

Accident Analysis and Costing Model Using System Dynamics

S.Bharathi, V.Mathiba,Arivazhagan, Punithan, Karishma

Abstract

The rapid increase in population growth and increasing economic activities have resulted in the tremendous growth of motor vehicles in Chennai. This is one of the most prime reasons for the road accidents, being the home of 7.5 million people. Chennai is the 6th most populated city in India. Anna Salai in Chennai is the most famous road which connects most of the Central to the South Chennai. Due to this increased population in Chennai, the volume of traffic has increased by about 35% to 45% for the past ten years. This results in increase in the road accident and road accident costing. This study explains the development of road accident prediction model using STELLA (Systems Thinking, Experimental Learning Laboratory with Animation) software. The details of accidents, accident cost and their forecast information have been incorporated in stella software simulation model for easy interpretation on Chennai city roads.

Key words: Accidents, Safety, Dynamic approach, Cost Analysis.

1.Introduction

Road accidents, also termed as road crashes, are stochastic events occurring in highways, and it is governed by many factors. In India 1,46,000 persons were killed and 4,65,282 were injured by motor vehicles annually. As for as Tamil Nadu state is concerned, 69,168 were injured and 15,563 were killed by motor vehicles in the year 2015. Tamil Nadu has the second place in the country in Accident Risk Index, and the number of accidents is estimated to increase three folds by 2026. The total accident in Chennai City is around 6000 per year and the fatal accident contributes one – tenth in it. Predicting the probability of occurrence of stochastic events gives a traffic engineer, an insight for the preventive measures from its occurrences. The rapid growth in population and increase in economic activities leads more usage of motor vehicles. This is one of the major factor responsible for the causes in road accidents in metro cities. Traffic accident leads to loss of life , injury, property , direct and indirect cost to individuals and governments . Thus the traffic engineers have to undertake a big responsibility of providing safe traffic movements to the road users and ensure their safety. Road accidents cannot be totally prevented but by suitable traffic engineering and management the accident rate can be reduced to a certain extent. For this reason systematic study of traffic accidents are required to be carried out. Proper investigation of the cause of accident will help to propose preventive measures in terms of design and control.

It is the responsibility for all the traffic engineers in providing safety movements of vehicles and the road users by adopting traffic engineering management thereby reducing the rate of accident to a certain extent. This study helps in reducing the number of fatal and disabling road accident. It is also important to provide suitable remedial measures to reduce accidents and reduce the losses economically. It also helps in creating awareness among the people on road safety and in wearing helmets. In India the GDP loss due to road Accident costing is in the order of 3 to 4 % formally but informally it is 6 to 8 % (which is in the order of 1 lakh crore to 55 ,000 crore from 2014 to 2018) Hence it is imperative that accident costing study should be taken up which will help government make important decisions

2. Estimation of Road Accident Cost

A number of alternative Methodologies are used to value the economic cost of an accident casualty Jacobs (1995) approaches has summarized the different approaches and has listed the following six . The gross output or human capital approach quantifies the cost of vehicle damage, medical expenditure and police cost and the discounted present value of victim's future cost. The net output approach subtracts the amount of victim's future consumption from the gross output value that is considering all the cost components of accident cost except the cost spent in for the victim's future output. The life insurance approach It treats the accident cost or the value of accident prevention as the sum of valuable resource cost and the amount for which the typical individuals are willing to insure their lives. The court ward approach With this approach, the sums awarded by the courts to the surviving dependants of those killed or

injured are regarded as an indication of the cost that society associates with the road accident. The implicit of public sector valuation approach With this method an attempt is made to determine the costs and values that are implicitly placed on accident prevention in safety legislation or in public sector decisions taken either for or against investment program that affect safety. The value of risk change approach With this method the value of a given improvement in safety (i.e. a reduction in risk) is defined in terms of the aggregate amount that people are prepared to pay for it. That is the value of a particular safety improvement is defined as the sum of all the amounts that people (affected by the improvement) would be willing to pay for the (usually very small) reduction in risk provided by that improvement.

