Analyzing the System Dynamics Model to Forecast Madurai City Accidents

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Abstract

The major objective of the study is to identify various factors responsible for the occurrence of the accident in selected stretch of Madurai, to quantify the effects on the causation of accidents through various scenario analysis, to suggest best scenario to ensure road safety in an effective manner and develop a system dynamics simulation model as conventional model lacks in reducing accident severity. In this work the System Dynamics Simulation software namely STELLA iv is used. The accident model is built on the year 2011 data and predicted the accidents up to 2026. The accident model is valuated by comparing the predicted and actual accident data for four consecutive years. Three scenarios were studied by changing the growth rate of causes of accidents in base year. The Macro level accident prediction model for whole Madurai City, the number of accident prone have been reduced decreased by 55% in horizon year under partial scenario as compared to Do Minimum Scenario, whereas in the desirable scenario it gets reduced 90% when compared to Do Minimum Scenario. The study reveals that enhancing the training to all transport, highway, and traffic police personnel and of course to all road users and regiment enforcement of rules and regulations would help in reducing accidents for ensuring v better traffic safety. Improving the road infrastructure as well proved to get very positive impact towards road safety. Hence the study recommends regiment enforcement in addition to the effective enhancement of training to all stakeholders which would ensure road safety in future years.

Key words: micro level, stella software, dynamic model

Introduction

The problem of accident is a very acute in highway transportation due to complex flow pattern of vehicular traffic, presence of mixed traffic along with pedestrians. Traffic accident leads to loss of life and property. 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.

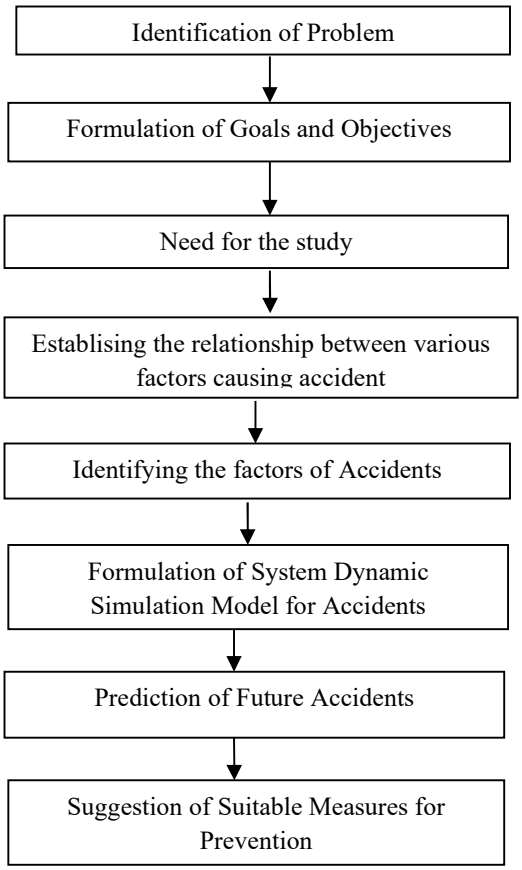
Need for the study

India has the highest accidents and fatality rates in the world. Tamil Nadu has reported maximum number accounting for 11% of the country accident in 2017. Road accident is the leading cause of unnatural deaths in the world. So it is essential to reduce the level of road accidents through some sort of advanced methodology since the conventional methods lack to prevent the accident occurrences and reduce the severity. Hence the System Dynamics (SD) methodology and its technique under the systems approach methodology presents the Planners and the Engineers a cohesive set of steps to be followed systematically by accounting the basic root cause of any problem under considerations.

Objective

- To study various accident prediction models developed locally and globally both through conventional and advanced model.
- To critically analyze various model developed and to establish difference between both modeling approaches.
- To build conventional and system dynamics simulation models for accident prediction for the study areas.
- To test developed model for possible scenario analysis.
- To suggest best scenario to ensure road safety through accurate accident prediction modeling

Methodology



Study Area

The study area of this project is „Madurai City" and it is maintained by Highways and Minor ports department corporation of Chennai. The length of the Goripalayam is 14 kms stretch which starts from Arwin Bridge near Madras medical college at park town in the east and ends at Simmakal junction in the west.

