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ANALYSING DEVELOPMENT ISSUES ALONG INFLUENCE ZONE OF METRO RAIL CORRIDOR USING SYSTEM DYNAMICS APPROACH

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Abstract: Provision of Mass Rapid Transport System (MRTS) is need of the hour for large metropolitan cities, like Pune. Bus Rapid Transit System has been implemented in Pune City and now Metro Rail is being implemented under various phases as part of MRTS. Implementation of Metro Rail is an expensive proposal and required financial assistance through various means for its financial viability. Implementation of Transit Oriented Development along proposed alignment of Metro Rail is one of the alternatives for financial viability. Accordingly, Influence Zone up-to 500 mt. on both side of Metro Rail corridor under Transit Oriented Development has been proposed by allowing Intensive FSI up to four.

Implementation of Transit Oriented Development with Intensive FSI is going to result into higher densifications of existing areas along proposed alignment of Metro Rail. This kind of densification is going to increase strain on existing infrastructure and demand for augmentation of additional infrastructure.

System Dynamics Approach is one of the most appropriate tools to analyse inter-sectoral relationships and linkages of infrastructure requirement resulting due to densification on account of Intensive FSI.

Index Term: Densification, Infrastructure, Intensive FSI, Mass Rapid Transit System, System Dynamics

1. Introduction

Mobility demands in Indian cities are increasing at an exponential rate due to rapid population growth coupled with lopsided urbanization phenomena and rising income levels. Exponential increase in mobility demand is met broadly by either personal or public modes of transportation. A significant aspect in the transportation scenario is the availability and requirement of Public Transportation System. It is widely recognized as an effective medium towards the improvement of people's mobility across the rapidly expanding cities and their metropolitan region. It provides access across various parts of cities and their metropolitan areas by linking major activities, population, and employment centres. It provides mass transportation as a primary or preferred mode of transportation and substitute for the private vehicles, and mobility for those with no other transportation alternative. Public Transport in any city makes it easier for common people to travel from one place to another at a faster speed and cheaper cost. Hence various Public Transport Systems like Bus Rapid Transit System (BRTS), Mass Rapid Transit System (MRTS), Mono Rail, etc. are developed depending upon the population, need of public transport and public ridership. Pune is the eighth largest city in India, and it has the sixth largest metropolitan economy; has followed similar kind of trends. Earlier BRTS had been implemented and now Metro Rail in the form of MRTS is being implemented to strengthen Public Transport System in the metropolitan region. Metro Rail under Phase-I having length of 16.5 km. is proposed from Pimpri to Swarget, and under Phase-II it will run from Vanaz to Ramwadi covering distance of 14.66 km. Metro Rail under Phase-III will cover distance of 23.33 km will run from the Rajiv Gandhi Infotech Park in Hinjewadi to Civil Court (Pune Metro, 2020). All three proposed Metro Rail lines under various phases will align at the Civil Court Interchange Station. Implementation of these proposed Metro Rails under various phases requires huge amount of investments. Apart from funding from various agencies, it is inevitable to explore various alternatives to raise funds for its implementation. Transit Oriented Development in the form of Influence Zone along proposed alignments of Metro Rail by allowing Intensive FSI, is one of the important alternatives available to its implementing agencies.

2. Transit Oriented Development (TOD) along Metro Rail Alignment

In Urban Planning, a Transit Oriented Development (TOD) is a type of urban development that maximizes the amount of residential, business and leisure space within walking distance of Public Transport System (Transit-oriented development, 2020). A TOD typically includes a central transit stop surrounded by a high-density mixed-use area, with lower-density areas spreading out from this center. It promotes a symbiotic relationship between dense, compact urban form and public transport use. In doing so, TOD aims to increase public transport ridership by reducing the use of private cars and by promoting sustainable urban growth. A TOD is also typically designed to be more walkable than other built-up areas, through using smaller block sizes and reducing the land area dedicated to automobiles. The densest areas of a TOD are normally located within a radius of 400 to 800 mt. around the central transit stop, as this is considered to be an appropriate scale for pedestrians, thus solving the last mile problem. Despite these issues, India is slowly opening to the concept of TOD (Transit-oriented development, 2020). Recently, the Government of India released a National TOD Policy, as a guideline for States. As per the said policy, TOD should be implemented in an influence zone of 500-800 mt. around Mass Rapid Transit Stations / Corridors. These zones should be notified in the City Master Plan and Local Area Plans, in a transparent manner.

Accordingly, Pune Municipal Corporation (PMC) has also frame regulation for TOD zone along proposed alignments of Metro Rail. Under this, an Influence Zone comprising a strip of 500 mt. width on either side of the Metro Rail alignment has been proposed. The maximum permissible Intensive FSI in TOD zone shall be up to four including the base permissible FSI. This FSI is subjected to a condition that the Intensive FSI over and above the base permissible FSI shall be allowed within the overall limit of maximum permissible FSI, as given in following Table No. 1. The maximum permissible Intensive FSI as given in following Table shall be calculated on the gross plot area. This will provide an impetus to the renewal of old and dilapidated city areas and bring about desired densification along the Metro Rail Corridors. In this Influence Zone, premium will be charged by PMC on Intensive FSI and raise money for the Metro Rail implementation and additional civic infrastructure to support the higher densification. Furthermore, PMC hopes to increase the use of Metro Rail.

