Research for Community Access Partnership

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Identification of hazardous sites and the recommendation of remedial measures on selected rural roads

FINAL REPORT

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Cover Photo: A typical unpaved low volume road in Ghana.

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ABSTRACT

The overall aim for the Research for Community Access Partnership (ReCAP) programme is to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider international community. Safer roads are critical for the socio-economic development of countries, and Ghana is no exception. Road safety has become a key issue of concern worldwide, as globally nearly 1.3 million people die each year as a result of road traffic crashes; 90 percent of these deaths occurring in developing countries.

In Ghana, on average, 2,000 people die each year through road traffic crashes and this is estimated to cost the nation some 1.6 percent of the Gross Domestic Product (GDP). Most of the road traffic deaths are vulnerable road users who for the most part do not own an automobile and are usually from the poorer rural communities. Roads are essential for reducing poverty as they improve access to markets, health services and employment opportunity; however increased roads and greater motorized traffic does lead to greater road deaths and injuries. The need to prevent road traffic crashes on the road networks and to reduce casualties has therefore become paramount.

The ***overall objective of the project*** is to develop an Accident Blackspot Management System (ABMS) which will form the basis of a coordinated approach to road safety on the rural road network which is the responsibility of the Department of Feeder Roads (DFR), to achieve a reduction in road traffic crashes and casualties.

This Main Report details the completion of road crash data collection, development of strip maps and a crash database for the project. It has clearly been demonstrated that the initial list of hazardous locations identified, based merely on crash frequency must be ranked based on the severity score criterion (weighted by crash severity) in order to identify those sites that warrant further in-depth analysis. Detailed analysis to identify the safety problems at these hazardous locations clearly aided the selection of appropriate and cost-effective countermeasures and that the First Year Rate of Return (FYRR) is an effective appraisal method to be used for prioritizing sites for remedial treatment.

Results showed that the most dominant crash types were ran-off-road, head-on and pedestrian-vehicular crashes, together contributing about 80% of all crashes and traffic casualties. Only 14 sections on the rural road network were identified as hazardous locations and their estimated economic benefits in terms of the first year savings in crash reduction is GHS 863,700 compared to the cost of treatment of the identified locations at GHS173,200, yielding an average FYRR of more than 450%. The country stands to gain enormously if a hazardous location improvement programme is implemented on the rural roads nationwide. The DFR should be supported with funds to treat the 14 identified hazardous locations as a minimum. The main achievements of the project are that a clearly defined ABMS is now in place at the DFR, Ghana; also eight DFR staff with at least a first degree qualification have been trained in the iMAAP cloud software application. Importantly, a methodology for the identification and prioritization of hazardous locations on rural roads for treatment has been set out, together with a list of potential constraints; suggestions for the way forward to accomplish the effective implementation of the project have been developed.

Key words: *hazardous locations; strip maps; iMAAP; stick diagram analysis; crash severity score; first year rate of return (FYRR); road safety countermeasures.*

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ABBREVIATIONS AND ACRONYMS

ABMS	Accident Blackspot Management System
ADMS	Accident Database Management System
AfCAP	African Community Access Partnership
ARF	Accident Reporting Form
BRRI	Building and Road Research Institute
DFR	Department of Feeder Roads
DUR	Department of Urban Roads
DVLA	Driver and Vehicle Licensing Authority
FYRR	First Year Rate of Return
GDP	Gross Domestic Product
GHA	Ghana Highway Authority
GIS	Geographical Information System
GoG	Government of Ghana
GPS	Global Positioning System
HICs	High Income Countries
iMAAP	Internet-based Microcomputer Accident Analysis Package
LMICs	Low-and-Middle-Income Countries
MAAP	Microcomputer Accident Analysis Package
MoT	Ministry of Transport
MRH	Ministry of Roads and Highways
MTTD	Motor Traffic and Transport Department
NRSC	National Road Safety Commission
NRSS	National Road Safety Strategy
PDO	Property Damage Only
ReCAP	Research for Community Access Partnership
ROR	Run Off Road
RSU	Road Safety Unit
TRL	Transport Research Laboratory
UK	United Kingdom
WHO	World Health Organization

EXECUTIVE SUMMARY

The overall aim for the Research for Community Access Partnership (ReCAP) programme is to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider international community. Provision of more roads is critical for the socio-economic development of countries, and Ghana is no exception; however expanded busier networks can also result in greater road crashes and casualties. Road safety has become a key issue of concern worldwide, as globally nearly 1.3 million people die each year as a result of road traffic crashes; 90 percent of deaths occur in developing countries (WHO, 2011).

In Ghana, on average, 2,000 people die each year as a result of road crashes (NRSC, 2015) and this is estimated to cost the nation some 1.6 percent of the country's Gross Domestic Product (GDP) (NRSC, 2011). Most of those dying are vulnerable road users who tend not to be automobile owners and are predominantly from the poorer rural communities (Nantulya, 2003; Nantulya, et al., 2003). The need to prevent crashes and reduce casualties on the road networks has therefore become paramount.

The ***overall objective of the project*** is to develop an Accident Blackspot Management System (ABMS) to result in a coordinated approach to road safety on the rural road infrastructure which is the responsibility of the Department of Feeder Roads (DFR). This ABMS will assist staff to effectively reduce road traffic crashes on the DFR roads.

This Main Report provides background information on the study area, the approved ABMS for DFR and the project deliverables. It details the progress made on the road crash data collection, development of strip maps and the crash database setup for the project. It also details the identification and ranking of the hazardous locations based on the severity weighted score. It covers the analysis and diagnosis of blackspot using the combined procedures of the stick diagram and collision diagram analysis and also site inspections. The proposed cost-effective countermeasures for the locations identified are listed; and results of applying FYRRs as a method to economically appraise and prioritize sites for treatment are set out. Only 14 sites qualified as hazardous locations and had recommended remedial measures selected to improve the safety of these locations.

The main achievements of the project have been that a clearly defined ABMS is now in place at the DFR, Ghana, and that more than five (5) DFR senior staff with a minimum of a first degree qualification have been trained in the iMAAP cloud software applications to effectively manage the system. In addition this ReCAP programme has clearly set out a methodology for the identification and prioritization of hazardous locations on rural roads for treatment. Constraints such as the lack of availability of strip maps or GPS coordinates to effectively reference the locations of crashes on the feeder roads networks and suggestions such as the need for a reliable internet facility for the iMAAP system and funding for the effective implementation, monitoring and evaluation of the project have been set out.

The total first year savings in crash reduction is predicted as GHS 863,700 compared to the total estimated cost of treatment of the 14 hazardous locations of GHS173,200, yielding an average FYRR of more than 450%.This ReCAP programme has clearly demonstrated that huge savings can be derived, if targeted low-cost remedial measures are implemented, which far outweigh the initial construction costs. Indeed, the benefits and economic returns can be enormous if the hazardous location improvement programme is applied nationwide. Thus, AfCAP research and its application has the potential to provide very significant economic returns to the whole country.