These six approaches produce substantially different costs and values for accidents involving one fatality based on the typical figures derived from studies carried out in developed countries over the period. As stated earlier by experts the point that the method used for costing road accidents depends on the objectives being pursued in a country by those planners and economists responsible for investment planning. The reasons for costing road accidents are most likely to be either the maximization of national output or the pursuit of social welfare objectives the only accident costing/valuation methods that appear to be directly relevant to these two objectives area the "Gross Output" method the "Willingness to pay". This study will adopt the "Gross Output Method" for costing the road accident that has taken place in the study area.

The methods focus on different aspects of the impact of a casualty with respect to specific aspects of the economy or society in general. As these methods can also give rise to substantially different estimates of costs and values, the choice of which method to use is dependent upon the objectives of the study. The main objective of this study is to analyze the trends of accidents in Chennai city and estimate the cost of the accidents through systems approach. The accident model is valued by comparing the predicted and actual accident data for the year 2008.Three scenarios were studied by changing the income growth rate and discount rate. Finally suggesting the best scenario for implementation.

3.Traffic Characteristics of Chennai City

Tamil Nadu is the southernmost state of India and 11th largest state with an area of 1,30,058 Sq.km and third most urbanized state next to Mumbai and Gujarat. In general it is noted that accidents are occur due to several reasons such as lack of awareness, congestion, on street parking, pedestrians, speed and lack of implementation in enforcement measurements but in Chennai accidents occur due to various reasons. Especially poor traffic management in reckless driving of share auto, buses and autorickshaws, poor road geometrics, road users, control at intersection, unspecified bus stops etc., are the major causes of road accidents. The study area selected for this study is Chennai city is the capital city of Tamil Nadu. The 400 years-old city is the 31st largest metropolitan in the world Being the home of 8.9 million (89 lakhs) people (CMA) where 46, 46,732 lakh people live in the city. A total of 63920 road accidents have been reported by the State in the calendar year 2018, claiming 12216 lives and causing injuries to 74537 persons. In Tamil Nadu, around 167 accidents and 30 fatalities were occurred every day during January 2019.The Chennai city and Kancheepuram are the leading districts in Road accidents and fatal deaths during January 2019(Government of Tamil Nadu Home Transport Department). The statistics clearly says that Chennai city is having high accident rates every year hence Chennai city is taken for the study area. The number of accidents based on their severity recorded from the year 2011 to 2018 was collected from the Transport Commission rate and State Transport Authority Government of Tamil Nadu website and the data are represented in table 1. The economic loss is enormous aside from untold human suffering, pain and grief. Here an effort is formed to estimate the loss of economics in traffic accidents. The Compensation cost awarded by the Madras High Court for the accidents based on their severity with all the cost components that included in accident costing was collected from the year 2010 to 2020. The data consisted of 55 cases that had final judgments in the Madras high court.

Table 1 Road Accident Data from 2011 to 2018 Chennai City

Type/Year	2012	2013	2014	2015	2016	2017	2018
Fatal	1367	1215	1020	859	1155	1264	1264
Major Injury	611	741	1139	2949	1888	1364	1799
Minor Injury	6581	6858	6551	3196	4162	4306	4304
POD	1104	891	755	324	281	323	246

4. System Dynamics Approach

System dynamics has a long history as a modeling paradigm with its origin in the work of Forrester (1961) from Massachusetts University in United States, who developed the subject to provide an understanding of strategic problems in complex and dynamic systems. System dynamics models, by giving insight into feedback processes, provide system users with a better understanding of the dynamic behavior of systems. It is a methodology whereby complex, dynamic and non linear interactions in social systems can be understood and analyzed and new structures and policies can be designed to improve the system behavior. It is the result of “Cross Fertilization” among elements of traditional management, feedback control theory and computer simulation.

