Modeling of Traffic Impact Analysis (TIA) with System Approach and GIS Integration

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Abstract: It is one of the important tools in assisting public agencies while making land use planning decisions especially for managing traffic in planning their respective transportation systems. Most of the cities have less than 20% of area under transport land use as against 30% or more. OMR/IT Corridor is one of the major roads in Chennai and it has the potential to become a world-class facility in the State of Tamil Nadu. Conventional models do no exhibit wide range of policy and scenario analysis. Hence, it is imperative to study the interaction between land use and transport with respect of traffic impacts by applying SD modeling. The major objective of the research work is to study and assess the prevailing situation for vital traffic parameters and land use disposition using Remote Sensing technology and to build a micro-level SD model using STELLA software up to the horizon year 2029.

Keywords: Traffic Forecast, Traffic Assessment, System Dynamics, Simulation Modeling of TIA, and Landuse in remote sensing with GIS

1. INTRODUCTION

Traffic Impact Analysis (TIA) is a powerful tool for engineers and planners to determine the possible effects of a project on the transportation and traffic system. Often, it is applied only to the direct impact area and counter measures for potential negative impacts are specific for the development. These studies vary in their range of details and complexity depending on the type, size and location of the development. All development generates traffic, and it may generate enough traffic to create congestion and to compel the community to invest more capital into the transportation network, whether it is in the form of new roads or traffic signals or turn lanes. Traffic congestion results in a number of problems, including economic cost due to delayed travel times, air pollution and accidents. As one roadway becomes congested, drivers may use other roadway not necessarily intended for through traffic. As a result, traffic impact analyses are becoming more common as a planning tool to predict demands on the transportation network Hence, TIA is considered important as budgets for public facility and infrastructure improvement become strained. Such studies can be used to help evaluate whether the development is appropriate for a site and type of transportation improvements required in order to maintain a satisfactory level of service.

2. LITERATURE REVIEW

2.1 Traffic Impact Analysis Guidelines for Site Development

Laurel Roennau (2005) states that the environmental topic which causes the most grief is traffic. Every time a new building application is submitted to the City, a new destination is being proposed. Hence, every new project proposed for Santa Monica must demonstrate that no net negative traffic effect will impact the city, before it can be built. The California Environmental Quality Act (CEQA) specifies those subjects which must be addressed in an EIR (Environmental Impact Report) which must be certified by the City Council before a building permit can be issued. If analysis shows that a proposed project will have a negative traffic effect on the community, a "significant impact" (as defined by the City), the developer must identify mitigations which will correct the traffic problem. If there are no "feasible" mitigations, Council can still approve the project if they find that there are "overriding considerations" – benefits to the community which make it worthwhile to accept the impacts.

Peter Weller (2007) this research report is stated that detailed comparison of overseas best practice for sustainable development of impact assessment as shown in Table 1. The qualitative assessment of the 'pros and cons' of each approach. This assessment takes into account the differing statutory requirements and land-use planning issues in the countries. The Comparison of the countries is Australia, Hong Kong, Singapore, United Kingdom, and United States.

Table 1. Detailed Comparison of Overseas Best Practice for Sustainable Development of Impact Assessment

Content of Guideline	Australia	Hong Kong	Singapore	UK	US
National statutory guidance document	No, New South Wales RTA guide used for most assessments	Yes − Part of Transport Planning and Design Manual	Yes–LTA guide	Yes, Scotland and Northern Ireland Only.	No
Methodology guidance	Yes, Checklist	Yes, Checklist	Yes, Checklist	England and Northern Ireland	Yes, both
Suggested study area Limits	No	No	No	No	Yes, land use Types/development Sizes.
Assessment of committed and consented developments	Yes	Yes- check that list of Developments are up to date. Assess cumulative impact	Generally in background growth, but nearby developments added	Local developments in addition to background growth	Local developments in addition to background Growth
Background traffic growth	Assessment of historical trends	Traffic growth factor from Annual Traffic Census report and historical data	Generally 2−3% per annum	Obtained from national model or traffic flow data	Model data or historical trends from existing data
Trip generation data	Guide includes trip rate data	Surveys of similar developments	Surveys of similar Developments	Usually obtained from TRICS database	ITE Trip Generation 7th edition
Assessment years	No specific mention	Future year data provided by models at 5-year interval	Opening year and Opening year +5. 2015 if significant	10 years where the development affects the strategic road	Generally 5 years after opening

			development	network	
Impact mitigation at intersections by developer	Yes- provided for under Section 94 legislation	Usually site access only	Usually site access only	Yes–provided for under legislation	Depends on local conditions
Public transport	Consultation with operators and planning authority	Identify nearby facilities; check for capacity deficiencies	Rail and bus stop Distances. Trip rates require adjustment if development not close to PT node	Full consideration of public Transport access. Developer contributions to services and infrastructure where appropriate	LOS-based on service frequencies
Construction impacts	Yes	Yes	Separate study may be required	No specific mention	Assessment of Implementation schedule and impacts

2.2 Traffic Impact Analysis by Using System Approach

Umadevi (2009) this report states that traffic impacts and circulation study with simulation modeling on inner ring road in Chennai by using system Approach. In this report was prepared one of the parts of EIA report. The following inventory along the study stretch is carried out; flow of traffic during peak and peak of peak hours, speed and delay studies, and complete road geometry along study stretch and at crucial points. The peak hour factors come around 0.98. It also noticed the speed of the study stretch during peak hours is 22.48 Kmph. The average inbound and outbound vehicles per hour are considered to be 2.78 percent of the hourly total PCU volumes of the study stretch. The given TSM proposed traffic circulation is only on a short term basis for 1 or 2 years and probably in a medium term basis say 2 to 3 years. But establish lasting solution the present volume should be projected to the future for various scenarios at least for one decadal period. The system simulation dynamic modeling is developed by using STELLA simulation software. SD modeling is developed 3 scenarios,

- Do Minimum - V/C ratio varies from 1.49 in the base year 2009 to 2.48 in the horizon year 2020 which is the worst situation obtained if the present trend is allowed to continue.
- Achieving Tolerable Service Level - V/C ratio varies from 1.49 in the base year 2009 to 1.54 in the horizon year 2020 and the proportion of public transport trips increases to 63 percent.
- Achieving Acceptable Service Level - in this scenario still more augmentation in terms of bus transport is done to achieve the service level to almost one. The public transport trip level is augmented to the level of 79 percent.

2.3 Traffic Impact Analysis (Tia) For Land Use and Decision Making

Xinhao Wang (2004) Study on Integrating GIS, Simulation Models, and Visualization in Traffic Impact Analysis is studied and analyzed an effective planning support system can significantly enhance the collaboration among stakeholders and facilitate agreement on the most appropriate alternatives. The integration of GIS, simulation modeling, and computer visualization is expected to greatly enhance the analytical capabilities of GIS-based spatial decision-making through a 3D format. The traffic impact analysis system developed in this study incorporates environmental data directly into decision-making through a more integrated treatment of a variety of spatially referenced data for analysis. The integrated approach is expected to assist planners in their task of developing and analyzing options for physical development, help clarify, in a more intuitive manner, the implications of different alternatives for decision-makers, and better demonstrate to the public the benefits of the planning decisions that have been taken. The net effect will be to improve both the decision-making process and communication among planners, decision-makers and the various groups comprising the public, as well as to encourage citizen participation through graphical presentations that are familiar and easy to understand.

