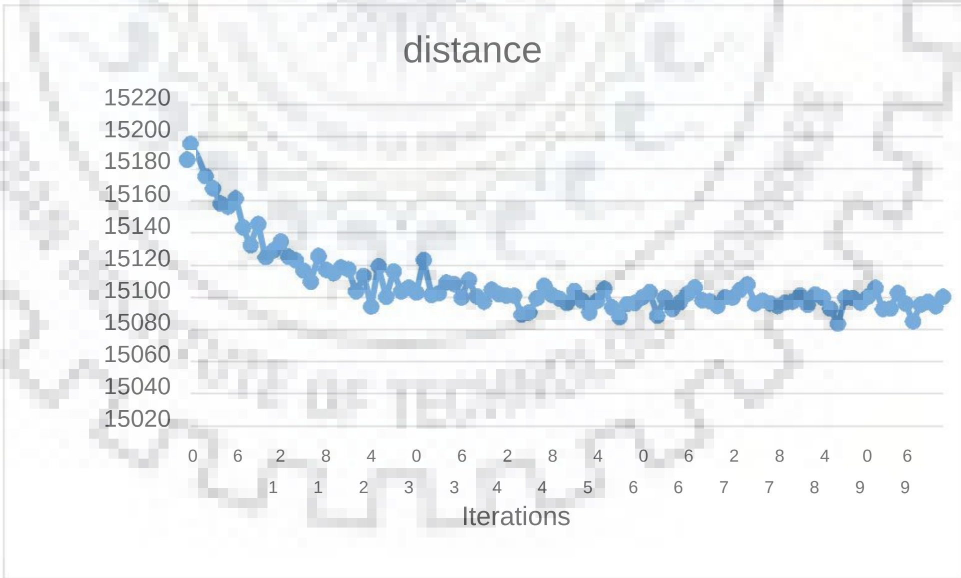


FIGURE 25 AVERAGE DISTANCE TRAVELLED

The graph below obtained from simulationdenotes the leg histogram for iteration 100. Here red line is showing number of departures, blue line is showing number of arrivalsand green is representing the number of vehicles enroute the point where arrival curve is overlapping the departure curve means there is very little congestion and other high peak of red curve shows congestion. The higher the peak of green line, the more agents will enroute.

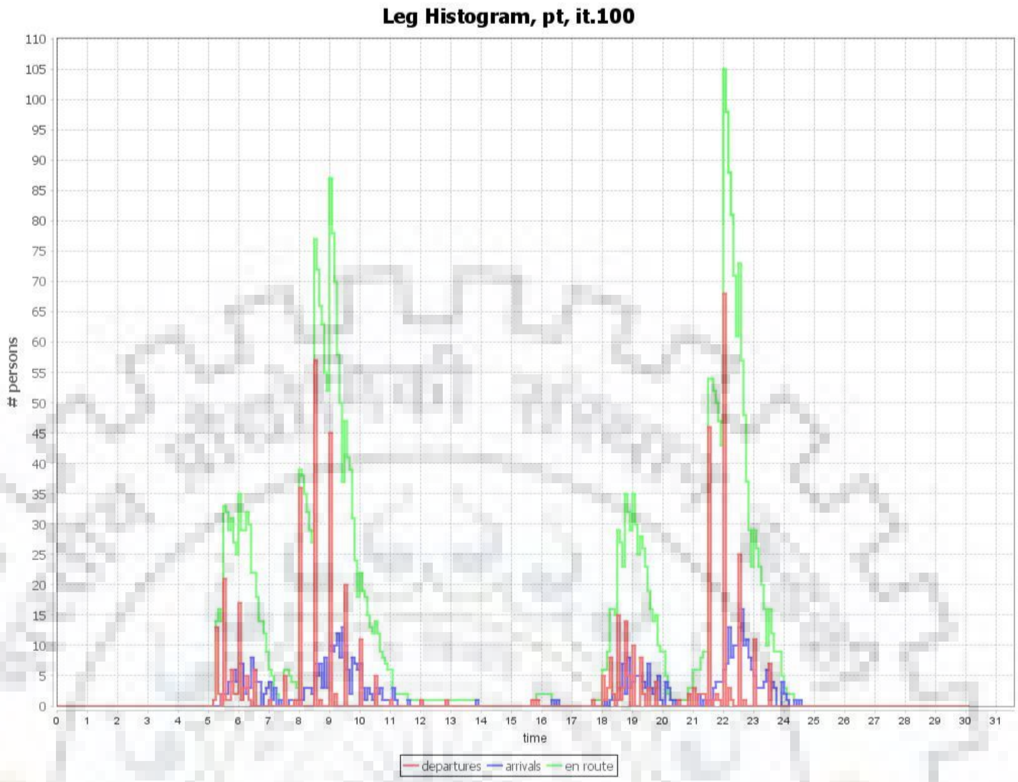


FIGURE 26 LEG HISTOGRAM FOR 100TH ITERATION

In the three graphs mentioned below, the variation between number of persons and time is shown based on the mode of transport. The morning peak for car as mode is between 8:00 am to 9:00 am and evening peak is between 9:30 to 10:30 pm.

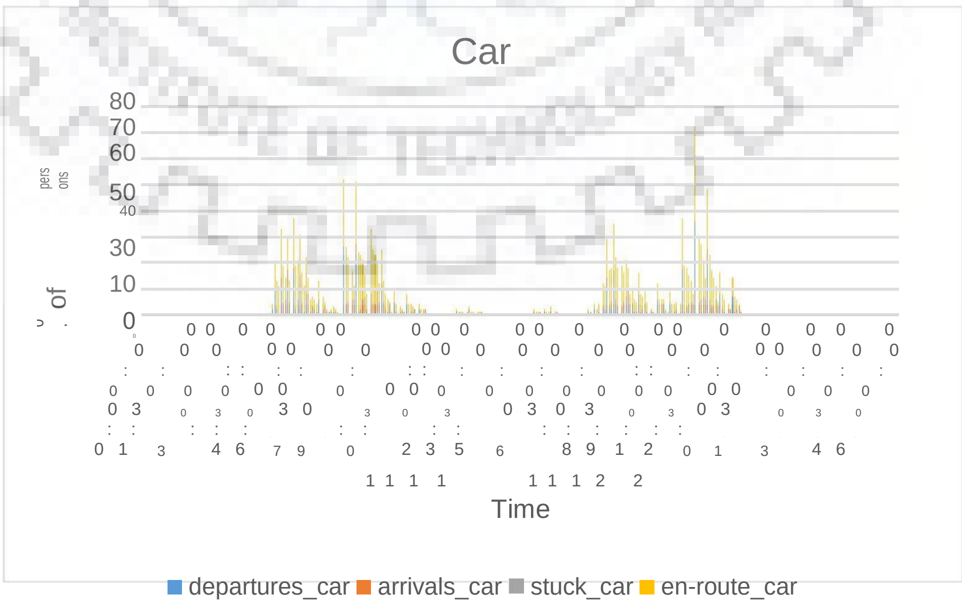


FIGURE 27 HISTOGRAM FOR CAR AS MODE

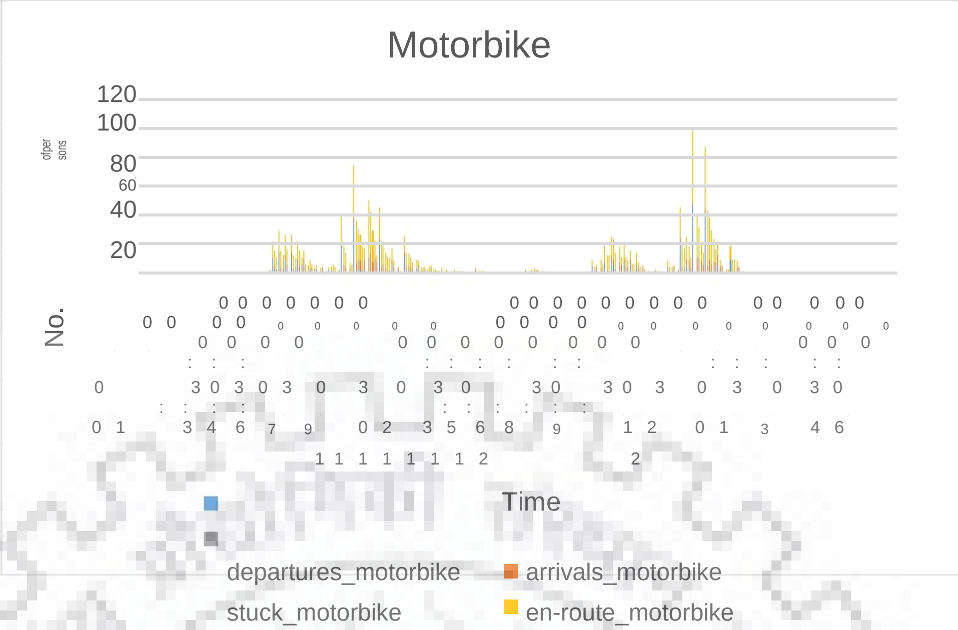


FIGURE 28 HISTOGRAM FOR MOTORBIKE AS MODE

The morning peak for motorbike as mode is between 8:00 am to 9:30 am and evening peak is between 9:30 to 10:30 pm. For public transport, the morning peak has shifted to 8:30 to 9:00am and evening peak as 9:00 to 10:00 pm with increased number of users as compared to motorbike and car.

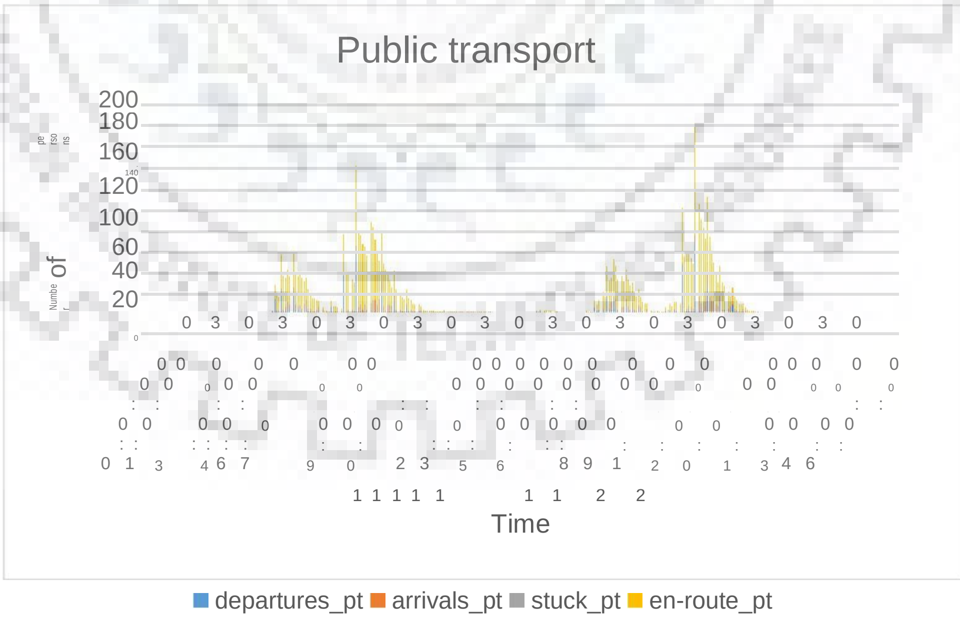


FIGURE 29 HISTOGRAM FOR PUBLIC TRANSPORT AS MODE

5.2.2 Distribution of agents

The graph below shows all the 651 agents performing their activities at different point of time consisting of their starting time from their origin i.e. home and departure time from destination i.e. business or office. Here agents are performing the activity and their distribution is varied based on their time, purpose and destination.

