Traffic Safety Evaluation on Urban Road Un-signalized Intersection using Proactive Approach: A Case Study in Adama City

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ABSTRACT

Deaths and injuries as a result of road accidents are a recognized global problem and authorities are aware of the consequences this global phenomenon might lead to. Because of the rapid development of urbanization and motorization in developing and transitional countries, like Ethiopia, actions to improve traffic safety conditions are urgently needed. Highway intersections are among greatest safety challenges because they are some of the most common highway features. Improving the safety level of the urban intersection is an important way to increase safety. Safety evaluations can help to develop effective safety countermeasures to lower crash rates and reduce crash severity. So how to diagnose safety problems and improve urban road intersection safety effectively become an important issue. Now, there have been quite a number of safety analysis methods and theories in the city intersection, but these methods and theories are formed on the basis of traffic accidents. However, the data of traffic accidents is not accurate enough, these theories are not appropriate for our country. Also, it is impractical and unethical to wait for accidents occur before being able to draw statistically sound conclusions regarding safety improvement. Hence there is a need to develop proactive approach, non-accident based approach, to evaluate urban road Un-signalized intersection safety performance. A proactive approach (indirect and non-accident based approach) was attempted to that of traditional reactive approach (direct and accident based approach) which is purely based on the existing conditions of the that have direct relationships or impacts to traffic safety such as the geometric, traffic control & engineering, road Surface and environment characteristics. The non-accident-based approach is based on field surveys under the conditions mentioned previously, summarizes the intersection safety diagnosis in a safety index to indicate the safety performance of the intersection. The study indicates that the proposed methodology and intersection safety diagnosis technique can be used to perform evaluation of traffic safety and improvement at intersection even when there are few resources available. Also, the use of intersection safety diagnosis is a more resource-efficient and ethically appealing alternative for fast, reliable and effective safety assessment.

KEYWORDS: Un-signalized intersection; traffic safety; safety diagnosis; safety improvement.

1. INTRODUCTION

The dramatic growth of motorization, urbanization and highway construction in the past several decades has led to a remarkable increase in mobility and prosperity worldwide. However, this increased mobility has resulted in large numbers of deaths and injuries annually due to traffic collisions. The World Health Organization (WHO) statistics shows that almost 1.26 million people are killed in road accidents each year worldwide and an additional 50 million people are estimated injured. Nearly half of them are seriously injured or disabled [1]. Due to the unreliability and under-reporting of data in most countries, these figures are still under-estimated.

The traffic accidents in Ethiopia compared to the number of cars in the country is very high. In fact, Ethiopia is leading the world in the number of traffic accidents per motor vehicle. Traffic accidents are also becoming the third biggest killer in the world. Compared with Norway, that has 1.2 persons traffic accident death per 10,000 motor vehicles Ethiopia has 197 persons killed Figure 1.1. Deaths from motor vehicle accidents are increasing [2]. For instance, Motor vehicle accidents in Addis Ababa between 2010 and 2012 have increased from 350 to 411. The national figure has increased from 2,135 to 3,132 for the same period [3]. These figures indicate a serious highway safety problem, and suggest the need for further research in the area of highway safety improvement.

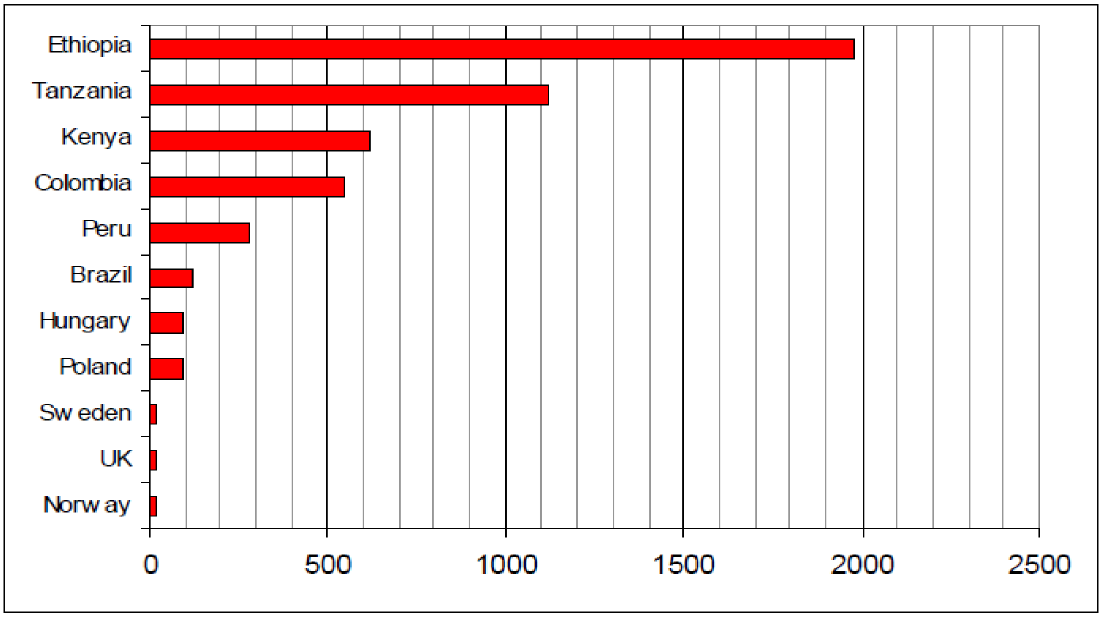

Fig 1, Road accident fatalities (deaths per 10,000 vehicles) in selected countries. Adapted from Jacobs (2000).

Highway intersections are among greatest safety challenges because they are some of the most common highway features. Thus, a thorough understanding of them needs to be achieved in order to evaluate and improve them in the most effective manner. Intersections are classified into two main types, signalized intersections and unsignalized intersections. Unsignalized intersections include intersections with stop control, yield control and no traffic control. Unsignalized intersections, which are seen frequently in urban areas, can be differentiated than their signalized counterparts in that their operational functions take place without the presence of a traffic signal [4].

