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Contemporary Developments In The Safety Analysis of Unsignalized Intersections

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***Abstract*—This paper deals with the developments in the field of accident modeling regarding Unsignalized intersection. A literature review of old techniques used for modeling is presented. More emphasis is being given to the parametrical changes that took place over the period of time. Three domains of intersection's safety are discussed namely vehicular safety, bicycle safety and pedestrian safety. Statistical techniques used in the above three domains are described along with the parameters used for analysis.**

Keywords*—*unsignalized intersection, accident analysis, vehicular safety, statistical modelling.

I. Introduction

Since the invention of pathways and roads, cross streets and junctions have remained an integral part of the road network and, their safety had remained of concern by many researchers. As paving materials improved better and cheaper roads were easy to build, increasing the road network and thereby the number of intersections. The need for mobility coupled with affordability brought numerous kinds of vehicles with different sizes and speeds to the traffic volume flowing through the facility. Hence the trend of accidents also changed. Apart from just major and minor street volumes other parameters were required to model the accidents occurring under heterogeneous traffic conditions. This gave rise to experimental studies and simulation techniques apart from field measurements to cope up with the changing trend in the users of unsignalized intersections. Hence researchers now have a broader horizon to conduct accident analysis in controlled environments. As the facility is used by a large number of pedestrians and bicyclists along with motorized traffic, modern research incorporates the effect of all users in the safety analysis of unsignalized intersections. This paper briefly describes the developments in the safety analysis and accident modelling of unsignalized intersections over the period of time.

II. Literature Review

First, Reports on the accident analysis of cross roads and junctions are as old as 1950's. The earliest accident analysis involved the measurement of indices such as number of accidents per left/right turning movement [01] as given by the following formula

$$A_L = R_L Q^a q^b{}_L$$
$$A_R = R_R Q^c q^d{}_R$$

Where,

A_L = Number of accidents for all vehicles turning Left in or out from the minor road
A_R = Number of accidents for all vehicles turning Right in or out from the minor road
R_L = Rate of accident for all vehicles turning Left in or out from the minor road
R_R = Rate of accident for all vehicles turning Right in or out from the minor road
Q = Through traffic flow major road both directions
q_L = Left turning traffic flow in or out from the minor road
q_R = Right turning traffic flow in or out from the

minor road
a,b,c,d = constants of the regression equation incorporating geometric and flow variation among sites

Apart from major and minor road volumes researchers started using speed as measure of intersection safety. While observing the danger compensation effect of the installation of STOP signs[02], at intersections which were previously not controlled by any kind of signs, it was found that the regular commuters showed positive effect of the sign installation by approaching the intersection more cautiously. As stop controlled intersections require the minor road drivers to come to a complete halt before entering an intersection, it was also argued that introduction of a stop sign unnecessarily also increases the number of accidents [03]. In a later study [04 and 05] it was concluded, using Generalized Linear Modeling (GLIM), that introduction of any kind of control measure to an uncontrolled intersection offers greater safety, especially at 4-leg intersections where STOP signs were introduced instead of no control. Emphasis on other geometric features, along with major minor road volumes and STOP sign provisions, on accidents started taking place. These geometric features included clear sight distances from major and minor roads, grade, curve, type of median (raised, mountable, flush, none), raised pavement markers, rumble strips and separate turning lanes[06]. But since precious modelling techniques, which used volume as modelling parameter, were unable to explain the variability of number of accidents effectively, further research was possible. Hence taking into account the fact that accidents follow Poisson distribution, a weighted least square method was used in the regression analysis [07] to come up with an improved model

$$A_i = 0.37 + 0.6 \text{ X } 10^{-3} I_i$$

Where,

A_i = Average number of accidents per year for junction i
I_i = Exposure Index for junction i given by $\sum_{i=1}^{n}\sum_{j=1}^{m} Q_i Q_j$
Q_i = traffic flow of stream i amongst the n traffic streams entering the junction
Q_j = traffic flow of stream j amongst the m_i traffic streams of the junction crossing or merging with stream i

The above model, though empirical in nature, explains 78% of the variability, thus making it better than the rest of the models that used traffic volume as modeling parameter.

As simple accidents involving only a fewer type of vehicles became obsolete, more complex type of accidents took their place. Determining the factors behind these accidents required innovative techniques and use of new parameters which are discussed in the next section.