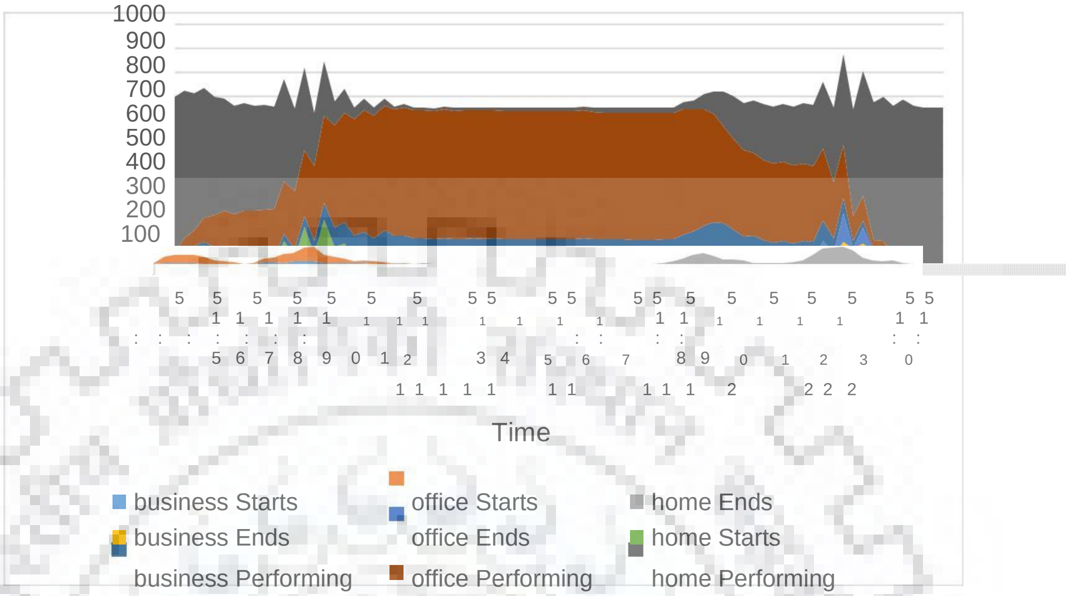


FIGURE 30 ACTIVITY STATISTICS

The graphs mentioned below shows the activity statistics representing the time on x axis and number of persons on the y axis. The peak is obtained based on purpose either home based business or home based office activity. The prominent movement of the agents from home towards office is observed between 5:15 to 6:45 am and from 8:00 to 10am in the morning people starting for business are also observed. In the evening, 6:00 to 7:30 pm and 8:30 to 11:00pm is observed as office ends hours where people are going back from office to home and some from business to home.

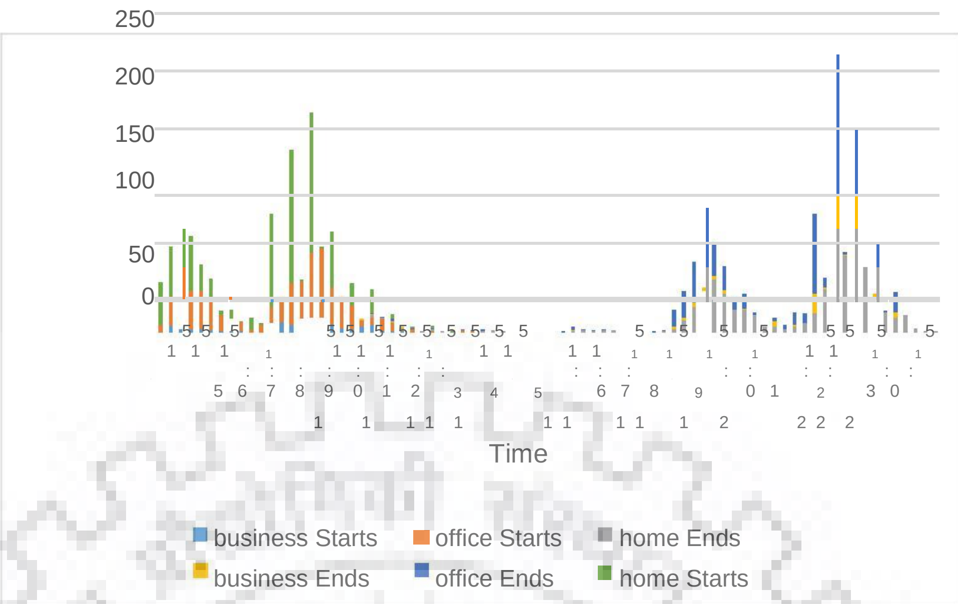


FIGURE 31 DISTRIBUTION BASED ON TRIP PURPOSE

5.2.3 Congested intersection flows

The volume of traffic on the congested intersection on the selected links is finally calculated at various point of time. According to the simulation there are various other prominent congested intersection but we have discussed in the study intersections which encompasses the selected link as mentioned in section 4.3.1. The location of the intersection on the selected link is shownin the figure 32. The detailed land use of the ward is described in

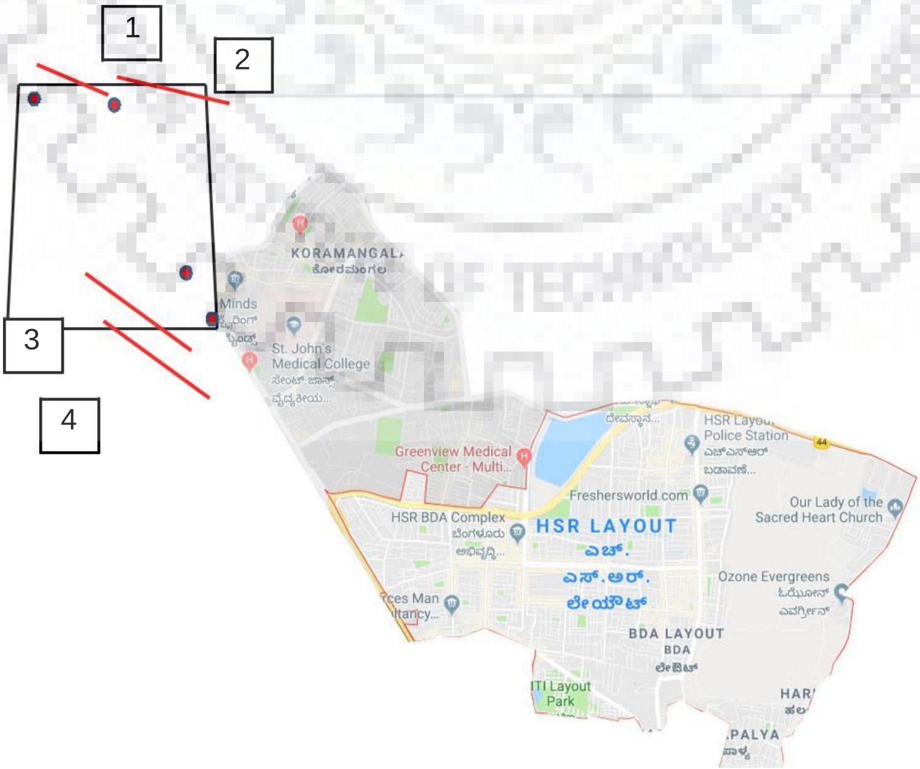


FIGURE 32 POSITIONING INTERSECTIONS

figure33 comprising of residential, commercial, public-semi-public, vegetation and bus stop of the area.