Software Used

- The model of the Transport and Economy interaction using the System Dynamics (SD) approach has been implemented in the 'STELLA' environment ('STELLA 9.1' package).
- The modeling tool which is an object-oriented simulation environment allows the development of interaction models with significantly less effort than using traditional programming languages.
- It has a user-friendly graphical interface and supports modular program development.

Data Collection

The accident data collected has been analyzed for observing the current trend of accidents in Chennai city. The secondary data collected from various sources. The secondary data collected includes details like total number of accidents and newly registered motor vehicles in Chennai city. The secondary data collected from the Chennai City Traffic Police (CCTP).Primary and secondary survey which combines to form the analysis of data then develops a simulation model and validates the model.

Analysis of accidents

From the collection of data, find out the stretch name grand northern trunk road. Due to various causes of occurring accidents in that particular stretch, the primary data collected through Road inventory included details on Name of roads, Occurrence of accidents, Injury types, type of vehicle and types of damages occurred and road geometrics. The accident data collected has been analyzed for observing the current trend of accidents in Chennai city. The accident data collected has been statistically analyzed to identify the pattern of occurrence of accidents. The secondary data collected includes details like total

number of accidents, causes, time, vehicles involved, date, time and no of persons involved.

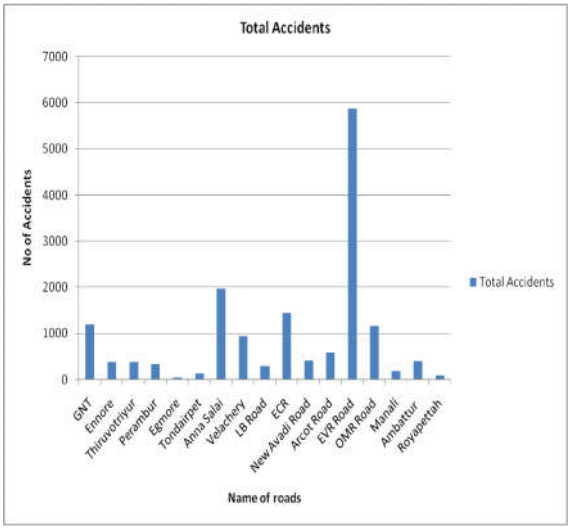


Fig 1 Total accidents occurred in Chennai Black Spots

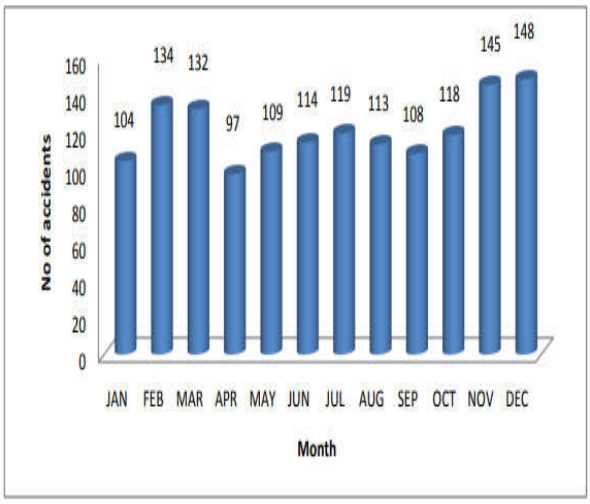


Fig 2 Distribution of accidents by Month wise

Building Blocks of model

The system dynamics modeling tool has four basic building blocks.

- Stocks or levels are used to represent anything that accumulates.
- Flows or rates represent activities that increase and decrease stocks. An example of flow includes birth rate or death rate.
- Connectors are used to establish the relationship among variables in the model, which is represented as arrows graphically in the model. They carry information, which can be a quantity, constants, an algebraic relationship, or a graphical relationship.
- Converters transform input into output. Converters can accept input in the form of algebraic relationships, graphs, and Tables.

