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Development of A Road Accident Prediction Model Based on System Dynamics Approach

KEYWORDS: Road accident, System Dynamics, Human Factor, Road Factor, Vehicle Factor, Simulation

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ABSTRACT *This paper deals on prediction of road accidents for Chennai city using system dynamics approach. In this case, the simulation road accident prediction model was developed from the base year 2010. Chennai City road accident data was collected from 2006 to 2010 from Chennai city traffic police. In this research an attempt is made to identify the various factors causing the road accidents. The road accident prediction model was developed using factors of human behaviors, vehicle factors and road factors. The system dynamics road accident prediction model was developed using STELLA software. STELLA software is a powerful tool for making a simulation model instead of stock and flow diagram, graphical interface, table and graph view, causal relational diagrams and build in functions. The main objective for the studies is to establish simple, practicable simulation road accident models that can predict the expected number of accidents from 2010 to 2020. The predicted number of accident in 2010 was 5255 and accident for the year 2020 will be 21612. The model was also validated by comparing the predicted accident values of the years 2010, 2011 and 2012 with actual accident values.*

1. INTRODUCTION

The rapid population growth and increasing economic and technological activities have resulted in the tremendous growth of motor vehicles. This is one of the primary factors responsible for road accidents in many metropolitan cities in India. Road accidents are essentially caused by improper interactions between vehicles, vehicles and other road users and/or roadway features. The situation that leads to improper interactions could be the result of the complex interplay of a number of factors such as pavement characteristics, geometric features, traffic characteristics, road users' behaviour, vehicle design, drivers' characteristics and environmental aspects. Thus, the whole system of accident occurrence is a complex phenomenon (Chakraborty and Roy, 2005). A number of studies on road safety have been carried out in India, in different cities such as Delhi, Mumbai, Chennai and Ernakulam as well as on some highways. It has been estimated that over 1.3 million persons die and 50 million persons get injured every single year in road accidents throughout the world.

According to the statistics released by National Crime Records Bureau (NCRB), as many as 1,39,091 persons lost their lives in 4,40,042 road accidents in India during 2012. Road accident scenario in the State of Tamil Nadu is also very alraming. As per NCRB report, Tamil nadu tops the list in India with 16,175 deaths in 67,757 accidents during 2012. In Chennai city, there are 35 fatalities per 10000 vehicles which are 2.5 times higher than the national average. Hence it is necessary to incorporate steps, which can reduce road accident rates and implement mitigating actions, which can be taken to reduce the number and severity of road accidents and also take quick remedial measures incase of accidents (Mohanraj, et.al, 2006). The steps include better road design and construction, rigorous driver training, stringent license requirements, effective enforcement of traffic rules and regulation to make automobiles safer. It is important to identify the relationship between road accidents and various influencing factors in order to reduce the number of road accidents. In this study a model was developed for road accident prediction using System Dynamics simulation. The model was developed by collecting the accident data on Chennai city roads.

2. SYSTEM DYNAMICS

System dynamics is a computer-aided approach to policy analysis and design. System Dynamics is a methodology, where in complex, dynamic and non linear interactions in social systems can be understood and analysed and new structures and policies can be designed to improve the system behavior. As the road accident prediction studies involve various complex systems namely the human, road, vehicle and all other environmental factors, it is vital to develop dynamic simulation model to understand the interactions between the various complex systems. This would evolve sustainable solutions towards ensuring road safety. In this study, the System Dynamics simulation software namely STELLA was used. Accident data pertaining to the public, transport, highway and police officials were collected from Government sources. The model has also been validated with the real world accident records.

3. STUDY AREA

The study area selected for this research work is Chennai, the capital city of Tamil Nadu. Normally road accident prediction model is done for urban and rural roads separately. In this study, the urban roads were considered. Chennai, the 400 years-old city is the 31st largest metropolitan in the world. Being the home of 8.9 million (89 lakhs) people, Chennai is the sixth most populous city in India. There is a rapid growth of population in Chennai between 2001 and 2011 with 49.6 % increase from 4, 343, 645 to 6, 500, 000 within a short span of ten years. The city and metropolitan area are served by major arterial roads that run either in an east-west or north-south direction. Anna Salai is the city's most famous road and it traverses most of central and south Chennai and leads on to the National Highways 45 to Thiruchirapalli. Other arterials include Kamaraj Salai (north-south), Poonamalee High Road (east-west), Broadway (east-west), Radhakrishnan Salai (east-west), and Sardar Patel Road (east-west). Chennai is also served by two ring roads namely the Inner Ring Road and Outer Ring Road that circle the metropolitan area. Most of the arterial roads lead to the National Highways and State Highways. As on 2012, the Corporation maintains 262 bridges, road-overbridges and road-underbridges, including 65 high-level bridges, 31 box culverts, 81 slab culverts, 11 rail-overbridges, 14 rail-underbridges, 6 pedestrian subways, 6 causeways, 35 footbridges and 13 grade separators The Metropolitan Transport Corporation (MTC) runs about 3637

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buses on 771 routes, moves an estimated 4.9 million passengers each day.

