CHAPTER 6
SAFETY MANAGEMENT SYSTEM

6.0 Introduction

As population increases traffic activity, economical restraints and potential and actual conflicts all increase but at the same time technical or procedural improvements do not take place. The crisis conditions associated with transportation are in operation and maintenance, environmental impact, and fuel availability. Each of these conditions affects personnel safety. Increase in transportation operations expose operators, passengers, pedestrians and by standees to greater risks of injury and death. Decline in the quantity and quality of maintenance produce greater risk and incidence of failure. The use of fossil fuels, and spillage's in the oceans, lake and rivers, affect ecosystems and eventually human health and well being.

Causes and problem areas

In general, traffic accidents are caused by failure of one of the three major elements of transportation system the human being (driver), the vehicle, and the road condition. Improvements in each of these areas can be expected to improve the general safety and to reduce the potential for failure. The basic causes of traffic safety problems are those forces or situations which bring about over crowding, a decline in maintenance of road ways, lacks of attention to clear and apparent hazards. The study of accident is a preventive point of view, that

is lessons learnt from the occurrence of a specific accident or a specific type of accident is applied towards the prevention of future accident, however in all modes the accident study approach and the preventive approach have developed separately.
Traffic accident studies:

Accident data, tabulated and analysed may be used by traffic safety personnel in the following ways

To define and identify high accident locations
To justify action on public request for installation of traffic control devices
To aid in evaluating different geometric designs and in determining and developing Proper designs of streets, intersections, drive ways, and traffic control devices
Accommodate local conditions.
To establish ranking, programming and scheduling of improvements at high accident locations as based on numbers of accident types preventable by traffic measures
To identify the need to for improving police traffic, parking restrictions, improved road way lighting.

With electronic data processing, a number of tabulations may be available including periodic print out listing of accidents by location, periodic listing of high accident locations, accident frequency rates to highway type, geometric features, pavement conditions, etc. In many cases, the coding is only for accidents on the numbered state route system and accident data may not be readily available for secondary routes and city streets.

6.1 Inventory

Inventories are listings of accidents, keyed to general location such as intersections, individual blocks of a city or sections of rural highway. When developing inventory sections it is important to realise that data from short links can readily be added together whereas subdivision of data from sections of excessive length is much more difficult.

The problem of traffic accident is more serious in India. Nearly 22% of accidental death are due to heavy traffic. It is stated that the accident ratios have increased faster than the population. One of the major adverse effects of traffic problem in urban area
apart from traffic congestion and deterioration in environmental quality is decline in road safety levels. Circulation of pedestrians is of prime importance for the substance of the cities. The share of the pedestrian trips in the total trips is of the order of 40% in many cities in India. This share is not likely to diminish in the near future in view of the increasing migration of rural population to urban areas. The pedestrian safety is a vital concern deserving immediate attention. The major measures to improve pedestrian safety includes side walk and crossing facilities. The main thrust of the measures should be to avoid pedestrian conflicting with vehicular traffic. Pedestrians crossing at signalised intersections are found to be very effective. However it is necessary to provide sufficient green time for a crossing pedestrian. Pedestrian underpasses are useful facilities to avoid conflict with vehicular traffic.

**Cyclists**

Bicycle is known as poor mans transport means. Comprehensive data on bicycle traffic and its characteristics are lacking for most of the urban areas due to its unregulated character and under representation in urban and traffic planning studies. In our country the existing database of road accident continues to be poor. An important implication for the design of new format of accident recording information is that it can be easily fed into the computer. Analysis also can be done on computer. The variables included in the form should be used on the kind of analysis which analysts expect to do later.

**Accident rate calculations**

There are three basic types of comparisons,

1. Parallel study (between different locations or areas for the same period of time)
2. Before and after study (between different time periods at the same location or in the same area.
3. Condition study (between physical features of the road way, regardless of the location or time)
In making comparisons, a measure of any change in exposure should be incorporated. The standard equation for calculation of accident rate is

\[
\text{rate} = \frac{\text{number of accident} \times \text{basis}}{\text{exposure}}
\]