It is therefore recommended that the DFR be supported with funds to promptly commence a hazardous location improvement programme across its rural road network, starting with the treatment of the 14 hazardous locations identified, in order for the country to realize the full economic benefits associated with such a programme.

It is also recommended that ABMSs are developed in other African countries to improve road safety on the rural roads.

1.0 INTRODUCTION

1.1 Background

The Research for Community Access Partnership (ReCAP) is a programme of applied research and knowledge dissemination which is a grant funded by the UK Government through the Department for International Development (DFID). The overall programme aim is to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between the participating target countries and the wider international community.

Cardno Emerging Markets (UK) Ltd has been contracted by DFID to manage ReCAP. There are two components under ReCAP: the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). AfCAP is working in twelve African Countries and Ghana is now an active participant.

Roads are critical for the socio-economic development of countries and these need to be provided safely for road users and the communities which the routes link to or pass through; this is also true for Ghana. Road safety has become a key development issue worldwide in view of the high levels of avoidable loss of life occurring and also the significant socio-economic losses associated with road traffic crashes and casualties (Peden, et al., 2004). The World Health Organization (WHO, 2011) reported that nearly 1.3 million people in the world die each year as a result of road traffic crashes, 90 percent of the road deaths occur in Low-income and Middle-Income Countries (LICs and MICs). Road injuries are the third most important cause of deaths in developing countries (Soderlund and Zwi, 1995). In comparison, in the majority of High Income Countries (HICs) road traffic deaths and injuries are reducing despite very high levels of traffic due to the systematic management of and investment in road safety. In HICs a range of measures are actively applied to prevent road traffic crashes and reduce injury severity. There is greater emphasis in HICs on safe road design and construction and a range of effective policies are applied which are formulated based on scientific research; the same cannot be said for most LMICs and this also includes Ghana.

The global road traffic injury fatality rate is highest in Africa at 24.1 per 100,000 population compared with 10.3 in Europe (WHO, 2013; Peden and Krug, 2002).Baguley (2001) also reported that some countries in Africa have high accident risks (per kilometer travelled) up to a hundred times greater than those in the UK, Sweden or Japan for example. In Ghana, on average 2,000 lives are lost every year through road traffic crashes (NRSC, 2015) and crashes are estimated to cost the nation some 1.6% of the Gross Domestic Product (GDP) (NRSC, 2011). Most of the road traffic deaths are vulnerable road users such as pedestrians, users of two-wheelers and passengers of cars and buses (NRSC, 2015). These vulnerable road users tend not to own automobiles and the majority are from the poorer rural communities in society (Nantulya, 2003; Nantulya, et al., 2003).

The need to prevent crashes on the road networks is becoming increasingly important. In Ghana, accident management systems have been put in place to identify blackspots which require treatment on the highways and for roads in the urban centers. A similar system is however not available for the Feeder Roads Network. As a result DFR has identified the need for an Accident Blackspot Management System (ABMS) to assist the identification of hazardous locations and to recommend cost-effective remedial measures on selected rural roads sections for treatment.

1.2 Project Objectives

The ***overall objective*** of the project is to develop an Accident Blackspot Management System for the management of road safety investments on the rural road network under the management of DFR to result in the reduction of road traffic crashes. The other project objectives encompass research, capacity building, and uptake and embedment:

1. The ***research objective*** is to develop an effective model-based management system for the (generally rural) feeder road network. This aims to identify sections with higher road traffic crash rates than at other sections, to assist staff to identify the infrastructure related causes of the crashes by evaluating how the design of the road interacts with traffic to result in accidents.
2. The ***capacity building objective*** is integral to the AfCAP programme requiring that the Consultant engages fully with assigned counterpart staff to ensure that the knowledge developed through the project activities is transferred and entrenched operationally within DFR. Accordingly, a minimum of five (5) counterpart staff were to be trained through a "train-the-trainer" programme; these staff to then undertake ongoing training of additional staff at DFR in the use of the system. This will enable DFR to identify the appropriate interventions to correct design errors at hazardous sections country-wide.
3. The ***uptake and embedment objective*** is a fundamental target for AfCAP. The uptake and embedment of the project is based on the premise that the framework for assessing hazardous rural road sections will be adopted, integrated and expanded into normal DFR operations in every part of the country to promote the safer development and improvement of rural roads in Ghana. This will be facilitated by the five (5) or more DFR trainers trained as part of the project.

1.3 Project Team

This project was implemented by the Building and Road Research Institute (BRRI), of the Council for Scientific and Industrial Research (CSIR), Ghana, in partnership with the Transport Research Laboratory (TRL), United Kingdom (UK).

The project team consisted of 3 key personnel from the BRRI (the Team Leader, a Civil Engineer and a Computer Analyst) and two experts from TRL, UK, composed of a Reviewer (Road Safety Expert) and an IT Specialist to enable access to the iMAAP software and offer training as backstopping technical support services for the successful implementation of the project.

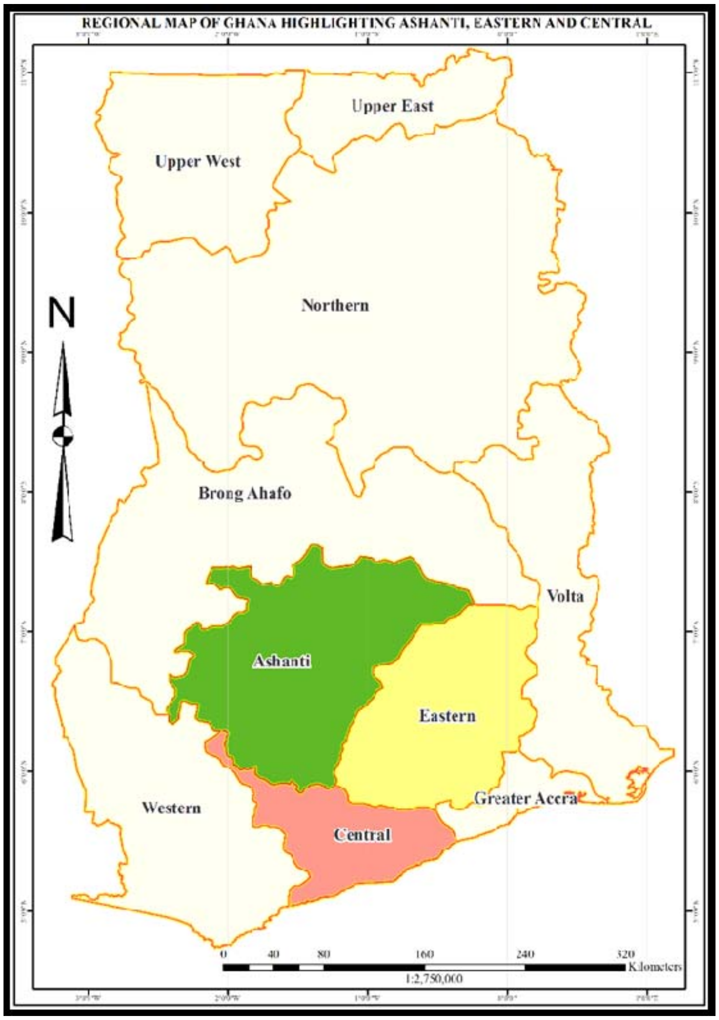
1.4 Study Area

The study was conducted in three of the ten administrative regions of Ghana. The study was piloted in the Ashanti, Central and Eastern regions because these regions are among those with worst crash records in Ghana. Furthermore, their road networks were believed to have high traffic interactions on them and so were likely to have more crashes. Together the study regions cover a land area of 53,538 square kilometers, representing 22 per cent of the total national land area. Based on the 2010 Population Census, the three regions have an overall population of 9,615,397 representing 39 percent of the national total (see Table 1 and Map 1).

