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Evaluation of Road Safety Hazardous Conditions in a Road Network

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Abstract

The paper presents a methodology to evaluate safety hazardous condition in a road network. Poor and delayed maintenance of roads leads to road accidents. Several maintenance components like poor surface condition (pothole, rutting, shoulder drop-off), improper traffic signs, road marking, poor lighting etc. affects road safety. Road maintenance is generally limited to improving carriageway surface condition like filling pothole etc. without replacing missing traffic signs, road marking and other safety features essential for a safe road network. Maintaining the roads in safe condition require huge resources in form of man machine and materials. Thus, Identification and evaluation of maintenance components effects on road safety is very important task for assessing the maintenance needs for improving road safety. Limited studies are available on identification of effects of maintenance components on road safety. A methodology is developed based on the identification of effect of poor maintenance on road safety and by considering inter-relationship between various maintenance components. Also a methodology is developed to evaluate the effects of these components on road safety. It is expected that this study will be useful in assessing the maintenance needs and effectiveness of various maintenance components in improving road safety.

Keywords: Road Maintenance, Road Safety, Maintenance Components, Safety Hazardous Conditions.

1. Introduction

Road accidents are the major cause of death and injuries worldwide. Every year more than 1.17 million people die in road accident around the world [6]. Road accidents impose huge economic losses and causes great emotional and financial stress to the families affected. The continued steep increase in the number of road accidents indicates that these losses are undoubtedly inhibiting the economic and social development of the countries and adding to the poverty and hardships of the poor. Thus, there is an urgent need to develop a methodology to improve safety on road network.

Accidents in India increased at a Compound Annual Growth Rate (CAGR) of 2.1 %.[8] Similarly, the number of road accident fatalities and the number of persons injured in road accidents in the country between 2001 and 2011 increased by 5.8 per cent and 2.4 per cent, respectively [5]. Poor and delayed road maintenance is one of the most ignored factors among all other factors affecting road safety in India [1]. A Critical review of the literature indicated that about 10 to 20 % accidents in India are due to poor condition of roads [4]. It is to be noted that road accident due to other causes also includes road accidents due to poor maintenance of street lighting, lack of signs and signals, absence of road markings etc. Poor maintenance of various road components leads to road accident.

Frequently, maintenance is limited to filling pothole and cleaning drainage facilities without replacing missing traffic signs, road marking, guard rails and other safety features essential to create a safe road network [7]. Therefore, it is important that road engineers need to be aware of maintenance components like poor lighting, traffic signs, road obstructions etc. that may require a higher than normal level of maintenance to keep the highway in good and safe condition [2]. Thus, Identification of maintenance components and their effects on road safety is the most important task of assessing the maintenance needs for improving road network safety. However, literature review indicates that limited studies are available on identification of effects of various maintenance components on road safety[3]. Hence, this study presents a rational methodology to evaluate condition of maintenance components affecting road safety.

This paper consists of seven sections. First section identifies the need of the study. Second section presents a methodology for identification of maintenance components. Third to sixth section presents the evaluation of various maintenance components condition. The last section presents the important conclusions drawn based on this study.

2. Identification of safety hazardous condition

The Main purpose of this study is to evaluate condition of maintenance components affecting road safety, this require development of a methodology for identification of maintenance components that affect road safety. The methodology is aimed at providing guidance in identifying maintenance components for improving road safety. This methodology is developed in such a manner that it includes all maintenance components that affect road safety. An overall methodology is developed for identification and evaluation of road safety hazardous conditions. At the top of this methodology is the main objective of Road safety hazardous conditions which are to be assessed at network level for maintenance. The road safety hazardous conditions are decomposed in four sections (I) poor maintenance carriageway condition (II) poor road side condition (III) poor road geometric conditions and (IV) poor traffic hazardous condition. Overall methodology is presented in Fig 1 attached at the end in Appendix I.

Further the process of decomposition is such that the maintenance components are structured in a framework for each road sections separately. At next level poor maintenance carriageway conditions identifies six major conditions these are (i) Rutting surface condition (RS) (ii) Bleeding Surface condition (BS) (iii) pothole surface (PT) (iv) Inadequate Road Width (RW) (v) Crack Surface (CS) and (vi) Deep Cut Surface (DCS). Further at next level, poor road side condition is decomposed in (a) poor drainage condition (b) poor shoulder condition. Poor Geometric condition is further decomposed in to (a) Improper Vertical Curve (b) Improper Horizontal Curve. Further, poor traffic hazardous condition is decomposed in to (a) Improper road furniture condition (b) Other Safety Hazardous Condition (c) Road Side Protection Work and finally, this methodology identified total twenty six maintenance components.