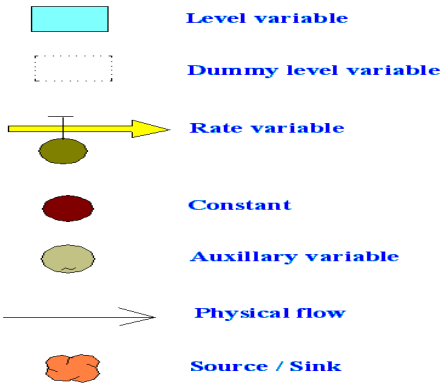


Fig 3 Flow Diagramming Symbols

Types of Injuries

Cases	2005	2006	2007	2008	2009	2010	2011
Property Damage	29	13	12	126	59	269	322
Minor Injury	148	126	158	190	127	449	612
Grevious Injury	91	106	48	69	55	290	95
Fatal	34	45	30	42	59	84	122

Table 1 Analysis of Accidents by types of Injuries

System Dynamic Model Development Process

The system Dynamics model development process is summarized in the schematic diagram of a model life cycle in Figure 4.5. The modelling process starts with defining the purpose/goal of the system. Then boundaries of the system to be modelled are specified. This is followed by identification of key variables in the system that affects the system, the most. Then behaviour of the key variable is described, the stocks and flows are identified, and their structure is mapped in the modelling tool using basic building blocks. Quantitative information, i.e., equations and data, is included in the model structure.

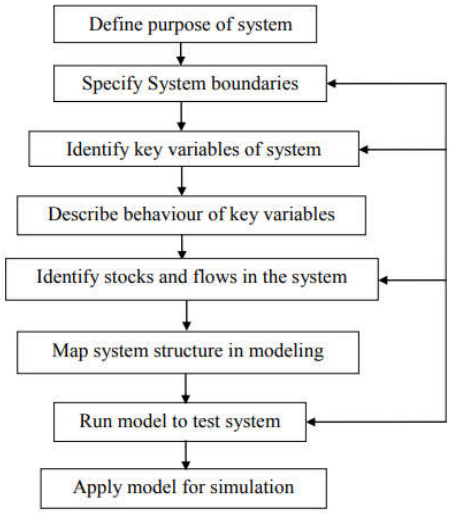


Fig 4 System Dynamic Model Development Cycle

Model Verification

The purpose of model verification is to assure that the conceptual model is reflected accurately in the computerized representation. The conceptual model quite often involves some degree of abstraction about system operations, or some amount of simplifications of actual operations. It provides answers to the question like, is the conceptual model accurately represented by the operational model (i.e., by the computerized representation). Verification and validation although conceptually distinct are conducted simultaneously by the modeller.

Model Calibration

Calibration is the iterative process of comparing the model to the real system, making adjustments (or) manipulation (or even major) changes to the model, comparing the revised model to reality, making additional adjustments comparing again and so on.

Model Validation

Validation is the overall process of comparing the model and its behaviour to the real system and its behaviour. 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 modeller must return to the calibration phase and modify the model until it becomes acceptable.

Model Conceptualization

In system dynamics modeling after defining the problem the next vital stage is model conceptualization. In this stage the complete concept based on which the model is built is derived. A causal loop diagram is a visual representation of cause and effect of variables in a system.