Table No. 1: Utilization of Intensive FSI in Transit Oriented Development Zone

Plot Area in sq. mt.	**Road Width in mt.**					
	Less than 9	9 and up to 12	12 and up to 18	18 and up to 24	24 and up to 30	30 and above
Below 1000	Principal DCPR	2	2	2	2	2
1000 to below 2000	Principal DCPR	2	2.5	2.5	2.5	2.5
2000 to below 3000	Principal DCPR	2	2.5	3	3	3
3000 to below 4000	Principal DCPR	2	2.5	3	3.5	3.5
4000 or above	Principal DCPR	2	2.5	3	3.5	4

Source: (Notice, Urban Development Department, Government of Maharastra, 2019)

3. Study Area

Alignments of Metro Rail under various phases have been proposed in Pune City including its metropolitan area to increase the efficiency of public transport. Influence Zone having width of 500 mt. on each side of Metro Rail alignment has been delineated as Transit Oriented Development zone. Applicability of Intensive FSI up to four in this zone will provide an impetus to the renewal of old and dilapidated city areas. Renewal of old and dilapidated city areas by utilizing Intensive FSI will bring about desired densification of TOD zone. Densification of TOD zone further attracts additional population and will raise demand for augmentation of additional civic infrastructure. This will result into either up-gradation of existing civic infrastructure or replacement of the same by new one with enhanced capacity. In this regard, it is inevitable to understand the extent of densification and subsequently, augmentation of civic infrastructure to sustain the increased densification in TOD zone. Considering this, a small stretch from Mandai to Swarget having length 1.2 km. forming part of Metro Rail alignment under Phase-I has been undertaken for analysing Development Issues along Influence Zone of Metro Rail Corridor. This stretch is undertaken particularly being from core and congested part of city; where, redevelopment is most feasible and construction work of Metro Rail under Phase-I has already commenced.

Influence Zone of 500 mt. on each side of proposed alignment of Metro Rail from Mandai to Swarget under Phase-I is delineated on City Map. The area that falls under this Influence Zone is comprises of four wards namely, ward numbers 15, 17, 18 and 29. Demographic details of these wards are presented in following Table No. 2. Population, Population Density and Household Size of Influence Zone is calculated on pro-rate basis from parameters of four wards areas. Accordingly, population of Study Area is 15,200; Household Size and number of Household in Study Area are 4.4 and 3,455 respectively. Details about various parameters in Study Area, mainly pertaining to Land Use, Housing Stock, Household Details, Social Infrastructure, Physical Infrastructure, Traffic Data, etc. have been collected through various appropriate sources. These collected details have been analysed by comparing them with Service Level Benchmarks (Handbook of SLB, 2019) and Urban and Regional Development Plan Formulation and Implementation (URDPFI) Guidelines framed by Ministry of Urban Development, Government of India (URDPFI Guidelines, 2020).

Table No.2: Demographics of Study Area forming Part of Influence Zone

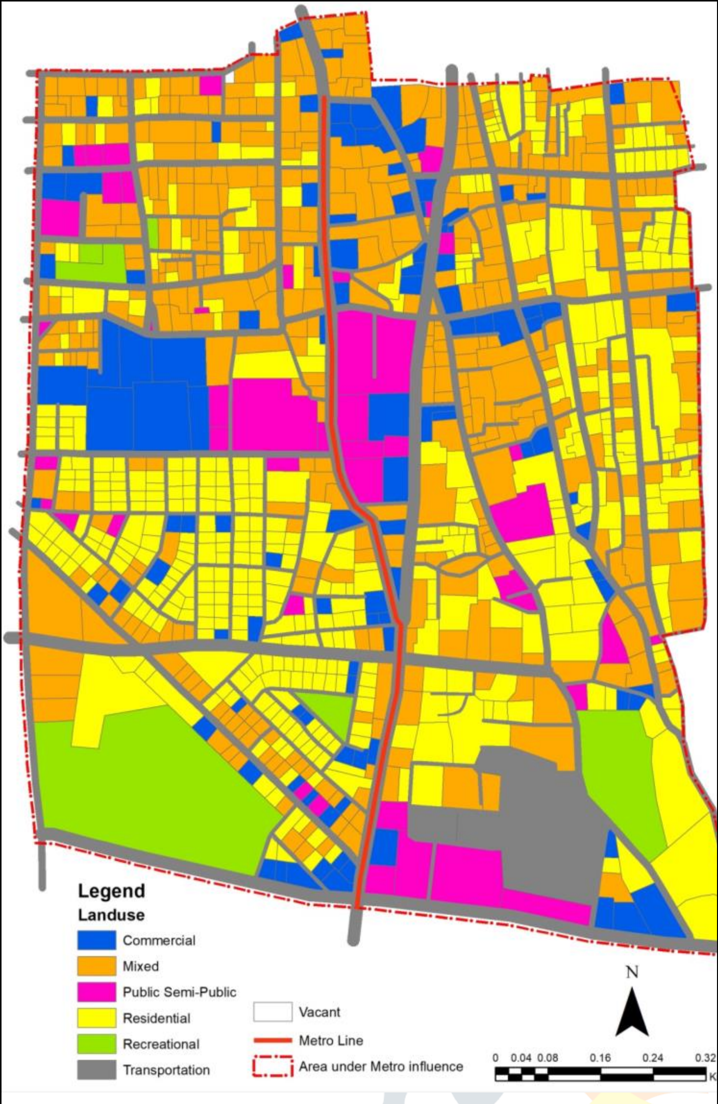
Sr. No.	Ward Number	Area in Ha.	Population	Population Density (ppl/Ha.)	Number of Households	Household Size
1	Ward 15	205.46	16,691	81.24	3,944	4.2
2	Ward 17	106.93	15,990	149.54	3,330	4.8
3	Ward 18	109.7	14,960	136.37	3,183	4.7
4	Ward 29	266.33	23,994	90.09	6,120	4
	Total	**688.42**	**71,635**	**104**	**16,577**	**4.32**