3. Evaluation of poor maintenance carriageway condition

A methodology is developed to evaluate poor maintenance carriageway condition. The poor carriageway conditions decomposed into six major components: (i) Rutting surface condition (RS) (ii) Bleeding Surface condition (BS) (iii) pothole surface (PT) (iv) Inadequate Road Width (RW) (v) Crack Surface (CS) and (vi) Deep Cut Surface (DCS). A methodology is developed to evaluate these components is presented below:

3.1 Rutting Surface Index (RSI).

A condition index is developed to evaluate the condition of rutting surface. Rutting surface condition can be determined using equation 3.1.

$$\boldsymbol{RSI = \frac{RSA}{TCA}} \qquad \textbf{(3.1)}$$

Where:

RSI= Rutting Surface Index

RSA=Rutting Surface Area in m^2

TCA= Total Carriageway Area in m^2

Rutting Surface Area (RSA) = Width of Rutting surface * Length of Rutting surface

Total Carriageway Area (TCA) = Length of carriageway section * Width of Carriageway section

3.2 Bleeding surface index (BSI)

Bleeding surface is shiny, black surface film of bitumen on the road surface caused by upward movement of bitumen in the pavement surface. Common causes of bleeding are too much bitumen in bituminous concrete, hot weather, low space air void content and quality of asphalt. This defect affects safety of road as friction between tyres and surface reduced and also create glare.

Bleeding surface index (BSI) can be determined using equation.3.2

$$BSI = \frac{BSA}{TCA} \quad \textbf{(3.2)}$$

Where:

BSI= Bleeding Surface Index

BSA= Surface Area of Bleeding

TCA= Total Carriageway Area

3.3 Potholes Surface Index.

A pothole is a type of failure in a bituminous pavement, caused by the presence of water in the underlying soil structure and the presence of traffic passing over the affected area. Introduction of water to the underlying soil structure first weakens the supporting soil. This condition of road leads to increase number of accidents in the network.

Pothole Surface Index (PSI) can be determined using equation.3.3

$$PSI = \frac{PSA}{TCA} \quad \textbf{(3.3)}$$

Where: PSI= Pothole Condition Index

PSA= Pothole Surface Area

Individual pot hole area can be calculated by multiplying length and width of each pothole.

Pothole Surface Area (PSA) is the summation of individual pot hole areas.

TCA= Total Carriageway Area

3.4 Inadequate road width Index

Adequate road width has to be provided according to the specification given in IRC and class of roads. If road width is inadequate it leads to increase in accidents on road network

Inadequate road width index (RWI) can be determined using equation.3.4

IRWI= RRW **(3.4)**

Where:

IRWI= Inadequate Road Width Index

RRW = Required Road Width, as per IRC

PRW = Present Road Width in meter

3.5 Cracks Surface Index

Crack surface is a most common distress. It may be due to relative movement of pavement layers or by repeated application of wheel loads. This distress also affects safety condition of road adversely. Cracks Surface Index (CSI) can be determined using equation 3.5.

$$CSI = \frac{CSA}{TCA} \quad \textbf{(3.5)}$$

Where:

CSI= Crack Surface Index

CSA=Crack Surface Area

Crack Surface area is the percentage of area cracked in the given section of road.

TCA= Total Carriageway Area

3.6 Deep Cut Surface Index

Deep Cut Surface Index (DCSI) can be calculated by using the equation 3.6

$$DCSI = \frac{DCSA}{TCA} \quad \textbf{(3.6)}$$

Where:

DCSI= Deep Cut Surface Index

DCSA= Deep Cut Surface Area

DCSA= Length of cut surface X width of cut surface

TCA = Total Carriageway Area

4. Evaluation of poor road side condition

The poor side condition is decomposed into two major components i) Poor drainage condition ii) Poor shoulder condition. Each components then divided in to three sub components. A methodology is developed to evaluate these components is presented below:

4.1 Improper Camber Condition Index

Camber is the slope provided to road surface in transverse direction**.** A methodology is developed to determine Improper Camber Condition Index. Improper camber leads to accumulation of water on road surface in rainy season. Accumulation of water leads to various distresses on road surface and thus adversely affects safety conditions on road network.

Improper Camber Condition Index (ICCI) can be calculated by using the following equation

$$ICCI = \frac{RC-PC}{RC} \qquad \textbf{(4.1)}$$

Where:

ICCI = Improper Camber Condition index
RC = Required Camber in % slope
PC = Present Camber in % slope

4.2 Improper Side Drain Index

Roadside drainage is the controlling of water beyond the roadway, including water coming from the roadway surface and out subsurface drains. This includes water in ditches, culverts, and coming from surrounding land. If side drains are improper water accumulate on road surface leading to deteriorate the road surface.