Jayantha (2005) this study states that traffic impacts assessment and land use development and decision making. Land use planning decisions creates more urban areas and thus creates changing travel patterns, which have an impact on traffic related risks to society as whole. Land use development decision making process and TIA study outcomes provide guidance to decision makers to approve the land use developments, this LUD decisions impacts society, economy, environment, travel patterns and performance of transport networks thus create traffic congestion and accidents. Informal LUD's are seen as the main problem that is causing all these traffic congestion, road safety and environmental pollution issues. Transport planning and coordination should be considered at all levels of government national, state, local) and international level. The transport system has its own complexities. Government and countries rely on the transport systems for promoting goods and services for economic gains. So the city decisions makers, to arrive at proper decisions. The council of Australian Government report has estimated that economic costs due to congestion in the city of Sydney is $3.5 billion in 2005 and will rise to $7.8 billion in 2020. Statistical evidence shows that the world populations have gone past 6 billion in 2000 and will be around 9 billion in 2050 and further adds that between 2007 and 2025, the world urban population is expected to increase by 3.1 billion people. Mega cities have estimated populations over 10 million people and cities will continue to attract people from rural areas and other cities and countries. The quality of life is low due to poor air quality, water and energy shortages, pollution and traffic congestion. It is stated that 20 largest cities consumes 80% of the world's energy and urban areas generate 80% of greenhouse gas emission worldwide.

Naila Sharmeen (2012) Study on Developing a Generic Methodology for Traffic Impact Assessment of a Mixed Land Use in Dhaka, Traffic impact analysis is the key means to take the transportation planning and land-use planning into account together. And also it has been considered as an efficient means to harmonize the relationship of land exploitation and transportation development. The data of the study area have been collected from secondary sources. Then the baseline year is fixed. Surveys of two reference buildings (situated nearby Mirpur road) have been done to estimate the future traffic condition of the study area. Based on the collected data and traffic survey of the baseline year the traffic volume, level of service of the forecasting year is calculated. In this way the traffic impact assessment of the proposed mixed-use development is carried out.

The selection of the study area is made considering three criteria. Firstly, in developing countries, TIA process is compulsory for large projects and above a certain size. For example, in Thailand especially in Bangkok, all projects occupying more than 300 parking units or larger than 2000 square meters of gross floor area must be studied about traffic impact. Secondly, TIA is Compulsory for those projects which will generate more than 100 new traffics in the peak hour. The availability of baseline traffic data is considered as the third criteria. The ongoing project of Biswas Builders named as The New Market City Complex, a residential cum commercial building is 217 parking units and the gross floor area of parking lot is 8164.87 square meter. And it is expected that the project will generate more than 100 new traffics. The volume data of 2009 have been collected for 8 AM to 12 PM and from 4 PM to 8 PM from secondary sources. These are the parameters are considered in this TIA,

- Forecasting Traffic Volume
    - Background traffic volume forecasting
    - Development traffic volume forecasting
        - Determination of growth rate
        - Forecasting of development traffic volume

For calculating the growth rate of traffic volume total PCU of a particular hour of both directions has been summed up for each year data. The highest hourly PCUs of each year dataset has been taken for determining or calculating the growth rate of annual traffic in the particular study area.

2.4 Inferences from Literature Review

The following observations are made from the literature review:

- The TIA takes into account the traffic growth and its impacts on the transport network in terms of congestion, safety and pollution.
- TIA is one of the Environmental Impact assessments and must be addressed in an Environmental Impact Report (EIR), which must be certified by concern authority before a building permit can be issued.
- Understood the importance of Traffic Impact Analysis for the developed and developing cities.
- Procedure for TIA studies and list of surveys & inputs to be carried out for analyzing the impacts of proposed development in future.
- Integrating GIS, simulation models, and visualization in TIA is the net effect to improve decision-making process and communication among planners, decision-makers and the citizen participation through graphical presentations.
- To understand the detailed comparison of overseas best practices and qualitative assessment of the ‘pros and cons’ of each approach.
- The system dynamics approach is found to be one among the suitable method to analyze TIA at various scenarios and policy options.
- It is most important for mixed traffic environment and mixed land use.
- TIA is also giving the best decision making for land use development planning.
- Analyze and assess the urbanization projects along the road network level of service (LOS).
- The mitigation measures like new road development, construction of flyover, staggering of working hours, Congestion charge and restraint of development of fixing the FSI limit is reducing the traffic impacts.

3. SIGNIFICANCE OF TRAFFIC IMPACT ANALYSIS (TIA)

The key potential and importance of TIA is to:

- Forecast additional traffic associated with new development, based on accepted practices
- Determine the improvements that are necessary to accommodate the new development
- Assist communities in land use decision-making
- Identify potential problems with proposed development which may influence the developer's decision to pursue it
- Allow the community to assess the impacts that a proposed development may have
- Help to ensure safe and reasonable traffic conditions on streets after the development is complete
- Reduce the negative impacts created by developments by helping to ensure that the transportation network can accommodate the development
- Provide direction to community decision-makers and developers of expected impacts
- Protect the substantial community investment in the street system

4. OBJECTIVES OF THE STUDY

- To study and assess the prevailing situation for vital traffic parameters and land use disposition using Remote Sensing technology.
- To build a micro level System Dynamics (SD) model for Chennai IT Corridor, which project service level and future land use disposition by various scenario analysis.
- To assess traffic impacts of the present and future developments along the study area.
- To recommend the necessary counter measures to enhance the Level of Service (LOS).

5. STUDY AREA

Chennai has become one of the preferred destinations for IT/ITES companies. Tamil Nadu, India is the second largest software exporter in the country, and 90% of the export is from Chennai alone. A large number of IT/ITES developments are happening along the Old Mahabalipuram Road (OMR). The study area selected (as shown in Figure 1) is now called 'Rajiv Gandhi Salai' or IT Corridor, the road earlier called as OMR. OMR or IT Corridor is a major road in suburban Chennai, India, beginning at the Madhya Kailash temple in Adyar in South Chennai and continuing south till Mahabalipuram in Kanchipuram district, ultimately merging with the East Coast Road. This is popularly called as the "IT Corridor" because this stretch has become home to many IT/ITES companies.

Figure 1 depicts the index map of the study corridor (Red color boxed region encompassing IT Corridor). The IT Corridor Project is an initiative of Government of Tamil Nadu to develop the Corridor as a world-class facility and to promote a progressive IT/ITES friendly image of Tamil Nadu. The entire stretch is built as 6 lane road and the IT expressway is in operation since October 2008.