Crashes at unsignalized intersections are considered complicated incidents involving the interaction between the driver, vehicle, roadway geometry, and traffic related factors. Improving the safety level of the urban intersection is an important way to increase safety, and thus, traffic safety at unsignalized intersections needs further study. One important reason for that is the unfamiliarity of drivers to traffic operations at unsignalized intersections, when compared to those of signalized intersections [5]. Very few studies have addressed the safety of unsignalized intersections, which make this issue of an urgent need to be addressed. Though research on them is not highly documented, the contributions from researchers across the nation and the world have proven to be significantly useful.

A review of literature reveals that numerous studies have proposed the safety evaluation methods for intersection condition. Traditional safety evaluations are mostly based on historical crash data or traffic conflict data. However, it is difficult to obtain sufficient reliable crash data for a highway intersection which basically has long length and runs across multiple regions. Also it is impractical and unethical to wait for accidents to occur before being able to draw statistically sound conclusions regarding safety improvement, and hence these theories are not appropriate for our country. Traffic conflict techniques have been attempted to analyze traffic safety performance of roadway intersections in recent years [6, 7&8]. But one limitation of such techniques is that the identification of traffic conflicts and their type relies on the experiences and knowledge of observers, which could easily generate human bias and adversely affect data reliability. Besides, collecting conflict data of an entire highway is a very challenging task even using automated video techniques. In recent years, some comprehensive evaluation methods have been developed by researchers. In 2008, Lu et al. introduced the concept of level of safety service and developed a non-crash based model for safety evaluation [9].

Safety evaluations can help to develop effective safety countermeasures to lower crash rates and reduce crash severity. The study presented deals with traffic safety evaluation and improvement on urban road Un-signalized intersections using a proactive approach (called intersection safety diagnosis) that is; indirect and non-accident based approach,, it is purely based on the existing intersection conditions that have direct relationships or impacts to traffic safety such as the geometric, traffic control & engineering, road Surface and environment characteristics, in Adama City.

1.1 Statement of the Problem

Any design & operational defects are a potential risk for road users. It was found some different geometric design defects, traffic engineering design defects, traffic design defects and environment design defects in some intersections, which may contribute to traffic crashes in Adama City. While accident analysis and investigations are very important this is a reactive approach to an existing situation, where a significant number of crashes must occur before a problem is identified and suitable corrective measures can be implemented.

Understanding these problems, researchers have proposed a framework for 'proactive' safety planning. A proactive (called intersection safety diagnostic approach) and systemic methodology (indirect and non-accident based approach) was attempted to that of traditional reactive approach (direct and accident based approach) which would help in improving the decision-making process (prioritization) when urban road intersections are considered. Also, the use of intersection safety diagnosis is a more resource-efficient and ethically appealing alternative for fast, reliable and effective safety assessment.

1.2 Research Objectives

The main objective of this study was to introduce proactive approach to evaluate the traffic safety of unsignalized intersections, in order to help in improving the decision-making process (prioritization) to find cost-effective solutions for reducing the frequency and severity of crashes, in Adama City. The Specific Objectives are;

- To identify the geometric and traffic factors leading to crashes and contributing to crash severity at unsignalized intersections.
- To evaluate the Safety Performance of Unsignalized Intersections based on the existing conditions.
- To develop Possible Safety Countermeasures and to recommend appropriate techniques in developing cost-effective solutions on unsignalized intersection to improve traffic safety problem.

Fig. The accident occurred at Un-intersection in the study area.

2. Material and Methods

Highway intersections have much more crashes compared to other road sections, due to complex traffic control strategies and numerous vehicle interactions (i.e., conflicts).According to historical crash data, in the USA, about 55% of total traffic crashes and 23% of fatal traffic crashes in urban areas happened at intersections and about 32% of total traffic crashes and 16% of fatal traffic crashes in rural areas happened at intersections [10]. In China, about 30% of urban traffic crashes happened at intersections and about 47% of rural traffic crashes happened at intersections [11]. These indicate that the intersection characteristics need to be carefully examined.

2.1. Procedure for the Evaluation safety performance degree of Road Intersection

The following subsections give a brief description to each step of the evaluation method described by a flow process shown in **Figure 2**.

2.2. Selection of intersection and Identification of safety problems for evaluation

To collect the required data according to the objectives of the study, a general reconnaissance in selection of sites carried out covering the study area of Adama city Three Sample unsignalized intersections were selected. The general guidelines that was considered in site selection are as follows:

- The past traffic crash history or a preliminary field safety survey,
- Safety complaints or concerns rose by others (departments, local politicians, the public),
- Planned reconstruction that would make it worthwhile to carry out a safety evaluation and improvements and
- Identified operational deficiencies [4].

In conducting a safety diagnosis at an unsignalized intersection, the researcher seek to identify contributing factors of crashes within the functional boundary of the intersection **Table 2** (On Site Observation Report Form) shows the summarized potential safety problems. Intersection data regarding potential safety problems on the basis of existing conditions that have direct relationships or impacts to traffic safety (Geometric, Traffic control & engineering, Road Surface and environment) characteristics at unsignalized intersections were collected including but not limited[12].

- Geometric characteristics: intersection angle, horizontal and vertical alignment of approaches, lane width, number of lane, drainage, curb, crosswalks ,sidewalk, left-turn or right-turn lane , auxiliary lanes etc.

- Traffic control & engineering characteristics: posted speed, sign, pavement mark, channelization features delineation, speed control, refuge island;

- Road Surface characteristics: Skid resistance, Pavement Distress (i.e., potholes, rutting, etc.), Surface Texture (Visibility in wet conditions or sunlight conditions)
- Environment characteristics : sight distance, street parking, illumination, roadside development

The detailed field assessment undertaken for each intersections locations were summarized and described on the *table2*, on site observation report form.