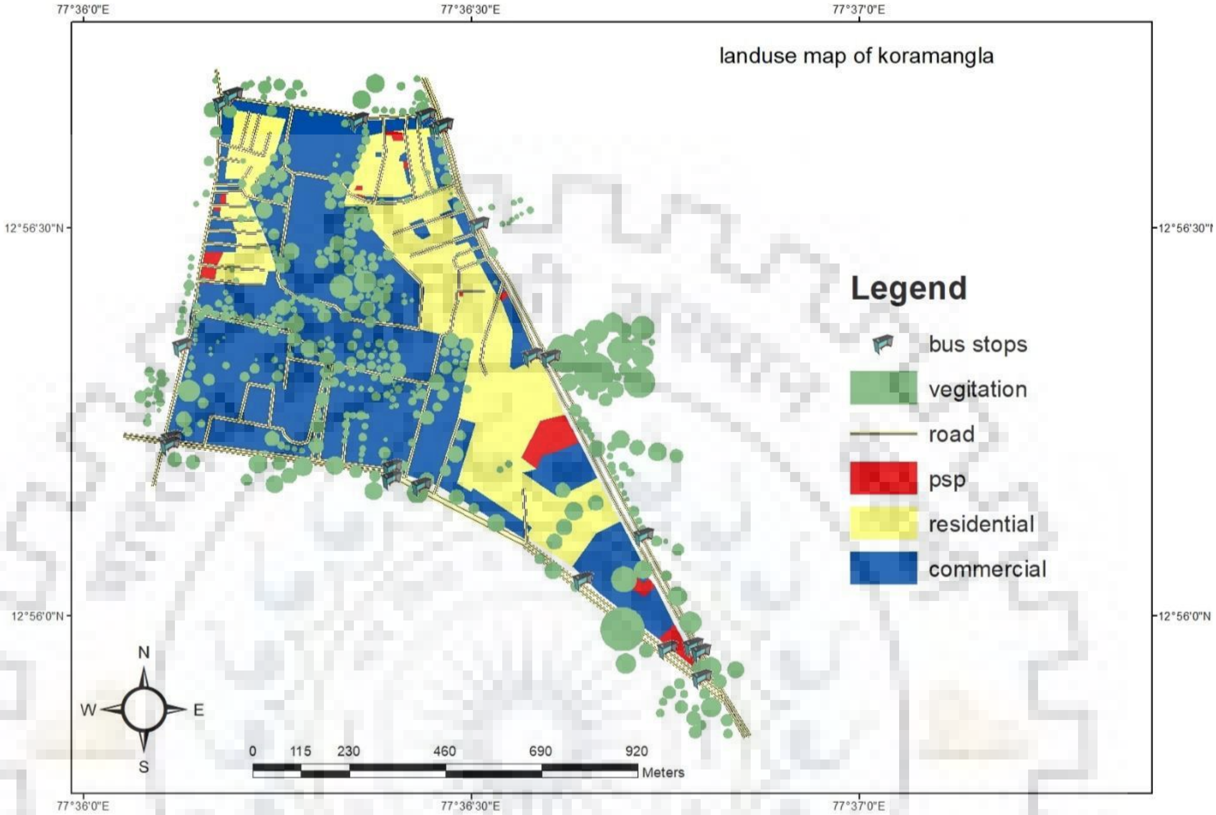


FIGURE 34 LAND USE MAP

FIGURE 33 POSITIONING INTERSECTIONS

Intersection 1

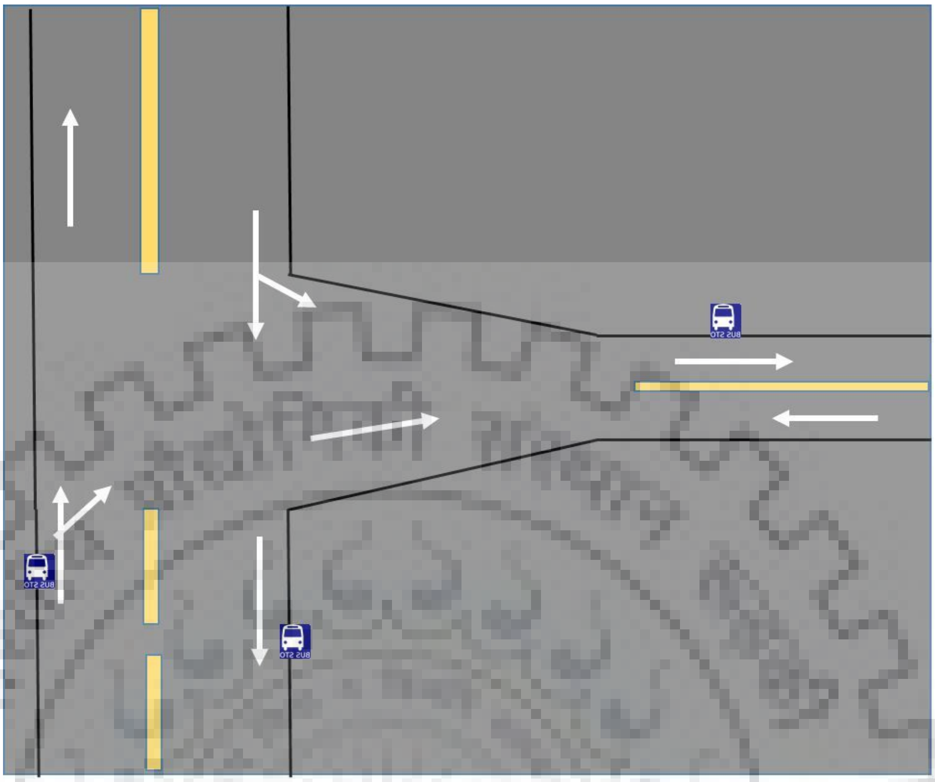
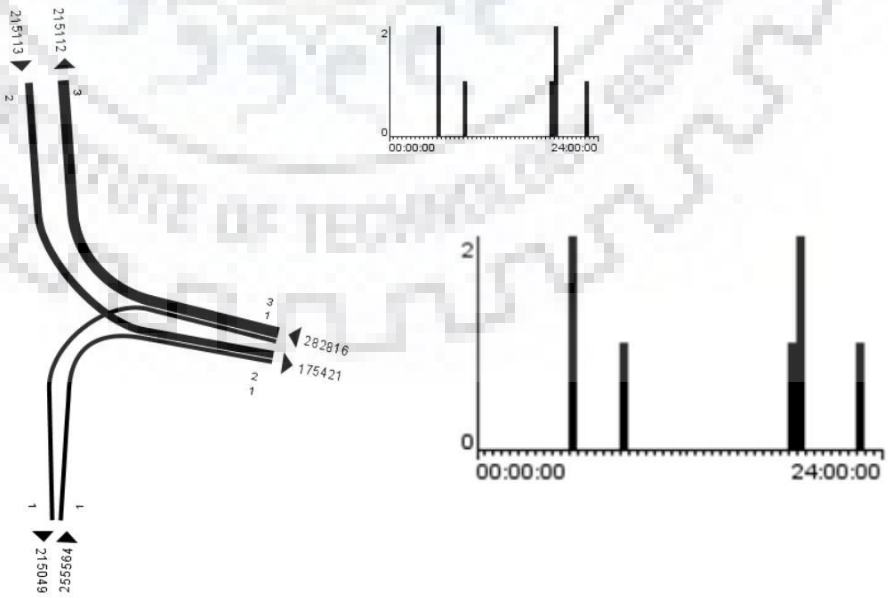


FIGURE 35 TRAFFIC FLOW ON INTERSECTION 1

The image above is the representation of the traffic flow on the intersection 1. This is one of the prominent traffic flow location on the selected link. This is entry location to Mico Bosch in Adugodi with a main bus stop destined to Bannerghatta road.



FIGUREFIGURE31(A)36LINKLINKSTATISTICSONONINTERSECTION1 1

The traffic flow diagrams below describe the volume of traffic flowing in each direction along with the node number of the link, adjacent to this is a histogram showing traffic volume versus time of the day. Here the movement of agents is notice between 5:30 am to 6:00 am and 8:15 am to 9:00 am in the morning peak. In the evening peak, 6:30 to 8:30 pm is the congested period for traffic because of rush for going back home from their work places. A significant movement is observed between 12:00 to 1:00 am in the night.

Intersection 2

The image below is the representation of the traffic flow on the intersection 2. This is one of the congested location on the selected link. This intersection connects New Mico road with Adugodi main road and Koramangala via Hosur road. The three traffic flow diagrams further below describe the volume of traffic flowing in each direction along with the node number of the link, adjacent to this is a histogram showing traffic volume versus time of the day.

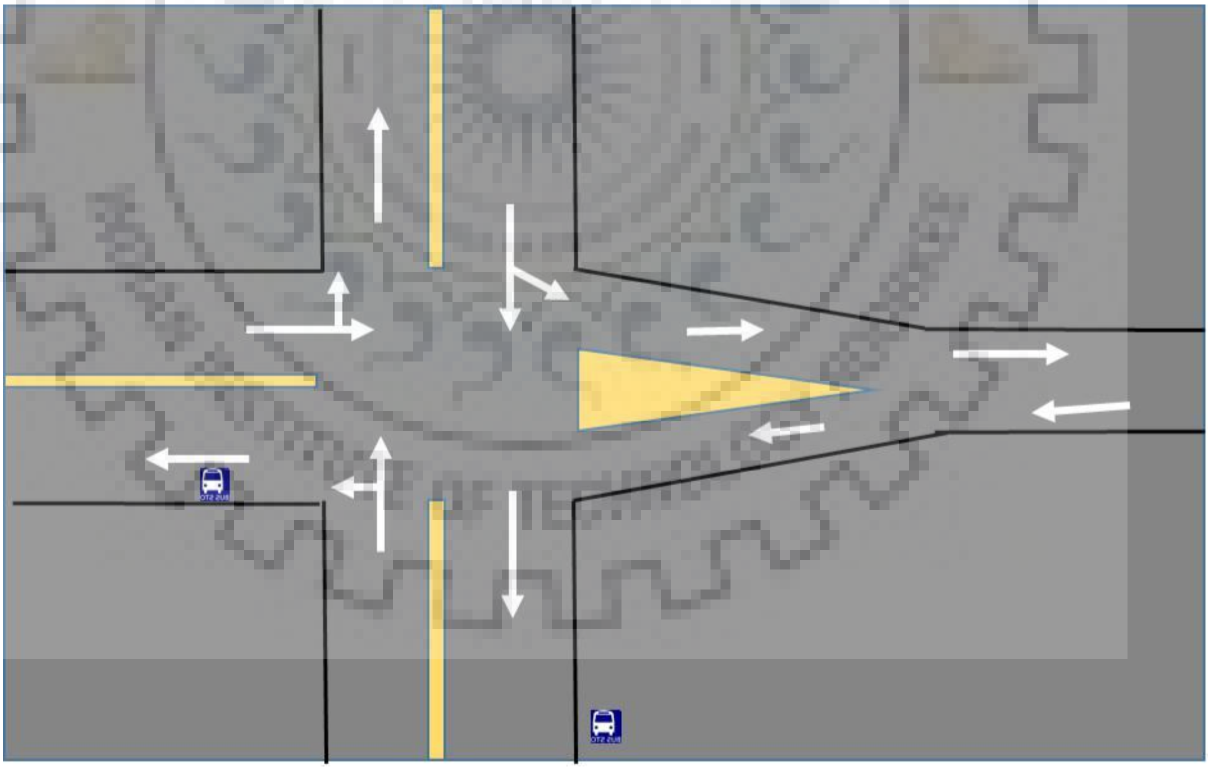


FIGURE 37TRAFFIC FLOW FOR INTERSECTION 2

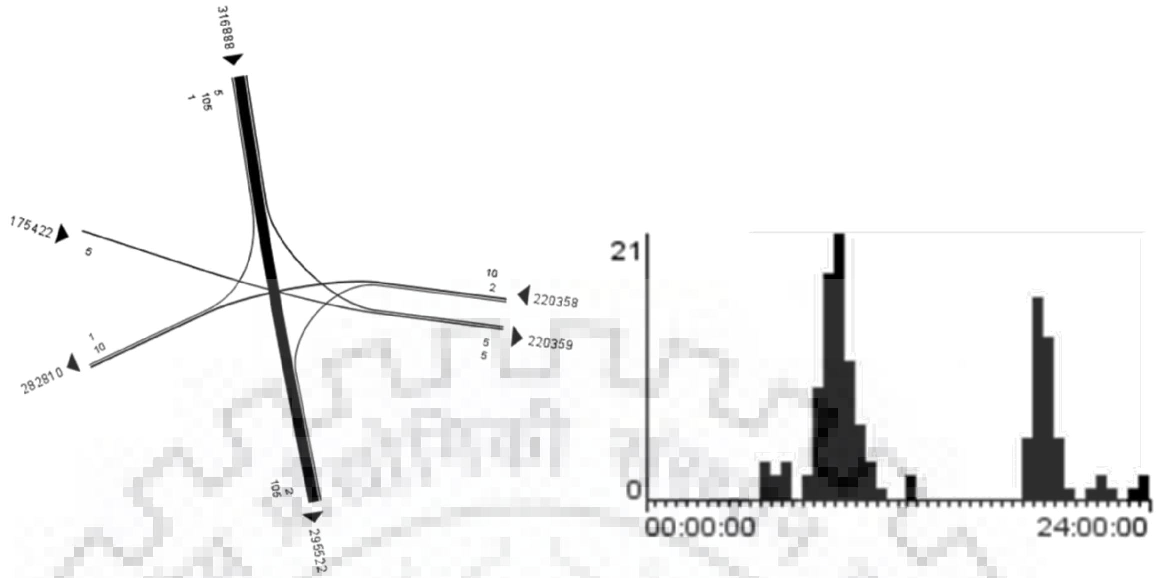


FIGURE 38FLOW ON INTERSECTION 2

In the traffic directions of intersection 2 described above, large movement of agents is observed between 8:30 to 11:30 am in the morning peak and 6:00 to 9:00 pm in the evening peak. Here thorough traffic is shown from Adugodi main road towards road Hosur road, thorough traffic from New Mico road, right turning from Adugodi main road towards New Mico road and left turning traffic from Adugodi main road towards Bhubaneshwari road. Also thorough traffic from Bhubaneshwari road towards New Mico road.