### 6.2 Mathematical Models

**Speed and Accident severity:** In the case of road accident the kinetic energy is dissipated mainly in the form of damage to the vehicle and their occupants leading to fatalities and injuries in the case of high energy level. The dissipated kinetic energy during traffic conflict between two vehicles can be calculated on the basis of an inelastic impact as follows

\[
\Delta E = \frac{1}{2} g \left[ \frac{g}{G_1 V_1^2} + \frac{g}{G_2 V_2^2} - \left(\frac{G_1 + G_2}{G_1 V_1 + G_2 V_2}\right)^2 \right]
\]

where

\[
\begin{align*}
V &= \sqrt{\frac{G_1 V_1^2 + G_2 V_2^2}{G_1 + G_2}} \\
\Delta E &= \text{dissipated energy during impact} \\
G_1, G_2 &= \text{weights of first and second vehicle respectively} \\
V_1, V_2 &= \text{Velocity of first and second vehicle before impact} \\
g &= \text{acceleration due to gravity} \\
\alpha &= \text{crossing angle}
\end{align*}
\]

For the case that \(G_1 = G_2 = G\). It can be reduced from the equation

\[
\Delta E = \frac{G}{4g} \left[ V_1^2 + V_2^2 - 2V_1 V_2 \cos \alpha \right]
\]

\[
= \frac{G}{4g} V_{rel}^2
\]

where

\[
V_{rel} = \sqrt{V_1^2 + V_2^2 - 2V_1 V_2 \cos \alpha}
\]

if the speeds are equal

\[
V_{rel} = V \sqrt{2(1 - \cos \alpha)}
\]

Thus accident potential of a highway increases significantly as the speed range increases. This increase becomes more and more pronounced as the conflict angle \(\alpha\) increases from 0 to 180.
Accident forecasting

It is possible to predict the number of deaths likely on Indian roads in the year 2010 based on past trend fatality rate and vehicle ownership rate. Vehicle ownership rate in the year 2010 is

\[
((N/P) \times 10^4)_{2010}
\]

where

- \( N \) = motor vehicle population per 10,000 people
- \( P \) = people population

The vehicle ownership rate \((N/P) \times 10^4\) has generally at the rate of 8.46% per annum

\[
(N/P) \times 10^4 = 13.719(1 + 0.0846)^n
\]

where \( n \) is the number of the year since 1960

\[
= 13.719(1.0846)^{2010-1960}
\]

\[
= 13.719(1.0846)^{50}
\]

\[
= 505.5
\]

There will be 795.7 vehicles for every 10,000 persons in the year 2010. Various agencies have projected Indian population to the year 2010 roughly it will be around 1020 million. Thus there will be 81 million vehicles in 2010.

The fatality rate in the year 2010 is

\[
(D/N) \times 10^4 = 86.285(1-0.0241)^n
\]

where \( (D/N) \times 10^4 \) death rate per 10,000 vehicle in the nth year.

\[
[(D/N) \times 10^4]_{2010} = 86.285(1-0.0241)^{2010-1960}
\]

\[
= 86.285 \times 0.9759^{50}
\]

\[
= 26
\]

Thus 26 will be killed per 10,000 vehicles. In 2010 AD we have estimated that 81.2 million vehicles on road. Thus all probability 2,11,120 persons will die out of road accidents.
Model for Comparing crash & Casualty rates

The crash occurrence results from a confluence of driver characteristics, vehicle characteristic and the people's environment

\[
\text{Crash} = f(\text{Driver, vehicle, people, environment})
\]

\[
\text{Causalities(or fatalities)} = \text{crashes} \times \text{severity}
\]

Severity can be defined as either fatalities or casualties per crash, depending upon the focus of the analysis. In developing countries, crash severity is impacted by a variety of factors including availability of emergency of medical service, vehicle type, and vehicle loading. Factors relating to crash involvement include road user characteristic such as driver age, years of driving experience, weather conditions or alcohol use.

6.3 Air Pollution

Environment has gained great importance in the world particularly during the last few decades. The Stockholm conference of 1972 that led to the declaration of the United Nation's conference on the human environment awakened international community to the need for a common outlook and for common principles necessary to be observed for the preservation and enhancement of the human environment. The Rio Declaration on environment and development 1992 was another epic event in the preservation of the environment so important for the survival of mankind. Today more than ever before nations become environment-conscious and people have begun to realise the disastrous consequences of reckless industrialisation and technological invasion of nature. Multinational corporations bent on profit making at any cost from anywhere often ignores environmental guards and victimises humankind.