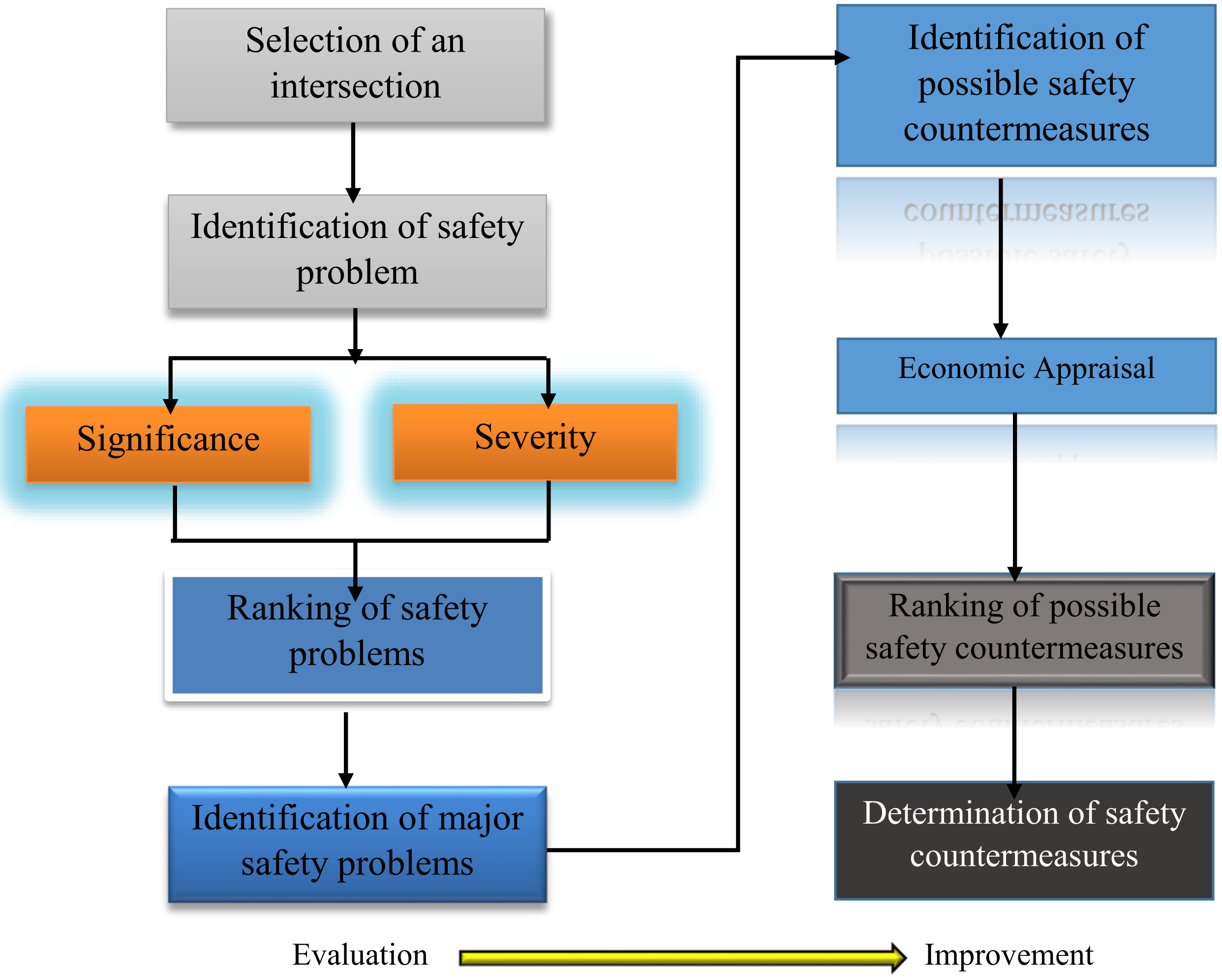

Figure 2. Scope of safety evaluations and Improvement that can be applied in intersection safety diagnostic approach.

2.3. Formulation of the Road Intersection Safety Evaluation Index

The safety index (**SI**) measures the safety performance degree of unsignalized intersections. It does not take into account road segment, and it refers on urban road Un-signalized intersection. The **SI** is formulated by two linear combination, "significance index" and "severity index ", of weighted parameters; "Significance" indicates whether the particular existing intersection element characteristics has significant safety problem, "severity" indicates whether the resulting consequences accident associated with the particular existing intersection element characteristics would result in a severe traffic crash [13].

General formulation of **SI** is as follows: **S**afety-**I**ndex = **S**ignificance-**I**ndex + **S**everity-**I**ndex

$$\mathbf{S.I_i = W_1S_{1i} + W_2S_{2i}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

Where:

- SI i= safety index for the ith safety problem,
- W1= weight for significance index,
- W2= weight for severity index,
- S1 i= significance indices for the ith safety problem,
- S2 i= severity indices for the ith safety problem, and
- (i = 1, 2, 3…., n) n= number of the safety problems.

W1&2 are constant weighting factors

S1&2 are individual measurable items.
Using safety diagnosis form

A strength of weighted linear combinations is that they can assist in determining how to allocate limited resources. Hence in estimating the weighting factors, the Expert Opinion were taken into account and the final estimated weighted parameters are; W1=0.38 and W2=0.68. Substituting the estimated weighted parameters in equation (1) looks the form;

$$\mathbf{S.I_i = 0.38S_{1i} + 0.62S_{2i}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

2.4. Safety diagnostic survey form

A list of potential safety problem summarized in safety diagnosis form **Table 3** was given to the trained Field engineers to score them under the category Significance/ severity on the scale of ((0-1) to (4-5)) and were instructed; the score 0 to the particular existing intersection element characteristics which they find no significant toward contributing safety problem and the score 5 to the particular existing intersection element characteristics which they find most significant toward contributing safety problem, the score 0 to the resulting consequences of accident associated with the particular existing intersection element characteristics which they find no severity toward accident and the score 5 to which they find very high severity toward accident. The five filed surveyors result summarized in **Table 4.**

2.5. Ranking of Potential Safety Problem

For each intersection in order to rank safety problem for improvements the safety index (**SI**) is calculated using equation (2), the higher **S.I** value indicates that particular existing intersection element have potential safety problem and should be given priority for improvements.