Source: Building Department, Pune Municipal Corporation, and Primary Survey, 2017

3.1. Development Issues along Influence Zone of Metro Rail Corridor

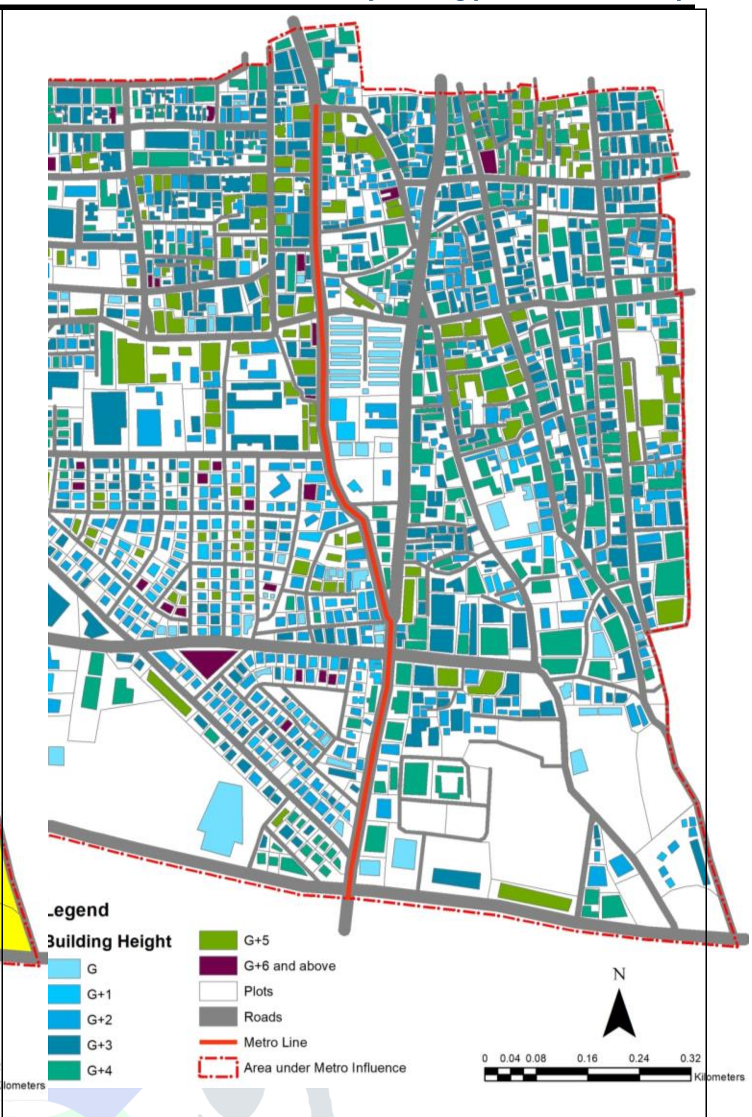
Analysis of existing scenario based on Service Level Benchmarks and URDPFI Guidelines has given understanding about prevailing circumstances in the Study Area. Densification of Influence Zone has been proposed by allowing Intensive FSI up to four in this TOD zone. This kind of densification is going to raise various Development Issues along Influence Zone of Metro Rail Corridor. It is going to increase strain on existing infrastructure and demand for augmentation of additional infrastructure. Intensive FSI is resulting into increase of built-up area which is going to attract additional population and additional activities in the Influence Zone. This addition of population and activities are going to demand for more civic infrastructure for its sustenance in long term. This will result into either up-gradation of existing civic infrastructure or replacement of the same by new one with enhanced capacity. Pace of densification shall match with pace of providing civic infrastructure to avoid any mismatch in demand and supply of it. This will require understanding about existing capacity of civic infrastructure and augmentation of additional one in tune with densification.

Accordingly, Land Use Map and Building Height Map analysed to understand existing land use and existing consumption of FSI in the Study Area and presented in Figure No. 1 and 2 respectively. By using these maps and prevailing Household Size; average tenement size in Study Area is calculated. In accordance with provisions of Utilization of Intensive FSI in TOD zone as mentioned in Table No. 1 above, quantity of additional FSI to be allowed in Study Area has arrived. This additional FSI is distributed as per their respective land use categories. Further, quantity of additional activities and increase in number of Households are calculated using average tenement size. It is assumed that same type of tenement size will be followed even after densification in Study Area. Increase in population of Study Area after densification is obtained by multiplying number of Household with prevailing Household Size. Based on these calculations, increase in vehicle ownership, increase in number trips, and increase in parking requirements have arrived. Also, based on Service Level Benchmarks and URDPFI Guidelines, requirements of additional civic infrastructure are arrived. System Dynamics Approach is used to analyse inter-sectoral relationships and linkages of infrastructure requirement resulting due to densification on account of Intensive FSI.



Mandai

Figure No.1: Land Use Map of Study Area



Mandai

Figure No. 2: Building Height Map of Study Area

4. Concept of System Dynamics Model

System Dynamics modelling is one of the approaches that can help the Urban Planners and Managers to meet the challenges of decision-making and policy formulation for the development of a system. It represents the key feedback structures in the system. Simulating the model shows the effect of the system structures on policy interventions. It is a problem evaluation approach based on the premise that the structure of a system, that is the way essential components are connected, generates its behaviour. It is well suited to analysis of problems whose behaviour is governed by feedback relationships, has a long-term time horizon, and not suited to one-time decisions. The process of creating a simulation model helps clarify the resource management problem and makes modeller assumptions about the way the system works explicitly. The most important advantage of this model is once the model is built; it can be used to simulate the effect of proposed actions on the problem and the system as a whole. In this regard, Forrester (1987) noted that this kind of tool is necessary because, while people are good at observing the local structure of the system, they are not good at predicting how the complex and interdependent the system will behave.