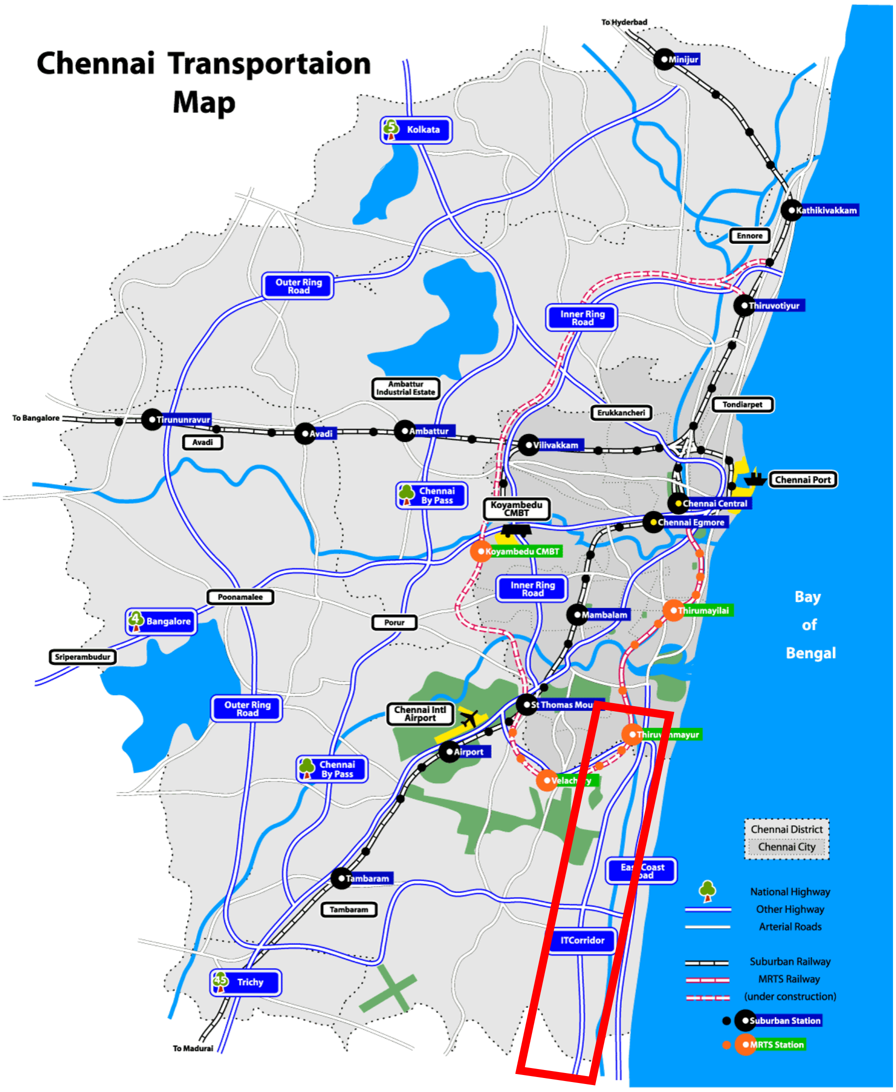

Figure 1. Index map of study corridor

IT Corridor is characterized by a continuous growth in population and area of urbanization, a proliferation of IT/ITES companies, industrial, commercial centers, institutional, an increase in vehicular ownership, all of which have created problems like congestion, road accidents and environmental degradation. Hence, it is imperative to conduct a Traffic Impact Analysis (TIA) for this corridor in order to enhance the future LOS within tolerable limits.

6. SOFTWARE USED

A preliminary visual interpretation of the base maps was carried out. ArcGIS 10.1 was used to digitize land use maps and edited in Arc Tool Box in GIS environment. After digitizing the study area, different themes like residential, commercial, institutional, industrial (all polygon themes) and the corresponding landuse were digitized from the land use data obtained from the remote sensing satellite image. The road theme has been created to indicate the location of the road in the region. The land use themes have been created to represent the type of land uses in and around the road corridor.

The model of traffic impact analysis using the System Dynamics (SD) has been implemented in the ‘STELLA’ environment using STELLA 9.1. This package is developed with various estimation (simulation) methods like Euler’s, Runge-Kutta 2 and Runge-Kutta 4. In this research Euler’s method was used to derive the simulation values. The modeling tool which is an object-oriented simulation environment allows the development of TIA models with significantly less effort than traditional programming languages. It has a user-friendly graphical interface and supports modular program development. Using this tool, the modeler defines objects representing physical or conceptual system components and indicates the functional relationships among these objects. Building on these strengths, the general architecture of a TIA model will be described (Umadevi.G, 2009).

7. METHODOLOGY

The methodology is a usage of simplified methods or techniques adopted for achieving the formulated objective. The methodology of this work is depicted in Figure 2. Essentially, the steps involved are data collection, analysis, model building and to suggest appropriate mitigation measures.

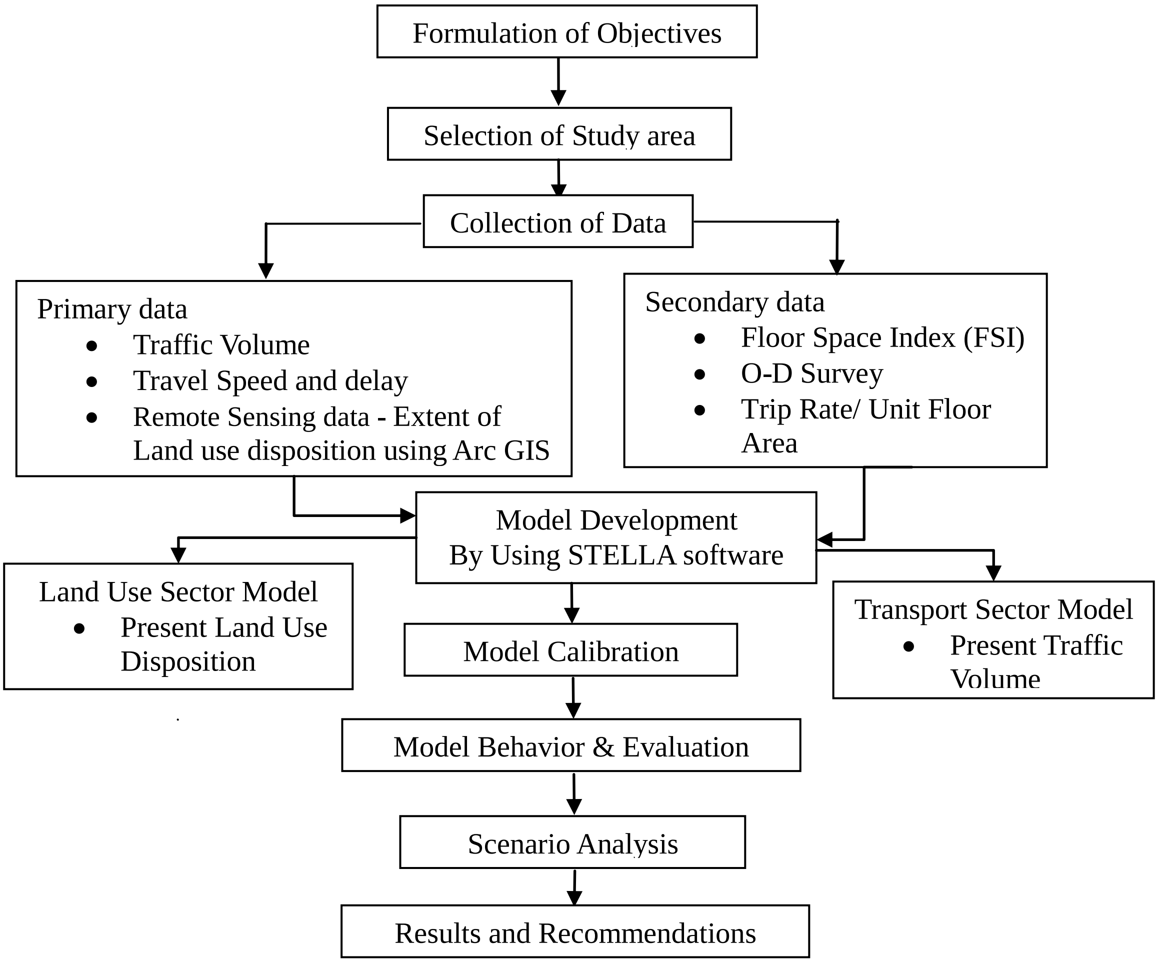

Figure 2. Flowchart depicting the methodology adopted in the study area

8. DATA COLLECTION AND ANALYSIS

The collection of data is necessary to assist in the crystallization of facts and figures, the interpretation of which will lead to more realistic analysis of the land use pattern, traffic and travel characteristics of the study area, which thereby helps in the formulation of mitigation measures against negative traffic impacts and spatial developments of along the corridor.