Air is a clean free life sustaining substance found in abundance. It is only after 50 years of independence, urban citizens are facing the risk of being gassed out their urban habitats. Particularly the metros are filled with smoke belching vehicles and a large number of polluting industrial units. The result is poisoned urban air. Recent survey indicates that one out 10 of Delhi
school children suffers from asthma. Worsening air pollution caused by motor vehicles affects 8,80,000 in Delhi. About 40,000 are dying early every year - 7,500 in Delhi, 5,700 in Mumbai, 4,500 in Calcutta because of air pollution. Indians spend Rs 4,550 crore annually to make up for health damages caused by air pollution. In most of the 23 Indian cities with million plus populations air pollution levels are dangerously higher than World Health Organisation limits. The levels of suspended particulate matter (SPM)-dust and carbon particles coated with toxic gasses are at least three times higher than WHO standards. The main culprit is vehicle exhaust. It accounts for 65% air pollution in Delhi, 52% in Calcutta and 30% in Mumbai (Source:- centre for science & environment studies)

Vehicle exhaust contains harmful gases such as nitrogen oxides Nox , Sulphur dioxide So2, Hydrocarbons Hc, Carbon monoxide Co, lead pb. Vehicles also emit spm less than 10 micrometers in diameter (PM10) which can be inhaled. About 80% of this are deposited in respiratory system. Ozone another poison form when exhaust reacts with sunlight.

Many effects of vehicle exhaust are hidden and the damage is visible only very late. Study shows that air pollution causes serious health problems even when the levels are much lower than WHO limits.

Respiratory problem

There is mounting evidence that air pollution is related to numerous respiratory problems and even deaths from such illnesses. The pollutants that are mainly responsible for this are So2, Nox, Ozone, PM10. The rise in PM10 levels by 10 μg/m3 (micrograms per cubic meter) rise causes bronchitis, a chronic cough.
Cancer

Cancer is believed to be caused by alternations in our cell structure (mutation) which results in abnormal and uncontrolled growth of more cells. Scientists have estimated that at least 60% of cancers are preventable through control of environmental factors such as breathing polluted air. Cell mutations are caused by exposure to PA and SPUME. The diesel exhaust that has a high fraction of both causes 10 times more mutations than leaded petrol. The unleaded petrol contains a high level of benzene widely known to cause lung cancer and leukaemia.

Heart Problem

Pollutants such as $\text{SO}_2$, $\text{PM}_{10}$, Ozone and $\text{NOx}$, cause death from heart problems. Congestive heart failures can be linked to $\text{CO}$ that presumably binds to the haemoglobin and decreases oxygen transport to the blood.

Brain damage

Lead is present in huge quantities in the petrol used in most vehicles in India. It is well-known cause of encephalopathy (a disease of the brain) in children that often results permanent brain damage. When children breathe in lead it can permanently lower IQ. In India leaded petrol is used in 90% of vehicles.

The ever increasing proliferation of the automobiles indicate that gaseous exhaust products would increase without limit. It is estimated that each vehicle annually emits on an uncontrolled basis, 0.15 tons of hydrocarbon, 1.06 tons of carbon monoxide, 0.053 tons of Nitrogen oxides, 0.005 tons of sulphur oxides and 0.004 tons of particulate. The later containing lead compounds. The total uncontrolled pollution emission for that year would be $0.15 \times \text{totals no of vehicles in that area etc}$. A variable source of air pollution
that is strongly dependent on traffic flow patterns and more directly on automobile commuting activities. In the design of highways no special recognition has been given to difference in vehicle size or speed range. Thus the bus & other type of vehicles with its different speed, different pollution emission characteristic travel along the same highway during the same time interval increase emissions more. The restriction of standard automobile entry to major traffic arteries might be accomplished by computer control method pave the way to reduce emissions.

6.4 Planning and Development

In our country most of the highways are unplanned that encourage proliferation of automobiles and travel mileage adds their own contribution to the air pollution problem. New approaches should be made to the planning, design and operation of the transportation systems and urban development to illustrate the relationship of air pollution, emission etc. With respect to operations the improvement of traffic flow and the encouragement of the use of mass transit systems reduce the pollution levels.

The evaluation of the air pollution which has an impact on a large urban area from vehicle emission is a cause for concern in the major cities of India. The problem of pollution emission as well as pollution transport towards it has been tackled in two ways. Experimentally by evaluating the input and output mass flow by remote - sensing technique. Measurements have been performed along the motorways around the city.