4.1. Casual Loop Diagram and Stock and Flow Diagram for Study Area

Causal Loop Diagram is a logical diagram which shows how the logic of the model is going to run and what will be the final outcome. As shown in following Figure No. 3, it starts with Intensive FSI; which induces dynamism in the model. Intensive FSI is going to increase built-up area and increase in built-up area going to increase number of Household and increase in areas under various activities. Increase in number of Household multiplied by Household Size result into increase in population. Increase in population is going to increase vehicle ownership. Increase in vehicular ownership is going to result into more demand for parking and increase in number of vehicle trips causing traffic congestion as the carrying capacity of the transportation system will remain same. This further used to calculate trips done using public and private modes. Eventually private ridership and metro ridership are found out. Then using private and metro ridership, Passenger Car Unit (PCU) of all the vehicles during the peak hour is calculated. Level of Service (LOS) for transportation system is derived by taking ratio of Carrying Capacity of the road to the PCUs during peak hour. Increase in population further result into increased demand for civic infrastructure causing stress on existing infrastructure as the serving capacity of them will remain same. Impact on physical infrastructure is mainly considered for analysis purpose as impact on social infrastructure is likely to be fulfilled from adjoining areas, hence not considered. Under Physical Infrastructure, three parameters are mainly studied namely, transportation, water supply and sewage generation. Increase in population is going to increase water requirement and subsequently increase in sewage generation. Increases in number of vehicular trips, parking demand, water requirement, and sewage generation are going to strain existing infrastructure. Level of Service (LOS) for water supply and sewage generation is arrived by taking ratio of their Serving Capacity to the peak hour demand. Mismatch in demand and supply of physical infrastructure; and inter-sectoral relationships and linkages of infrastructure requirement are manifested into Development Issues resulting due to densification in the Study Area. Stock and Flow Diagram for model is presented in following Figure No. 4. This model is developed for simulation duration of 10 years from 2019 to 2029 and has 10 iterations of one year each. In this model, diamond shape blocks are constants and rectangular blocks are levels. There is only one rate variable which is loading rate of Intensive FSI, i.e., change in rate of loading of Intensive FSI affects all other level variables. Details arrived as mentioned above have been assigned to various parameters in the model.