For ranking intersections for safety improvement, the average summary of the safety index calculated using equation (3): the intersection higher **R** value indicates have potential safety problem and should be given priority for improvements.

$$\mathbf{R} = \Sigma\ \mathbf{S.I} \qquad \mathbf{(3)}$$

The overall safety index is the average summary of the safety index for each particular potential safety problem.

3. Results and discussion

3.1 Characteristics of the Study Area

Adama is the largest city in Oromia National Regional State. Adama is located 100 km to the south east of Addis Ababa along the main route of the country’s import and export corridor from the port Djibouti. Adama is situated 1600-1700 meters above sea level and in a Latitude from 80 -33.8N to 80-36N and a Longitude from 390 11‟ 57E to 39021‟15E in the Rift valley of warm climate. Due to the rapid growth and change there is high mobility of goods and passengers. Which leads to highly efficient and safe transportation demand.

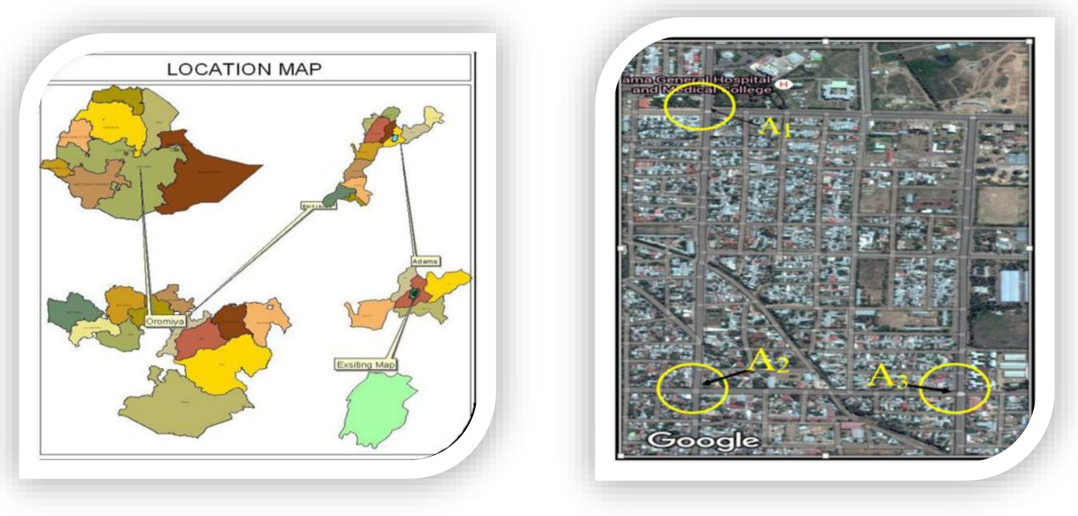

Figure 3 .location map of the study area and Google map of the selected intersection

There are many numbers of unsignalized intersections in Adama City and their main function is mobility whereas safety given a lower priority. All the unsignalized intersections are in flat area and many of these intersections are controlled by police men or by signs and some of intersections are uncontrolled. Potential safety problems such as; lack of geometric design, high traffic conflict, lack of visibility of traffic signs and pavement marking, improper pedestrian crosswalks placement and design, pavement distress, inadequate intersection channelization are observed at unsignalized intersection in the study area and some experience sufficient number of particular crash types that indicate a need to improve safety Figure 4.

Field survey was performed by several field engineers (surveyors) have sufficient safety and operational experience and well trained in using the diagnostic survey forms. In the research, the diagnostic approach was applied to evaluate the safety performance of the selected unsignalized intersections A1, A2, and A3 which are showed in Figure 3**.**

Figure 4. Photo taken at intersection A2 & A3

The survey results (scores under the categories of “significance” and “severity ") by five field surveyors collected from the three 4-legged, 90^0 crossed unsignalized intersection (at Adama General Hospital and Medical college, at 04- kebele office, and at 04-kebele condominium) were presented and summarized in Table 2.

3.2 Ranking of Potential Safety Problem

According to the traffic safety problems ranking model (Equation 2), the total score and the order of traffic safety affecting degree was gained. The safety problems and corresponding safety scores (which are the average scores from all surveyors) listed under the categories of “significance” and “severity ". The overall safety index of those intersection (A1, A2, and A3) is the average summary of the safety index for each particular potential safety problem. Based on the safety index values, potential Safety problems and corresponding safety scores according to their rank presented in **Table 1 and Figure5**.

Hence according to the study result the major top five potential safety problem of those intersection is;

- Improper Traffic Signs as to Number, Size, Message, Placement, &Visibility
- Insufficient sight distance
- Vehicle speed too high for existing condition
- Insufficient Intersection channelization and
- Insufficient Lighting.

The above describes the real application case with the use of the diagnostic approach developed in the research. The results from this study from the diagnostic approach for evaluating safety at unsignalized intersections can be applicable to diagnose some safety deficiencies identified.

Table 1 Safety problems and corresponding safety scores for overall safety index of those intersection (A1, A2, and A3) in the ranking order.