8.1 Classified Traffic Volume Count Surveys (CTVCS)

One of the major components of the transportation inventory is the volume count of traffic on the study corridor during peak hours on a typical working day. The classified traffic volume counts are conducted manually by counting vehicles on both directions at two selected locations of the study corridor for five hours. The volume data has been converted into Passenger Car Unit (PCUs) by utilizing recommended PCUs factors as specified in IRC: 106-1990. The first location is near Indira nagar railway station; the second location is Karapakkam, near Apollo Hospital.

Table 1. Traffic flow along the Chennai IT corridor

Time	Car/ Jeep	Auto	Two Wheeler	Bus	HCV	LCV	Cycle	Other	Total (Nos)	Total (PCU's)
3:30-3:45	355	37	477	65	9	55	10	3	1008	1008
3:45-4:00	424	39	558	58	6	50	5	2	1159	1150
4:00-4:15	496	49	611	85	10	63	11	4	1326	1325
4:15-4:30	543	37	647	61	14	64	10	2	1376	1337
4:30-4:45	478	40	689	72	15	60	6	3	1362	1328
4:45-5:00	458	39	646	62	12	62	18	2	1298	1252
5:00-5:15	494	44	699	64	12	57	12	4	1384	1336
5:15-5:30	563	43	716	58	12	59	14	3	1466	1403
5:30-5:45	519	42	749	66	6	59	9	4	1452	1388
5:45-6:00	503	59	772	92	9	54	23	1	1511	1461
6:00-6:15	573	45	1020	63	13	62	11	4	1788	1661
6:15-6:30	534	48	941	72	11	44	16	4	1669	1563
6:30-6:45	543	40	953	57	11	45	13	4	1665	1537
6:45-7:00	529	30	886	49	8	44	17	3	1565	1434
7:00-7:15	480	38	876	71	4	38	14	4	1523	1420
7:15-7:30	554	40	819	61	5	55	9	3	1543	1448
7:30-7:45	537	37	784	55	5	49	13	3	1481	1385
7:45-8:00	486	35	804	51	4	48	9	3	1438	1331
8:00-8:15	467	32	756	48	3	36	5	3	1347	1243
8:15-8:30	517	37	894	55	2	42	6	2	1554	1425
Total	10048	809	15291	1275	169	1039	225	58	2891	27434
%	35	3	53	4	1	4	1	0.2		

*Government bus, ǂ Private and Institutional bus

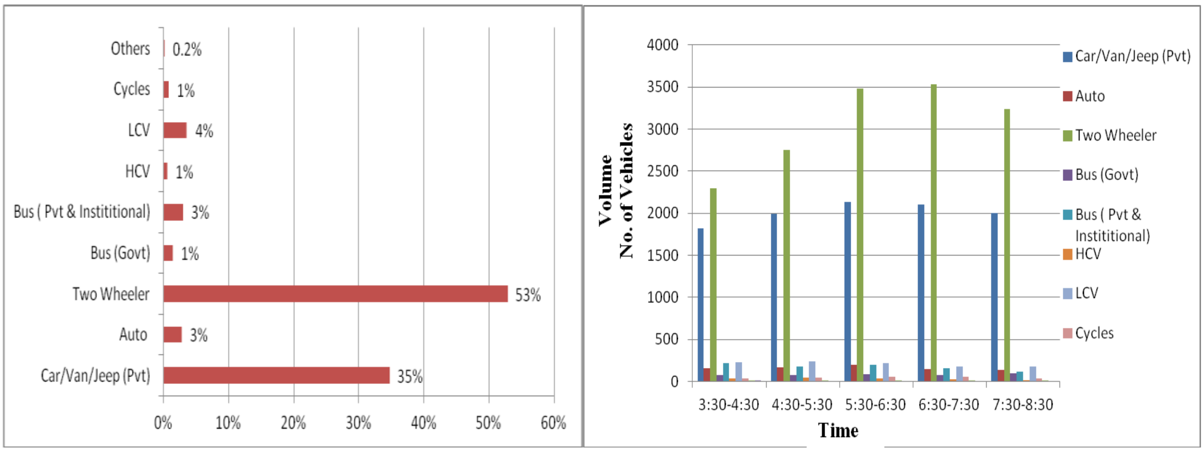

Figure 3. Vehicle composition and Hourly share of vehicles for study stretch

Table 1 shows the total traffic flow pattern and it is found that peak of peak hours occur from 6:00 p.m to 7:00 p.m with 6686 vehicles per hour. Peak hour factor is 0.93 which indicates the flow variations within the hourly time period is almost uniform. A maximum of 1661 PCUs ply on the stretch in 15 minute period. Vehicle compositions have been calculated based on the collected volume count data. Since India has heterogeneity in its traffic composition, it is vital to collect data on its mode share so as to get a clear picture of proportion of various categories of vehicles in the traffic flow. Figure 3 elucidate vehicle composition and hourly shares of the vehicles, Two wheeler and car proportion in the total volumes are observed as around 53% and 35% respectively whereas buses proportion stand at 4% only. It seems to be an unhealthy proportion with regard to environmental consideration and Level of Service (LOS). The distribution of various vehicles in study corridor is observed that along both directions the flow is almost smooth except during 6:00 p.m to 7:00 p.m.

8.2 Origin – Destination (O-D) Survey

In order to assess the component of traffic along Chennai IT Corridor, Origin - Destination surveys have been carried out for 24 hours on a sample basis of around 20 % to 40%. Information regarding origin, destination of the trip, trip frequency, commodity type and purpose of the trip are collected by road side interview method. The O-D survey results provide a clear indication of the zones that contribute to the traffic on the existing roads. Number of trips originating from and destined to any zone represents the influence of that zone on the traffic.

Table 2. Influence factors summarizing the Zone wise for commercial and passenger (Car) vehicles by IT corridor

Zone	Commercial Vehicles	Passenger Vehicles
Chennai City	50%	49%
Rest of CMA	9%	4%
Pondicherry	38%	44%
Chengalpattu	2%	2%
Sriperumbudur	0%	0%
Tiruvallur	0%	0%
Tada	0%	0%
Total	**100%**	**100%**

Source: L&T Ramboll ORR, 2014

The above result (Table 2) indicates the influence area of the traffic is within Chennai city and the share of traffic is predominantly from internal to external and vice versa is around 88%. The trip frequency is mostly twice the time of daily for both passenger and commercial vehicles.

8.3 Speed and Delay Study

The detail of delay and travel time of speed-delay survey along the study corridor is conducted on a typical working day during morning hours by using standard vehicle (car). It is observed that, on an average, vehicle can traverse at a speed of 31 kmph towards Kelambakkam direction and 32 kmph towards Madhya Kailash direction. The delay is found to be more due to two major reasons, namely, signalized intersections and U-turn movements. Overall delay is in the order of 10 minutes towards Kelambakkam and 14 minutes towards Madhya Kailash.