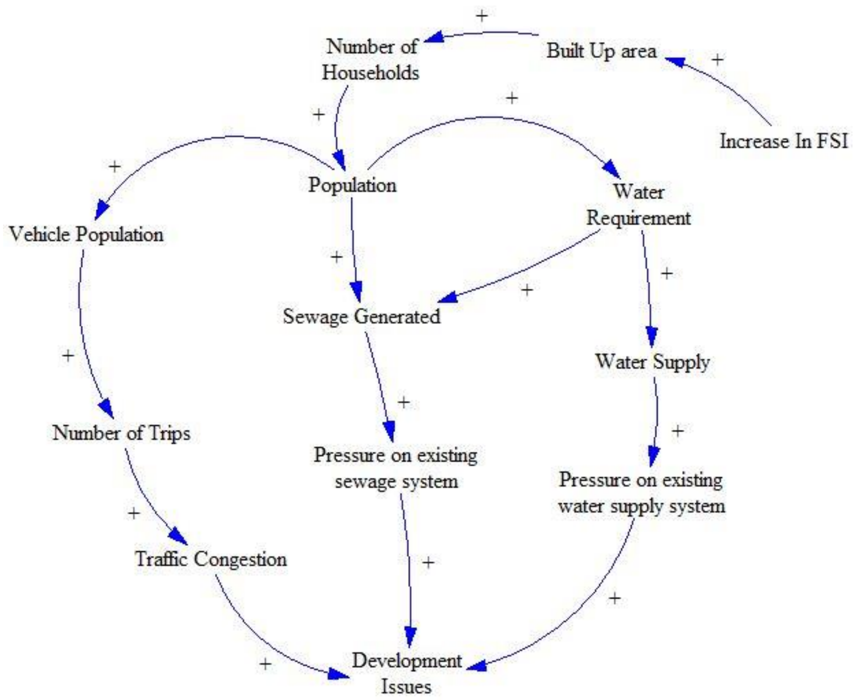


Figure No. 3: Casual Loop Diagram for Study Area

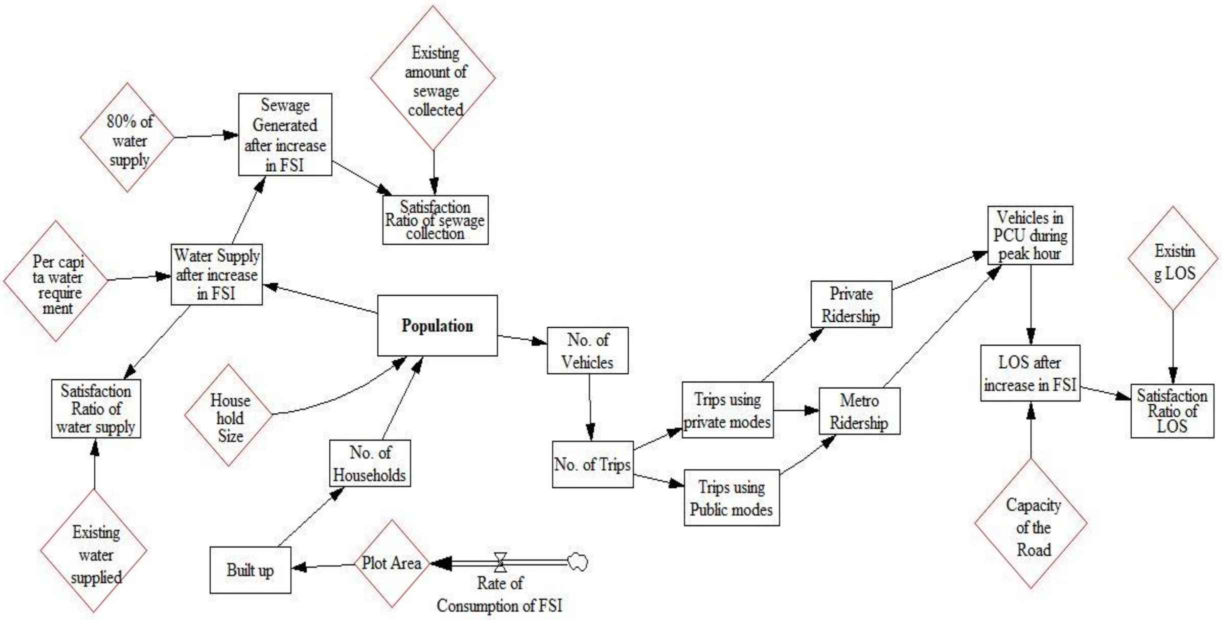


Figure No. 4: Stock and Flow Diagram for Study Area

5. *Analysis Development Issues using System Dynamics Approach*

Analysis of Development Issues along Influence Zone of Metro Rail Corridor is carried out using System Dynamics Approach. System Dynamics modelling helps in understanding the inter-sectoral relationships and linkages of infrastructure requirement under dynamic circumstances. It also helps in selecting the Most Optimum Policy to achieve Overall Level of Satisfaction in the model. Stress on physical infrastructure resulting due to loading of Intensive FSI in the model is analysed by running simulations. Level of Services pertaining to physical infrastructure, namely transportation, water supply and sewage generation are adversely affected due to increased demand and no improvement in their existing capacity. Policy intervention is required for augmentation in existing capacity of these infrastructures to maintain Level of Services at desired level. Loading rate of Intensive FSI and varying nature of physical infrastructure are going to have varying impact on augmentation of these infrastructures. Minimum policy intervention is expected in augmentation of existing infrastructure to achieve Overall Level of Satisfaction in the model. Accordingly, various simulations run in the form of policy intervention have been carried out using numerous permutations and combinations of varying values of parameters for these infrastructures. Selection of policy intervention for respective infrastructure is governed by achieving desired Level of Service with minimum intervention in their existing capacity. System Dynamics Approach is basically used for identification of minimum policy intervention to achieve overall desired Level of Satisfaction of the model. For each physical infrastructure, set of various values for respective parameters are selected, considering their minimum and maximum range of values. These set of values have been used for running simulations to achieve desire Level of Services for respective physical infrastructure. Range of maximum and minimum values for particular parameters is based on their primary data. Minimum and maximum range of values for parameters adopted for simulation runs are presented in following Table No. 3. This table represents various range of values adopted for each infrastructure. In total, 125 permutation and combinations of these values have been identified to find the best combination for utilizing optimal resources. In this model, delay factor is also considered as there will be some time required for augmentation of particular infrastructure. All these permutations and combinations are used in running simulations in System Dynamics software. Desired Level of Services for individual infrastructure and for overall performance of model are obtained through various simulation runs. Projected graphs for Number of Vehicles and Number of Trips, Trips using Private Modes and Public Modes, Water Supply and Sewage Generation and Overall Level of Satisfaction obtained through System Dynamics Software are presented in Following Figures No. 5 to 8 respectively.

Table No. 3: Minimum and Maximum Range of Values Adopted for Parameters

Sr. No.	Infrastructure Facility	Run - I	Run - II	Run - III	Run - IV	Run - V
1	Transportation	20	17.5	15	12.5	10
2	Water Supply	60	65	70	75	80
3	Sewage Generation	20	17.5	15	12.5	10
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