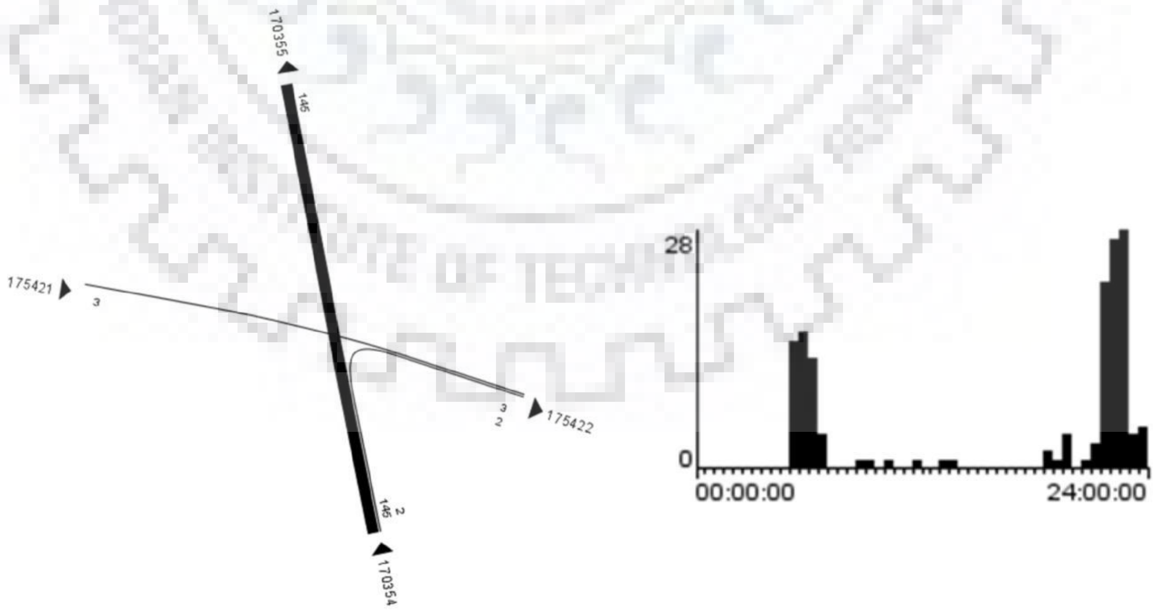


FIGURE 39FLOW ON INTERSECTION 2

In the traffic directions described above, large movement of agents is observed between 5:00 to 7:30 am in the morning peak and 8:00 to 11:30 pm in the evening peak. Here thorough traffic is from Hosur road towards Adugodi main road and thorough traffic road from New Mico road and right turning traffic from Hosur road towards Bhubaneshwari road.

FIGURE 40FLOW ON INTERSECTION 2

In the traffic directions described above, large movement of agents is observed between 5:00 to 7:30 am in the morning peak and 8:00 to 11:30 pm in the evening peak. Here, left turning traffic is shown from Hosur road towards New Mico road and thorough traffic from Bhubaneshwari road towards Adugodi main road.

Intersection 3

The image below is the representation of the traffic flow on the intersection 3. This is one of the main congested location on the selected link. This intersection connects Hosur road with forum mall exit and Koramangala 80 ft. road.

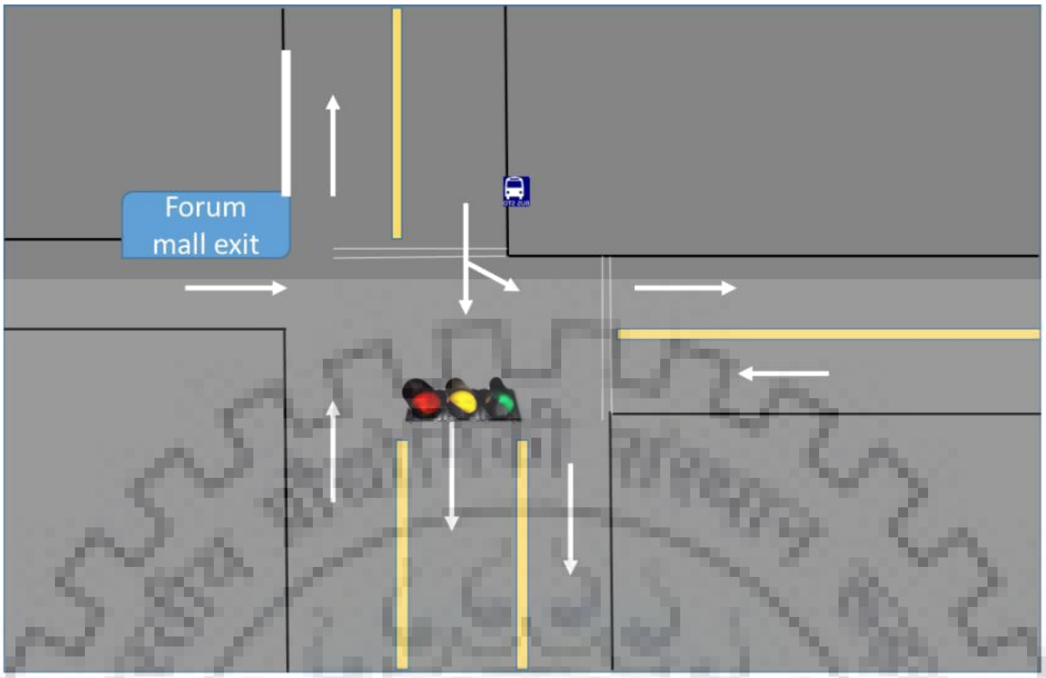


FIGURE 41TRAFFIC FLOW ON INTERSECTION 3

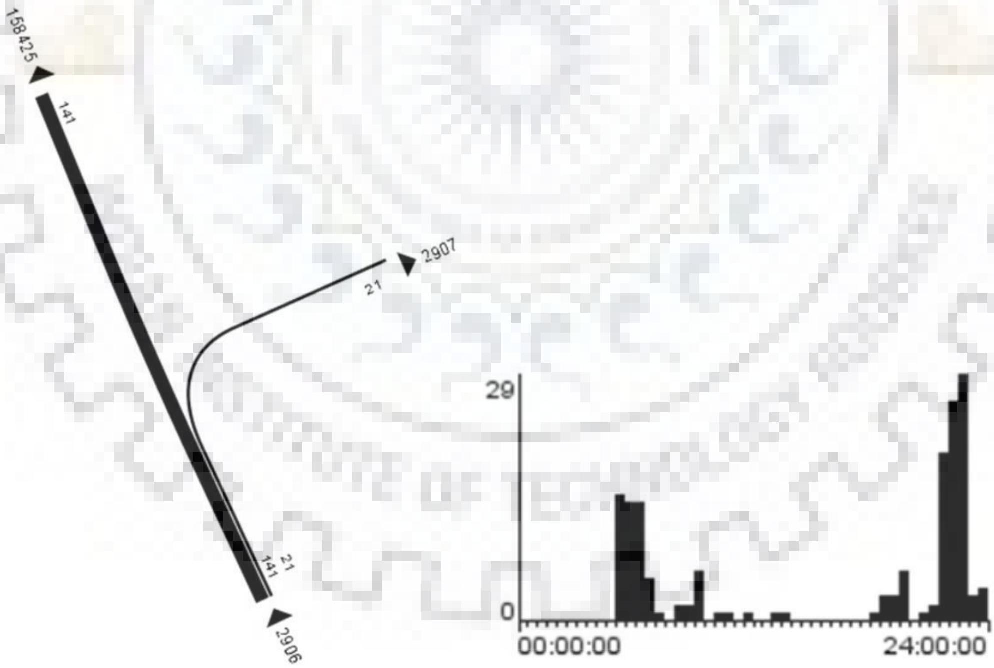


FIGURE 42FLOW ON INTERSECTION 3

The right turning traffic from Hosur road to Koramangala 80 ft. road and thorough traffic on Hosur road towards forum mall is shown with movement of agents between prominent movement between 5:00 to 7:30 am, 6:00 to 7:30 pm and 8:00 to 11:00pm.

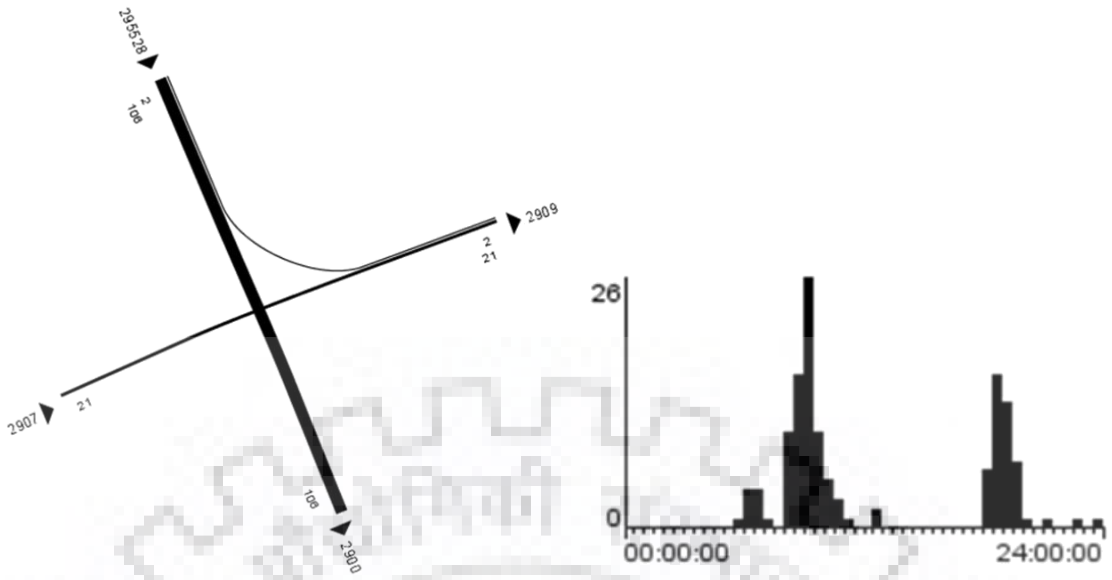


FIGURE 43 FLOW ON INTERSECTION 3

The left turning traffic from Hosur road to Koramangala 80 ft. road and thorough traffic on Hosur road towards central silk board is shown with movement of agents between prominent movement between 7:45 to 11:30 am and 6:00 to 8:00pm.