III. Non-Conventional Analysis Techniques

Safety analyses of roadway facilities such as unsignalized intersections have come a long way from just accident indices to state of the art accident prediction models. Such models used different statistical distributions such as Poison-gamma, Hypererlang, Pearson type III, Schuhl's, etc. and new parameters such as gap or lag acceptance, time to arrival or time to collision and Post Encroachment Time (PET). The application of these models can be broadly classified into three domains of intersection safety as follows:

A. *Vehicular Safety*

Use of gap acceptance as a parameter for modelling accidents had been argued in previous research [3], until it was used extensively by [08]. Unsignalized intersections are a facility which is usually provided on low volume roads. This provokes the drivers to increase their speeds. In a comprehensive study [09] involving the effect of time gap, speed and time to cross on the accident probability of minor stream vehicles assumed all the vehicles of major road stream to be 'Free Vehicles'. A logit model was derived which provides the probability of crossing against not crossing the major stream, given a set of values for the time gap, major road approach speed and time required to cross the intersection by the minor road vehicle. The model was then extrapolated theoretically for conflict and accident probabilities respectively. It was found that the chances of a minor stream vehicle colliding with a major stream vehicle increases with the increase in major stream vehicles' approach speed. It was concluded that the increase in accident probability indicates the speed dependency of gap acceptance behavior. Since accidents occur rarely and those which occur are not 100% reported, therefore, an alternative is required to estimate the probability of accidents at intersections with little or no history of accident occurrence at all. Traffic conflicts were considered to be the solution to this problem; hence microsimulation technique was utilized to generate traffic conflicts at three legged and four legged unsignalized intersections in Italy using AIMSUN simulation software along with SSAM software [10]. Intersection related traffic parameters such as Post Encroachment Time (PET) and Time To Collision (TTC) were used to identify critical conflicts i.e. a collision is very probable to occur if the values of TTC and PET lie within the range of 0 to 1.5 seconds and 0 to 5 seconds respectively. The number of accidents predicted by the conflict model was then compared with the conventional model which uses volumes of major and minor road as explanatory variables. Although major road time headway, which is a very important parameter, was not used in the modelling process but it was concluded that traffic conflicts can be successfully utilized as an alternative to actual crashes for estimating accidents per year at unsignalized intersections. Initial investigations regarding the effect of conspicuity of vehicles, especially Non-Motorized Two Wheelers (NMTW), on accident rates involved common parameters such as daytime running light and use of fluorescent garments [11, 12, and 13]. Techniques like driver's gap acceptance behaviour [14 and 15] and judgements regarding time to arrival or time to collision [16 and 17]were put into analysis by contemporary researchers to investigate the effect of vehicular conspicuity along with other geometric and environmental factors for road safety modelling of unsignalized intersections. Speed and diminished light conditions were found to be significant factors contributing in accidents involving ROW infringement of major stream vehicles of low conspicuity by minor stream motorists [18].

B. *Bicycle Safety*

Among all the users of a roadway facility, bicyclist or non-motorized two-wheelers (NMTW) are the least conspicuous. Difficult maneuvers such as left turning on a multilane intersection coupled with sight obstructions further increases their vulnerability towards accidents. Earlier studies have used the total flow of bicyclist as the measurement parameter for calculating the accident risk associated with them [19]. Later studies used negative binomial models for the estimation of accidents involving bicycles. Other parameters such as sight distance, raised bicycle crossings, separate bicycle paths, cycle track markings and effect of separate turning lanes were utilized by researchers. It was concluded that cycle lanes are safer than cycle tracks and speed reducing methods such as raised bicycle crossings help reduce accidents [20].

C. *Pedestrian Safety*

Like vehicular and bicycle safety, pedestrian safety also utilized the parameter of major and minor road traffic volume for the analysis and modelling of accidents involving pedestrians [03 and 06]. Modern day researchers found that intersections having wider cross walks are more prone to accidents as compared to intersections having narrower ones [21, 22, and 23]. A very novel statistical technique known as the Intervention Penetration variable was used in a recent report [24] to measure the amount to which the new improvements penetrate into the total number of treatment sites. Nowadays current technology such as use of vision-based techniques is being employed into research to help reduce accidents involving pedestrians [25].

IV. Conclusion and Further Research

It can be concluded that the course of research has significantly changed over the period of time. The findings of this paper can be briefly summarized as:

i- Traffic flows such as major and minor road volumes alone cannot describe all the variances in the accident data.

ii- The speed dependency of gap acceptance behavior gives rise to the accident probability.

iii- Traffic conflicts can be effectively used as an alternative to actual crashes for accident predictions.

iv- Use of fluorescent garments and improved motorcycle lightings can help reduce conspicuity related accidents.

v- Providing cycle lane and raised bicycle crossings reduce accidents involving bicyclists.

vi- Narrow cross walks with centre refuge for pedestrians can decrease the number of pedestrian related accidents.

It has already been reported by [26, 27 and 28] that producing a model that gives the best fit is not difficult any more. Selection of an appropriate functional form combined with suitable co-variates should be the aim of the research.

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