8.4 Analysis of Land Area

The optimum utilization of land resource in a well planned manner is very essential. Landuse is a classification by which a piece of land is assigned a particular use and has a planned development. Undeveloped development results in congestion, environmental degradation. Hence it is required to study the landuse changes over a period and offer solutions using spatial techniques like remote sensing and Geographic Information System (GIS) tools and the study area are digitized by using Arc GIS software and thereby the extent of land use is obtained and depicted in Table 3. Figure 6 shows the land use disposition map of Chennai IT corridor with 1.0 km buffer zone.

9. SYSTEM DYNAMICS SIMULATION MODELING

System dynamics has a long history as a modeling paradigm with its origin in the work (Forrestor 1969), who developed the subject to provide in understanding of strategic problems in complex and dynamic systems. System dynamics model, by giving insight feedback processes, provide system uses with a better understanding of the dynamic behaviour of systems. Areas of application of system dynamics have always been very wide, however, with an emphasis on socio-economic applications.

9.1 Model Conception

Formation of Causal Lop (CL) diagram constitutes the model conception. It shows the cause and effect of each variable with respect to each other variables. Usually a positive effect is indicated using the '+' sign and negative effect with '-' sign. The causal loop diagrams are represented as a land use sector in figure 4 and transport sector in figure 5.

9.2 Land Use Sector Model Building

In this Sector, various land use disposition of the base year is obtained from the primary analysis of land area along the study corridor with 1 km buffer zone using ArcGIS software. Hence the Land Use sector model is developed in each category of land use with respective with growth rates. The land use model is shown in Figure 7, the model is simulated for various land use disposition of along the study area from base year 2018 to horizon year 2029.