A system is a collection of interacting elements that function together for some purpose. The systems approach in planning emphasizes the connections among the various parts that constitute a whole system. By its nature, a systems view of a problem cuts across interdisciplinary boundaries as defined in many traditional sciences, a systems view of a city might involve aspects of political science, geography, economics and sociology. Exactly how these various interdisciplinary perspectives can be integrated is one of the major intellectual challenges of the systems approach.

Urban transportation system is a complex system with multiple variables and feedback loops between subsystems and influencing factors. Ordinary linear quantitative approach proves to be inadequate to describe the characteristics of this complex system. Therefore, system dynamics (SD) approach is intended to be used in this study to simulate the evolution of urban transportation system. System dynamics approach in the simulation modelling has been extensively used by several of the advanced countries in traffic planning and impact studies to analyse the cause and effect scenarios, impact of change in one options and forecasting various system dynamics simulation options under varying policy options. The STELLA system dynamics software is object oriented software which facilitates formulation of dynamic models which are simulated to a real world situation. For instance, in the conventional approaches, the impact analysis is carried out in isolation.

5. Cost Components of accidents

The fatal accident cost is the cost spent for the Loss of Income, Medical cost, Pain Greif and suffering, and costs spent for Transportation, Damaged cloths, Funeral expenses, Administrative cost, Medical service were major components in which the awarded cost were split-up. The cost spent for medical service, funeral administration on the whole is taken as other costs and model developed is shown in fig 1. The major Injury cost that is spent for an accident victim who has suffered a serious injury such causing a permanent disability or injury that takes long period for curing such as Loss of Income, Medical cost, Pain Greif and suffering, cost given for victim’s Permanent disability, Transportation cost, Administrative cost, Medical service cost which were the major components considered. Costs spent for transportation, medical service, administrative are taken as other cost as a whole as shown in fig 2.

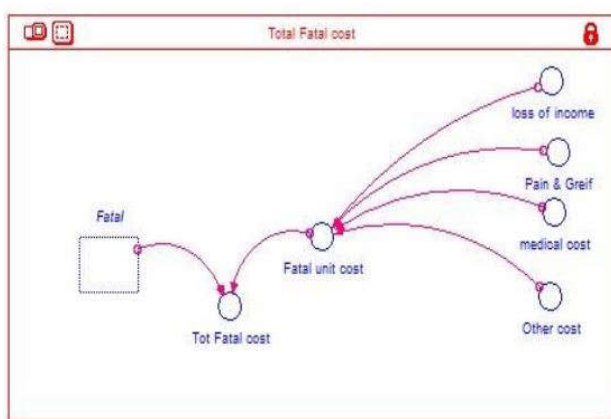


Fig 1: Model for Total Fatal Injury accident cost

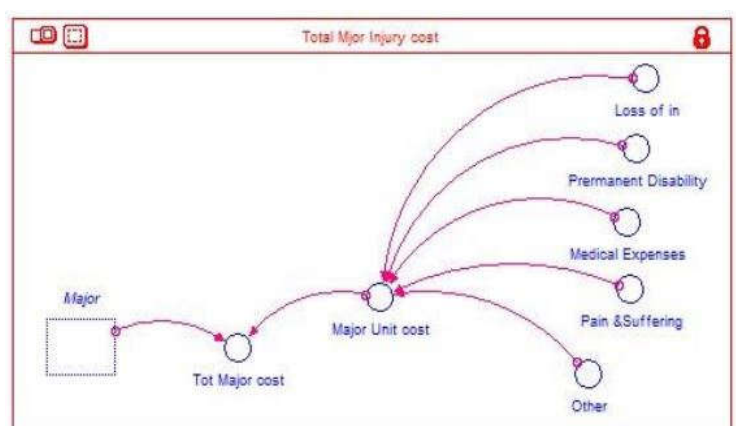


Fig 2: Model for Total Major Injury accident cost

The Minor Injury cost is the cost spent for a victim who has suffered from a slight injury that lasts for a short period of time such as Loss of Income during the period of treatment, Medical cost, and cost of lost amenities during the time of accident, cost for extra nourishment, Transportation cost that were majorly considered during judgment are taken and the unit cost spent for an minor injury accident is calculated. The property damage cost is the cost that is spent on the damages caused due to an accident to the properties such as vehicles that involved in the accident and the properties on the roads.