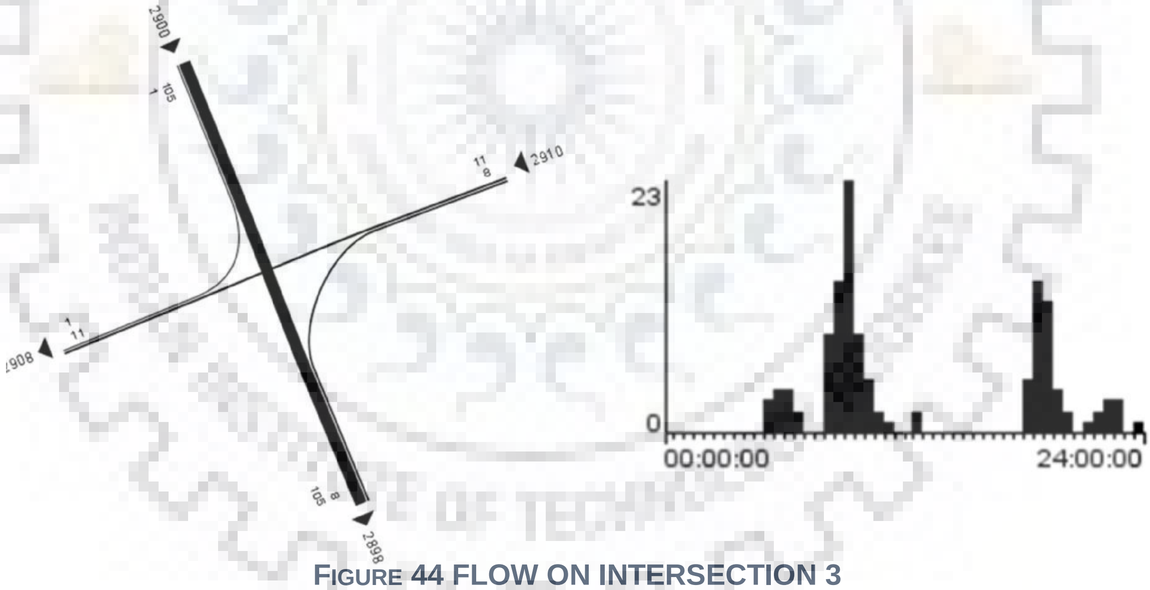


FIGURE 44 FLOW ON INTERSECTION 3

The left turning traffic from Koramangala 80 ft. road to Hosur road, thorough traffic on Hosur road towards central silk board and right turning traffic from Hosur road to forum mall is shown with movement of agents between prominent movement between 7:45 to 11:30 am and 6:00 to 8:00pm.

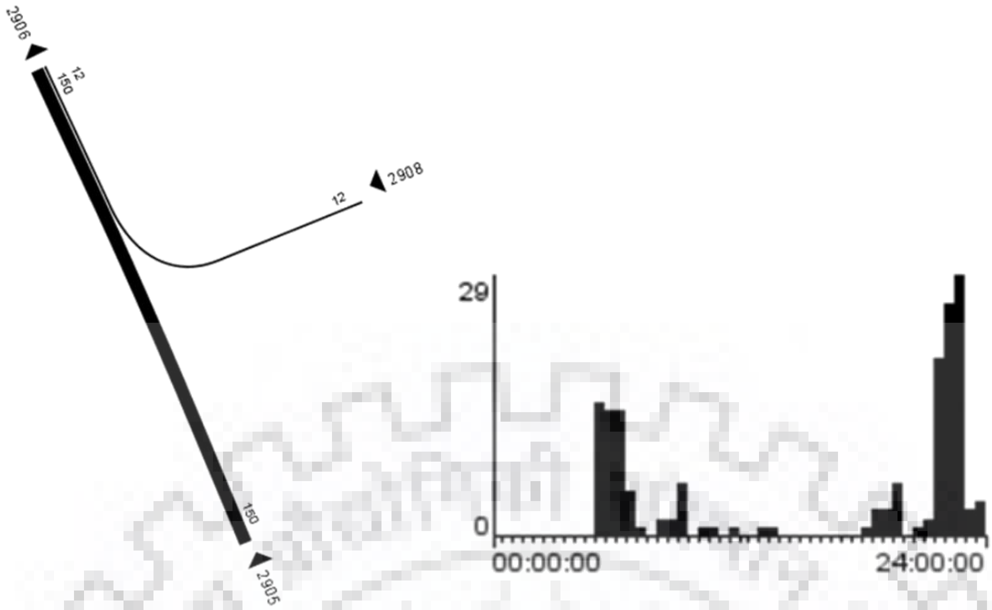


FIGURE 45 FLOW ON INTERSECTION 3

The right turning traffic is shown from Koramangala 80 ft. road towards Hosur road with movement between 5:15 to 9:30 am and 6:00 to 11:00pm.

Intersection 4

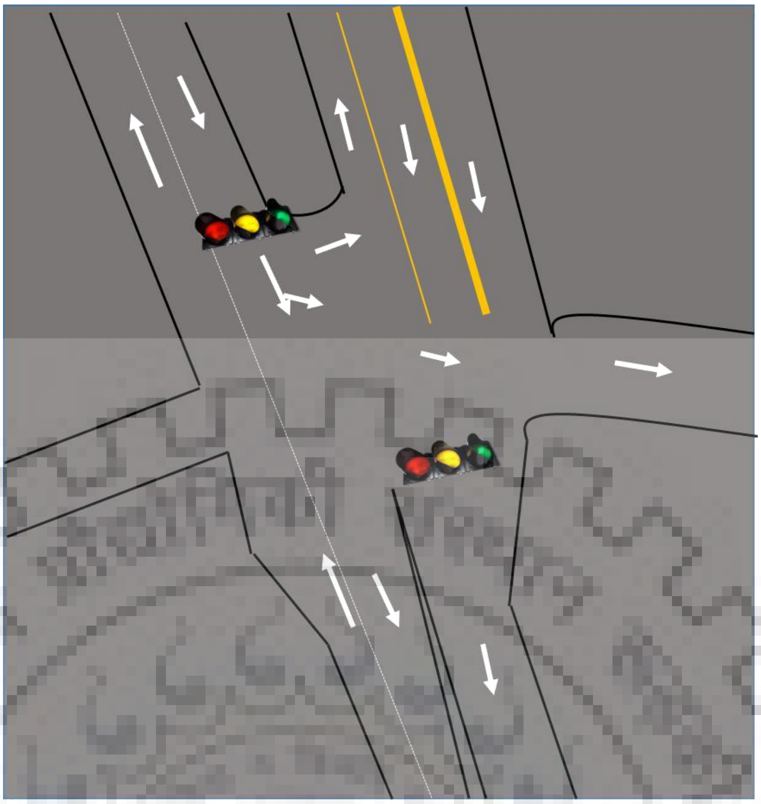


FIGURE 46 INTERSECTION 4

The image below is the representation of the traffic flow on the intersection 3. This is one of the most congested location on the selected link. This intersection connects Hosur road (towards forum mall exit)with Hosur main road and Hosur road (towards central silk board).

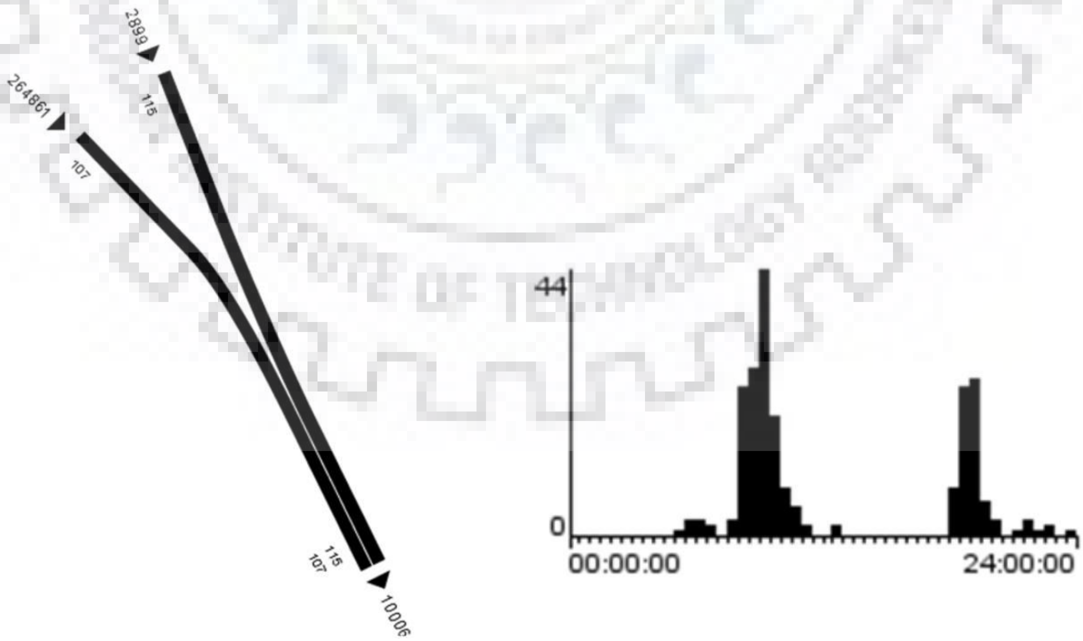


FIGURE 47FLOW ON INTERSECTION 4

Here thorough traffic movement is shown from Hosur main road and connects Hosur road (towards forum mall exit) towards Hosur road (towards central silk board). The movement of agents is observed from 8:00 to 11:30 am and 6:00 to 8:30 pm in the evening.

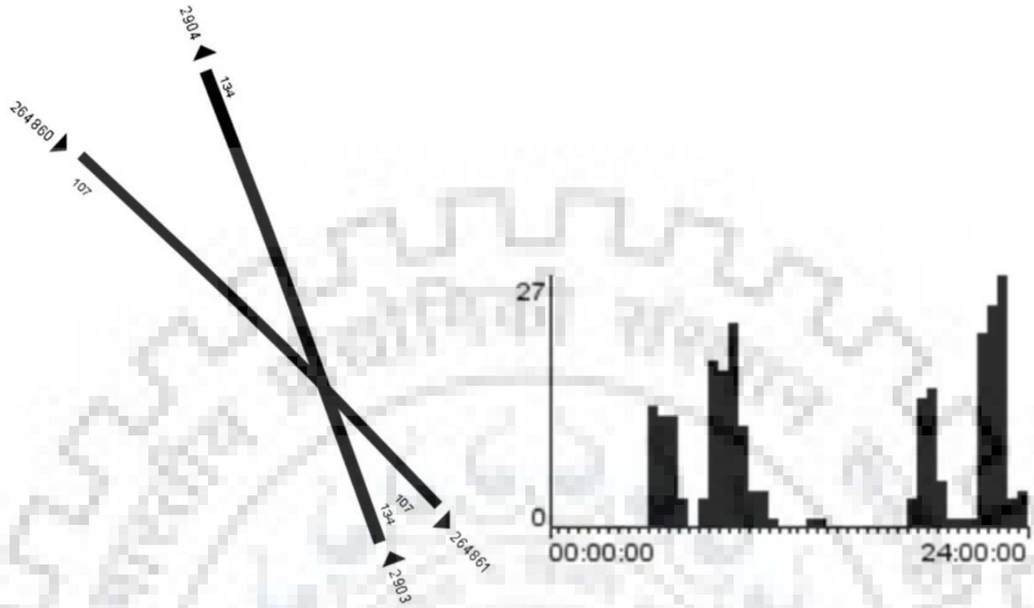


FIGURE 48FLOW ON INTERSECTION 4

The thorough traffic movement is shown from Hosur road (towards central silk board) towards Hosur road (towards forum mall exit) and from Hosur main road towards Hosur road (towards central silk board). The movement of agents is observed from 5:00 to 11:30 am and 6:00 to 11:30 pm in the evening.