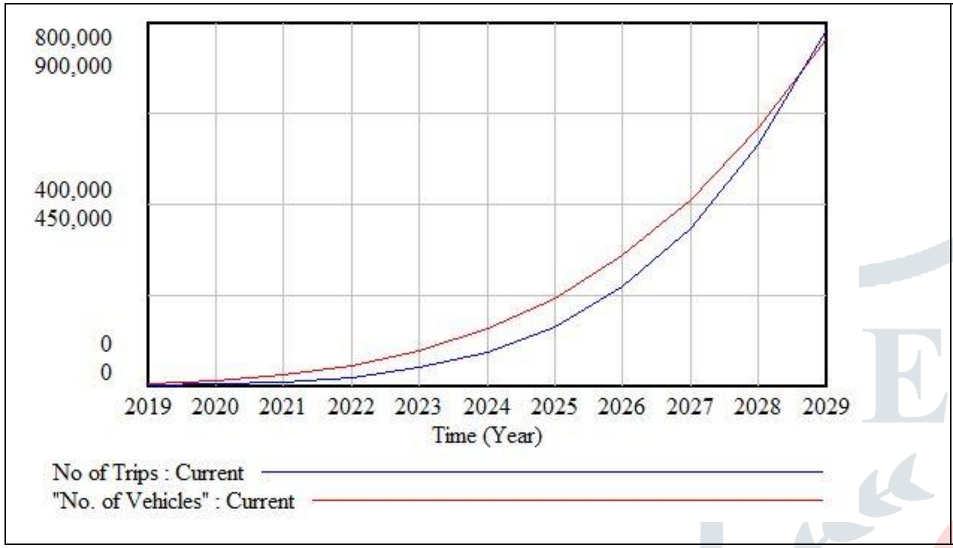


Figure No. 2: Number of Vehicles and Number of Trips Projection

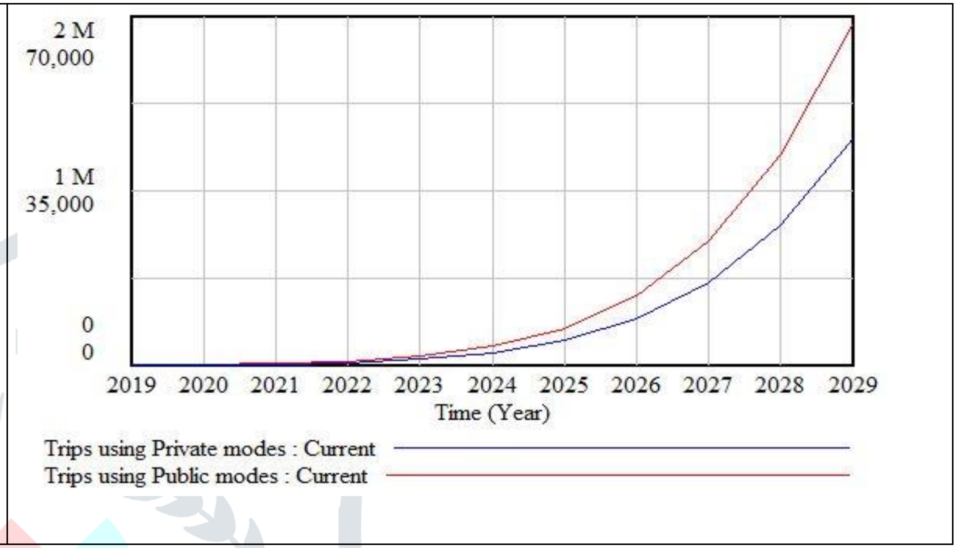


Figure No. 3: Trips Projections using Private and Public Modes

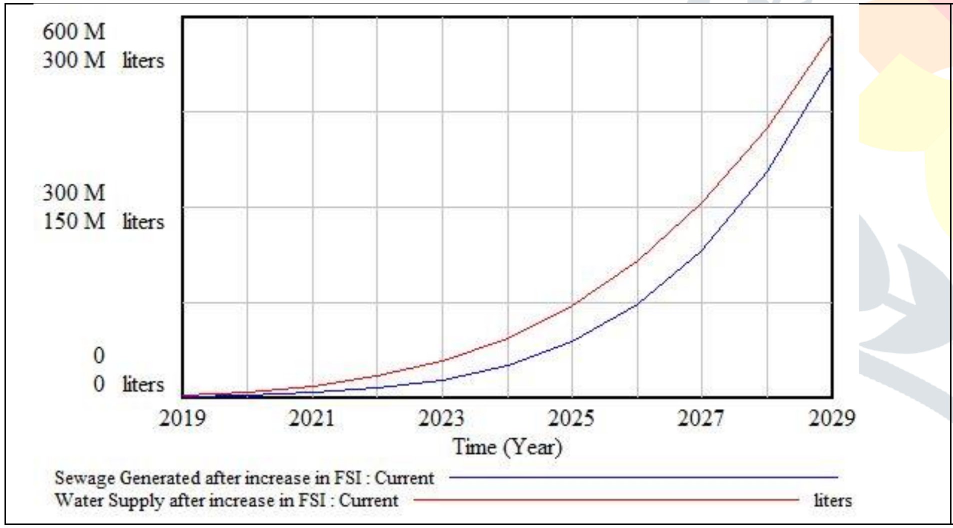


Figure No. 4: Water Supply and Sewage Generation Projections

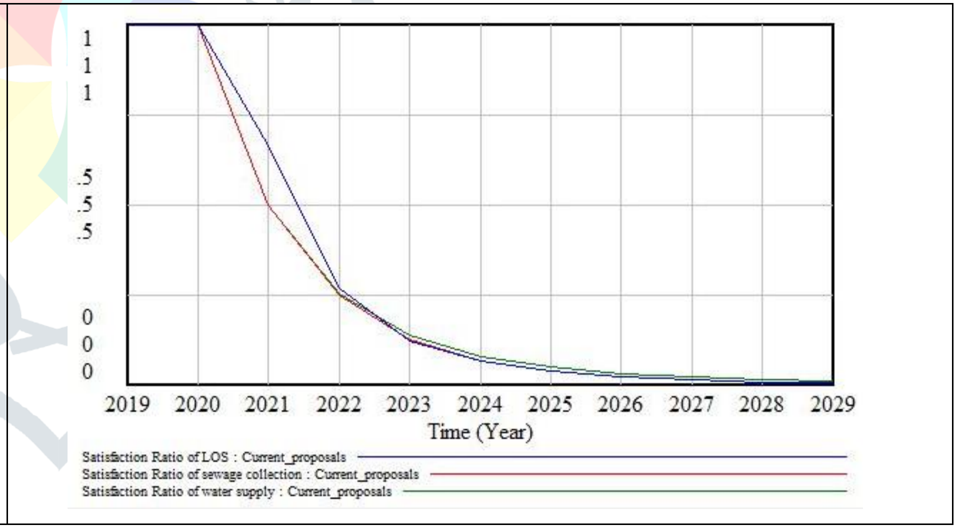


Figure No. 8: Graph of Overall Level of Satisfaction

5.1. Optimum Policy Formulation using System Dynamics Model

Various policy interventions have been used to achieve desired Level of Services varying due to loading of Intensive FSI in the model. Particular policy intervention gives an idea about extent of augmentation required in particular infrastructure for achieving desired Level of Services of these infrastructure resulting into Overall Level of Satisfaction of the model. Many policy interventions are likely to result into desirable Level of Service for particular infrastructure and Overall Level of Satisfaction of the model. However, selection of Most Optimum Policy is governed by achieving Overall Level of Satisfaction of the model with least policy interventions for each type of physical infrastructure. Therefore, numerous permutations and combinations having varying parameter values within maximum to minimum ranges pertaining to physical infrastructure have tried in simulation runs. In total, 125 permutation and combinations of these values have been identified to find the best combination resulting into Overall Level of Satisfaction of the model with least interventions in each type of physical infrastructure. Simulation results for these numerous permutation and combinations in terms of Overall Level of Satisfaction of the model are presented in following Figure No. 9. Most Optimum Policy has been identified from these simulation results and presented in following Table No. 5. Thus, System Dynamics modelling helps in understanding the dynamic behaviour of the system under dynamic circumstances and selecting the Most Optimum Policy.

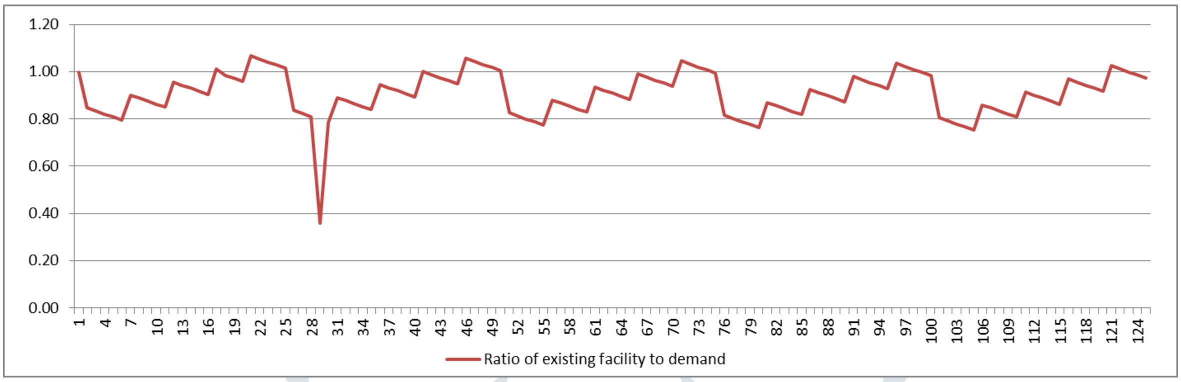


Figure No. 9: Overall Level of Satisfaction of the Model

Table No. 3: Parameter Values of Physical Infrastructure for Most Optimum Policy

Sr. No.	Type of Infrastructure	Transportation	Water Supply	Sewage Generation
1	Range Number	Run - II	Run - IV	Run - I
2	Range Value	17.5	75	20

6. Conclusion