Remote sensing Measurements

For experimental evaluation of pollution transport over the city, surveys were made along the motorways around the urban area with a mobile laboratory equipped with remote sensors. The measurements were performed while the van moved along the motorways. On board simultaneous information about the time and location were stored together with the measured data in a computer. For the modeltic approach, the emission inventory has been assembled not only for urban sources but also for isolated sources located inside and outside the area under investigation.
Optimal air quality control strategies

Let us assume we have chosen a certain control strategy depending on L control parameter's $x_i$ (i= 1,2,3, L) with which concentration patterns of N pollutants can be influenced. If $\gamma$ denotes the total cost due to a given set of the L parameters $x_1, x_2, x_3, x_L$, the general optimisation problem can be stated as follows

$$\text{minimise } z = \sum_{k=1}^{n} E_k C_k$$

subjected to

$$\sum_{k=1}^{n} E_k C_k \leq 1:1$$

$$\sum_{k=1}^{n} (1 - E_k) P_k(x,y) \leq P^* \quad \forall x,y$$

where $p_k(x,y)$ is a pollutant concentration at (x,y) due to emissions within $S_k$, k=1,2,3, n be the non intersecting sub regions of the urban area, which can be potentially supplied with heat $E_k$, the thermal heat that is needed to supply $S_k$. ET is the total amount of the thermal energy available $C_k$, the cost for supplying sub region $S_k$ with thermal energy.

$$E_k = \begin{cases} 1 & \text{if } S_k \text{ is supplied} \\ 0 & \text{otherwise} \end{cases}$$

In our country Centre for Science and Environmental studies proposes three variations for calculating environmental excise duty that will be in addition to the existing excise duty.

Slab 1:- For 2 and 3 wheelers, vehicles with emissions greater than 2.0 gm/km of carbon monoxide (CO) and 1.5 gm/km of hydro carbons (Hc) and nitrogen oxides (Nox) Rs 550 /gm/km of (CO + Hc + Nox)

Slab 2:- For vehicles with emissions up to 2.0 gm/km of CO and 1.5 gm/km of Hc + Nox Rs 55/gm/km
Slab 1: For 4 wheelers' vehicles with emissions greater than 2.72 gm/km of carbon monoxide (CO) and 0.97 gm/km of hydro carbons (HC) and nitrogen oxides (NOx) Rs 650/gm/km of (CO + HC + NOx)

Slab 2: For vehicles with emissions up to 2.72 gm/km of CO and 0.97 gm/km of HC NOx Rs 65/gm/km.

Though zero emission vehicles are unlikely to hit the market in the very near future, an extra incentive will be needed for their production keeping in mind that the vehicle population in India is growing rapidly, while traffic and road infrastructure are not keeping pace, leading to congestion and enormous pollution. This means that our standards have to be more stringent than the rest of the world.

6.5 Noise Pollution

Noise levels generated by highway traffic can be measured. It is however the reaction of human beings to noise, levels which is of importance in attempting to determine the impact of the noise. Different people have different reactions to the same noise level and it is to determine the distribution to noise by the use of attitude surveys. Social surveys may be conducted in which respondents were assessed to give their reactions to traffic noise levels experienced at home. The range of sound pressure levels are given below.

<table>
<thead>
<tr>
<th>Sound</th>
<th>Approximate sound pressure dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal conversation</td>
<td>60</td>
</tr>
<tr>
<td>Library</td>
<td>40</td>
</tr>
<tr>
<td>Quite conversation</td>
<td>30</td>
</tr>
</tbody>
</table>

when sound pressure levels are measured adjacent to a highway, a meter measuring in dB might indicate the same value when a fast moving motor cycle with high frequency note and when a slow moving vehicle passes with lower frequency note. The major factors which influence the generation of road traffic noise are
a. The traffic flow
b. The traffic speed
c. The proportion of heavy vehicle
d. The gradient of the road
e. The nature of the road surface

Noise reduction techniques can be applied to buildings themselves, such as double glazing and noise absorbing insulation. One certain way of reducing the nuisance from noise and vibration would be to reduce the amount of traffic in the first place, a strategy which would of course mitigate transports other environmental impacts too.

6.6 Conclusion

The chapter deals with the importance of the safety of passengers and the environment. The amount of degradation of environment due to traffic pollution has been analysed, and the methods for the reduction of pollution with the help of mathematical models has been discussed. Further many models have been developed to forecast traffic accident rates. The role of noise pollution due to heavy traffic has also been discussed.