The total length of feeder roads in the study area is 12,824km of which the Ashanti region alone has 5,559km (43.4% of the total), the Eastern region, has 4,117km (32.1%) and then the Central Region, has 3,148km (24.5%). These feeder roads are further classified into inter-district, connector and access roads as indicated in Table 1.

Table 1: Profile of the Study Area

Characteristics	Region			Total
	Ashanti	Central	Eastern	
Regional Capital	Kumasi	Cape Coast	Koforidua	
Land Area (sq. km)	24,389	9,826	19,323	53,538
Population (2010 Census)	4,780,380	2,201,863	2,633,154	9,615,397
Pop. density (per sq. km)	196.0	224.1	136.3	179.6
Feeder Road Length (km)	**5,559.5**	**3,147.6**	**4,117.0**	**12,824.1**
Inter-District	2,133.0	1,183.3	1,608.8	4,925.1
Connector	2,174.4	1,247.1	1,716.1	5,137.6
Access	1,252.1	717.2	792.1	2,761.4



Map 1: Map of Ghana showing the study area

1.5 ABMS framework for DFR, Ghana

The first project Stakeholders' Workshop discussed the Accident Blackspot Management System framework, set out in Figure 1, and accepted it to be adopted for the Department of Feeder Roads, Ghana. From international best practices (Risks Solutions, 2012; Bliss and Breen, 2009; Meuleners and Fraser, 2008; Bener, et al, 2003), the ABMS must have supporting institutional arrangements in place, in this case, an established Road Safety Unit (RSU). The RSU must have capacity such as staff trained in road safety management practices, adequate resources with systems for crash (accident) storage and analysis. Appropriate funds need also to be available to manage an accident blackspot improvement programme to reduce road traffic crashes on the rural roads networks.

In summary, the ABMS must have the following interrelated components:

i. A committed Road Safety Unit within the DFR with motivated, trained staff, working in close collaboration with the NRSC, to champion accident blackspot programmes and activities. Accident blackspot management must become an integral operation of the DFR and must be firmly rooted as a regular institutional activity.
ii. A well-functioning accident database system, for accident data collection, analysis and reporting, together with the availability of good quality crash reports. The established access to the iMAAPcloud system at the DFR is essential to the successful implementation of an accident blackspot programme and for wider research. The RSU staff at DFR also requires training in the use of the iMAAP cloud.
iii. Adequate and sustained funding to implement an on-going blackspot improvement programme to reduce the incidence of road traffic crashes on the feeder road networks.

The approved ABMS framework is illustrated in Figure.1.

The benefits of an active Road Safety Unit within the DFR, to champion blackspot programmes and activities are enormous, ensuring continuous and sustainable road safety improvement on the feeder roads in Ghana. For example, this study has shown

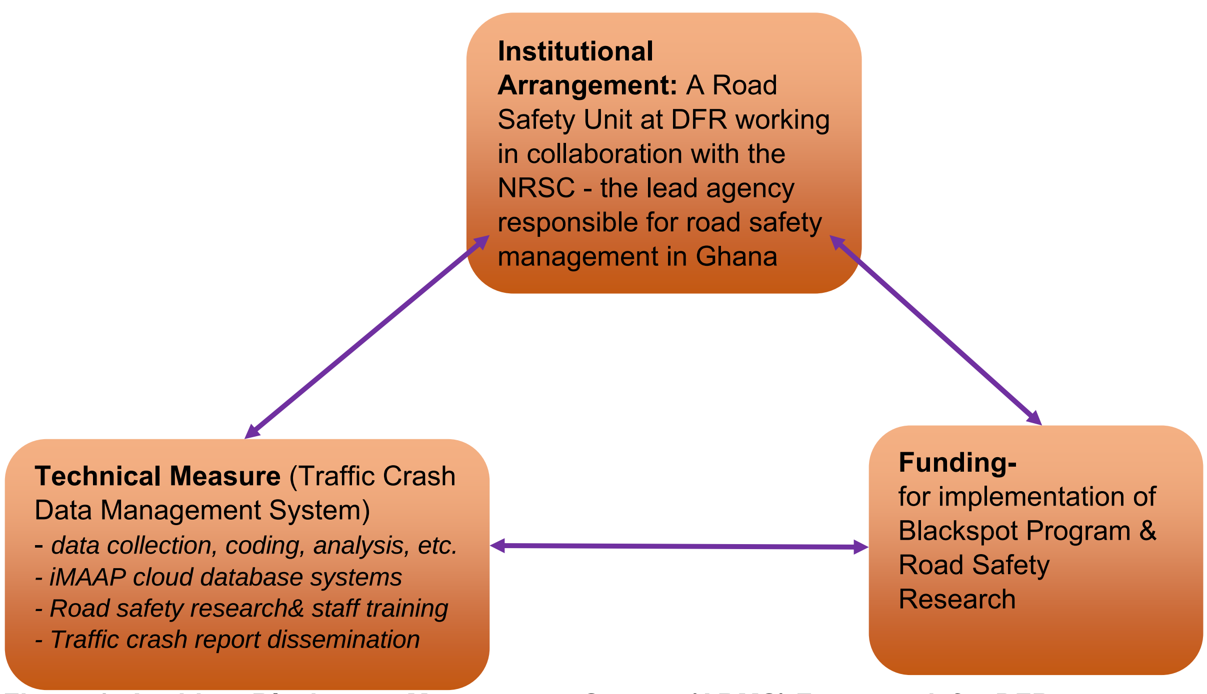


Figure 1: Accident Blackspots Management System (ABMS) Framework for DFR, Ghana

that the economic benefits in terms of traffic crash cost savings for just the first year, on an average, is more than four and half times the construction costs for implementation of low-cost countermeasures at the identified hazardous locations on the rural roads. Furthermore, the scale of the total economic benefits can be enormous if the hazardous locations improvement programme is implemented nationwide.