Metro Rail has emerged as one of the best alternatives under Mass Rapid Transit System across rapidly expanding cities like Pune. Influence Zone comprising a strip of 500 mt. width on either side of the Metro Rail alignment has proposed under Transit Oriented Development. Intensive FSI up to four has proposed to allow densification of this Influence Zone to support financial viability. Proposed densification is going to result into augmentation of civic infrastructure due to increase in population and other activities. Timely intervention in civic infrastructure has become inevitable to maintain desired Level of Services in this Influence Zone. Loading rate of Intensive FSI and varying nature of physical infrastructure in particular are going to have varying impact on existing capacity of infrastructures. Any mismatch in demand and supply of these civic infrastructures are going to raise Development Issues along Influence Zone of Metro Rail Corridor. In these dynamic circumstances, System Dynamics Approach is useful in understanding the inter-sectoral relationships and linkages of infrastructure requirement to achieve Overall Level of Satisfaction. This approach is further helpful in selecting the Most Optimum Policy with least intervention in infrastructure augmentation to achieve sustainable densification of Influence Zone along Metro Rail Corridor.

References and Bibliography

1) Ackoff, R. L. (1971). Towards a System Concepts, Management Science, 17(11).
2) Akkermans, H. A., P. Bogerd and Vos, B. (1999). Virtuous and Vicious cycles on the road towards International Supply Chain Management, International Journal of Operations and Production Management, 19 (5/6). 565-581.
3) Andersen, D. F., and Richardson, G. P. (1997). Scripts for Group Model Building, System Dynamics Review, 13(2). 107-129.
4) Ashby, W. R. (1956). An Introduction to Cybernetics, Chapman and Hall, London.
5) Barlas, Y. (1996). Formal Aspects of Model Validity and Validation in System Dynamics. System Dynamics Review, 12. 183-210.
6) Barlas, Y. and Aksogan, A. (1999). Product Diversification and Quick Response Order Strategies in Supply Chain Management (Web Page). Bogazici University 1997 (cited 27 August 1999). Available from http://ieiris.cc.boun.edu.tr/faculty/barlas.
7) Beer, S. (1959). Cybernetics and Management (2nd ed.). English Universities Press, London.
8) Beer, S. (1979). The Heart of Enterprise. The Managerial Cybernetics of Enterprise. John Weily and Sons, London.
9) Bertanlanffy, L. V. (1950). An Outline of General System Theory, The British Journal of the Philosophy of Science, 1(2). 134-65.
10) Bertanlanffy, L. V. (1968). General System Theory, George Braziller, New York.