	Problems	Average Score of Significance	Average Score of Severity	Total Scores	Rank
1	Improper Traffic Signs as to Number, Size, Message, Placement, &Visibility	4.27	4.74	4.560	1
2	Insufficient Intersection Sight Distance	4.47	4.31	4.370	2
3	Vehicle Speed too High for Existing Condition	3.89	4.62	4.341	3
4	Insufficient Intersection channelization	3.33	3.91	3.689	4
5	Insufficient Lighting	2.43	3.91	3.348	5
6	Pavement Marking Faded and Poor Visibility	3.18	3.35	3.283	6
7	Improper Pedestrian Crosswalk Placement &Design	2.61	3.08	2.903	7
8	Poor Pavement Skid Resistance	1.91	3.11	2.655	8
9	Inadequate Curb Radius for Turning Vehicle	2.40	2.11	2.218	9
10	Inadequate Lane Width	2.19	1.83	1.968	10

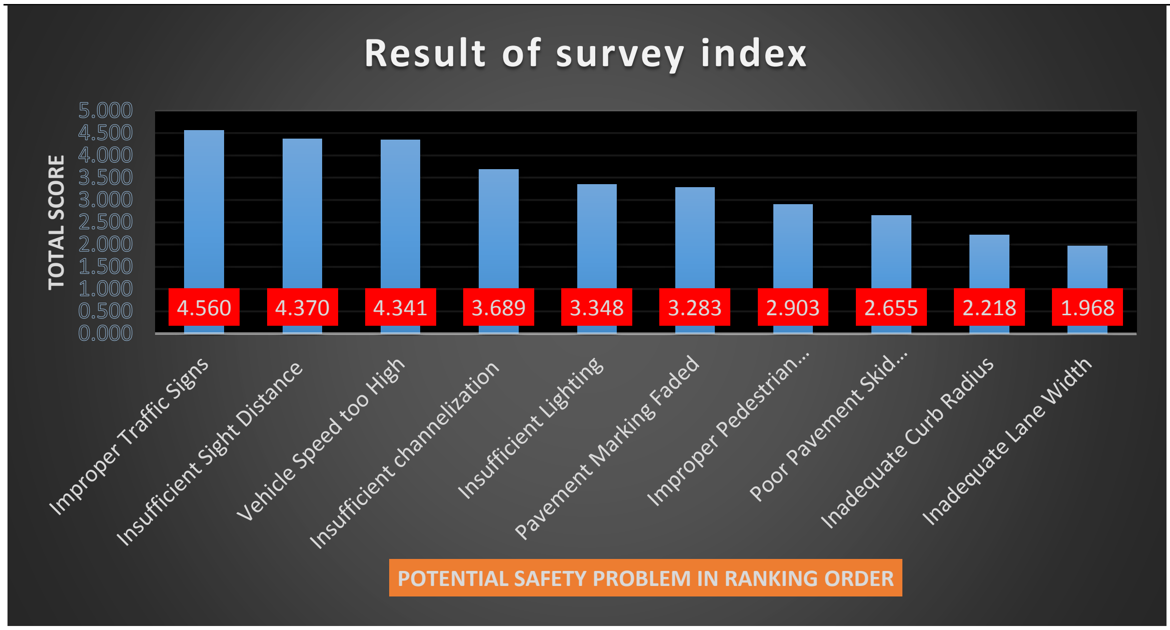

Figure 5 result of survey index in ranking order

3.3 Countermeasures to Improve Intersection Safety

After the safety problems were identified and ranked in the research, possibly safety countermeasures were proposed. Intersection crashes have many causes including, but not necessarily limited to, poor geometry and design, deficient operational control, insufficient maintenance, and human error. Considering all of these elements, the optimal approach to improve intersection safety is multidisciplinary in nature. However, many low cost countermeasures focused on the intersection design and operation can be both implemented and effective at the local level [14]. Practically, a safety problem may have several corresponding countermeasures and one countermeasure may be used to improve several safety problems. When improving an intersection the general strategies to be considered.

- Attempt to minimize intersection conflicts and crashes, and lessen the impacts of crashes when they do occur,
- Attempt to match a countermeasures to an identified safety problem,
- Evaluate implemented countermeasures to identify what works and what does not, for consideration at future locations, and
- Select countermeasures that are technically feasible and practical, and provide an advantageous benefit/cost ratio [4].

Countermeasures have been classified as basic or supplemental. Basic Countermeasures are those that are usually very low in unit cost and effective in term of reducing future crash potential. The type of countermeasure depends on the nature of the intersection and the safety concerns apparent at a particular location. The following methods were listed [14-18].

- Provision of warning signs
- Treatment to reduce speed
- Provision of adequate sight distance
- Improvement of intersection geometric design
- Provision of lighting at unsignalized intersections
- Improve Management of Access near Unsignalized Intersections
- Provide Skid Resistance in Intersection and on Approaches
- Improve pedestrian, Motorcycle and Bicycle Facilities to Reduce Conflicts between Motorists and None-motorist

3.4 Functions of Traffic Control Devices

The main purpose of a traffic control device is to provide information to drivers so they can operate their vehicles safely along a highway or street.

The five basic criteria of a traffic control device are to:

- Fulfill a need;
- Command attention;
- Convey a clear, simple meaning;
- Command respect from road users, and
- Give adequate time for response.

Signs, signals, pavement markings, cones, barricades and warning lights are designed with dedicated colors, shapes and sizes based on the different functions they provide. They regulate, guide and warn vehicle and pedestrian traffic about road conditions. Uniformity of design (color, shape, size and location) helps drivers to quickly understand the messages of traffic control devices. Consistency is important for driver respect, recognition and proper reaction to the devices.

3.4.1 Characteristics of Uniform Traffic Control Devices

a) *Color*. Certain colors are used to trigger instant recognition and reaction; for example, STOP signs are always red. Similarly, signals at intersections must have the same sequence of red/yellow/ green to communication stop/warning/go to drivers and pedestrians.

b) *Nighttime visibility*. Traffic control devices are made visible under nighttime operating conditions by either being separately lighted or retro-reflectorized so that the light coming from vehicle headlamps is bounced off signs and other devices back to the eyes of drivers.

c) *Daytime visibility***.** Traffic control devices are designed with highly visible colors or a sharp contrast of messages against a background. Sometimes traffic control devices are lighted even for daytime viewing to draw the attention of drivers to their messages.

d) *Shape and siz***e.** Signs have standard shapes and sizes to trigger instant recognition and reaction. For example, STOP signs have an octagonal shape of a particular size that no other sign is permitted to have. There are similar specifications for the shapes and sizes of many other traffic control devices for both permanent and temporary conditions.

e) *Location***.** Traffic control devices must be placed in locations that provide enough time for all drivers to make the appropriate safe maneuvers, such as entering or departing a road or stopping and turning to avoid conflicts with other vehicles and pedestrians.

f) *Messages***.** Traffic control devices are designed with carefully chosen symbol or word messages of specific sizes and content. Locations and functions are then selected in relation to the amount of time that drivers need to detect, read and understand messages to make appropriate vehicle maneuvers.