As of April 2013, the total vehicle population of Chennai was 3,881,850, including 3,053,233 two wheelers. Due to the increase of human population and vehicle population, the volume of traffic has increased by about 35% to 250% on the roads of Chennai city in the past ten years (Gunasekaran et al 2003). The growth trend of motor vehicles in the Chennai city is presented in Table 1.Utilization of industrial waste products in concrete has attracted attention all around the world due to the rise of environmental consciousness. Accumulations of stockpiles of Tyres are dangerous because they pose a potential environmental concern, fire hazards and provide breeding grounds for mosquitoes that may carry disease. Tyre pile fires have been an even greater environmental problem.

Table 1 Motor Vehicle Growth in Chennai City

Year	Total Registered Vehicle
1981	120,000
1986	228,000
1991	544,000
1996	812,000
1998	975,000
2012	3,760,000

The total number of accidents on the major roads of Chennai for the period 2006-2012 is given in Table 2. It is seen from Table 2 total accident in the year 2010 was less due to various traffic and control measures and except major accident other accidents are in declining trends. It is also observed from the Table 2 that the minor injury is more number of accidents. The percentage of various factors causing the road accident is presented in Table 3 which are collected from Chennai Traffic Police department First Information Reports.

Table 2 Road Accidents in Chennai

Type \ Year	2006	2007	2008	2009	2010	2011	2012
Fatal	1112	1110	612	602	604	906	1367
Major injury	1693	1564	1193	1299	1470	271	611
Minor injury	4050	4367	3077	2403	2227	4513	6581
Non-injury	545	529	1504	873	832	876	1104
Total	7400	7570	6386	5177	5133	6566	9663

(Source: Chennai Traffic Police)

Table 3 Factors Causing Accident

Factors	Percentage
Human Factor	94
Vehicle Factor	3.5
Road Factors and other	2.5

4. ANALYSIS OF ROAD ACCIDENT FACTORS

It is found that the following are the various causes of accident from the collected accident data are Over speed, Bad over taking, Signal violation, Careless driving, Applying sudden brake, Rash driving, Skidding, Sudden turning, Close vehicle following, Wrong side entry, Passenger felling down from the running bus, Crashing in the fixed object and Wrong indication of turning. Experts point out that these kind of people prone to accidents, they are Aggressive thinker, People who grow up dominating, Distracted personalities, People riding bigger or costly vehicles (bus, lorry, etc.), Egocentric personalities, Short-tempered people, Overconfident people, Individuals lacking judgment (decision-making) and Persons responding to emergency situations (fire, accidents, etc.). Such persons either involve in rash driving or violate traffic rules which will lead to accidents when police assistance or a traffic signal is absent. No day passes without one hearing of road accidents in Chennai which could be either simple or fatal. Depending on the nature of the crash, vehicles involved, road condition, accident time, urgency of the persons, the accident locations vary to a great extent. Road accidents happen across Chennai and are common occurrences in some places known as black spots or accident spots. Of all the accident locations, intersections or junctions record the most number of accidents.

In addition to intersections, places near colleges and schools, in and around hospitals, areas close to religious places, in the vicinity of marriage halls, theatre halls, hotels and restaurants, park and playgrounds, near bus stops, wine shops and police stations are also witness accidents. In this study, for development of accident predictive model, analyzed the relations between accidents and factors such as human factors, vehicle factors and road factors. Accident data were collected for the years 2006 to 2010 and used the average accident of these five years. The model development and various factors causing road accident are described in the following sections.

5. DEVELOPMENT OF ACCIDENT PREDICTION MODEL

In general there are two approaches to computer based modeling. One approach is referred to as Systems Dynamics and the other are termed Discrete Event Simulation. Either can be effective in analyzing real life problems. The road accident prediction model was developed in this research, using the System simulation Software STELLA. This software is user friendly simulation software which allows the development of any complex, dynamic and non linear systems with significantly less effort, more interaction and conventional tools than using other traditional programming languages.

This paper focuses on development of a System Dynamics Simulation prediction model for road accident. This model considers Human factors, Vehicle Factors, Road Factors and Environmental and other factors for the accident causes. This simulation model is commonly three types of implementations of model like that Human factors, Vehicle Factors, and Road Factors. Most of the results based on the human factors simulation model. These models are used to define the inflow factors are speed, bad overtaken, rules violation, Drunk and driving etc to increase the existing model value as the same the outflow participates are enforcement of traffic rules decrease the present model value. A simulation expert must enter information about the flow of events. Table 4 shows factors considered for developing road accident prediction model.