1.6 Main Project Deliverables

The main deliverables of the project are listed in the following:

- ***Inception Report*** setting out the approach and methodology for implementation of activities relating to the defined scope of work, including a draft framework for an Accident Blackspot Management System for discussion at the first stakeholder workshop. A report to be delivered **4 weeks** from start of the project.
- ***1st Stakeholder Workshop Report*** summarising the views of stakeholders on the inception report which reviewed international blackspot management systems to assess their suitability for Ghana and proposing a draft framework for an ABMS system. The report contained stakeholder inputs on the ABMS framework before a pilot test with field data. The report was to be delivered **6 weeks** from start of the project.
- ***Draft Report*** on the progress of work, achievements made and constraints, and suggestions for the way forward for effective project implementation. The report was to be presented at a stakeholder workshop to discuss the final outcomes of the study and agree on the recommendations for improving on the ABMS for effective use at wider roll-out and application. The report was to be delivered **20 weeks** from start of the project.
- ***2nd Stakeholder Workshop Report*** on the proceedings and outcomes of the stakeholder inputs of the Draft report. This was to be delivered **22 weeks** from start of the project.
- ***User Manual and Training Course notes*** to be prepared for the training of trainers sessions for selected DFR staff. This was to be delivered ***24 weeks*** from start of the project.
- ***Final Report*** to incorporate the outcomes of the stakeholder workshop and other comments. The report is also to include agreed recommendations for improving the ABMS made at the stakeholder workshop. The report is to be delivered **28 weeks** from start of the project.

1.7 Scope of Work for the Project

The scope of work and summary of activities carried out under the project, as shown in Figure 2 included the following:

i. *To propose a framework for Accident Blackspot Management System (ABMS):* this involved a literature review of international ABMSs and discussion of a proposed framework at the first Stakeholder Workshop.
ii. *To develop an accident database for DFR:* this involved collection of traffic crash data on the feeder roads network from the police, coding and entering the data into the iMAAP cloud software to develop a database. Strip maps were also prepared to help reference the crash locations.
iii. *To identify hazardous locations and rank by severity:* hazardous locations were established as locations with clusters of 5 or more crashes on a fixed 5km length of rural road sections. The identified locations were then ranked using their weighted severity scores.
iv. *To analyze and diagnose the hazardous locations:* the identified hazardous locations were analysed using the stick diagram procedure in the iMAAP, collision diagrams

and road inspection to establish the dominant crash types and associated environmental risk factors.

v. *To propose cost-effective countermeasures, evaluate and prioritize the locations for treatment:* based on the dominant crash types identified, low-cost countermeasures were recommended to treat the hazardous locations. The FYRR was then applied as an economic appraisal tool to prioritise the hazardous locations for treatment.

vi. *To organise two stakeholder workshops:* the first stakeholder workshop was organised after approval of the inception report to discuss the proposed ABMS for DFR. The second workshop was also held after approval of the draft report to discuss the report and implementation of the ABMS.

vii. *To develop user manual, training notes and to train selected DFR staff:* a user manual for the iMAAP cloud software was developed for the project highlighting the software applications. Training notes were also prepared for the training of a minimum of 5 DFR staff in the use of the iMAAP software for hazardous location identification.

viii. *To prepare and obtain technical approvals for project reports:* in all, five reports were prepared under the project, which are the Inception report, 1st Stakeholder Workshop report, Draft report, 2nd Stakeholder Workshop report and the Final report.

For this project, only steps 1 – 5 fall under the scope of works and have been described further in the following sections.

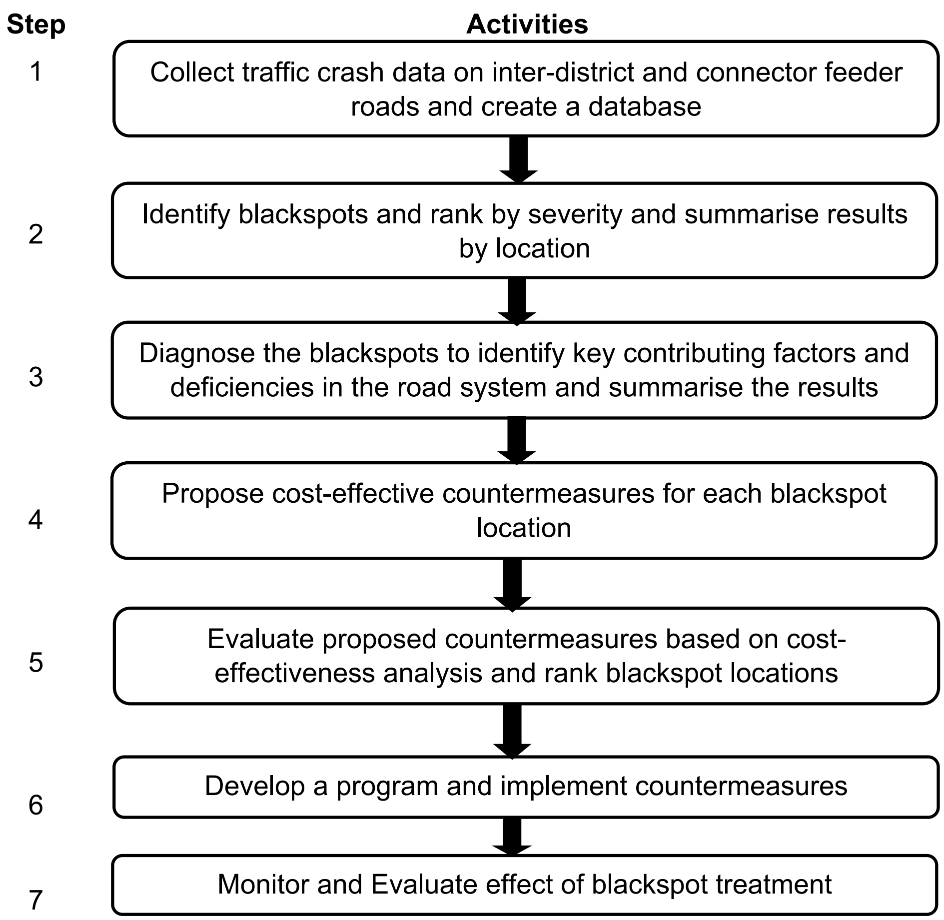


Figure 2: Framework for Accident Blackspot Management for DFR, Ghana

Adapted from Sorensen (2007)

1.8 Report Structure

The Report is set out in two parts: the main report and the annexes. The main report material covers nine chapters in total.

The first chapter presents the general background to the project, highlighting the project objectives, outlining the study area, the approved ABMS framework and the main project deliverables.

Chapter two provides detailed progress made on the road traffic crash data collection and development of strip maps and the crash database for the project.

The identification and ranking processes of the hazardous locations have been described in Chapter three.

Chapter four covers accident blackspot analysis and diagnosis which entails stick diagram analysis, collision diagram analysis and site inspections.

In Chapter five, proposed cost-effective countermeasures for hazardous locations were outlined.

In Chapter six the appraisal of the countermeasures and prioritization of sites for treatment is covered.

A summary of the User Manual guidelines has been provided in Chapter seven.

The achievements made, constraints and suggestions for a way forward have been highlighted in Chapter eight.

Chapter nine provides the conclusions and recommendations for the study.

References identified from the literature searches and key appendices have also been provided.

The Annex to this Main report provides details of the strip maps prepared for the project to help with referencing the locations of road traffic crashes. It has been documented separately as an Annex to this report.