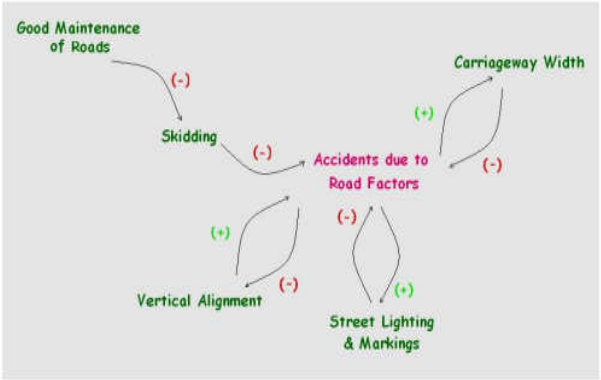


Fig 5 Road Factors Influencing Road Accidents

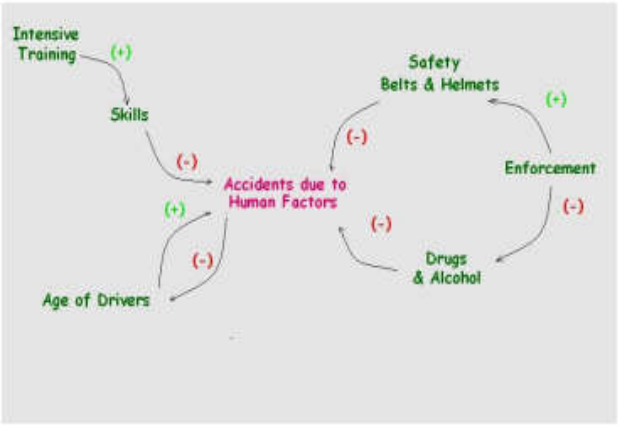


Fig 6 Human Factors Influencing Road Accidents

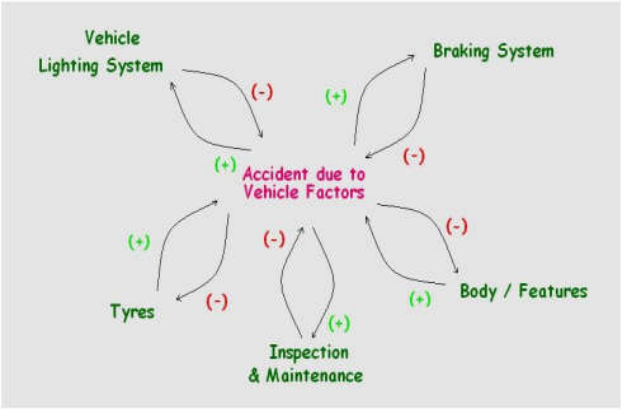


Fig 7 Vehicle Factors Influencing Road Accidents

Scenario Analysis

I Macro level Model for EVR Salai

Macro level Analysis is made to run for different scenarios like Do minimum, Partial scenario and Desirable scenario. Macro level accident prediction 42 model explains the probable reasons and causes for the accident occurrences and with that knowledge as the basis various scenarios are formed for model analysis. The data from 2005 to 2011 in „EVR Periyar Salai" recorded that more than two and a half times increase in accidents occurred in the study corridor in hardly 6 years looks very alarming. In 2005, 639 accidents occurred in the study corridor after six years 2011, 1532 accidents occurred, which is dramatically increased in that corridor. This increase is attributed to several causes and factors namely Road factors, Human factors, Vehicle factors and Environmental factors.

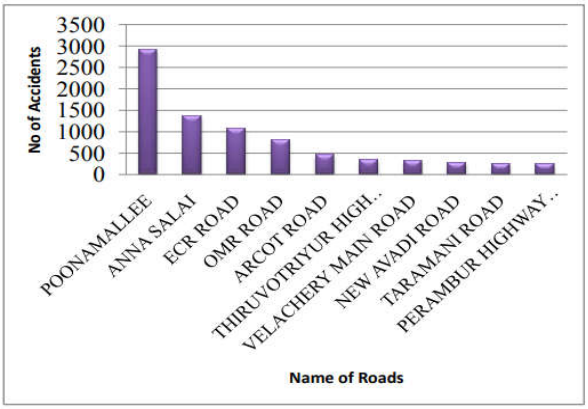


Fig 8 Road wise data on Accident Occurrence

In the Human factors over speed, improper overtaking, and pedestrian accidents are the major parameters taken as inflows in the model.

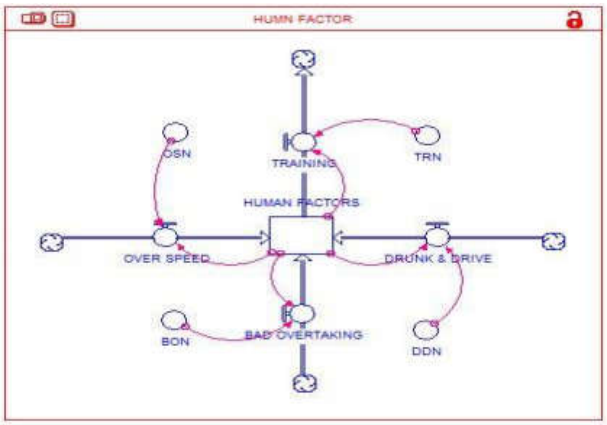


Fig 9 Human Factors SD Model

In the road factors inattentive turn, head/ rear end collision and hit an object on road is taken as main parameters and the model for road factors shown in Fig. 5.7.