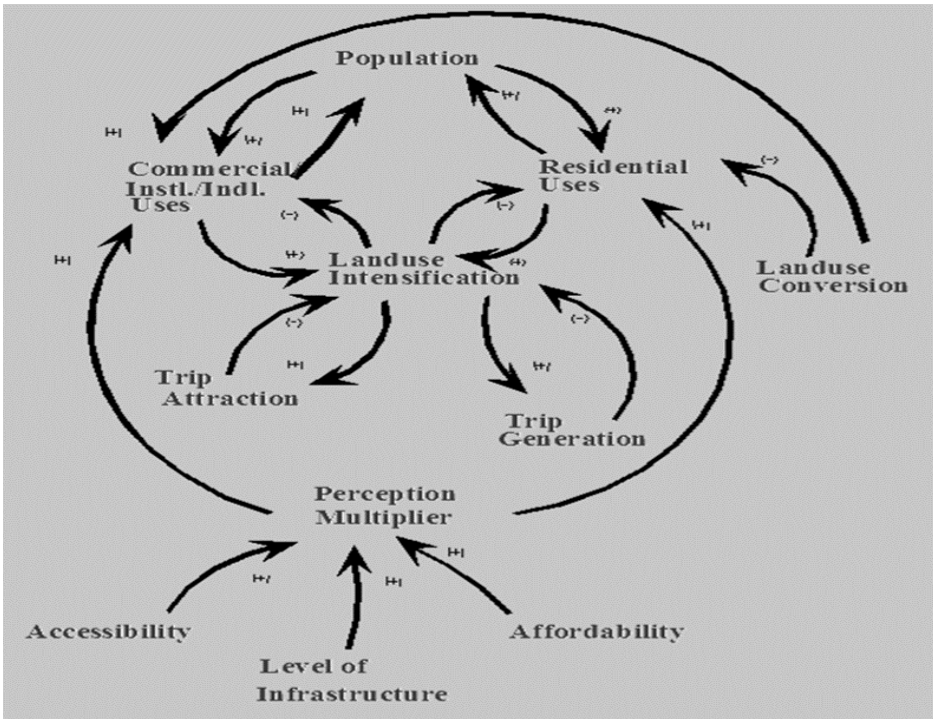

Figure 4. Model conception for land use sector

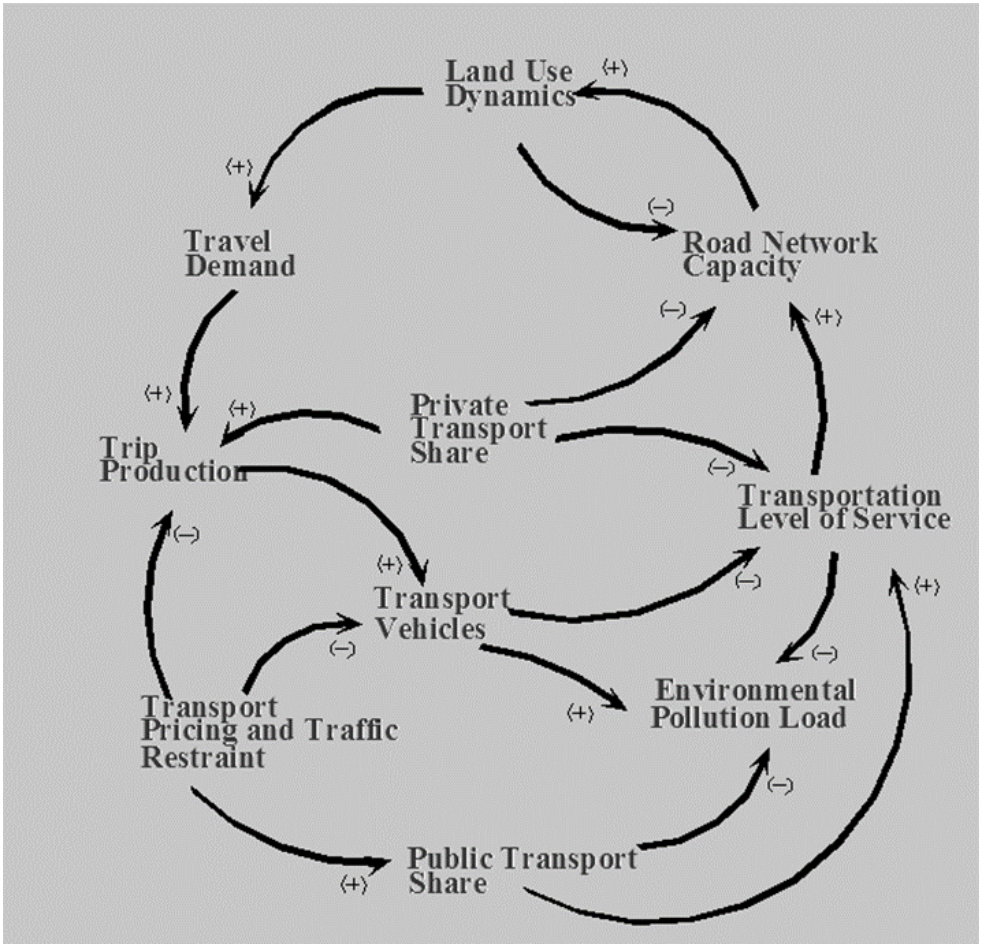

Figure 5. Model conception for transport sector

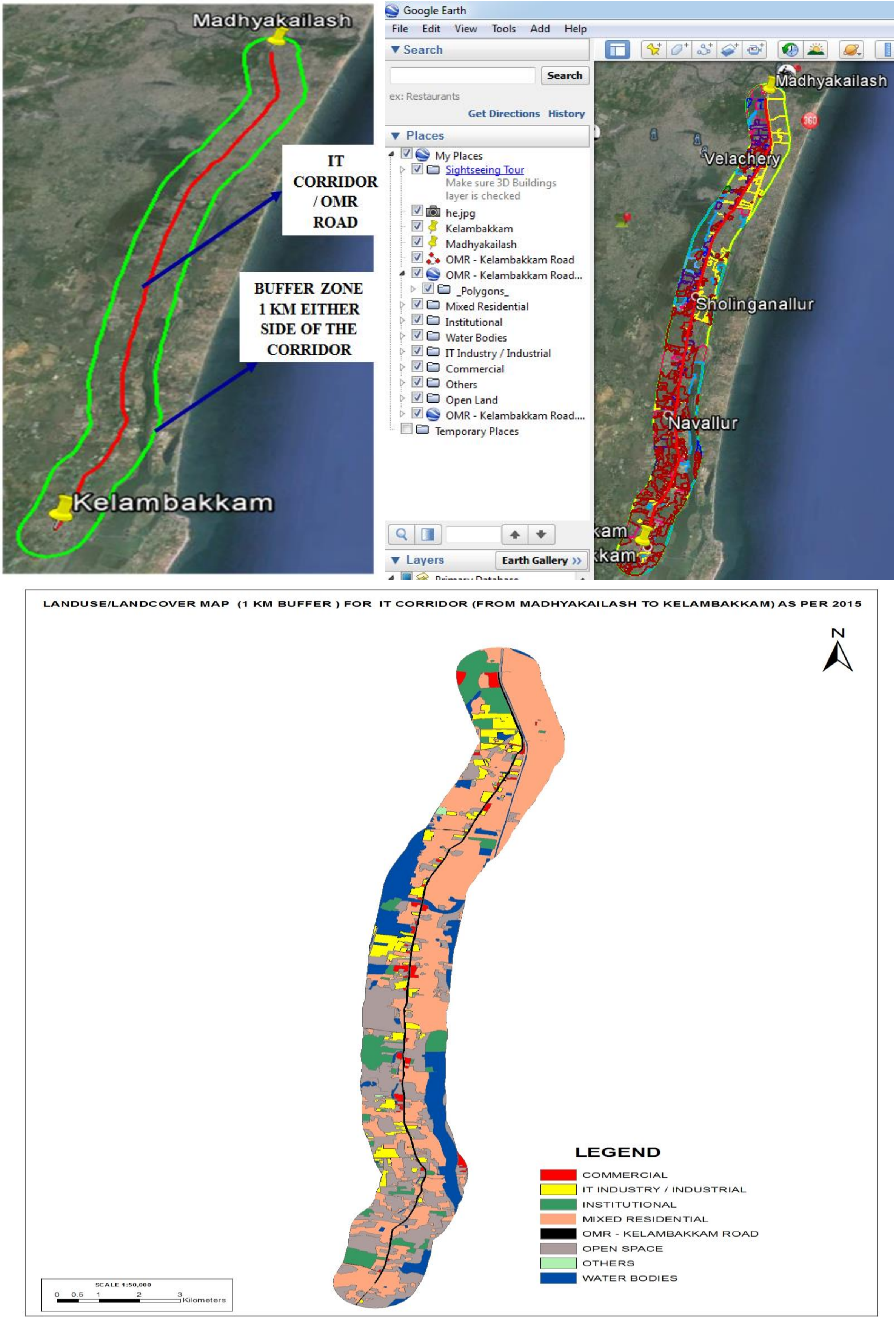

Figure 6. Process of Land Use disposition Analysis in GIS

Table 3. Land use disposition of Chennai IT Corridor (2015) - 1.0 km Buffer Zone

Sl.no	Land Use Category	Area (Sq.m)	Area (Sq.km)	Area (Acres)	% of Developed Area
1	Mixed Residential	23,554,303	23.55	5820.37	43.53
2	IT Industry / Industrial	3,708,415	3.71	916.37	6.85
3	Institutional	4,544,948	4.54	1123.08	8.40
4	Commercial	1,030,017	1.03	254.52	1.90
5	Water bodies	7,020,822	7.02	1734.88	12.97
6	Open Space	12,939,635	12.94	3197.44	23.91
7	OMR - Kelambakkam Road	1,315,461	1.32	325.06	2.43
8	Total Area	54,113,601	54.11	13371.71	100

Source: Study Analysis

These land use areas are used as different level variables. The levels are influenced by the growth rate as well as conversion rate of each land uses of the models. The growth rate and conversion rate is collected from Ministry of Urban Development through Right to Information Act (RTI), 2005 and the same has been portray in Table 4.

Table 4. Land use growth rate and conversion rate

Land Use Category	Growth Rate / Year	Conversion Rate / Year
Residential	15.03%	2.5%
Industrial	10.51%	2.0%
Commercial	28.91%	-
Institutional	0.022%	-

Source: Ministry of Urban Development, RTI Act, 2005

The various variables are considered for building the land use sector model as follows:

Mixed Residential - Total Mixed Residential land area
MRGR - Mixed Residential growth rate
MR Inc - Mixed Residential increment
MR Conversion Fraction - Mixed Residential conversion rate
RC Inc - Residential conversion increment
Open Space - Total Open land area
IT Industry / Industry - Total IT Industry / Industry land area
ITIGR - IT Industry / Industry growth rate
ITI Inc - IT Industry / Industry increment
ITI Conversion Fraction - IT Industry / Industry conversion rate
ITIC Inc - IT Industry / Industry conversion increment
Commercial - Total Commercial land area
CGR - Commercial growth rate
C Inc - Commercial Increment
Institutional - Institutional land area
IGR - Institutional growth rate
I Inc - Institutional Increment

Hence the transport sector model is used the following equations as stated below:

Mixed Residential (t) = Mixed_Residential (t - dt) + (MR_Inc + RC_Inc) * dt
Commercial (t) = Commercial (t - dt) + (C_Inc) * dt
IT Industry & Industry (t) = IT_Industry_&_Industry (t - dt) + (ITI_Inc + ITIC_Inc) * dt
Institutional (t) = Institutional (t - dt) + (I_Inc) * dt

Generating Land Area = Mixed_Residential
Attracting Land Area = Commercial+Institutional+IT_Industry_&_Industry
Total Developed Land Area = Generating_Land_Area+Attracting_Land_Area

9.3 Transport Sector Model Building

Based on the causal loop diagram, the System Dynamics model for addressing the interaction between land use and transport sector has been developed which is given in figure 8. The different land use trip rate per floor area is used as per the Institute of Transportation Engineering (ITE) trip rates. The trip rates are depicted in above Table 5.