2.0 ROAD TRAFFIC CRASH DATA COLLECTION AND DEVELOPMENT OF CRASH DATABASE

2.1 Field Traffic Crash Data Collection

Road traffic crash data collection for the project has successfully been undertaken by a team of officers from the BRRI in the three study regions, which are Ashanti region, Central region and Eastern region.

The BRRI mobilised two teams to collect the traffic crash data from the various police stations of the Motor Traffic and Transport Department (MTTD) in the study regions. Data collection covered the latest full five-year period, from 2011 to 2015 inclusive. Both teams started together in the Ashanti region, from July 4, 2016 to July 28, 2016 and then worked separately in the Central and Eastern regions from August 15, 2016 to September 8, 2016.

Traffic crash details were extracted from the police dockets and transferred onto standard Accident Reporting Forms (ARFs) for coding in the office and keying into the iMAAP software for storage, management and analysis. The traffic crash data collected from the police contained information on the vehicles involved, the road characteristics, persons involved and general information on the weather, date, region, district, town/village and prevailing traffic control at the collision location.

In all, 423 crashes were retrieved for the 5-year period on the feeder roads networks in the three regions. Ashanti region accounted for 40% of the crashes, Central region (16%) and Eastern region (44%). Appendix 1 provides the distribution of crashes and casualties on the feeder routes in the study area.

2.2 Development of Strip Maps

BRRI developed the strip maps for the project after consultations with the counterpart Engineer at DFR's Head Office for the regional feeder roads maps. Advice and assistance was also obtained from the various Regional Directors and District Engineers for the identification of the various routes for the assignments.

A strip map is a schematic line diagram representation of the roadway showing the key roadside features and kilometer posts which is used for referencing road traffic crashes spatially particularly when GIS mapping and coordinates are not available. A typical strip map is as shown in Figure 3

Route No: AR-OFF-C-034 Route Name: Offinso Old Town Junction to Oboasi Junction

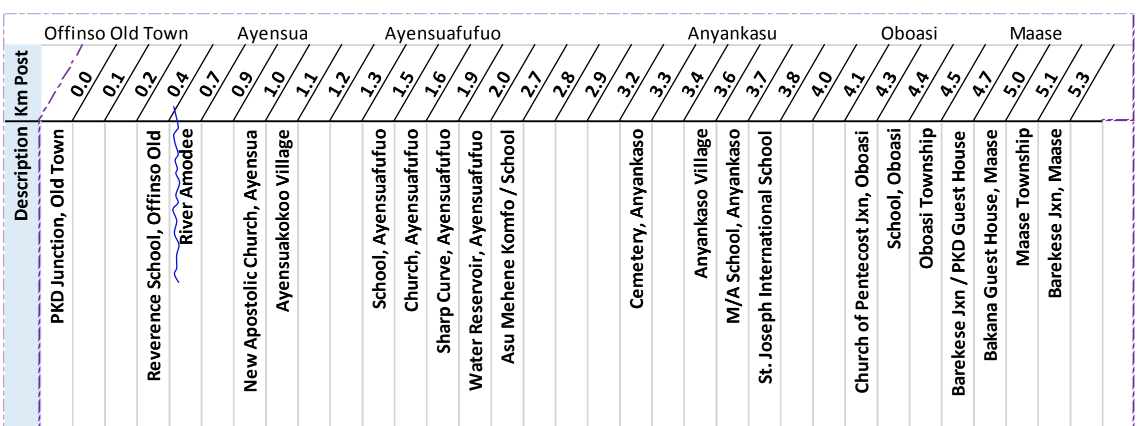


Figure 3: A Typical Strip Map showing kilometer posts and roadside landmarks

Strip maps have been developed for the inter-district and connector road networks, mainly for the routes on which road traffic crashes had occurred. The strip maps were produced by providing detailed information on the route names, route numbers (route ID), kilometer post/chainage, with the addition of significant details such as rivers/streams, junctions, rail crossings and also roadside features such as fuel stations, schools, churches/mosques, police stations/barriers, existing kilometer posts, towns/villages, etc.

On each candidate route, a 4x4 (four wheel) drive vehicle was driven slowly from the beginning to the end of the route. At the beginning chainage (Km 0.0), the odometer reading of the vehicle was set to zero and while driving along the route, all the key road side features at their various distances relative to the beginning chainage were noted given by the odometer recordings of the vehicle. The readings were recorded to the nearest 100m.

In all, 2,270km length of strip maps for 162 routes, requiring roughly six weeks of field work, have been developed under the project for the inter-district and connector rural roads, in addition to other access roads of high importance in the DFR road network system in the 3 study regions. The distribution of road lengths and number of routes surveyed is as shown in Table 2. The lists of inter-district and connector rural roads and some of the accesses which were strip mapped under the project in the study area are shown in Appendix 2. Details of the strip maps are, however, presented separately in the Annex.

Table 2*: Distribution of length and number of routes surveyed for strip maps*

Region	**Inter-district, km *(No. of routes)***	**Connector, km *(No. of routes)***	**Total, km *(No. of routes)***
Ashanti	386 *(30)*	277 *(27)*	**663 (57)**
Central	311 *(19)*	350 *(25)*	**661 (44)**
Eastern	546 *(26)*	400 *(35)*	**946 (61)**
Total	**1243 (75)**	**1027 (87)**	**2270 (162)**

2.3 Traffic Crash Location Referencing

Under the project, each traffic crash has been geo-referenced using the kilometer post from the strip maps as well as by more precise GPS coordinates in eastings (longitudes) and northings (latitudes) by using a '*Garmin Dakota 20'* hand held GPS device.

Currently, in Ghana, a crash location is described by the Police in their report in words giving the road name and the general landmarks nearby. Based on these descriptions and the strip maps, the BRRI team visited the crash sites to establish the crash locations more precisely. Generally, the crash location description information was cross-checked with persons with local knowledge from the towns and villages along the routes. Once the exact location was established, the kilometer post of the crash and the GPS coordinates were then recorded for further processing in the office.

The information on the road traffic crashes and from the strip maps were then transferred onto standard Accident Reporting Forms for coding and were subsequently entered into the iMAAP cloud system via computers for storage, management and analysis.

2.4 Development of Traffic Crash Database for the Rural Roads

A licensed iMAAP (*internet microcomputer accident analysis package*) cloud system, developed by TRL, UK, has been procured under the project for the development and management of road traffic crashes at the DFR.

In line with the contractual arrangements with TRL, UK, the IT Specialist from TRL, Mr. Pradeep Raj Panekkat, visited the project in Ghana during mid-September, 2016 to provide access to the iMAAP cloud system which was licensed for five-user dedicated computers at DFR. Mr Panekkat also customized the software to meet the needs of the local road traffic crash reporting form format as well as offering an initial training to the BRRI/DFR project staff in the software use. The IT Specialist has also linked the iMAAP cloud to the GIS database platform available at the DFR for spatial analysis of road traffic crashes using electronic road mapping.

iMAAP cloud, functioning as a database for the project, has the capabilities to store a large amount of data and to perform diverse detailed road traffic crash analyses. The project team has also transferred all the crashes held in the database at BRRI onto the iMAAP cloud for additional data analysis. Existing road traffic crash records at BRRI are therefore now available in the iMAAP system.