3.4.2 How to Select the Correct Traffic Control Device

Traffic control devices work in concert with the basic “rules of the road” contained in traffic laws and ordinances, including each states’ uniform code that regulates vehicle movements. One example is the “right-of-way” principle that determines which driver has priority when approaching or entering an intersection.

Traffic control devices have undergone a long evolution of design and installation criteria. Current designs and the standards for using them are the result of several decades of scientific investigation and the combined experience of many professional engineers, human behavior and vision researchers and safety policy-makers. One of the major resources for determining the design and use of traffic control devices is the *Manual on Uniform Traffic Control Devices* (MUTCD) 2003.

3.4.3 Common Problems with Traffic Control Device Placement and Installation

Due to resource constraints, many jurisdictions do not have traffic engineers or traffic engineering technicians on staff. These jurisdictions may rely on personnel that may have an engineering background; however, they may not be specifically trained in traffic engineering. Knowledge of the standards, guidance and applications included in the MUTCD is an essential element in the design, construction, operation and maintenance of roadway segments and intersections. A few of the common problems with traffic control device placement and installation are provided below.

i. *Use of an improper device.* Placing an unwarranted traffic signal where a less restrictive control would be more appropriate may result in unnecessary delays, excessive violations, increased crashes and diversion to less desirable routes such as residential streets.

ii. *Improper placement.* A traffic control device at the wrong location may result in the device being seen too late by drivers to safely react (e.g., placing a properly designed sign too far around the bend of a sharp curve).

iii. *Wrong color, shape, or size.* Using a color, shape, or size for a sign or other traffic control device that is in conflict with the MUTCD can result in the inability of drivers to detect and comprehend the need to make safe maneuvers and can cause inattention or visibility problems (i.e., “I didn’t see the STOP sign.”)

iv. *Land use, traffic and other changes can cause existing traffic control devices to become obsolete.* As an example, traffic signs that may have controlled the movement of vehicles and pedestrians for years may no longer be effective in doing so.

v. *Lack of signs or other devices to warn drivers and pedestrians of unexpected, potentially hazardous conditions.* For example, neglecting to provide advance warning of an upcoming signal or STOP sign over the top of a steep hill can result in inappropriate braking and steering maneuvers that may result in collisions.

vi. *Poor Maintenance.* Signs and pavement markings need to be maintained on a regular basis. Faded signs and pavement markings make them harder for road users to detect and may lead to potentially dangerous situations. For example, faded STOP signs may lead to drivers entering an intersection without stopping.

3.5 Purpose of a STOP Sign

The STOP sign is a regulatory sign that is used when traffic is required to stop. It is a red octagon that has a white border and large white letters that read STOP. At multi-way stop intersections, a small plate is placed below the stop sign to inform the driver of how many approaches are required to stop. STOP signs are used to assign right-of-way at an intersection. Since a STOP sign causes inconvenience to motorists, it should be used only where warranted.

i. Where A STOP Sign Should Be Installed?

STOP signs should be located where vehicles are to stop or as near to that point as possible. The sign may also be supplemented with a STOP line and/or the word STOP on the pavement. Where there is a marked crosswalk, the STOP sign should be located approximately 4 ft. in advance of the crosswalk line. When only one STOP sign is used on an intersection approach, it should be on the right side of the roadway.

At wide intersections however, placing an additional sign on the left side of the approach may reduce violations of the STOP sign and the likelihood of right-angle crashes. If two lanes of traffic exist on an approach, at least one STOP sign should be visible to each lane of traffic.

ii. Under What Conditions a Two-Way STOP Sign Should Be Installed?

Intersections must have one or more of the following conditions for two-way STOP signs to be installed:

- An intersection of a minor and major road, where the application of the normal right-of-way rule would be hazardous;
- A Street enters a highway;
- An unsignalized intersection in a signalized area; and
- Locations where there is a combination of high speed traffic, restricted view, and a previous crash record that indicates a need for STOP sign control.

The advantage of a two-way stop is that the major flows do not have to stop and they incur almost no delay at the intersection (i.e., the majority of the traffic does not have to stop).

iii. Under What Conditions a Four- Way (Multi-way) STOP Sign Should Be Installed?

Four-way STOP signs are often used at the intersection of two roadways that exhibit approximately equal traffic volumes. The following criteria should be considered:

- A traffic signal is going to be installed and the intersection needs a temporary solution to control the traffic;
- Within 12 months, at least five crashes have occurred at the intersection that could have been prevented by STOP signs. Previous crash records include right- and left-turn collisions, as well as right-angle collisions;
- Minimum traffic and pedestrians volumes;
- 85th percentile major-street vehicle speeds in excess of 40 mph;
- Average minor street vehicle delays of at least 30 sec. during the maximum hour;
- The need to control left-turn conflicts;
- The need to control vehicle/ pedestrian conflicts near locations that generate high pedestrian volumes;
- Locations where a road user, after stopping, cannot see conflicting traffic and is not able to safely negotiate the intersection unless conflicting cross traffic is also required to stop; and
- An intersection of two residential neighborhood collector (through) streets of similar design and operating characteristics where multi-way stop control would improve traffic operational characteristics of the intersection.

iv. Failure to Stop at Existing STOP Signs

- When there is a history of drivers failing to heed STOP signs that clearly have adequate visibility, the following approaches could be considered:
- Install STOP AHEAD sign; Increase size of STOP and STOP AHEAD signs to 36 in.;
- Install two transverse rumble strips in the approach lane in advance of the STOP AHEAD and before the STOP sign;
- Consider installation of two additional transverse rumble strips to supplement the first two locations;
- Install intersection illumination;
- Consider adding a flashing red beacon in conjunction with the STOP signs or an overhead intersection control beacon with flashing red for the minor street and flashing yellow for the major street;
- Place actuated flashers on the top of a STOP sign. A detector would be in the pavement in advance of STOP sign. As a vehicle approaches, a red flasher would appear. This solution would address the driver expectancy problem and give more attention to the STOP sign; and
- Use of double-indicating left-side STOP sign.