Table 5. Land use trip rate per area

Land Use Category	Trip Rate per Area
Residential	0.4 trips / 1000 Sq.ft
IT Industrial	1.48 trips / 1000 Sq.ft
Commercial	1.43 trips / 1000 Sq.ft
Institutional	1.87 trips / 1000 Sq.ft

Source: ITE Trip Rate, 9th Edition

The various variables are considered for building the land use and transport interaction sector model as follows:

Total Trips - Sum of all Land Use total trips
Mixed Residential - Mixed Residential land area
Resi Trip Rate - Residential Trip rate per Unit area
Total Resi Trip - Total Residential trips
IT Industry / Industry - IT Industry / Industry land area
ITI Trip Rate - IT Industry / Industry trip rate per Unit area
Total Ins Trip - Total Institutional land area
Institutional - Institutional land area
Inst Trip Rate - Institutional trip rate per Unit area
Total ITI Trip - Total IT Industry/ Industry trips
Commercial - Commercial land area
Com Trip Rate - Commercial trip rate per Unit area
Total Com Trip - Total Commercial Trips

Hence the transport sector model is used the following equations as stated below:

Total_Resi_Trip = Mixed_Residential*Resi_Trip_Rate
Total_ITI_Trip = IT_Industry_&_Industry*ITI_Trip_Rate
Total_Com_Trip = Commercial*Com_Trip_Rate
Total_Ins_Trip = Institutional*Inst_Trip_Rate
Total_Trips (t) = Total_Trips (t - dt) + (Total_Resi_Trip + Total_ITI_Trip + Total_Com_Trip + Total_Ins_Trip) * dt

Table 6. Occupancy ratio for different modes

Vehicle Category	Occupancy Ratio
Car	2.3
Two Wheeler	1.5
Bus	65
IPT	2.6
NMT	1.0

Source: CCTS, Wilbur Smith, 2010

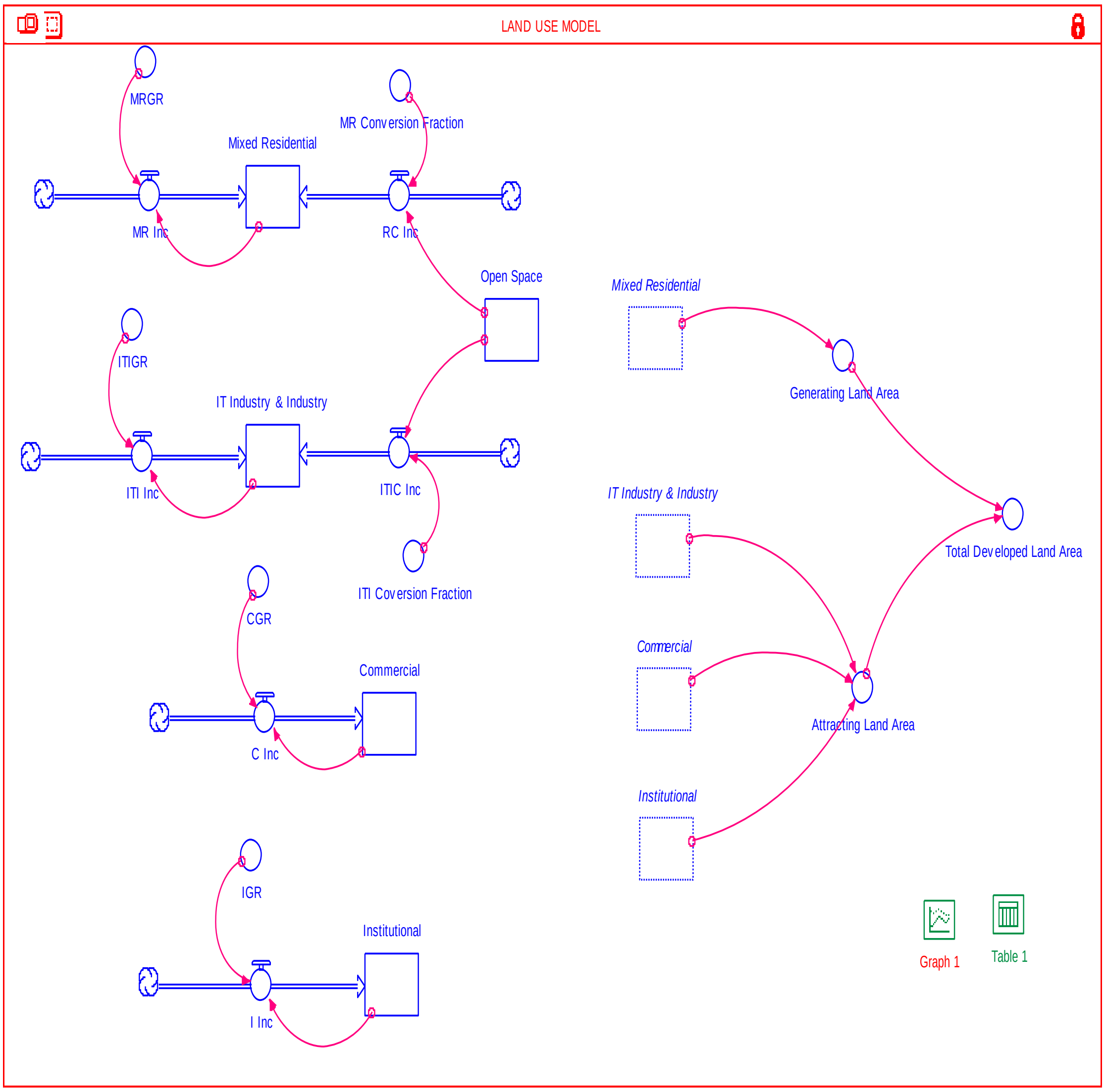

Figure 7. System Dynamics model for Land Use sector

10. SCENARIO ANALYSES

10.1 Scenario – I Do Minimum (Allowing existing trend to continue)

In the Scenario I, the existing trend of growth rates of different land uses like Mixed residential, IT Industry / Industry, Commercial, Institutional have been allowed to continue till the year 2029. The system dynamic simulation model is developed for transport sector with different land use trip rates from that total trips of the different land uses are obtained. These total trips have been converted into total volume with respective occupancy ratio. At last the main result is simulated in terms of volume/capacity (V/C) ratio; this V/C ratio reveals that level of service of the corridor. The result is depicted in the Table 7 and it is observed that the V/C ratio varies from 0.83 in the base year 2018 to 3.13 in the horizon year 2029 which is about 4 times increase when compared with base year data. It is the worst situation obtained if the present trend is allowed to continue till the horizon year. Hence, it should be counter acted with respect to proper planning measures and preventive methodologies to bring down the V/C ratio of the corridor.