11) Chadwick, G. F. (1971). A System View of Planning, Pergamon Press, New York, p.36-37.
12) Checkland, P. (1981). System Thinking and System Practice, John Weiley and Sons, Chichester.
13) Costanza, R. and Ruth, M. (1998). Using Dynamics Modelling to Scope Environmental Problems and Build Consensus, Environmental Management, 22(2). 183-195.
14) Coyle, R. G. (1977). Management System Dynamics, John Weiley and Sons, London.
15) Forrester, J. (1971). World Dynamics, Cambridge, M. A. Wright- Allen Press.
16) Forrester, J. (1987). Lessons from System Dynamics Modelling. System Dynamics Review, **3(**2). 136–149.
17) Forrester, J. W. (1961). Industrial Dynamics, Cambridge, MA. M. I. T. Press.
18) Forrester, J. W. (1968). Principles of Systems, Cambridge, M. A. Productivity Press. Mass.
19) Forrester, J. W. (1969). Urban Dynamics, Cambridge, MA. M. I. T. Press.
20) Forrester, J. W., and Senge, P. M. (1980). Tests for Building Confidence in System Dynamics Models, In System Dynamics (A. A. Legast, J. W. Forrester and J. M. Lyneis, eds). Amsterdam. North- Holland.
21) Homer, J. B., and C. L St. Clair. (1991). A Model of HIV Transmission Through Needle Sharing, A model useful in analyzing public policies, such as needle cleaning campaign, Interfaces, 21 (3). 26-29.
22) Katsuhiko, Ogata. (2004). System Dynamics, Pearson Education, Pasupathi Printers Pvt. Ltd., New Delhi, p.1-2.
23) Lyneis, J. M. (1989). Corporate Planning and Policy Design. A system Dynamics Approach, Cambridge (MA). Paugh-Roberts Associates.
24) Michel, Batty. (1974). The Use of Models in British Planning. Applications in the Central Berkshire Sub-Region, in Jean Pearson and Richard Baxter (ed). 1974, Models, Evaluation and Information Systems for Planners, MTP Construction, U. K. p.80.
25) Miller E. J. and et el (2004). “Micro Simulating Urban Systems”, Computers, Environment and Urban Systems 28 (2004) 9-44.
26) Stave, A. Krystyna. (2002). Using System Dynamics Model to Improve Public Participation in Environmental Decisions, System Dynamics Review 18(2). 139-167.
27) Sterman J. D., Forrester J. W., Graham A. K. and Senge P. M. (1983). An Integrated Approach to the Economic Long Wave. Paper read at Long Waves, Depression, Innovation, Siena- Florence, Italy.
28) Sterman, J. (2000). Business Dynamics. Systems Thinking and Modelling for a Complex World, McGraw-Hill, Boston p. 982.
29) Sterman, J. D. (1989). Modelling Managerial Behaviour. Misperceptions of Feedback in a Dynamic Decision-Making Experiment, Management Science, 35(3). 321-339.
30) Towill, D. R. (1996). Industrial Dynamics Modelling for Supply Chains, Logistics Information Management, 9(4). 43-56. (1996b) Time Compression and Supply Chain Management- a Guided Tour, Supply Chain Management, 1. 5-27.
31) Venix, J. (1996). Group Model Building. Facilitating Team Learning Using System Dynamics, Wiley, New York pp. 297.
32) Wiener, N. (1950). The Human Use of Human Beings. Cybernetics and Society, Houghtons Miffilin, New York.

Website

1) Handbook of SLB. (2019, November 5). Retrieved May 12, 2020, from CPHEEO, GOI: http://cpheeo.gov.in/upload/uploadfiles/files/Handbook.pdf
2) Notice. (2019, March 8). Retrieved May 11, 2010, from Pune Municipal Corporation: https://pmc.gov.in/sites/default/files/Building_permission/Tod_development_plan/2019.03.08_TOD_37_(1%20AA).pdf
3) Pune Metro. (2020, May 4). Retrieved May 11, 2020, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/wiki/Pune_Metro
4) Transit-oriented development. (2020, March 29). Retrieved May 11, 2020, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/wiki/Transit-oriented_development
5) URDPFI Guidelines. (2020, May 11). Retrieved May 12, 2020, from Ministry of Housing and Urban Affairs: http://mohua.gov.in/upload/uploadfiles/files/URDPFI%20Guidelines%20Vol%20I.pdf
6) Notice. (2019, March 8). Retrieved May 11, 2010, from Pune Municipal Corporation: https://pmc.gov.in/sites/default/files/Building_permission/Tod_development_plan/2019.03.08_TOD_37_(1%20AA).pdf
7) Pune Metro. (2020, May 4). Retrieved May 11, 2020, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/wiki/Pune_Metro
8) Transit-oriented development. (2020, March 29). Retrieved May 11, 2020, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/wiki/Transit-oriented_development
9) https://www.itdp.org/library/standards-and-guides/tod3-0/what-is-tod/
10) http://www.ris.org.in/sites/default/files/AIIB%20MRTS%20Meeting%20Background%20Note.pdf