Clearly, the benefit in using TRL's iMAAP cloud software has been with the seamless use of the older MAAP for Windows archive dataset (inclusive of data on the feeder roads and other road networks) held for Ghana, which was transferred easily onto the new iMAAP system allowing its use. In particular, archive crash datasets on the feeder roads have been merged in the new iMAAP system.

3.0 IDENTIFICATION AND RANKING OF HAZARDOUS LOCATIONS

3.1 General considerations for hazardous location identification

The general purpose of hazardous location identification is to identify high traffic crash frequency road sections on a network so that their safety can be improved (Nguyen, et al, 2014). At the identification stage, the object is to select sites that should have a better probability of requiring remedial action which also may be treated in a cost-effective way.

Blackspot or hazardous location identification is primarily about road administration professionals recognizing sites that are deficient either because they were constructed incorrectly or because the design is inappropriate or because the engineered elements have deteriorated becoming dangerous over time (Hauer, 1996).

The correct identification of blackspots which have a higher crash occurrence and a “real” safety problem prevents the waste of resources that may result if “false” locations which do not require treatment are identified. Sorensen (2007) recommended that blackspot management should be ***road crash-based***. Road crash reports are still considered as the best indicator of blackspots and so their identification is still based on the available police traffic crash records in most countries actively managing safety.

Longer time periods of crash data may be used if crash occurrence is generally low since low crash numbers amplifies the random elements in their generation that leads to errors identifying real blackspots. Meuleners and Fraser (2008) indicated that an aggregated crash data period of five (5) years generally provides statistical reliability and should be adopted particularly for low volume roads where traffic exposure is low resulting in low numbers of crashes and casualties, even though the risks can be very high.

In this study, a period of 5 years has been chosen to ensure that there are sufficient crash data to improve statistical reliability for the analysis. A non-statistical model based method of blackspot identification has also been adopted for use for this DFR study because it is simple and the majority of countries in the world still use it (Meuleners and Fraser, 2008).

For this study, the crash criterion based on a minimum of 5 crashes in 5 years for a fixed road section length of 5 km has been adopted for the blackspot identification. This is in line with the practice in Western Australia where black sections are defined as road lengths of more or equal to three kilometers(i.e. ≥ 3km) with an average of one (1) crash per km over 5 years (Meuleners and Fraser, 2008).

3.2 General results from crash analysis

From Table 3, a total of 423 crashes were recorded during the 5-year period on only 92 rural roads classified either as inter-district or connector feeder roads in the three study regions, resulting in an average of 4.6 crashes per route. The table further shows there is an average

Table 3: Distribution of crashes and crash density by region

Attributes	Region			Total/Average
	Ashanti	Central	Eastern	
No. of crashes	169	68	186	423
No. of routes	37	19	36	92
Total route length, km	427	277	329	1033
Avg. route length, km	11.5	14.6	9.1	11.2
Range of route length, km	3.3 - 35.7	3.7 - 27.5	4.4 - 61.0	3.3 - 61.0
Crash density: ***Crashes per route***	4.6	3.6	5.2	4.6
Crashes per km	0.40	0.25	0.57	0.41

route length of 11.2 km and a crash density of 0.41 crashes per km, indicating generally low levels of crashes on the rural road networks.

The average route length in the study area is between 9km and 15km; the crash density per kilometer occurring on the road networks in Ashanti and Eastern regions range from 1.6 to 2.3 times those in the Central region.

The apparent low average density of 0.41 crashes per km is likely the result of low vehicle flows on the routes and also underreporting of crashes to the police. This means the crashes are likely to be dispersed along the routes, thus only relatively few sections of the routes are likely to satisfy the selected blackspot definition of 5km road section with greater than 5 crashes in 5 years.

3.3 Characteristics of crashes and Injuries in the study area

Macroscopic analyses have been carried out to establish the global nature and pattern of crashes and injuries occurring on the road networks for all the inter-district and connector routes and also for the routes where five or more crashes were recorded. Results have also been presented for the road sections identified as hazardous locations (blackspots).

3.3.1 Pattern of crashes on all routes

From Table 4 and Figure 4 the most dominant crashes in the study area are ran-off-road crashes (31.7%), followed by pedestrian crashes (29.3%) and head-on collisions (15.8%). Together, they accounted for 76.7% of all the crashes and 82.8% of all the road traffic casualties. In addition, Figure 4 shows that, generally the crash outcomes of head on and ran off road collisions resulted in more casualties per crash than the other types. This may partly be due to the greater involvement of minibuses and cars in most of these crashes (which carry multiple passengers and can also be overloaded) and the relatively high speeds of these vehicles on impact. The analyses clearly suggest that if these dominant crashes are targeted for road safety improvement the gains would be greatest.

Table 4: Distribution of crashes and casualties by crash type

Crash Type	Region			Total Crashes	%	Total Casualties	%
	Ashanti	Central	Eastern				
Head On	35	10	22	67	15.8	170	19.1
Rear End	10	4	10	24	5.7	44	4.9
Side Swipe	14	4	15	33	7.8	53	5.9
Right Angled	3	3	5	11	2.6	20	2.2
Ran Off Road	40	22	72	134	31.7	400	44.8
Hit parked Veh.	4	3	4	11	2.6	13	1.5
Hit Pedestrian	59	18	47	124	29.3	169	18.9
Hit Animal	0	2	1	3	0.7	7	0.8
Other	4	2	10	16	3.8	16	1.8
TOTAL	**169**	**68**	**186**	**423**	**100.0**	**892**	**100.0**

Source: GHA2076A_ReCAP Blackspot study

It could also be observed from Table 5 and Figure 5 that, approximately 60% of all the crashes were either fatal or serious resulting in 14% deaths and 36% being seriously injured and hospitalized. The low level of slight (27.4%) and property damage only (PDO) crashes (12.3%) compared to fatal and serious crashes when compared to internationally typical ratios indicates high underreporting. Furthermore, the national PDO level of more than 30% suggests under reporting of these non-injury crashes may be greater in the rural locations compared to more built-up areas in Ghana.