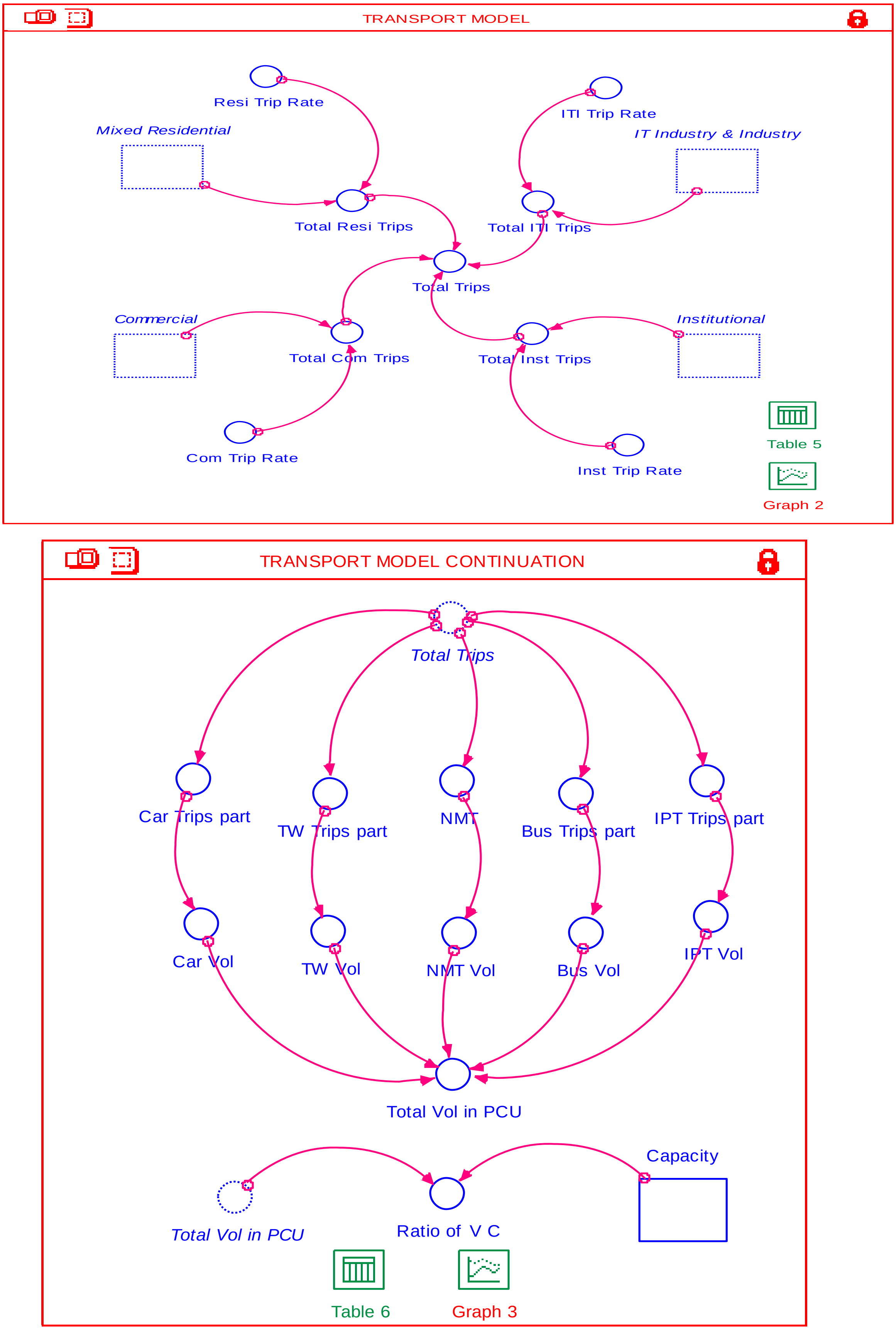

Figure 8. System Dynamics model for Transport sector

Table 7. System Dynamics Results for Scenario I

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
V/C	0.83	0.93	1.04	1.17	1.28	1.45	1.65	1.89	2.16	2.39	2.70	3.13

10.2 Scenario – II Partial Condition (Increasing the capacity of the corridor)

In this scenario, simulation has been carried out such that increasing the capacity of the corridor in terms of providing elevated corridor along the study stretch shown in figure 9. Here, the proposed corridor capacity is also considered which would be a four lane divided road with reference to feasibility study report to be operated in the year 2023. The system dynamics model results are shown in Table 8. This increase in capacity results in reduction of V/C ratio from 1.89 to 1.01 in the year 2025 and also 3.13 to 1.52 in the horizon year 2029. Compared to scenario I, the V/C ratio is decreased to 51 %. This is only a medium term solution and increasing the capacity alone is not sufficient, as reduction in V/C ratio in 2029 is not to the expected level of less than one. Hence the, scenario III is attempted to achieve better LOS.

Figure 9. Proposed Elevated Corridor along the IT corridor

Table 8. System Dynamics Results for Scenario II

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
V/C	0.83	0.91	1.00	1.11	1.19	1.31	1.46	1.01	1.12	1.22	1.35	1.52

10.3 Scenario – III Desirable Condition (Augmentation of public transport and restricting the personalised vehicles)

It is not possible to escalate the transportation infrastructure facilities at all times. Hence, in order to establish a sustainable solution, the present public transport should be augmented from the composition of 4% to 43% and also restricting the composition of personalized vehicles from 88% to 47%. This desirable solution will retain the level of service at the same level till the horizon year 2029 which is shown in Table 9 or even enhanced further from the 2029 level of service.

Table 9. System Dynamics Results for Scenario III

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
V/C	0.83	0.87	0.93	0.98	1.00	1.06	1.13	0.74	0.77	0.80	0.83	0.85

11. MODEL VALIDATION

Validation is the overall process of comparing the model and its behavior to the real system and its behavior. After the model has been calibrating using the original system data set, a "final" validation is conducted using the second system of data set. If unacceptable discrepancies between the model and the real system are discovered in the "final" validation effort, the modeler must return to the calibration phase and modify the model until it becomes acceptable. Validation is not an 'either/or proportion'. No model is ever totally representative of the under study. (Banks and Carson 1996). In this research, ground check validation is carried out.

12. RESULTS

Table 10 shows the results obtained from the system dynamics simulation model towards sustainable solution of the corridor. This study could be used to help in evaluating whether the development is appropriate for a site and what type of transportation improvements may be necessary in order to maintain a satisfactory level of service (LOS).

Table 10. System Dynamics Results of the Traffic Impact Analysis of the Corridor

Scenario	V/C Ratio		Inference
	2018	2029	
Do Minimum	0.83	3.13	Compared with 2018, more than 3 folds increase.
Partial Condition	0.83	1.52	Compared with Do min, reduced more than 50%.
Desirable Condition	0.83	0.85	Compared with partial, reduced more than 40%.

13. RECOMMENDATIONS

- To achieve the desirable v/c ratio of 0.85 in the horizon year 2029, an augmentation of public transport should be increased to 43% and simultaneously the personalized vehicles should be restricted to 47%.
- At present, maximum allowable floor space index (FSI) in Chennai it corridor is 3.75 for IT/ITES land uses and 2.5 for other than IT/ITES. Hence, it is recommended to increase the mixed residential FSI from 2.5 to 3.5 because of the growth potential along study corridor. According to the model results, there is a greater need for mixed residential land use.
- The government could implement soon, the proposed elevated expressway and BRTS to public in year 2023 instead of 2025.This reduces the V/C ratio and increase the LOS to a greater extent.
- Since the results of partial scenario prove to be much better than minimum condition, it is recommended that even if the desired condition cannot be achieved at least the government should strive towards achieving partial results.
- TIA study is not only suggesting short term management measures but also it is capable of addressing the problem in a holistic way through system dynamics simulation modeling effort to ensure sustainable solutions.
- Normally, TIA study is assessing the total trips generating by any proposed (individual) development and what is the impact on the intersections nearby. In this TIA study deals with, total trips generating by all kind of developments along the corridor and predict the existing or future transportation infrastructure can accommodate the same.

14. LIMITATIONS OF THE STUDY

This study is limited to the land use disposition is digitized by Arc GIS software and obtained area only 1 km buffer zone of along the study corridor. In this study total trips are arrived using different land use trip rate of the ITE trip rates as latest 9th edition, rather than per capita trip rate. The land use trip rates are to be estimated based on our Indian conditions. This TIA study is only deals with V/C ratio of the corridor in terms of level of service and the impact of air pollution, noise pollution has not been analyzed. The above cited limitations of the study are outstanding to time restraint. Further studies could be carried out in this field with the existing model as the base for the future and validate the same.

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