Improper Side Drain Index (ISDI) can be calculated by the following equation.

$$ISDI = \frac{RSD-PSD}{RSD} \qquad \textbf{(4.2)}$$

Where:

ISDI = Improper Side drain Index
RSD= Required length of Side Drain in meter

Required Side Drain can be obtained by assessing the condition of side drain and rainfall of that area.

PSD= Present Side Drain length in meter

4.3 Improper Cross Drainage Index

A cross drainage work is a structure carrying the discharge from a natural stream across a canal intercepting the stream. A methodology is developed to determine Improper Cross Drainage Index.

Improper Cross Drainage Index (ICDI) can be calculated by the following equation.

$$\text{ICDI} = \frac{RCD \ \ -PCD}{RCD} \qquad \textbf{(4.3)}$$

Where:

ICDI = Cross Drainage Index
RCD= Required number of CD
PCD= Present Number of CD

4.4 Improper Shoulder Width Index.

A shoulder, often serving as an emergency stopping lane, is a reserved lane. Minimum width of shoulder is 2.5 meter as per IRC. If shoulder width is not adequate then affects safety. A methodology is developed to evaluate the Improper Shoulder Width Index.

Improper Shoulder Width Index (ISWI) can be calculated by the following equation:

$$ISWI = \frac{RSW-PSW}{RSW} \qquad \textbf{(4.4)}$$

Where:

SWI = inadequate shoulder width index
RSW = required shoulder width in meter as per IRC
PSW= present shoulder width in meter

4.5 Shoulder Edge Drop off Index

When a vehicle leaves the travel lane, pavement edge drop-off poses a potential safety hazard because significant vertical differences between surfaces can affect vehicle stability and reduce a driver's ability to handle the vehicle. A methodology is developed to find out the Shoulder Drop off Index.
Shoulder Edge Drop off Index (SEDI) can be calculated by the following equation:

$$\textbf{SEDI} = \frac{EDL}{TCL} \qquad \textbf{(4.5)}$$

Where:

EDI = Edge drop off Index
EDL = Edge drop Length in meter
TCL= Total Carriageway Length in meter

4.6 Improper Shoulder side slope index (ISSI)

Improper Shoulder side slope index (ISSI) can be calculated by the following equation.

$$\textbf{SSI} = \frac{RSS \quad -ASS}{RSS} \qquad \textbf{(4.6)}$$

Where

SSI = Side slop index
RSS = required side slope in %
ASS = Available side slope in %

5. Evaluation of poor road geometric condition

A methodology is developed to evaluate poor road geometric condition. The poor road geometric conditions decomposed into tow major components and these sub divided in to five sub components. These components evaluated below.

5.1 Improper Gradient Index

Gradient is the rate of rise or fall with respect to horizontal. Provision of proper gradient is important for road safety. A methodology is developed to determine Improper Gradient Index
Improper Gradient Index (IGI) can be calculated using the following equation

$$\textbf{IGI}= \frac{AGR \quad -RGR}{AGR} \qquad \textbf{(5.1)}$$

Where:

IGI= Improper Gradient index
AGR = Available Gradient in %
RGR = Required Gradient in %

5.2 -Inadequate Sight Distance Index

It is the distance a driver needs to be able to see in order to stop before colliding with something in the roadway, such as a pedestrian in a crosswalk, a stopped vehicle, or road debris. Insufficient sight distance can adversely affect the safety or operations of a roadway or intersection. A methodology is developed to determine Inadequate Sight Distance Index.
Inadequate Sight Distance Index (ISDI) can be calculated using the following equation

$$\textbf{SDI}= \frac{RSD \quad -ASD}{RSD} \qquad \textbf{(5.2)}$$

Where

SDI= sight distance index
RSD= Required Sight Distance in meter
ASD=Available Sight Distance in meter

5.3 Inadequate extra widening Index

Extra widening refers to the additional width of carriageway that is required on a curved section of a road over and above that required on a straight alignment.
The total widening needed at a horizontal curve We is: We = Wm + Wps

$$We = \frac{nL2}{2R} + \frac{v}{2.64\sqrt{R}} \qquad \textbf{(5.3)}$$

Where

We =Extra widening on the road
Wm =Mechanical widening
Wps = Psychological widening
n = no of lanes of road
l = distance between the front and rear wheel
R = Radius of Horizontal curve

v = Design speed of vehicle

5.4 Improper Super Elevation Index

Improper Super Elevation Index (ISEI) can be calculated using the following equation

$$SEI = \frac{RSE - ASE}{RSE} \qquad \textbf{(5.5)}$$

Where

SEI= Super elevation index
RSE = Required Super elevation in %
ASE = Available super elevation in %

5.5 Improper Curve Radius Index

Improper Curve Radius Index can be calculated using the following equation

$$CRI = \frac{RCR - ACR}{ACR} \qquad \textbf{(5.6)}$$

Where:

CRI= Curve Radius Index
RCR= Required Curve Radius in meter
ACR= Available Curve Radius in meter

6. ***Evaluation of poor traffic hazardous condition***

A methodology is developed to evaluate poor traffic hazardous condition. The poor traffic hazardous conditions decomposed into nine major components described below.