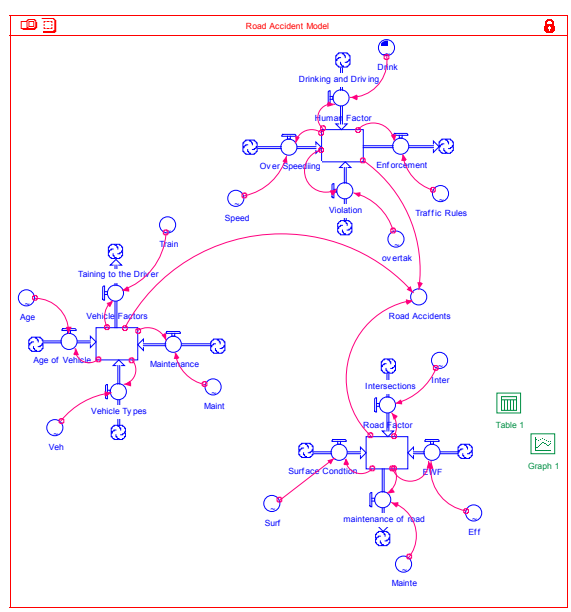

Fig. 1 Road Accident Prediction Model Developed Using STELLA

Fig. 1 shows the road accident prediction model developed in this study, using the System Dynamics Simulation Software

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'STELLA'. The STELLA is object oriented simulation software which allows the development of any complex, dynamic and non linear systems with significantly less effort than using traditional programming languages. It has a user-friendly graphical interface and supports modular program development. The model has three sub-models namely sub-model for human factors, sub-model for road factors and sub-model for vehicle factors. The following sections discussed about these three sub-models in detail.

Table 4 Factors Identified for Developing the Road Accident Model

Human Factors	Road Factors	Vehicle Factors	Other Factors
Drivers Behavior	Vertical Alignment	Breaking System	Rain
Pedestrians	Sight Distance	Lighting System	Snow
Road Users	Carriage Width	Body its features	Weather
Age of Driver	Width and Shoulder	Tyres	Climate
Sex of Driver	Signs and Markings	Vehicle Inspection	Pollution
Marital Status	Junction Design	Vehicle Maintenance	Population
Training of Driver	Pavement Surface	Age of Vehicle	Birth Rate
Alcohol and Drugs	Median Width	No. of Reg. Vehicle	Death Rate
Fatigue	Bridges and Culverts		In-migration
Use of Helmet and Safety belt	Formation Delineators and Guard rails		Out Migration
Physical Factors	Street Lighting		Encroachments

5.1 Sub-Model for Human Factors

Various human factors which are responsible for causing road accidents are shown in Fig. 2. The inflow human factor includes speed, drunk and driving, violation are increases the accidents and the outflow factor of enforcement rules will decrease the level of accidents. From the Fig. 2 the influence of enforcement and age of drivers on the accident occurrences, either positively with a reinforcing effect or negatively with an inhibiting effects, is observed. The various factors which are responsible under human factor with its involving increase or decrease the road accidents.

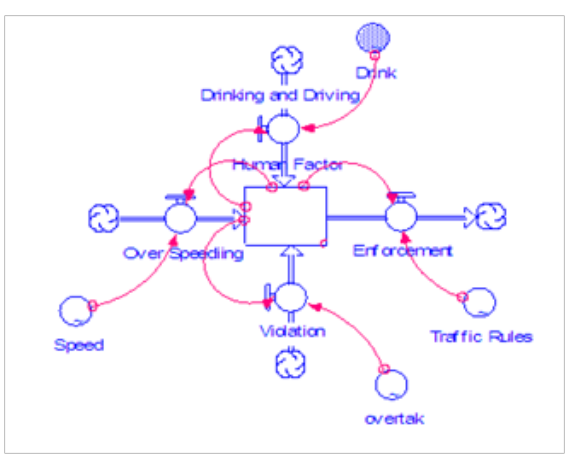

Fig. 2 Sub-Model for Human Factors Causing Accidents

5.2 Sub-Model for Road factors

Various factors which are responsible under road factor with its influence between the variables are shown in Fig. 3. From Fig. 3 the influence of vertical alignment of road, two way lane roads and road specification are positively decreasing the road accidents. In the road factor model increasing accidents major parameters are Skidding, Intersection, without median and Curve road.

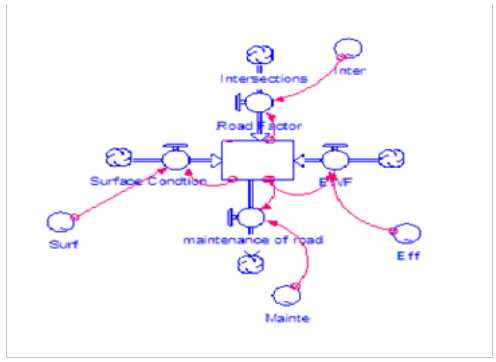

Fig. 3 Sub-Model for Road Factors Causing Accidents

5.3 Sub-Model for Vehicle factors

This sub-model explains the vehicle factors which are influencing the road accidents. Fig. 4 shows the vehicle factors for road accidents such as Driver training and its effects, Age of the vehicle, Vehicle maintenance and vehicle type. From the Fig. 4, the influence of vehicle maintenance, age of vehicle and breaking system are positively decreasing the road accidents. In the vehicle factor model increasing accidents major parameters are poor maintenance of vehicle and brake failure.

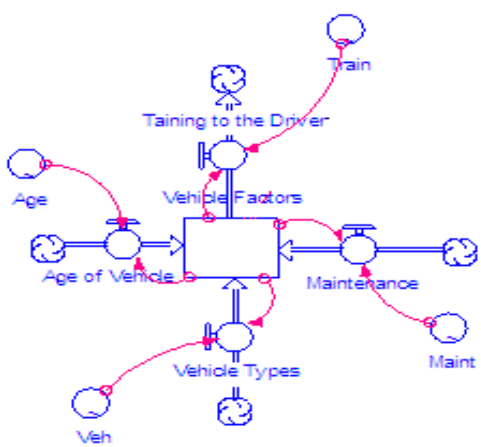

Fig. 4 Sub-Model for Vehicle Factors Causing Accidents

6. RESULTS AND DISUSSIONS

Several variables responsible for causing road accidents are found and their relationship is also established. Some variables found increase the number of accidents and less number of variables is meant for reduction of accidents. One probable explanation is that a wider roadway likely encourages speeding as motorists may feel more comfortable and thus travel at higher speed. This could also be the case for the presence of road median regardless of its type, which is found to cause accidents to more severe.

The increase in accident due to age of the vehicle, frequency of the maintenance, type of vehicle, road conditions and its maintenance, environmental conditions, over speeding and enforcement of rules. The road accident can be reduced by providing driver training, issuing of license system, removing of aged vehicles and controlling of drunken drivers. After development of model the input values for the base year 2010 were input in the model and which are collected from the city traffic police department. The model is simulated to predict the road accidents. The results obtained from three sub models and the total accidents predicted are presented in Table 5. It is clear from the table the major cause of accident is the

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human factors while comparing to road factor and vehicle factor. It is also found that increasing rate of road accident is due to human factors. It is found that the accident in 2020 will be increased 4.2 times of 2010 accidents. Hence there is an urgent need to reduce the accidents and the human factor has to be controlled. Such as driver training, drunken driving, issuing of license system, over speeding and enforcement of strict traffic rules. The model is validated by comparing the predicted accident values with actual accident values for the years 2010, 2011 and 2012. It is found that the percentage of variation is ranging from -1.12 to +5.44 and the same is presented in Table 6.

Table 5 Predicted Road Accidents

Year	Human Factor	Road Factor	Vehicle Factor	Total Accidents
2010	4928	189	138	5255
2011	6412	298	213	6923
2012	8977	334	239	9550
2013	9932	370	265	10567
2014	10967	408	292	11667
2015	12107	451	322	12880
2016	13411	499	357	14267
2017	14883	554	396	15833
2018	16475	613	439	17527
2019	18294	681	487	19462
2020	20315	756	541	21612

Table 6 Percentage of Variation of Predicted Accidents

Year	Actual Accidents	Predicted Accidents	Percentage of variation
2010	5133	5255	+2.38
2011	6566	6923	+5.44
2012	9663	9550	-1.12

7. CONCLUSIONS

It is clear that road accidents are a serious problem nowadays. The purpose of the study is to develop accident prediction models and investigate factors contributing to the occurrence and severity of accidents on Chennai City using data that obtained from City Traffic Police department. This study suggested a method to prediction of accident model by considering physical and traffic characteristics of each road. The standard for selection is main factors which could be acquired at the road plan steps. It is observed that each cause was similar to accident data. Based on this, the proposed model is to predict accident-occurring possibilities of those sections according to the physical factors of the roads. The results from accident prediction model developed by selected variables showed the good relationship between each case of human factors, vehicle growth factors and other road factors.

In this study, more detailed classification standard and predicted accidents are applied. If the results are used for the research, it is easy to execute safety evaluation about various alternatives in case of planning new road business and calculate results in detail for accidents reduction benefit when survey for validity of road business.

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