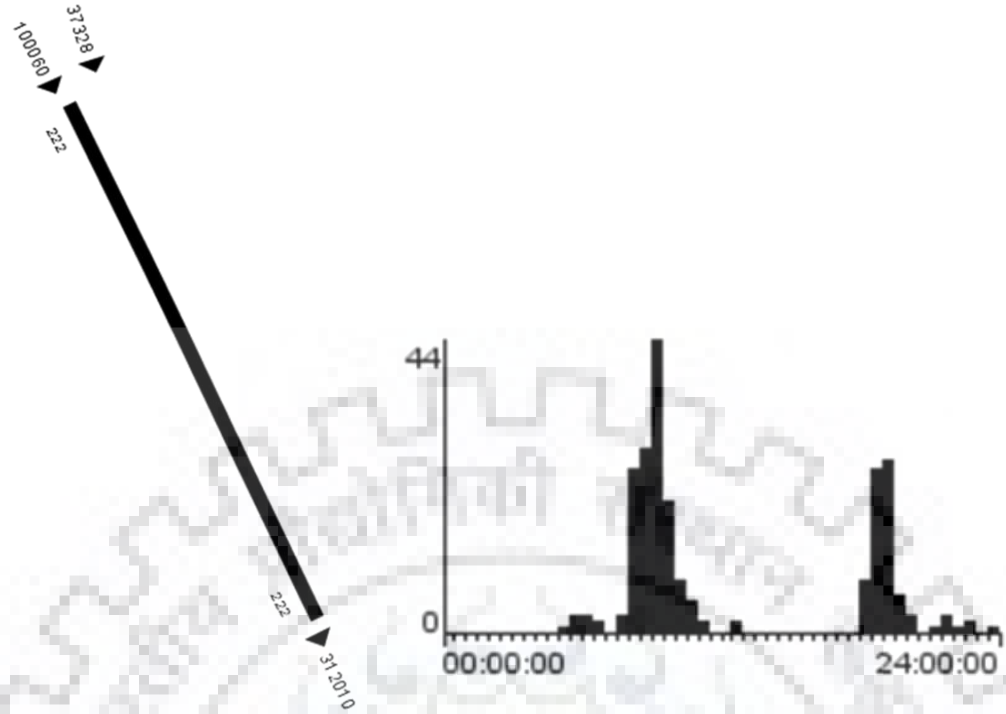


FIGURE 49FLOW ON INTERSECTION 4

The thorough traffic movement is shown from Hosur road (towards forum mall exit) and Hosur main road towards Hosur road (towards central silk board). The movement of agents is observed mainly from 7:30 to 12:00 am and 6:00 to 9:00 pm in the evening.

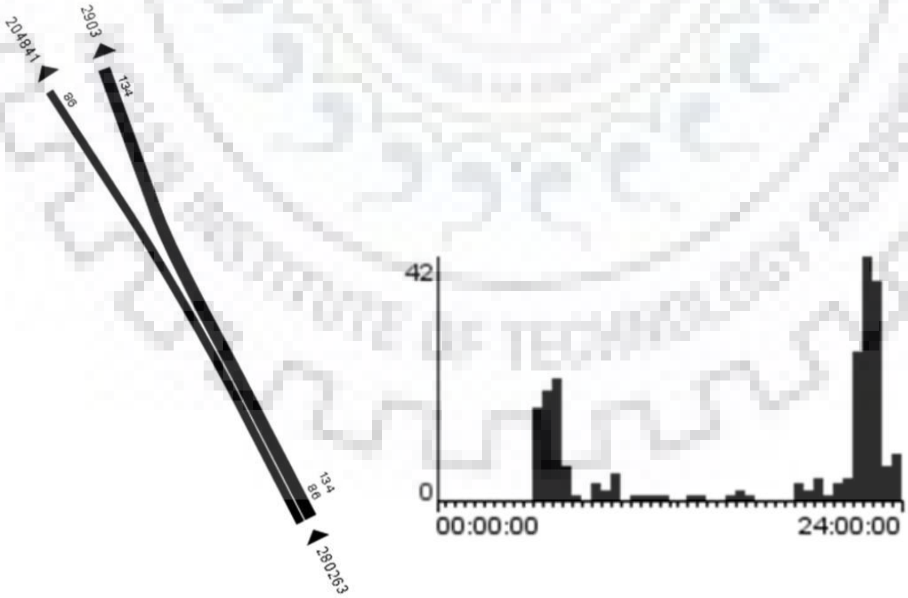


FIGURE 50FLOW ON INTERSECTION 4

The thorough traffic movement is shown from Hosur road (towards central silk board) towards Hosur road (towards forum mall exit) and Hosur main road. The movement of agents is observed mainly from 5:30 to 7:30 am and 6:30pm to 12:00 am in the evening.

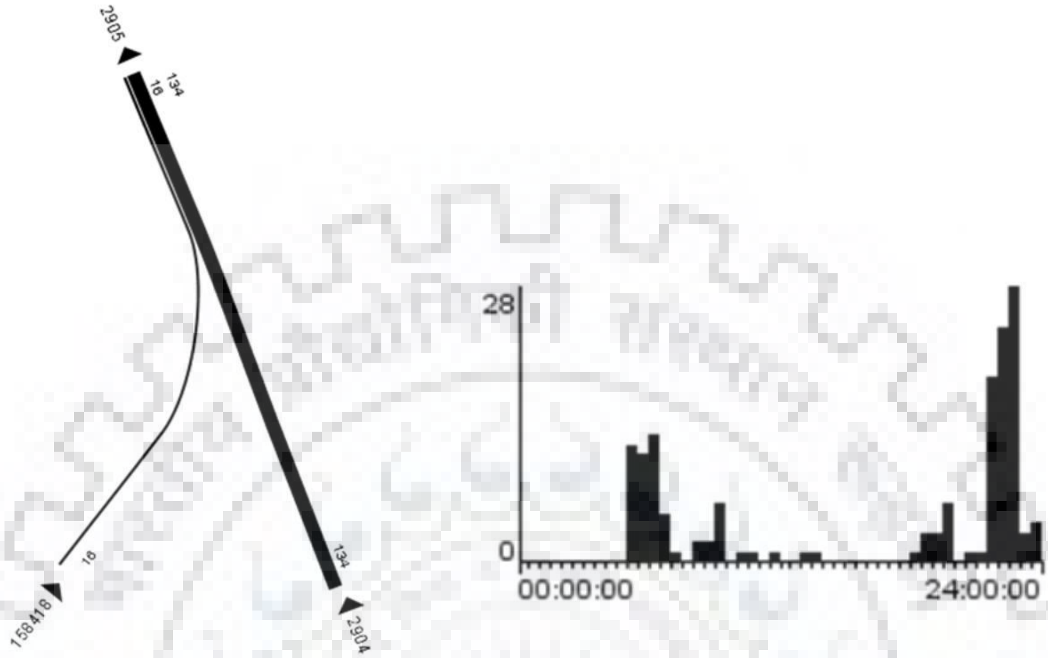


FIGURE 51FLOW ON INTERSECTION 4

The thorough traffic movement is shown from Hosur road (towards central silk board) towards Hosur road (towards forum mall exit) and merging traffic towards Hosur road (towards forum mall exit). The movement of agents has started from 5:15am with rush hours between 7:45 to 11:00 am and 5:45pm to 9:00 pm in the evening.

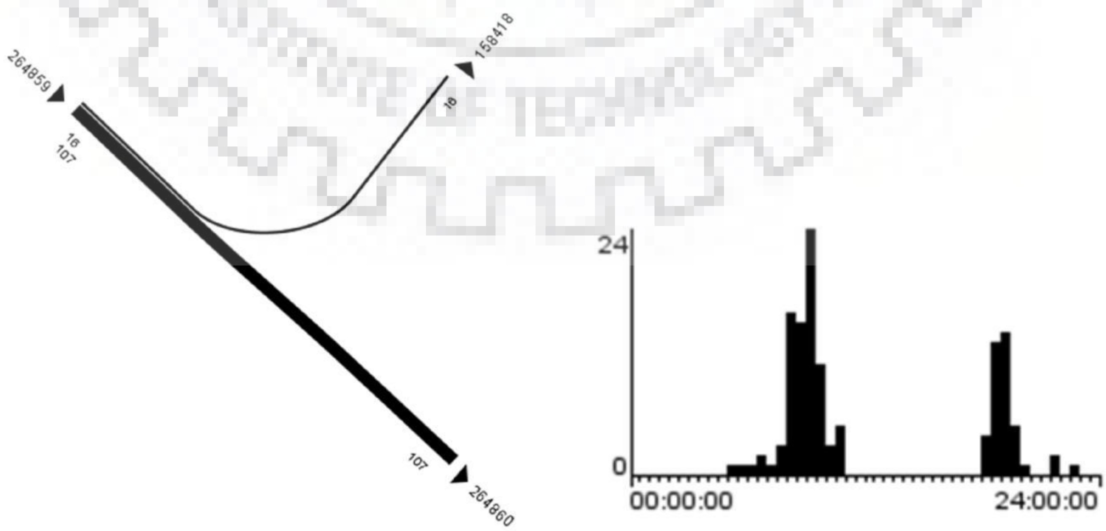


FIGURE 52FLOW ON INTERSECTION 4

The thorough traffic movement is shown from Hosur main road towards Hosur road (towards central silk board) and diverging traffic from Hosur main road towards Hosur road (towards central silk board). The movement of agents has started from 5:15am with rush hours between 7:45 to 11:00 am and 5:45pm to 9:00 pm in the evening.

Chapter 6 CONCLUSIONS AND FUTURE SCOPE

6.1 Conclusions

The research work has been conducted to study flow pattern of people on the physical network of three specified wards of Bengaluru named Adugodi (ward no 147), Koramangala (ward no 151) and HSR Layout (ward no 173) and the distribution of these flows which is leading to congestion.The land use of the area is specifically commercial and residential with few public, and semi-public units.The work based trips are considered and classified into home based office and home based business trips.

i. The first objective is achieved in Section 4.3.1 and 4.3.2 based on the survey done and data collected which has helped in understanding movement of people for work based trips.
ii. The second objective is demarcated by section 4.3.2 and more precisely fulfilled by section 5.2 showing trip generation based on their origin and destination and further their distribution on the network at various point of time showing demand on the particular areas represented by commuters using various modes with different trip purposes.
iii. The development of framework has been done in pilot study shown in section 4.2 which is further improved while executing the actual scenario described in 4.3. The methodology for the scenario has been followed in section 4.3.3.
iv. The final objective with recommendations will be discussed below.

Major findings from the work has been described as follows-

Based on mode of transportation used, the morning peak is observed between 8:00 to 9:30 am and evening peak is observed between 9:00 to 10:30 pm. Public transport and motorbike is used by more number of persons in comparison of car.

Based on trip purpose, most of the people are starting from their home for between 5:30 to 7:00 am and 8:00 am to 10:00 am. The business trips start around 8:00 am and ends in the evening between 6:00 pm to 10:30 pm. People start returning back to their home from 5:30 pm to 1:00 am. The morning peak is observed to between 8:30 to 9:00pm and evening peak from 9:45 pm to 10:30 pm.

Based on the congestion on intersections, most congested intersection is intersection 4 with more than 100 number of users on all the links. Intersection 1, 2 and 3 are also prominent locations of congestion. The morning peak observed on the intersections is 7:30 am to 11:00 am and evening peak as 6:00 pm to 10:00 pm.

6.2 Limitations and Future scope

The scenario generated in this thesis is based on one-day travel diary based on household survey. The work has been done on the two stretches of 500 m and 880 m that are major roads feeding traffic to the ward, other sub arterials and feeder roads are not considered that can add much importance to the traffic coming to the major links. The validation of the traffic count has not been done due to limitation of availability of data.

For expanding the scope of the study, the travel diaries can be considered more number of days say a week or month to have clearer picture of changing travel demand on network. The workcan be advanced with development of more modules in MATSim considering more demographic attributes to know their effect on the travel choice made by people which can connect it to a better urban planning scenario so that more users can be encouraged for sustainable transport system by minimising use of private vehicles and increasing use of public vehicles. Arterials, sub arterials and other feeder roads of the adjoining links of the network can be considered to improvise the demand generation which may provide more precision in the scenario. Further the modes of transport can be taken more diversely as public transport in Bangalore consists of bus, auto rickshaws, car pool and metro which are significant modes of commute.

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APPENDIX

Appendix 1.1

The below mentioned tables shows the data schema and data type explained respectively obtained for the study scenario.

Location	Segment	Home location	Work / Education Destination	Demographic					#Vehicle owned	^Average daily distance travel (Km)	$Average travel Time / Day (In Hours)	&Number of transfer	@Mode of payment	^^Mode wise
				*HH	**G	***AG	****IG	*****ED						
				Segregation shown below	"do"	"do"	"do"	"do"	Segregation shown below	Segregation shown below	Segregation shown below	Segregation shown below	Segregation shown below	Segregation shown below
Bengaluru	HBW	Jp Nagar	Electronic City											
Bengaluru	HBO	Byrathi	Cv Raman Nagar											
Bengaluru	HBE	Banashankari	Rajaji Nagar											
Bengaluru	HBE	Rt Nagar	Mg Road											
------------	------------	------------	------------											
Bengaluru	HBO	Jp Nagar	Banashankari											
Bengaluru	HBW	Laxmipura	Bannerghatta Road											

Demographics	
*Household size (HH)	1 & 2
	3 & 4
	5 & Above
**Gender (G)	M
	F
***Age Group (AG)	6 to 20
	21 - 35
	35 - 45
	45 - 60
	> 60
****Income Group(IG)	< 0.4 Mn
	0.4 - 0.6 Mn
	0.6 - 0.8 Mn
	0.8 - 1 Mn
	1 - 1.5 Mn
	Above 1.5 Mn
*****Education (ED)	Illiterate
	< Secondary
	Secondary
	Higher Secondary
	Graduation
	Post Graduation & Higher

#Vehicles Owned
Single 2W
Single Car
Single 2W + Single Car
Double 2W
Double Car
Double 2W + Double Car
Multiple 2W
None

^Average daily distance travel (Km)
Up to 10
>10 to 20
>20 - 30
>30 - 40
>40

$Average travel Time / Day (In Hours)
Up to 1
> 1 to 2
> 1 to 2
> 3 - 4
> 4

&Number of transfer
None
1
2
3
4 & Above

@Mode of payment
Pre payment
Post payment
During Travel
Own Vehicle

^^Mode wise
2W
4W
PT

FIGURE 53 SCHEMA OF DATA COLLECTION

APPENDIX 1.2


```xml
<node id="579395251" x="1367339.723452867" y="-476126.3162721144" >
</node>
<node id="5795239499" x="1374127.4675918585" y="-481323.162959798" >
</node>
<node id="5795390720" x="1372940.0849096125" y="-473880.10732794227" >
</node>
<node id="5795933309" x="1372134.6921144102" y="-463530.32697814493" >
</node>
<node id="5795933310" x="1372168.353133043" y="-463443.1327322668" >
</node>
<node id="579891683" x="1352590.1636917463" y="-479388.91048405156" >
</node>
<node id="579891684" x="1352479.1549253927" y="-478970.0809327625" >
</node>
<node id="579891732" x="1352919.3816126273" y="-475129.8083273154" >
</node>
<node id="579891797" x="1352575.6209645716" y="-479259.7746841756" >
</node>
<node id="579891799" x="1352494.0291864888" y="-478958.0205404463" >
</node>
<node id="579892001" x="1353757.5078310268" y="-469682.17951943935" >
</node>
<node id="579892009" x="1353794.8404184016" y="-469553.9072979605" >
</node>
<node id="579900018" x="1352630.4464894398" y="-479257.1000834524" >
</node>
```


FIGURE 54INPUT NETWORK FILE IN XML FORMAT


```xml
<!-- ====================================================================== -->

    <person id="331">
        <plan selected="yes">
            <activity type="home" x="1371365.70644792" y="-458877.52594079426" end_time="10:30:00" >
            </activity>
            <leg mode="pt">
            </leg>
            <activity type="office" x="1370801.971474475" y="-479397.8844882576" end_time="23:30:00" >
            </activity>
            <leg mode="pt">
            </leg>
            <activity type="home" x="1371365.70644792" y="-458877.52594079426" >
            </activity>
        </plan>

    </person>

<!-- ====================================================================== -->
```


FIGURE 55 INPUT PLANS FILE IN XML FORMAT

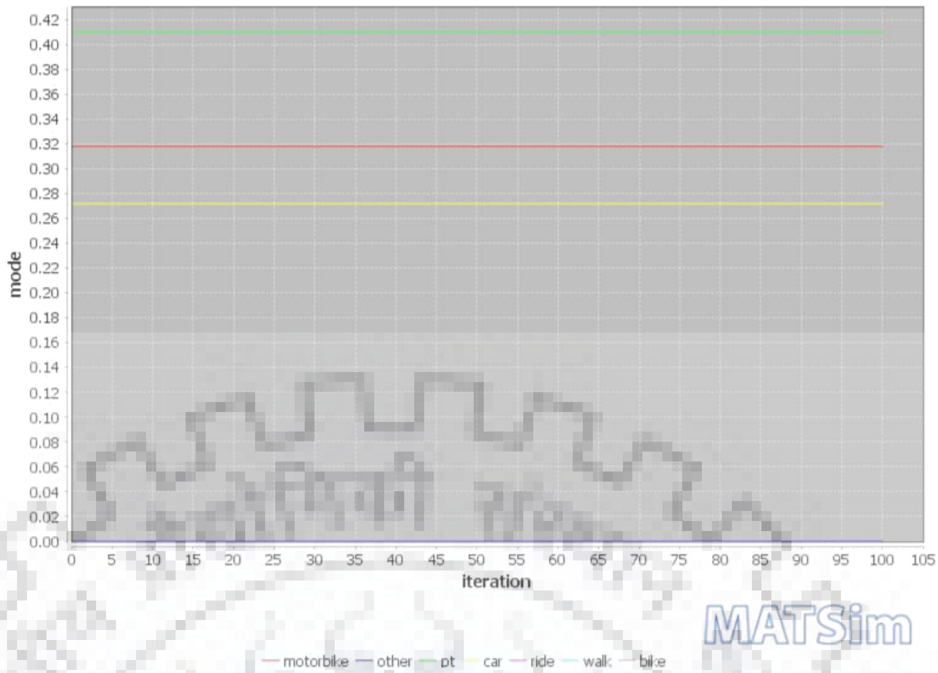

FIGURE 56 MODE STATISTICS OBTAINED FROM SIMULATION

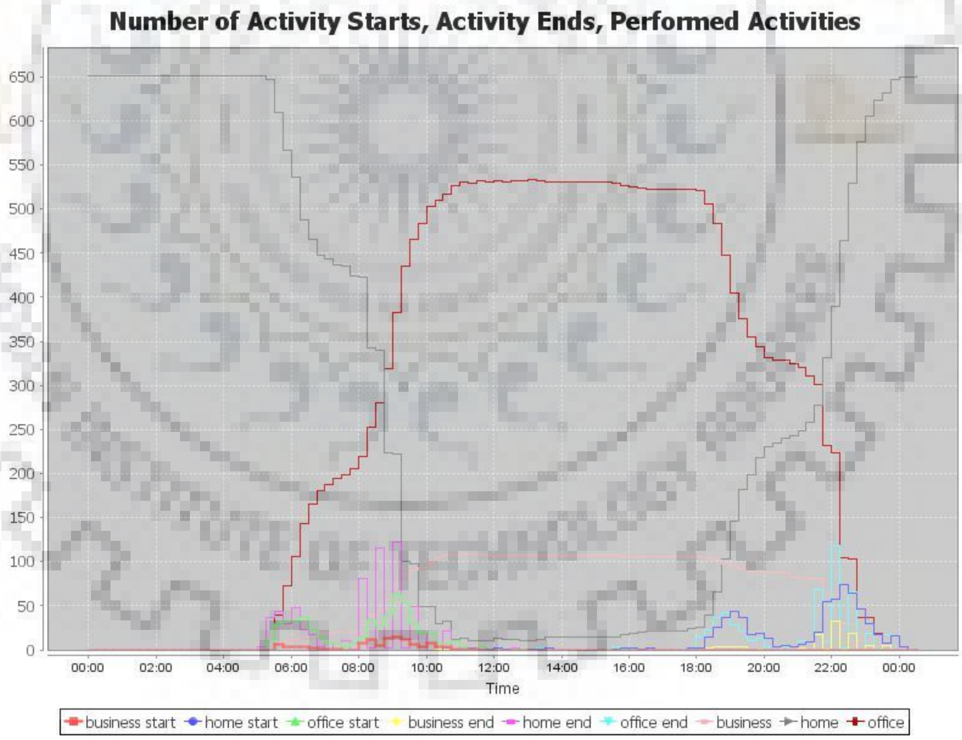

FIGURE 57 ACTIVITY STATISTICS

The simulated network is shown below with agents described as performing home activity as blue, office activity as yellow and business activity as green.