6.1 Traffic Sign/ Marking Index

Traffic Sign/ Marking Index can be calculated by the following equation

$$TSMI = \frac{RTSM - ATSM}{RTSM} \qquad \textbf{(6.1)}$$

Where:

TSMI = Traffic sign / Marking index
RTSM = required number of traffic sign / Marking
ATSM = available number of traffic sign/ Marking

6.2 Improper Traffic Sign / Marking maintenance index

Improper Traffic Sign / Marking maintenance index (TSMI) can be calculated by the following equation.

$$TSMI = \frac{RTSM - ATSM}{RTSM} \qquad \textbf{(6.2)}$$

Where

TSMI = Traffic sign / Marking index
RTSM = required number of traffic sign / Marking
ATSM = available number of traffic sign/ Marking well maintained

6.3 Improper Traffic Signal maintenance index

Improper Traffic Signal maintenance index (ISMI) can be calculated using the following equation

$$ISMI = \frac{RSM - AS}{RSM} \qquad \textbf{(6.3)}$$

Where

ISMI = Traffic signal Maintenance Index
RS = traffic signal require maintenance
AS = available number of traffic signal

6.4 Road side obstruction index

Road side obstruction index (OI) can be calculated using the following equation:

$$OI = \frac{NOB}{MOB} \qquad \textbf{(6.4)}$$

Where

OI = Obstruction index
NOB = Number of obstruction in the road section
MOB = Maximum no. of obstruction in network

6.5 Improper Clearance of Power Line Crossings index

Improper Clearance of Power Line Crossings index (PLCI) can be found out by using the following equation

$$PLCI = \frac{NPLC}{TNPLC} \qquad \textbf{(6.5)}$$

Where

PLCI= Power line crossing,
NPLC= Number of improper clearance in power line crossing
TNPLC= Total Number of power line crossing

6.6 ***Street Lighting Index***

Street Lighting Index (SLI) can be found out using the following equation

$$SLI = \frac{PLL}{TSL} \qquad (6.6)$$

Where

SLI= poor street light index
PLL = poor street light in length of section in meter
TSL = total length of section in meter

6.7 Retaining Wall condition index

Retaining Wall condition index can be found out from the following equation

$$RWCI = \frac{RRW - ARW}{RRW} \qquad (6.7)$$

Where

RWCI= Retaining Wall Condition Index
RRW = Required length of Retaining wall in meter
ARW=Available Retaining wall length in meter

6.8 Parapet wall condition index

Parapet wall condition index (PWCI) can be found out using the following equation

$$RWPI = \frac{RPW - APW}{RPW} \qquad (6.8)$$

Where

PWCI= Parapet Wall Condition Index
RPW = Required Parapet wall length in meter
APW=Available Parapet wall length in meter

7. Conclusions

Main objective of this study is to develop a methodology to evaluate conditions of maintenance components affecting road safety. The important conclusions drawn are as follows:

- Accidents are increasing at a very high rate in India; there is urgent need to enhance safety conditions in road network.
- Timely maintenance of road network improves road safety.
- A critical review of the literature indicated that limited studies are available on identification of maintenance component affecting safety.
- A methodology is developed to identify maintenance components by considering inter relationship between various maintenance components and sub components.
- The safety hazardous condition is decomposed into four conditions: Poor Maintenance Carriageway Conditions, Poor Road Side Condition, Poor Road Geometrics Condition and Poor Traffic hazardous Condition. These conditions are further decomposed into sub components. Total twenty six components affecting road safety are identified.
- Maintenance component Condition indices are also developed to assist road maintenance engineers and staff for assessing road safety hazardous conditions and also propose a methodology as to how the condition of these maintenance components can be measured at different road section.

It is expected that this study will be useful for assessing the maintenance needs of road network and to assess the effectiveness of various maintenance components in safety improvement. Thus, the study will also be useful to justify the resource requirement for road safety improvement.

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Appendix I

Safety Hazardous Structure to identify Maintenance Component: