A Rational Method for Evaluation of Safety at Unsignalized Intersection in India

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Abstract: The amount of road accidents and fatalities at intersection in worldwide is alarming. A large number of traffic accidents take place at Un-signalized Intersections on urban roads in India. These statistical data indicate that Un-signalized Intersections are the places of serious safety concern. Highway Un-signalized Intersections are nodes of road networks and accident-prone locations. They are the places where vehicles coming from different approaches and moving towards different directions interact and conflict with each other. Due to the conflicts from all users, more traffic crashes could happen at un-signalized intersection as compared with roadway segment. Its major function is to guide vehicles to their respective directions. Hence, objective of this study is to develop a methodology to evaluate safety at un-signalized intersection. A four stage methodology is presented in this study. Stage I presents the development of a hierarchical structure to identify hazardous components affecting Safety at un-signalized Intersections.

Index Terms– Un-signalized intersection, control delay measurement, level of service, Safety Index.

I. INTRODUCTION

All Un-signalized Intersections road designated for the vehicles to turn to different directions to reach their desired destinations. Un-signalized Intersections are complex locations on any highway. Generally, un-signalized Intersections are provided in low volume roads. Three modes of transportation are generally used for the movement of people and goods viz. Rail, road, and airways. In this study, we are interested to discuss the various problems and their solutions related to road safety. Un-signalized Intersections are the most hazardous locations in any road network. Especially in any urban road network, functioning of un-signalized intersection affects the overall efficiency of the entire transport system of country. Hence it is necessary to identify all the major and minor factors which are responsible for improving road safety at these locations as it is because vehicles moving in different direction want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing. Figure 1 shows the geometrical elements of an un-signalized intersection.

Figure 1 Geometrical Elements of an Unsignalized Intersection
(Source: Adapted from a Policy on the Geometric Design of Streets and Highways, AASHTO, 2004)

Un-signalized movement of vehicles, heavy traffic, and lack of awareness of road user makes it more accident-occupied area. Hence it is necessary to evaluate the road safety at un-signalized Intersections to reduce the accidents and to make un-signalized Intersections more safe and smooth. This study develops a methodology to evaluate the safety at un-signalized Intersections. This chapter introduces the thesis, describes intersection safety scenario, need of the study, objective of the study, scope of the study and thesis organization.
II. ROAD ACCIDENTS SCENARIO IN INDIA

Road transport is the most important mode of transport in India, both in terms of traffic share and in terms of contribution to the national economy. To meet the demand for road transport, the number of vehicles and the length of road network have increased over the years. Dark side of transportation system is nothing but the accidents. Every developed and developing nation is facing this trouble on their respective transportation system. Accidents are one of the major causes of death all over the world. For developing the sustainable transportation system first of all it is required to identify the severity of the accident and the locations where most of the accidents occurs over a roadway network. Before coming to our study area i.e. un-signalized Intersections let us discuss the accident scenario of the world.

Road Un-signalized Intersections are points of traffic merging and hence are prone to accidents. Table 1 gives the number of accidents, persons killed and injured at traffic junctions.

<table>
<thead>
<tr>
<th>Junctions</th>
<th>Accidents</th>
<th>Killed</th>
<th>Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Junction</td>
<td>63,243</td>
<td>19,884</td>
<td>59,923</td>
</tr>
<tr>
<td>Y-Junction</td>
<td>41,006</td>
<td>12,706</td>
<td>40,048</td>
</tr>
<tr>
<td>Four arm Junction</td>
<td>42,829</td>
<td>12,342</td>
<td>40,704</td>
</tr>
<tr>
<td>Round about Junction</td>
<td>25,612</td>
<td>7,771</td>
<td>26,797</td>
</tr>
<tr>
<td>Rail Crossing</td>
<td>3,314</td>
<td>1,326</td>
<td>2,915</td>
</tr>
</tbody>
</table>

About 41 per cent of total accidents took place on the junctions itself during the calendar year 2017 as against 39 per cent reported during 2015. The main objective of this thesis is to develop a comprehensive methodology for evaluation of Road safety at Un-signalized Intersection. To achieve the objective of the thesis, scope of the study is presented as follows:

- Development of a framework for proposed methodology.
- Development of a hierarchical structure to identify safety hazardous components.
- Determination of relative importance of hazardous components.
- Assessment of hazardous condition of different hazardous component.
- Evaluation of safety hazardous condition at different Un-Signalized intersection

III. METHODOLOGY

3.1 Evaluation of Safety at Unsignalized Intersection

The main objective of this is to develop a methodology for evaluation of safety at un-signalized intersection. To achieve this objective with minimum complexity and easier way of presentation the work is divided into three major steps viz. Identification of factors, Evaluation of factors affecting safety at un-signalized Intersections and Development of safety index. The breakdown of the work is discussed below in detail with the help of Framework. Developed methodology will be useful for evaluation of safety of new proposed un-signalized intersection and it can also be used for comparing two or more un-signalized Intersections as far as safety is concern.

3.2 Framework for Proposed Methodology

There is a need to develop a comprehensive methodology for evaluation of safety at un-signalized intersection. The objective of this section is to develop a framework for the proposed methodology for evaluation of safety at un-signalized Intersections, also the brief introduction and details of each stage is discussed in this section. Figure 3.1 presents the framework for proposed methodology.

Based on the framework four major stages identified to evaluate the safety at un-signalized Intersections are summarized as follows:

- Stage I: Development of a hierarchical Structure to identify critical factors affecting safety at un-signalized Intersections.
- Stage II: Determination of relative importance of identified hazardous factors.
- Stage III: Assessment of un-signalized intersection safety hazardous factors.
- Stage IV: Evaluation of overall weighted hazardous factors at un-signalized intersection by developing un-signalized intersection Safety Index (USISI).

Based on the framework presented in Figure 2, four stages are identified for methodology of ranking of road safety hazardous locations. Stage I is identification of safety factors, it discusses about factors affecting road safety. At stage II relative importance of safety factors are determined using analytical hierarchy processes. Stage III discusses determination of rating of safety factor condition and stage IV presents development of safety hazardous index for ranking of road safety hazardous locations. Details of each of these stages are presented in the following sub sections.

Stage I: Development of a hierarchical structure to identify hazardous factors affecting Intersection Safety

The first stage of this proposed methodology is to develop a hierarchical structure to identify hazardous factors affecting safety at Un-signalized Intersections. A hierarchical structure is needed to be developed to identify hazardous factors affecting Un-signalized Intersections safety in a well-defined hierarchy manner so that all hazardous components can be identified. An overall hierarchical structure is developed to identify hazardous components in Un-signalized Intersections. Therefore, first at Un-signalized Intersections is decomposed in to different factors i.e. (i) Geometrical Safety Hazards (ii) Traffic Operational Safety
Hazards. Further, separate hierarchical structures are developed at each condition factors in a comprehensive manner so that all hazardous factors affecting Un-signalized Intersections can be identified. This stage of this proposed methodology is to identify hazardous factors affecting Un-signalized Intersections safety. The basic purpose of this stage is to provide lists of hazardous factors to guide highway engineers to evaluate the condition of these identified hazardous factors to improve safety at Un-signalized Intersections.

Stage-I Evaluation of Safety at Unsignalized Intersection

Stage-I
Development of a hierarchical structure to identify hazardous components affecting Safety at Unsignalized Intersections

Stage II
Determination of relative importance of identified hazardous components

Stage III
Assessment of Unsignalized Intersection safety hazardous components

Stage IV
Evaluation of overall weighted hazardous condition at Unsignalized Intersections by Developing Intersection Safety Index

Figure 2: A Framework for Proposed Methodology for Ranking Road Safety Hazardous Locations

Stage II: Determination of Relative Importance of Hazardous Components

Second stage of the proposed methodology is to determine the relative importance of hazardous factors affecting Un-signalized Intersections safety. The hazardous factors may not equally affect the safety of Un-signalized Intersections. The relative weight of each hazardous factor is determined using expert opinion using questionnaire survey by Analytical Hierarchical Process. Method of determining the relative weight of different factors is explained in previous chapter. A system of weights therefore needs to be introduced to reflect the contribution to the Un-signalized Intersections safety. Therefore the objective of this stage is to determination of relative importance of identified performance indicators using Analytical Hierarchical Process.

Stage III: Assessment of Un-signalized Intersections safety Hazardous components

Third stage of the anticipated methodology is to assess the hazardous condition of different hazardous factors affecting Un-signalized Intersections safety. In this stage, safety hazardous condition index is developed for each hazardous component at Un-signalized Intersections. Condition indices for each hazardous factor are developed in such an approach so that the value obtained should be lie between zero to one. Where zero indicates the safety at its highest level and one indicates minimum safety.

Stage IV: Evaluation of Overall Weighted Hazardous Condition at Un-signalized Intersections by Developing Un-signalized Intersections Safety Index

Fourth stage of the proposed methodology is to evaluate the overall safety hazardous condition at Un-signalized Intersections. In this stage an overall Un-signalized Intersections Safety Index (SHI\textsubscript{USRS}) is developed at existing Un-signalized Intersections to evaluate the safety level at a particular Un-signalized Intersections. Un-signalized Intersections Safety Index lies between zero to one. Value of Un-signalized Intersections Safety Index equal to one shows the least safe Un-signalized Intersections. And value of Un-signalized Intersections Safety Index equal to zero shows the safest Un-signalized Intersections.
Table 4.3: List of identified Unsignalised Safety Hazardous Components

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Hazardous Component ID</th>
<th>Hazardous Component</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>UHC-1</td>
<td>Inappropriate intersection traffic control.</td>
<td>IITC</td>
</tr>
<tr>
<td>2.</td>
<td>UHC-2</td>
<td>Regulatory traffic control devices</td>
<td>RTCD</td>
</tr>
<tr>
<td>3.</td>
<td>UHC-3</td>
<td>Inadequate intersection sight distance.</td>
<td>IISD</td>
</tr>
<tr>
<td>4.</td>
<td>UHC-4</td>
<td>Inadequate guidance for motorists.</td>
<td>IGM</td>
</tr>
<tr>
<td>5.</td>
<td>UHC-5</td>
<td>Excessive intersection conflicts within or near the intersection</td>
<td>EICW</td>
</tr>
<tr>
<td>6.</td>
<td>UHC-6</td>
<td>Vehicle conflicts with non-motorists.</td>
<td>VCWM</td>
</tr>
<tr>
<td>7.</td>
<td>UHC-7</td>
<td>Misjudgement of gaps in traffic.</td>
<td>MGT</td>
</tr>
<tr>
<td>8.</td>
<td>UHC-8</td>
<td>Poor operational performance.</td>
<td>POP</td>
</tr>
<tr>
<td>9.</td>
<td>UHC-9</td>
<td>Speeding</td>
<td>SPD</td>
</tr>
<tr>
<td>10.</td>
<td>UHC-10</td>
<td>Non-compliance with intersection traffic control devices.</td>
<td>NITCD</td>
</tr>
</tbody>
</table>

3.3 Determination of Relative Importance of Hazardous Components

To quantify the weight or the relative importance of various components identified, an opinion survey of transportation professionals was undertaken. Questionnaire forms to take the expert opinion for the preparation of pair wise comparison matrix are prepared. Each expert was requested to complete the questionnaire. The questionnaire required experts to compare components at a certain level to each other with reference to their impact on the component at a higher level. An example of a filled questionnaire for Roundabout is given in Appendix A. A total 15 response were obtained from transportation experts for hazardous components. Relative importance of hazardous components is calculated and presented below.

Table 4.4 Related Weights Obtained for Safety Hazardous Components at Roundabout

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Hazardous Component ID</th>
<th>Hazardous Component</th>
<th>Notation</th>
<th>Local Weight</th>
<th>Global Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>UHC-1</td>
<td>Inappropriate intersection traffic control.</td>
<td>IITC</td>
<td>0.47</td>
<td>0.102</td>
</tr>
<tr>
<td>2.</td>
<td>UHC-2</td>
<td>Regulatory traffic control devices</td>
<td>RTCD</td>
<td>0.59</td>
<td>0.186</td>
</tr>
<tr>
<td>3.</td>
<td>UHC-3</td>
<td>Inadequate intersection sight distance.</td>
<td>IISD</td>
<td>0.15</td>
<td>0.067</td>
</tr>
<tr>
<td>4.</td>
<td>UHC-4</td>
<td>Inadequate guidance for motorists.</td>
<td>IGM</td>
<td>0.24</td>
<td>0.086</td>
</tr>
<tr>
<td>5.</td>
<td>UHC-5</td>
<td>Excessive intersection conflicts within or near the intersection</td>
<td>EICW</td>
<td>0.28</td>
<td>0.096</td>
</tr>
<tr>
<td>6.</td>
<td>UHC-6</td>
<td>Vehicle conflicts with non-motorists.</td>
<td>VCWM</td>
<td>0.32</td>
<td>0.158</td>
</tr>
<tr>
<td>7.</td>
<td>UHC-7</td>
<td>Misjudgement of gaps in traffic.</td>
<td>MGT</td>
<td>0.08</td>
<td>0.047</td>
</tr>
<tr>
<td>8.</td>
<td>UHC-8</td>
<td>Poor operational performance.</td>
<td>POP</td>
<td>0.25</td>
<td>0.073</td>
</tr>
<tr>
<td>9.</td>
<td>UHC-9</td>
<td>Speeding</td>
<td>SPD</td>
<td>0.93</td>
<td>0.103</td>
</tr>
<tr>
<td>10.</td>
<td>UHC-10</td>
<td>Non-compliance with intersection traffic control devices.</td>
<td>NITCD</td>
<td>0.95</td>
<td>0.082</td>
</tr>
</tbody>
</table>

Total  4.26  1.000

3.4. Assessment of Hazardous Condition of Different Hazardous Component at Intersections

In this section, a methodology is developed to evaluate hazardous condition of different hazardous components. In the view of simple methodology, condition indices are developed to measure hazardous condition of different components. Condition indices are developed in such a manner so that field engineers can evaluate hazardous condition without using sophisticated equipment. The value obtained from the condition indices lies between Zero to one. Concept of value obtained between Zero to One is to compare the condition of a hazardous component at different locations. “One” value presents least safety at unsignalized intersection and “Zero” suggests safest condition at unsignalized intersections.

**UHC-1 Inappropriate intersection traffic control.**

In different road sections like unsignalized intersections, U-turns at intersections are utilized as an option to administer left turns keeping in mind the end goal to lessen clashes and enhance movement operation along divided arterial streets when the volumes on both directions are high. At median openings has been broadly utilized as a part of the outline of a divided arterial road. Left turn departure onto the main street is disallowed in a few outlines of the arterial roads. As an option, turn bays at medians ahead of time of unsignalized intersections is provided to oblige these developments.
The intersection is susceptible to frequent near-misses or conflicts and resulting collisions between vehicles due to a combination of traffic volumes, operating speeds, and turning movements at or near the intersection. A conflict point is a location at which traffic paths routinely cross, merge, or diverge. By their very nature, conflict points are generally more prone to near-misses or collisions between vehicles than other locations on the road network.

Where:

\[ EICW_{EU} = \frac{DEICW-AEICW}{DEICW} \] .......................... Equation 5

Where:

\[ EICW_{EU} = \text{Excessive intersection conflicts within or near the unsignalized intersection} \]
\[ DEICW = \text{Desired Excessive intersection conflicts within or near the intersection} \]
\[ AEICW = \text{Available Excessive intersection conflicts within or near the intersection} \]

**UHC-6 Vehicle conflicts with non-motorists.**

Safety concerns exist related to the interactions between motorists and pedestrians or bicyclists at the intersection. Non-motorists at unsignalized intersections are typically classified as either pedestrians or bicyclists. Not unlike motorcyclists, both groups are much smaller than passenger vehicles and more difficult to detect by drivers. Non-motorists can be particularly vulnerable to serious injuries at intersections at which vehicles on one or more approaches are not required to stop. This can be especially true for right turns (or left turns onto a one-way street), at which turning drivers may tend to look in only one direction to scan for conflicting vehicular traffic and not consider the potential for pedestrians and bicyclists to be in their path from the other direction.

Where:

\[ VCWM_{EU} = \frac{DVCWM+AVCWM}{DVCWM} \] .......................... Equation 6

Where:

\[ VCWM_{EU} = \text{Vehicle conflicts with non-motorists at existing Unsignalized intersection} \]
\[ DVCWM = \text{Desired Vehicle conflicts with non-motorists} \]
\[ AVCWM = \text{Available Vehicle conflicts with non-motorists} \]
UHC-7 Misjudgement of gaps in traffic.

Heavy volumes, high speeds, limited visibility—or some combination thereof—and the major street inhibits the drivers’ ability to safely judge suitable gaps in traffic for crossing or turning manoeuvres. All unsignalized intersections having at least one uncontrolled approach will present the following condition to drivers on the other approaches: they must wait for a gap in traffic that will allow them to safely complete their manoeuvre. One of the most frequent requests that local officials receive from citizens is for a traffic signal to be installed at a specific intersection to allow easier access onto the major road.

\[ \text{MGT}_{\text{EUI}} = \left( \frac{\text{DMGT} - \text{AMGT}}{\text{DMGT}} \right) \]  

Where:

\[ \text{MGT}_{\text{EUI}} = \text{Misjudgement of gaps in traffic at existing unsignalized intersection.} \]

\[ \text{DMGT} = \text{Desired Misjudgement of gaps in traffic.} \]

\[ \text{AMGT} = \text{Available Misjudgement of gaps in traffic.} \]

UHC-8 Poor operational performance.