3.6Ranking of possible safety countermeasures

3.6.1 Economic Appraisal

Comparing the countermeasures to improve the traffic safety, it can be found that they are different in cost and efficiency. After a list of countermeasures have been identified that are based on local practice at the intersection through the diagnosis step. The economic appraisals include three steps, Highway Safety Manual (2010):

Step 1: Estimate benefits of countermeasures.
Step 2: Estimate costs of countermeasures.
Step 3: Evaluate cost effectiveness of countermeasures.

3.6.2 Project Prioritization

The following two simple methods can help prioritize projects:

- Ranking by economic effectiveness measures & Incremental benefit-cost analysis ranking.

The ranking by economic effectiveness methods is the simplest method for prioritization of projects. In this method, economically justified projects are ranking from high to low by any of the following measures: Net present worth, Projects costs, monetary value of project benefits and Total number of crashes reduced.

3.7 Tackling the Intersection Safety Problem Requires a Multi-disciplinary Approach

Intersection safety is a complex public health issue that cannot always be solved by making changes in signs and signals, but can be helped by a national comprehensive effort of improved intersection vehicle and pedestrian safety management.

The following actions address ways to achieve substantial reductions in annual crashes, injuries and fatalities:

A. *Analyze the reasons for traffic conflicts at intersections.*

   Multidisciplinary teams (engineers, enforcement, human factors professionals, etc.) are recommended since they can have a broader perspective on crash causes.

B. *Engage in innovative and strategic thinking.*

   Engineers must delicately balance the requirement for efficient traffic movement and congestion reduction and, at the same time, the need to protect vehicle occupants and pedestrians from the consequences of dangerous vehicle maneuvers and unwise pedestrian behavior.

C. *Modify the intersection design and operations* based on engineering analysis

D. *Identify the safety benefits of reconstruction or construction projects and/or operational changes that are planned at intersections.*

   Select alternatives that have the greatest safety benefit. Integrate safety evaluations of projects into the planning and design processes.

E. *Provide sustained and consistent law enforcement efforts.*

F. *All levels of government must play a central role*

   by providing improved funding, and cooperation with highway and vehicle engineers, health care authorities, law enforcement, national safety organizations, and local citizen safety groups.

4. Conclusion and Recommendation

4.1 Conclusion

Intersection accidents on highways are one of the main challenges of road safety in the developing world. The promotion of road and road intersection safety should be priority for every road authority. Attention is generally focused on situations where a relatively large number of accidents and/or fatal accidents occur. Measures designed to tackle those accident concentrations should be based on thorough, objective analysis of the problems (determination of the origins). While accident analysis and investigations are very important this is a reactive approach to an existing situation, where a significant number of crashes must occur before a problem is identified and suitable corrective measures can be implemented. A pro-active attitude by the road authority is essential to avoid situations that can result in accidents.

Understanding these problems, researchers have recently proposed a framework for 'proactive' safety planning. A proactive approach that is; indirect and non-accident based approach but uses intersection safety diagnosis purely based on the existing intersection element characteristics, i.e. the geometric, traffic control & engineering, road Surface and environment characteristics, to evaluate urban road Un-signalized intersection safety performance. Also, the use of intersection safety diagnosis is a more resource-efficient and ethically appealing alternative for fast, reliable and effective safety assessment.

4.2 Recommendation

To further enhance the results of this study the following recommendations are formulated:

- Further research should be conducted to extend all aspects of this research, such as various non-accident base evaluation method innovative low cost countermeasures and traffic crash data handling.
- The result shows traffic sign as to number, size, massage, placement is major contributing factor at the time of the study followed by sight distance and speed. Provision of warning sign was selected as a countermeasures. Therefore, it is recommended that the suggested countermeasures be implemented in Adama City, potentially as a pilot study. A before-and-after study could then be conducted to prove their benefits in improving safety.
- Finally, it is recommended to continue monitoring other research studies to determine when, or if, other promising countermeasures may be suitable for implementation (e.g., the Intersection Decision Support System) and to monitor other experiences with various other countermeasures that have been proposed in an attempt to improve safety conditions, therefore the city administration should consider this issue and formulate various improvement methods.

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Table 2, On Site Observation Report and **Table 3**. Survey Diagnosis Field Form

	ON SITE OBSERVATION REPOERT			
	LOCATION____A1. **A2 and A3**_ DATE___ ____			
	RVEYOUR______RESEARCHER__ TIME____________________			
	List of intersection safety problems	No	Not sure	YES
1	Is appropriate sight distance available to all users on each intersection approach?	√		
2	Is the horizontal and vertical alignment appropriate on each approach leg?		√	
3	Are pavement markings and intersection control signing appropriate?	√		
4	Are all approach lanes adequately designed based on the composition of traffic using the intersection?	√		
5	Is the roadway cross-slope adequately draining rainfall runoff?		√	
6	Is the layout of the curbs and channelization appropriate?	√		
7	Is roadway lighting appropriately installed and operating?	√		
8	Are turning radius and tapers adequately designed based on the traffic composition using the intersection?	√		
9	Are traffic signs appropriately located and clearly visible to the driver on each approach leg?	√		
10	Is the pavement free of defects, and is there adequate skid resistance	√		
11	Is the pedestrian crosswalk placement and design is appropriate?	√		
12	Are parking provisions satisfactory?	√		
13	Do vehicles speed too high for existing condition?			√
14	Are driveways and other access points appropriately located on each intersection approach leg?	√		