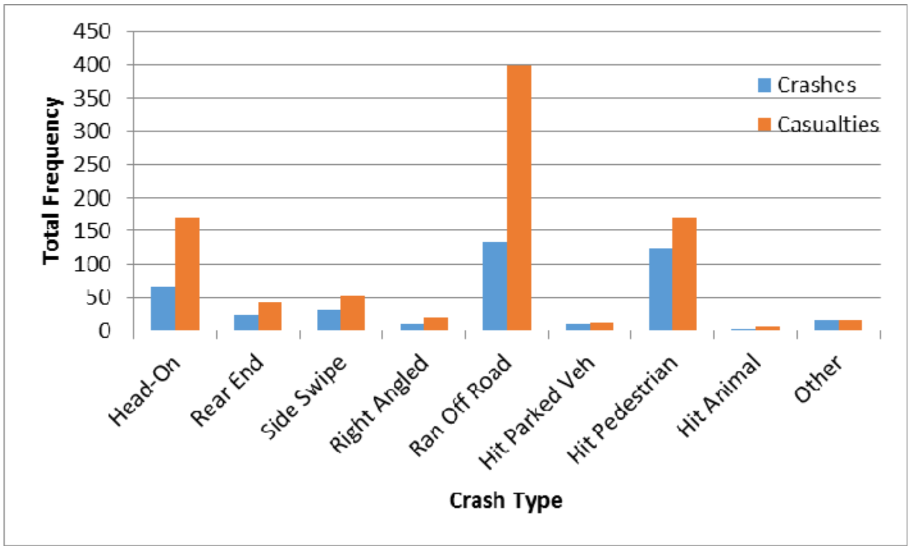
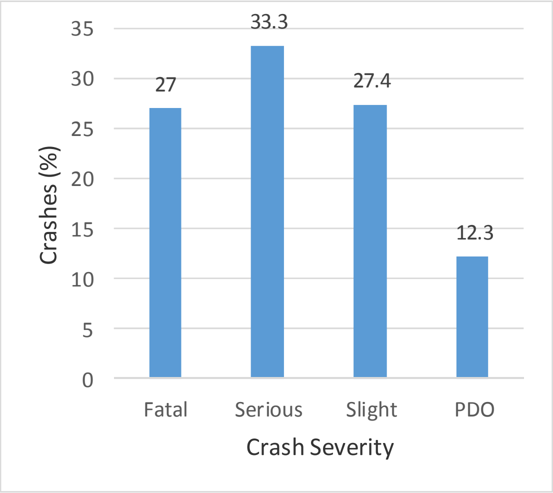


Figure 4: Distribution of Crashes and Casualties showing dominant crash types

Table 5: Regional distribution of crashes and casualties by severity

Region	Crash Severity				Total	Injury Severity			Total
	Fatal	Serious	Slight	PDO		Killed	Serious	Slight	
Ashanti	52	64	38	15	169	56	131	158	345
Central	22	14	21	11	68	27	41	68	136
Eastern	40	63	57	26	186	43	147	221	411
TOTAL	114	141	116	52	423	126	319	447	892
%	**27.0**	**33.3**	**27.4**	**12.3**	**100.0**	**14.1**	**35.8**	**50.1**	**100.0**



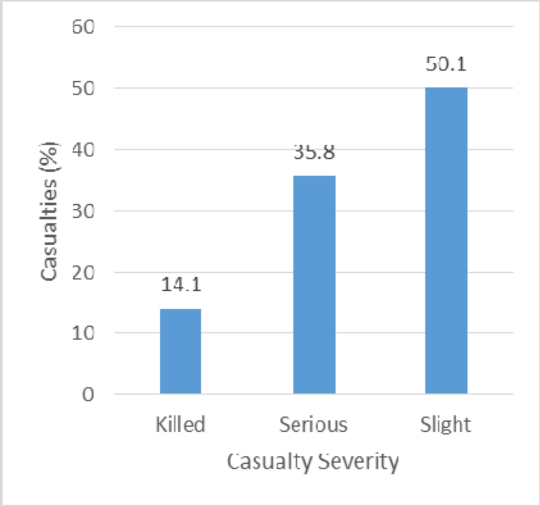


Figure 5: Percentage distribution of a) Crashes and b) Casualties by severity

3.3.2 Pattern of crashes on routes with 5 or more crashes

There were 36 out of the 92 routes representing 39.1% which recorded 5 or more crashes on them. These routes together accounted for 320 crashes (i.e. 75.7% of all the crashes) and 713 casualties, representing approximately 80% of all the road traffic casualties in the study area. Thus, roughly 40% of the routes surveyed produced nearly 80% of all the crashes and casualties on the road networks and these routes were the focus for the blackspots study.

It is also apparent that the ran-off-road, head-on and pedestrian-vehicular crashes were the most dominant crashes making up about 78% of all the crashes on the routes. This may imply that just improving sites on only 36 routes could impact on nearly 80% of crashes and casualties in the study area. As demonstrated in section 6.2, the savings in crash reduction to be derived if low-cost remedial measures are carried out far outweigh the construction costs of implementation, yielding an average FYRR of more than 450%.

3.4 Identification of hazardous locations

The study focused attention on only the 36 routes in the study area which recorded 5 or more crashes for further detailed analysis. For this rural roads study, the hazardous location identification was based on the criteria of 5 crashes or more in 5 years for a fixed road section of 5km, in line with the practice in Australia (Meuleners and Fraser, 2008).

Thus, all the routes whose lengths were more than 10km were subdivided into 5km sections, but routes with lengths less than 10km were maintained as one section. Using the iMAAP Corridor Analysis facility all the sections which produced clusters of 5 or more crashes within the fixed 5km sections were initially considered as hazardous locations for further detailed analysis.

In all, 31 sections on 27 routes, as shown in Table 6, were identified to have clusters of 5 or more crashes and were selected for further examination and ranking based on the crash severity weightings as set out in the next section.

3.5 Ranking of Accident Blackspots by Severity

In spite of the fact that most road safety policies focus concern on reducing the number and severity of injuries, the identification of blackspots is still generally based on the number of crashes.

Sorensen (2007) recommended that crash severity should not be included at the identification stage but rather the severity weighted score of the sites should be used in order to prioritize them for more detailed analysis. Here, it is recommended that severity is taken into account by using a weighting principle where fatal crashes and crashes with more severe injuries are weighted more than crashes with minor injuries and crashes with only property damage. The basis for this is that blackspot sites with severe crashes deserve prior attention, in line with the Safe System approach to road safety policy which seeks to prevent the most serious crashes and casualties as a strong priority. Better economic returns may be achieved at the locations with more severe casualties and crashes occurring making them a higher priority. Elvik (2008) proposed that a hazardous road location should focus on identifying sites at which fatal and serious injury crashes are over-represented.

During the first Stakeholders' Workshop at DFR, it was discussed and agreed that the project adapt the Belgian formula as set out in Elvik, (2008), for ranking the hazardous locations by crash severity. A weighting score of 5 points was set for a fatal crash, 3 points for a serious (hospitalized) crash and 1 point for a minor or damage only crash. The formula based on severities becomes:

$P = 5(X) + 3(Y) + Z$, where

X = total number of fatal crashes

Y = total number of serious crashes

Z = total number of slight/property damage only crashes

A site is said to be a hazardous location when the crash severity score (P), calculated using the formula, equals 20 or more, representing a site with at least 2 fatal and 3 serious crashes during the 5-year period. This was further discussed and agreed upon during the Second Stakeholders Workshop under the project.