Users on the minor street frequently experience long delays in making crossing or turning maneuvers because of the lack of safe gaps in the major road traffic flow; this can also apply to motorists desiring to turn left from the major street. The operational efficiency of an unsignalized intersection will naturally decrease as its traffic volume increases. High traffic volumes on the major road can cause significant delay for minor road drivers seeking to enter or cross the intersection, as well as for major road drivers looking for a gap in traffic to make a left-or U-turn maneuver.

\[ \text{POP}_{\text{EUI}} = \left( \frac{\text{DPOP} - \text{APOP}}{\text{DPOP}} \right) \]  

Where:

\[ \text{POP}_{\text{EUI}} = \text{Misjudgement of gaps in traffic at existing unsignalized intersection.} \]

\[ \text{DPOP} = \text{Desired Poor operational performance.} \]

\[ \text{APOP} = \text{Available Poor operational performance.} \]

UHC-9 Speeding.

A significant percentage of motorists is travelling over the posted speed limit to create an unsafe condition for road users, or the posted speed limit is not appropriate for the roadway conditions and use of the road. The problem of speeding at an intersection can also be related to the posted speed limit itself. A governing agency may have purposely or inadvertently set a speed limit that is not appropriate for the road type, design, or conditions. The impacts of speed on safety can be more glaring at unsignalized intersections that are frequented by more vulnerable users—such as children, the elderly, and individuals with limited vision or mobility restrictions.

\[ \text{SPD}_{\text{EUI}} = \left( \frac{\text{DSPD} - \text{ASPD}}{\text{DSPD}} \right) \]  

Where:

\[ \text{SPD}_{\text{EUI}} = \text{Speed Limit at existing unsignalized intersection.} \]

\[ \text{DSPD} = \text{Desired Speed.} \]

\[ \text{ASPD} = \text{Available Speed.} \]

UHC-10 Non-compliance with intersection traffic control devices.

There is evidence of frequent violations of traffic laws associated with the intersection traffic control devices and observance of right-of-way. Drivers are not the only intersection users who must obey traffic control devices and traffic laws. When travelling on a roadway, bicyclists are expected to follow all traffic laws—including compliance with STOP and YIELD signs and yielding the right-of-way to others, as appropriate.

\[ \text{NITCD}_{\text{EUI}} = \left( \frac{\text{DNIITCD} - \text{ANIITCD}}{\text{DNIITCD}} \right) \]  

Where:

\[ \text{NITCD}_{\text{EUI}} = \text{Non-compliance with intersection traffic control devices at existing unsignalized intersection.} \]

\[ \text{DNIITCD} = \text{Desired Non-compliance with intersection traffic control devices.} \]

\[ \text{ANIITCD} = \text{Available Non-compliance with intersection traffic control devices.} \]

3.5 Ranking of road safety for unsignalized intersections at hazardous locations

This stage presents a methodology to rank road safety hazardous locations. The Safety Hazardous Index is developed using weight of safety factors and condition rating of safety factors. The Safety Hazardous Index is developed separately to evaluate safety at straight section, safety at curve section and safety at intersection and presented in equation 11 to equation 12 respectively. Ranking of road safety hazardous locations is evaluated by determination of safety hazardous index at unsignalized intersections.

\[ \text{SHI}_{\text{USI}} = \sum_{k=SF} W_{SFI} \times R_{SFI} \]  

Where,

\[ \text{SHI}_{\text{USI}} = \text{Safety Hazardous Index at Unsignalized intersection} \]

\[ W_{SFI} = \text{Weight of safety factors at intersection} \]

\[ R_{SFI} = \text{Condition rating of safety factors at intersection} \]

Further, Safety hazardous index for entire road section (SHI_{USRI}) can be obtained by summation of safety hazardous index at unsignalized intersections as presented in equation (12).
\[
SHI_{USRS} = \sum_{i=1}^{n} SHI_{US,I_i}, \quad \text{Equation} \cdots \cdots \cdots \text{(12)}
\]

Where,

\[SHI_{USRS} = \text{Safety Hazardous Index at Unsignalized entire road section}\]

\[SHI_{US,I_i} = \text{Safety Hazardous Index at Unsignalized intersection}\]

Further, it is to be noted that higher safety hazardous index at a particular location indicates more safety hazardous conditions at that particular location.

**IV. CONCLUSION**

The main objective of this study is to develop a methodology for evaluating the safety at unsignalized intersections. Further this study is also helpful in comparing the level of safety among different identified unsignalized intersections. Following are the main conclusions drawn from the study. All around the world, road accidents are considered as one of the major factors causes death. Intersections are the most dangerous location of any roadway network. Further unsignalized intersections are supposed to be safe and efficient traffic movement nevertheless still many severe crashes occurs at these locations. Various types of crash pattern occurred at unsignalized intersection has shown in this study and cause of their occurrence is also discussed.

**REFERENCES**