	survey list of safty problems	survey index									
		Significance					Severity				
		Low scale → high					Low scale → high				
No.		(0-1)	(1-2)	(2-3)	(3-4)	(4-5)	(0-1)	(1-2)	(2-3)	(3-4)	(4-5)
1	Insufficient Intersection channelization										
2	Vehicle Speed too High for Existing Condition										
3	Insufficient Intersection Sight Distance										
4	Improper Traffic Signs as to Number, Size, Message, Placement, &Visibility										
5	Pavement Marking Faded and Poor Visibility										
6	Inadequate Lane Width										
7	Improper Pedestrian Crosswalk Placement &Design										
8	Poor Pavement Skid Resistance										
9	Inadequate Curb Radius for Turning Vehicle										
10	Insufficient Lighting										

Table 4; the Field survey result collected by five surveyor at intersection A1,A2 and A3 in the study area, Adama city

PERIOD	Field Surveyor	Insufficient Intersection channelization		Vehicle Speed too High for Existing Condition		Insufficient Intersection Sight Distance		Improper Traffic Signs as to Number, Size, Message, Placement, &Visibility		Pavement Marking Faded and Poor Visibility	
		Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity
Day 1 A1	1	3.3	4	4.2	4.3	3.7	4.5	4.1	4.8	2.8	2.3
	2	3.1	3.8	4.4	4.1	3.5	4.9	4	4.5	3.1	2.1
	3	3.4	4.3	4.5	4	4	4.7	4.3	4.7	2	1.7
	4	2.9	3.7	4.8	4.2	3.8	4.1	4.5	4.8	2.8	1.8
	5	3.5	4.2	4.5	4.3	4.3	5	4.2	4.7	2.1	2.3
Ave. score		3.24	4	4.48	4.18	3.86	4.64	4.22	4.7	2.56	2.04
S.I			3.71		4.29		4.34		4.52		2.24
Day 2 A2	1	3.5	4	4.8	4.2	3.3	4.7	4.5	4.8	2.6	2.5
	2	3.9	3.9	4.1	4	3.9	4.4	4.3	4.7	2.5	1.8
	3	3.4	3.1	4.5	4.4	4.1	4.5	4.2	4.6	2.2	2.2
	4	3.7	3.8	4.8	4.2	4	4.3	4.4	4.9	2.6	2.1
	5	3.6	4.1	4.2	4.1	4.1	4.9	4.3	5	1.9	2.2
Ave. score		3.62	3.78	4.48	4.18	3.88	4.56	4.34	4.8	2.36	2.16
S.I			3.72		4.29		4.30		4.63		2.24
Day 3 A3	1	3.4	4.2	4.7	4.6	3.7	4.8	4.3	4.8	2.4	2
	2	2.9	3.6	4.4	4.7	3.8	4.5	4.2	4.5	2.1	1.9
	3	3.1	4	4.3	4.5	4	4.3	4.3	4.8	2.5	2.3
	4	3.3	3.9	4.6	4.2	4.4	4.9	4.1	4.7	2.3	2
	5	3	4	4.3	4.8	3.7	4.8	4.3	4.8	2.1	2.4
Ave. score		3.14	3.94	4.46	4.56	3.92	4.66	4.24	4.72	2.28	2.12
S.I			3.64		4.52		4.38		4.54		2.18

Table 4; the Field survey result collected by five surveyor at intersection A1,A2 and A3 in the study area, Adama city

PERIOD	Field Surveyor	Inadequate Lane Width		Improper Pedestrian Crosswalk Placement &Design		Poor Pavement Skid Resistance		Inadequate Curb Radius for Turning Vehicle		Insufficient Lighting	
		Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity
Day 1 A1	1	2.4	3	2.2	3.1	3.5	3.7	2	1.9	2.4	4.2
	2	2.3	2.8	1.7	3.5	3.4	2.5	1.7	1.4	2	3.4
	3	2.6	3.1	2.4	2.9	3	3.2	1.9	1.7	2.6	4.2
	4	3.3	3.4	1.6	3.2	3.2	3.4	2.3	1.3	2.2	4
	5	2.3	3.2	1.9	3.3	2.8	3.3	2.4	1.6	2.3	4.2
Ave. score		2.58	3.1	1.96	3.2	3.18	3.22	2.06	1.58	2.3	4
S.I			2.90		2.73		3.20		1.76		3.35
Day 2 A2	1	2.3	2.6	2	2.8	2.9	3.1	2.4	2.1	2.9	4
	2	2.7	3.1	1.7	3.7	2.8	3.2	2.5	1.8	2.8	3.8
	3	2.6	3	2	3.1	3.5	3.7	2.3	2	3	3.9
	4	3.1	3.4	2.2	3.3	3.3	3.4	2.2	2.3	2.3	3.7
	5	2.5	3.2	1.7	3.2	3	3.3	1.7	1.9	2.7	4.2
Ave. score		2.64	3.06	1.92	3.22	3.1	3.34	2.22	2.02	2.74	3.92
S.I			2.90		2.73		3.25		2.10		3.47
Day 3 A3	1	2.3	3.1	2.2	3.4	3.4	3.5	2.3	2.1	2.3	3.8
	2	2.4	2.8	1.6	1.6	3.2	3.3	2.1	1.8	2.4	3.7
	3	2.5	2.9	1.9	3.3	3.3	3.5	2.2	2.1	2.1	3.5
	4	3.2	3.5	1.7	3.2	3	3.3	2.3	2.1	2.3	4
	5	2.7	3.1	1.8	3.1	3.4	3.8	2.5	1.4	2.1	4.1
Ave. score		2.62	3.08	1.84	2.92	3.26	3.48	2.28	1.9	2.24	3.82
S.I			2.91		2.51		3.40		2.04		3.22