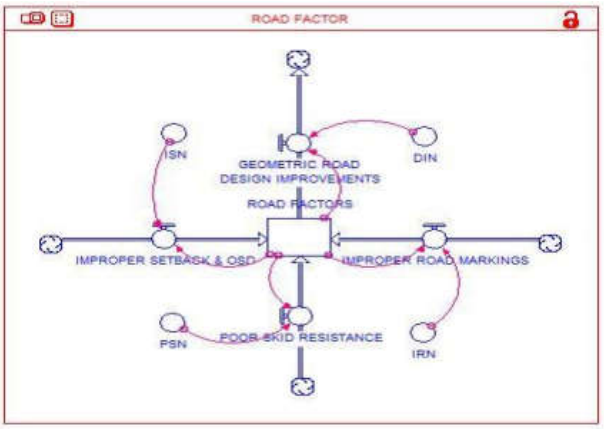


Fig 10 Road Factors SD Model

Whereas for the vehicle factors skidding is considered as the main parameter in western corridor and Intersections in EVR road. But at Maduravoyal intersection, the accidents has occurred only due to human and road factors so the vehicle factor has not been considered for developing the model. It is shown in Figure 5.8.

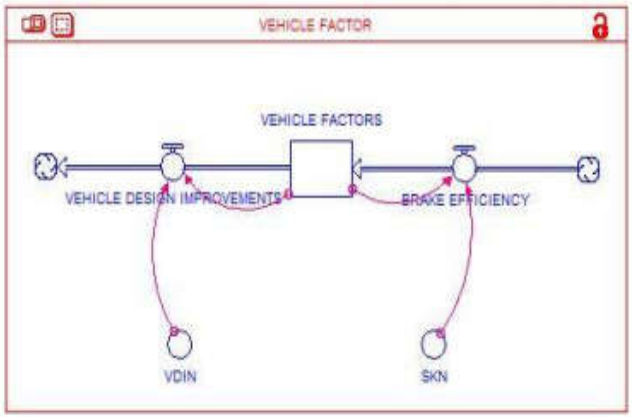


Fig 11 Vehicle Factors SD Model

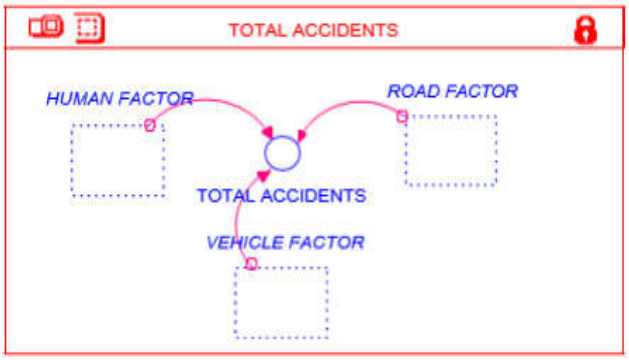


Fig 12 Total number of Accidents

Scenario I – Do Minimum

The total accidents which is 49 increased from 122 accidents to 485 accidents in the year 2011 to 2026 if the existing trend is allowed to continue without any changes in the do minimum scenario

Years	Human	Road	Vehicle	Environment	Total Accidents
2011	99	12	2	9	122
2012	107	13	2	10	132
2013	115	13	3	10	141
2014	123	15	3	11	152
2015	142	16	3	11	172
2016	143	17	4	11	175
2017	156	18	4	13	191
2018	202	24	4	13	243
2019	228	29	4	14	275
2020	248	32	5	14	299
2021	278	36	5	16	335
2022	315	43	6	16	380
2023	334	45	6	17	402
2024	371	53	6	17	447
2025	385	54	7	17	463
2026	**402**	**58**	**7**	**18**	**485**

Table 2 Do Minimum Scenario

Scenario II – Partial (50% Reduction)

In this partial scenario, causes of human factor, road, vehicle, and environmental factor 50% reduction is executed similar to that of macro model attempted earlier. In partial scenario, due to human factor 231 accidents, road factor 18 accidents, vehicle factor 6 accidents, and environmental factor 12 accidents will occur.