5.1 Scenario I

The scenario analysis is a part of the study involves testing the model by giving various percentages of rates to the influencing factors of the problem such that to find the best rate to frame the suitable mitigation measures to reduce the problem. The scenario-1 is the do-minimum scenario where only minimum efforts are being put to reduce the number of road accidents. Taking the percentage of outflow for enforcement level 35% to 40%, and training for authorities 25% to 30% having the percentage of outflow taken for all the accident factors. Table 2 gives the output of Do minimum Scenario. The number of accident have got increased about 2.4 times from the base year value of 7613 if the current trend in the accident continues when only a minimum effort of enforcement and training is carried out for the road safety and the corresponding cost spending for accidents based on the severity is also increased by 2 times. The total cost of accident for the base year is Rs.975.63 crores and there is a sudden increase in the total cost of accident for the year 2020 nearly 110 times comparing to 2018.This rise is because of modification in the economic policy of country, latest technology and income of the people.

Table 2 Accident cost for Do-minimum scenario

Total Cost in Crs	Years				
	2018	2022	2026	2030	2035
Fatal Accident Cost	703.41	885.29	1014.14	1169.22	1337.97
Major Injury Accident Cost	254.55	323.23	404.97	498.05	621.58
Minor Injury Accident Cost	16.78	21.68	27.26	33.37	41.54
Property Only Damage Cost	0.87	1.27	1.80	2.49	3.53
Total Cost	975.63	1231.48	1448.19	1703.13	2004.64

5.2 Scenario-2

The scenario-2 is called the desirable scenario where the percentage of the traffic enforcement, road maintenance and the training level is increased to the maximum such that more efforts are taken to reduce the accident as well as the corresponding accident cost. The percentage of outflow having the enforcement level 35% to 90%, and training for authorities 25% to 90% . The initial value for enforcement and training is assumed to be 35% and 25% respectively. The desirable scenario is performed. With values obtained in desirable scenario as shown in table 3 it is seen that there is a reduction in number of accident if the current trend in the accident dose not continues and a maximum effort is taken towards the road safety and the corresponding cost spent for the accidents also simultaneously reduced with reduction in number for accidents. It is observed that the total cost of accident decreases for the base year 2018,2026 and 2036 respectively compared to scenario 1. Comparing the changes from the year 2018 to 2035 the final result obtained is due to an extreme effort is taken for road safety and also the simultaneous decrease in the accident cost when accidents get decreased

Table 3 Accident cost for Desirable scenario

Total Cost in Crs	Years
-------------------	-------

	2018	2022	2026	2030	2035
Fatal Accident Cost	703.41	517.50	284.72	116.29	24.43
Major Injury Accident Cost	254.55	202.46	133.05	71.57	23.18
Minor Injury Accident Cost	16.78	13.87	9.34	5.03	1.63
Property Only Damage Cost	0.87	0.79	0.56	0.30	0.08
Total Cost	975.63	734.64	427.69	193.21	49.33

6. Comparison of Accident cost awarded in India and other countries

In India the MACT for pain, grief and suffering has fixed an value of 20% of the victims future lost output due to accident where as in other countries for example in United states the value of pain, grief and suffering is almost 3 times a victims medical bill that is approximately 40 to 50 % of their claimed amount. On comparing the cost awarded for pain, grief and suffering from the data collected from Indian court and data collected from ALLlaw.com, www.justinziegler.net for US there is huge difference in cost awarding which is shown in Table 4 having the average value of pain, grief and suffering for India and United states for different severity of accidents.

Table 4 Average pain, grief and suffering cost

Accident severity	Average pain, grief and suffering cost	
	INDIA (INR)	UNITED STATES (INR)
Fatal	500000	1000000
Minor Injury	100000	350000
Major Injury	5000	7000

The result on comparing the total accident cost as per Indian value as well as US value for the pain, grief and suffering in Table 4 shows about 428crs difference in amount is spent on accident cost if we adopt the US value for Pain, grief and suffering but on the other hand this might increase the standard of an individual human’s life.