5:30

FIGURE 58 SIMULATION AT 5:30 AM

8:00

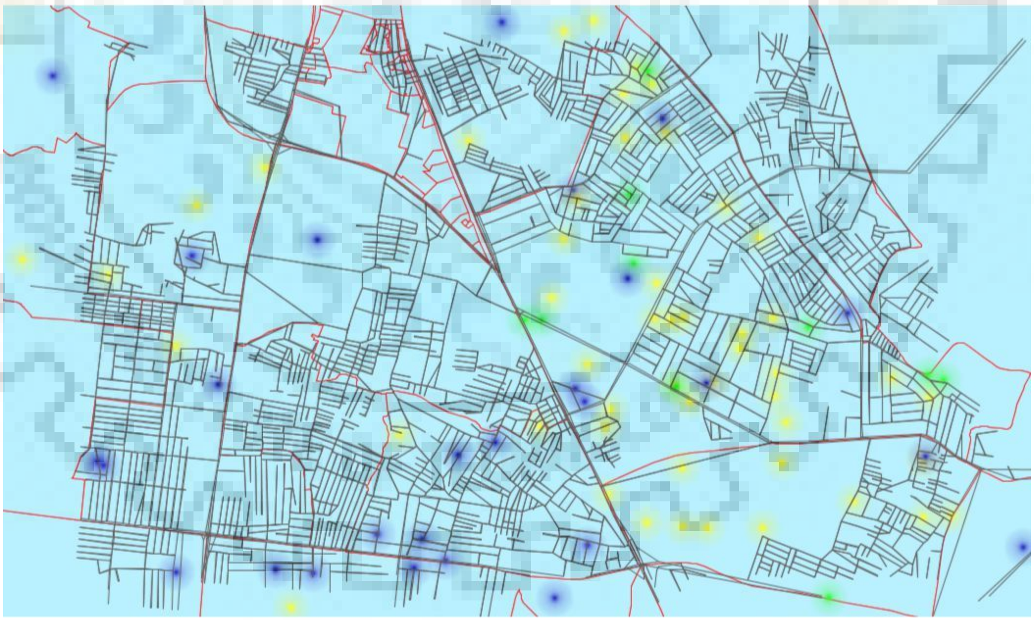

FIGURE 59 SIMULATION AT 8:00 AM

10:00

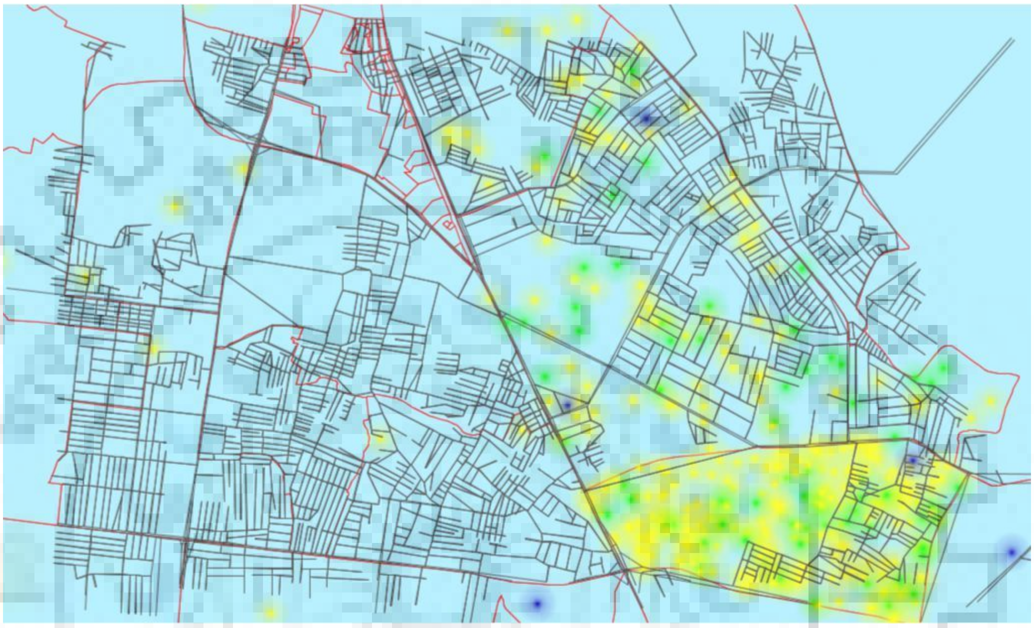

FIGURE 60 SIMULATION AT 10:00 AM

2:30

FIGURE 61 SIMULATION AT 2:30 PM

6:30

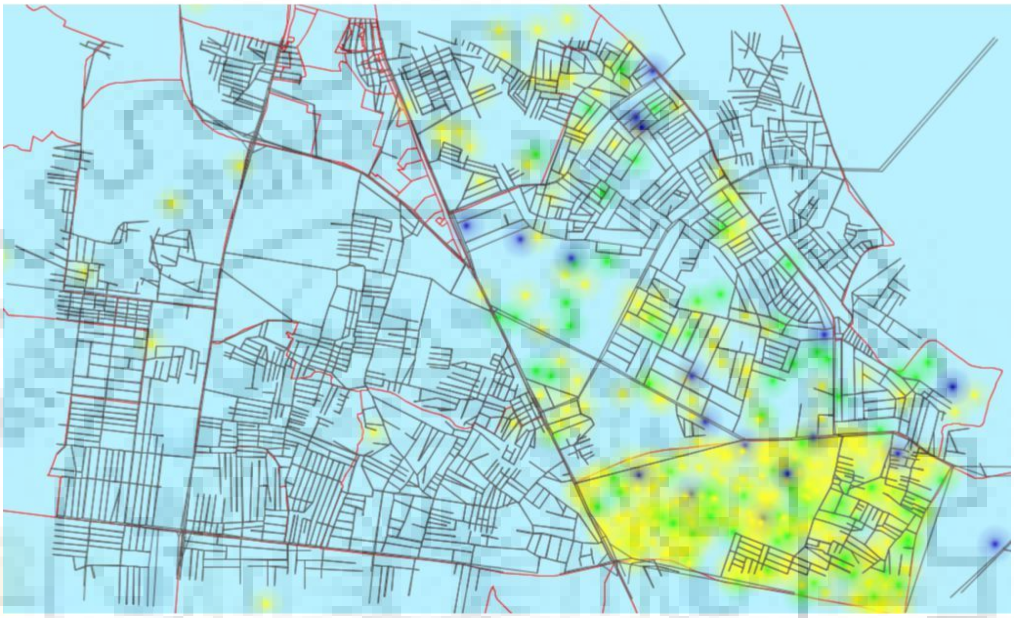

FIGURE 62 SIMULATION AT 6:30 PM

11:30

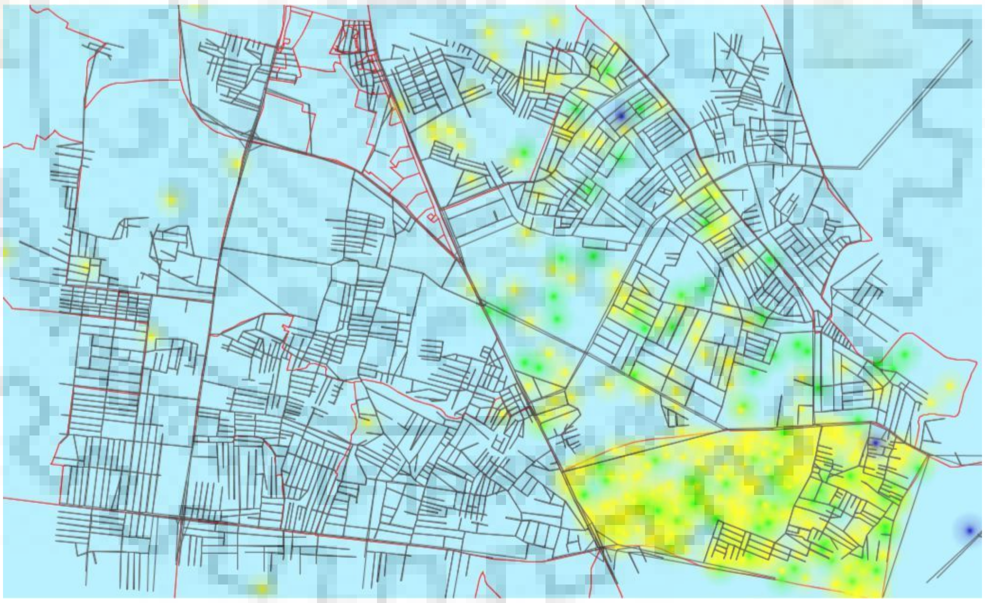

FIGURE 63 SIMULATION AT 11:30 PM

12:30

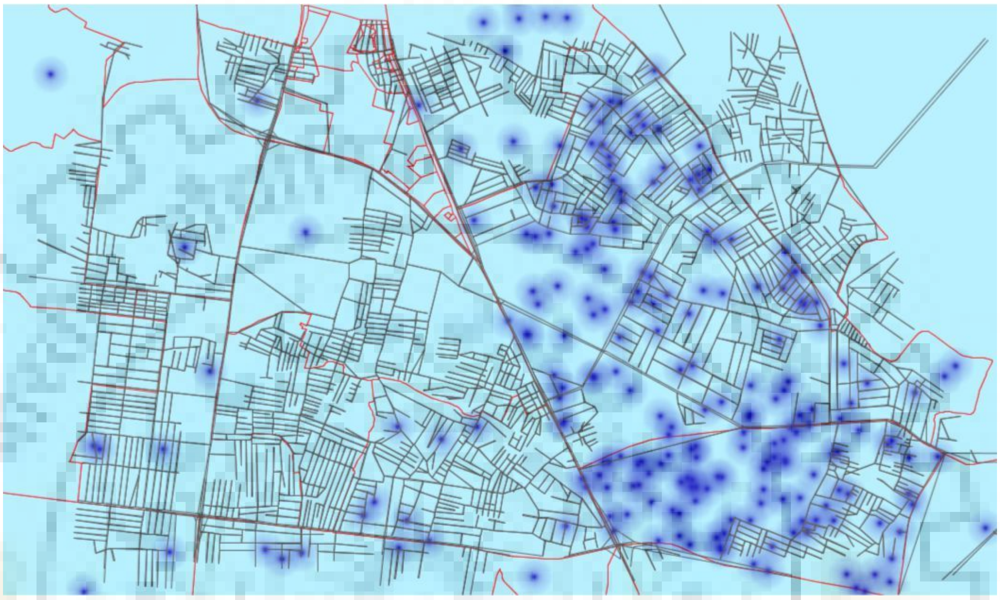

FIGURE 64 SIMULATION AT 12:30 AM