Years	Human	Road	Vehicle	Environment	Total Accidents
2011	99	12	2	9	122
2012	101	12	2	9	124
2013	104	13	2	10	129
2014	107	13	3	10	133
2015	111	13	3	10	137
2016	116	14	3	10	143
2017	119	14	4	10	147
2018	130	14	4	11	159
2019	141	15	4	11	171
2020	144	15	4	11	174
2021	149	15	5	11	180
2022	165	16	5	11	197
2023	174	16	5	12	207
2024	185	18	5	12	220
2025	207	18	6	12	243
2026	**231**	**18**	**6**	**12**	**267**

Table 3 Partial Scenario

Scenario III – Desirable

In Desirable condition,90% of accident is reduced when engineering measures followed strictly by the authority is assumed.In desirable scenario, due to human factor 42 accidents, road factor 5 accidents, vehicle factor nil accidents.

Years	Human	Road	Vehicle	Environment	Total Accidents
2011	99	12	2	9	122
2012	93	11	2	9	115
2013	89	10	2	8	109
2014	85	9	2	7	103
2015	77	9	2	6	94
2016	71	9	2	6	88
2017	66	8	2	5	81
2018	62	8	1	5	76
2019	60	7	1	4	72
2020	53	7	1	4	65
2021	48	7	1	4	60
2022	46	6	0	3	55
2023	45	6	0	3	54
2024	45	5	0	2	52
2025	44	5	0	2	51
2026	**42**	**5**	**0**	**2**	**49**

Table 4 Desirable Scenario

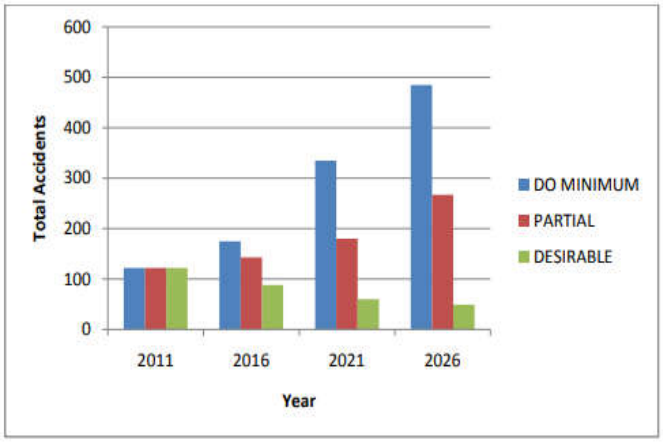


Fig Comparing total number of accidents in three scenario

Model Validation

Most of statistical mathematical modeling always begins with the collection of data from which the model is developed, whereas the System Dynamic methods reverse this order beginning with the development of a model and afterward collecting the data to populate it and to validate its dynamic behavior. Statistical models must rely on mathematical tests because models can only describe correlations. Any casualty between variables must be inferred from the correlation and that only close correlation supports such influences.

$$\%\text{Error} = \frac{\text{predicted value} - \text{Actual value}}{\text{Actual Value}}$$

RESULTS

- In macro level model the intersections of EVR Salai, the total number of accidents is increased from 122 to 485 in Do minimum scenario.
- The Partial scenario depicts that the total number of accidents is decreases by 55% in the year 2026 as compared to Do Minimum scenario.
- In Desirable scenario accidents get reduces by 90% as compared to Do-Minimum scenario in the year 2026.

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- It shows that System Dynamic Model gives accurate results.
- Allowing existing trend to continue would worsen the current accident scenarios almost in all models with many folds to the maximum of more than ten-fold in some model cases. Hence all effective measures are applied and simulations have been conducted to enhance the existing and forecasted worst situations.

CONCLUSIONS:

- To reduce the accidents, equal importance must be given for training the public, transport, highways and police officials. Then only appropriate reduction in accidents will be achieved.
- To achieve target of Tamil Nadu Road Safety policy to reduce 20 percent of accidents (by 2013 taking 2006 as a base year) around 65 lakhs rupees per year is needed for training (for training sector alone) the police, transport and highway officials and increase the public awareness.
- If 65 lakhs rupees is spent per year the accident trend will reduce from 4543 to 3605 by the year 2013 which is the target of the Tamilnadu road safety policy.
- Desirable scenario gives best results more than the Road Safety Policy of Tamil Nadu. Though it appears unrealistic this scenario is obviously presented here just to show the influence of extensive training and public awareness.

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