When comparing the total predicted the Chennai city’s accident from the results that have been obtained with the city’s GDP it was found that the total accident cost would approximately be 1% of the city’s GDP where the city’s estimated GDP for the year 2020-2021 being \$42 million (Economy of Chennai Wikipedia) that is 3.07 lakh crore Indian rupees.

7. Conclusion

The accident cost is found by individually considering various cost components and calculated by multiplying their unit cost with their respective total number of accident predicted. The models were analyzed under two scenarios such as do minimum that is letting the current trend to continue or only taking minimum effort for future and Desirable scenario were maximum efforts are taken to reduce

the accidents rate. This results in very much increase in the total number of accidents in future in do-minimum scenario with corresponding increase in the cost that are spent for the accident. On comparing to the Chennai city's GDP for the year 2020 which is 42billion US\$ (Economy of Chennai Wikipedia) the total accident cost spent is nearly about 1% of the city's GDP. The models were analyzed under two scenarios such as do minimum that is letting the current trend to continue or only taking minimum effort for future and Desirable scenario were maximum efforts are taken to reduce the accidents rate. This results in very much increase in the total number of accidents in future in do-minimum scenario with corresponding increase in the cost that are spent for the accident. On comparing to the Chennai city's GDP for the year 2020 which is 42billion US\$ (Economy of Chennai Wikipedia) the total accident cost spent is nearly about 1% of the city's GDP.

Acknowledgement

The authors are thankful to the authorities of road transport Chennai for providing data and extending help in other areas for this research work.

REFERENCES

- [1] Ms.S.Bharathi (2021) Pavement Construction by Using Synthetic Fiber Ilkogretim Online, Volume 20 Issue 1
- [2] Dr.G.Umadevi and Vinothkumar L, S (2017), 'Application Of Advanced Methodologies To Ensure Road Safety' Division of Transportation Engineering, Department of Civil Engineering, Anna University Chennai.
- [3] Dr.G.Umadevi and Dhanalakshmi S (2016), 'Accident Prediction Models For A Road Transport Corridor Using System Dynamics Modelling In Chennai' Division of Transportation Engineering, Department of Civil Engineering, Anna University Chennai.
- [4] Naveen Kumar and Umadevi.G (2011), 'Application of System Dynamic Simulation Modeling in Road Safety', Division of Transportation Engineering, Department of Civil Engineering, Anna University Chennai.
- [5]Ms.S.Bharathi Road Accident Cost Prediction using a Multi- Objective Adaptive Convolution Neural Network 2023 N0 6,1876-1887 "Journal of Environmental Protection and Ecology 24"
- [6]Gupta S (2010), 'Development of accident prediction model' published in International Journal of Advanced Engineering Technology, eISSN 0976 – 3945.
- [7]Ioannis Golias (2001), 'Effects of road geometry and traffic volumes on rural roadway accident rates', published in the National Academic of Science Engineering.
- [8]Manpreet Singh and Rajiv Gupta (2014), ' Accident Black spot validation using GIS' 15th conference of Esri India User Conference 2014.
- [9]Poul Greibe (2001), 'Accident prediction models for urban roads', published in International Journal of Advanced Engineering Technology, vol no 35, pp 273 – 285.
- [10]Sivakumar and Krishnaraj (2012), 'Road traffic Accidents due to drunken driving in India – challenges in prevention' published in International research in management and Technology, vol no 2, ISSN 2249 – 9563.
- [11]Vigneswari and Minachi (2013), ' Study on Road Accident Data Management System, published in International Journal of Science, Engineering and Technology Research, vol no 2, Issue 11, ISSN : 2278 – 7798.
- [12] Dynamic Simulation Models for Road Safety and Its Sustainability Implications a report sponsored by Safety research using simulation University of Central Florida