Table 6: Unranked road sections initially identified as hazardous locations

Category	No.	Route	Route Name	Road Section Identified	No of Crashes	Route Length (km)
Routes with Length <10km And having 5 or more crashes	1	AR-EJB-I-030	Bonwire Jxn to Bonwire	2.0 – 3.5 km	5	3.5
	2	AR-ADW-C-032	Akrofuom Jxn to Jxn	0.0 – 4.7 km	5	4.8
	3	AR-OFF-C-045	Namong Jxn to Offinso Jxn	1.7 – 4.8 km	8	4.8
	4	AR-OFF-C-034	Offinso Old Town Jxn to Oboasa Jxn	1.6 – 5.1 km	9	5.3
	5	ER-EAK-C-011	Apapam to Kyebi Low Cost	0.0 – 4.6 km	11	5.7
	6	ER-YIL-C-015	Sikabeng to Obawale Jxn	0.2 – 5.4 km	6	6.7
	7	AR-KWB-C-011	Ahodwo Jxn to Ahodwo	2.7 – 4.8 km	5	7.4
	8	AR-AAN-C-049	Akwasiase Jxn to Mamfo	1.0 – 7.1 km	6	7.5
	9	AR-SKE-I-001	Akrofonso Jxn to Wioso	2.5 – 8.5 km	9	8.9
	10	CR-ASI-I-005	Besease to Bedum	1.3 – 8.9 km	7	9.7
Routes with Length equal or more than 10km And having 5 or more crashes	11	AR-ASE-C-051	Boanim Jxn to Amanase Jxn	0.3 – 4.5 km	5	10.0
	12	AR-KWB-I-014	Hemang to Kona	1.8 – 6.2 km	6	11.0
	13	AR-AKS-C-042	Morso Jxn to Krofa	7.7 – 10.1 km	5	12.5
	14	CR-AGO-I-007	Duakwa to Kokoado	A. 0.2 – 4.5 km B. 6.1 – 10.4 km	6 5	13.1
	15	AR-AKN-I-032	Konongo to Dickson	0.5 - 3.1 km	6	15.6
	16	CR-GOM-C-048	Fawomanye to Ekotsi	14.0 – 14.7 km	5	16.6
	17	AR-KWB-I-018	Edwinase Jxn (Atimatim Jxn) to Kwamang	0.6 – 4.6 km	20	17.2
	18	ER-BIS-I-042	Akim Manso to Osenase	8.8 – 12.3 km	6	18.1
	19	CR-AES-C-001	Awutu Bereku to Obrakyire	11.6 – 13.6 km	5	19.1
	20	ER-WAK-I-024	Osenase to Apinamang	A. 0 – 3.5 km B. 3.9 – 9.1km	13 5	20.1
	21	ER-KWA-C-003	Bawdua Jxn to Takyiman	A. 0.5 – 4.9 km B. 5.6 – 9.6 km	7 7	23.4
	22	CR-KEE-I-015	Bando Jxn to Ekutuase	1.6 – 4.2 km	5	23.7
	23	ER-BIS-I-049	Akim Swedru to Apoli Ningo Jxn	1.7 – 5.0 km	10	25.2
	24	AR-ASE-I-041	Wiamoase Jxn to Kofiase	10.6 – 15.7 km	5	27.6
	25	ER-KWA-I-025	Kade to Ofoase	A. 27.6 – 29.7 km B. 33.1 – 36.5 km	11 10	37.9
	26	AR-SKE-C-020	Drobonso Jxn to Drobonso	6.5 – 8.2 km	5	33.6
	27	ER-AWS-I-001	Adoagyir to Oworam	2.9 – 6.9 km	9	35.4

Source:GHA2076A_ReCAP Blackspots study

By this selection criterion, the most serious crash locations generating more fatal and serious crashes and casualties were ranked ahead of locations with less severe crashes for further appropriate analysis and treatment. Appendix 3 gives detail information on the ranked blackspot sections.

3.6 Results of crash severity score

The formula for the crash severity score (P) has been applied to rank the road sections identified as hazardous locations and the results have been summarized into Table 7.

From Table 7, only 14 out of the 31 sections met the hazardous location identification criterion which was set for "P", being 20 or more, which therefore qualified sites as candidates for further analysis and diagnosis. As expected and intended most locations with fewer crashes or less severe crashes did not meet the criterion and were therefore not selected.

Of the 14 hazardous locations identified, 8 locations were from the Eastern Region and 6 locations from the Ashanti Region. There was none from the Central Region. Thus Regions with higher crash density (crashes per km) produced the most identified hazardous locations.

Table 7: Ranking of Identified Hazardous Locations Based On Crash Severity Score

No.	Route No.	Route Name	Km Post		Crash Severity					Length of Route	Section Length	Crash Severity Score,'P'	Region	Severity Index (S.I.)
			From	To	Fatal	Hospitalized	Injured Not-Hospl.	Dam	Total					
1	AR-KWB-I-018	EdwinaseJxn(AtimatimJxn) to Kwamang	0.6	4.6	4	7	6	3	**20**	17.2	4.0	50	Ashanti	2.5
2	AR-OFF-C-034	Offinso Old Town Jxn to OboasaJxn	1.6	5.1	4	4	1	0	**9**	5.3	3.5	33	Ashanti	3.7
3	AR-SKE-I-001	AkrofonsoJxn to Wioso	2.5	8.5	4	2	3	0	**9**	8.9	6.0	29	Ashanti	3.2
4	ER-KWA-I-025	Kade to Ofoase	27.6	29.7	4	1	5	1	**11**	37.9	2.1	29	Eastern	2.6
5	ER-EAK-C-011	Apapam to Kyebi Low Cost	0.0	4.6	1	7	2	1	**11**	5.7	4.6	29	Eastern	2.6
6	ER-AWS-I-001	Adoagyir to Oworam	2.9	6.9	3	1	3	2	**9**	35.4	4.0	23	Eastern	2.6
7	AR-AKN-I-032	Konongo to Dickson	0.5	3.1	2	4	0	0	**6**	15.6	2.6	22	Ashanti	3.7
8	ER-KWA-I-025	Kade to Ofoase	33.1	36.5	1	4	2	3	**10**	-	3.4	22	Eastern	2.2
9	ER-KWA-C-003	BawduaJxn to Takyiman	0.5	4.9	2	3	2	0	**7**	23.4	4.4	21	Eastern	3.0
10	ER-KWA-C-003	BawduaJxn to Takyiman	5.6	9.6	2	3	2	0	**7**	-	4.0	21	Eastern	3.0
11	ER-WAK-I-024	Osenase to Apinamang	0.0	4.1	1	1	7	6	**15**	20.1	4.1	21	Eastern	1.4
12	AR-KWB-I-014	Hemang to Kona	1.8	6.2	3	1	2	0	**6**	11	4.4	20	Ashanti	3.3
13	ER-YIL-C-015	Sikabeng to ObawaleJxn	0.2	5.4	2	3	0	1	**6**	6.7	5.2	20	Eastern	3.3
14	AR-AAN-C-049	AkwasiaseJxn to Mamfo	1.0	7.1	1	5	0	0	**6**	7.5	6.1	20	Ashanti	3.3
15	AR-EJB-I-030	BonwireJxn to Bonwire	2.0	3.5	3	1	0	1	**5**	3.5	1.5	19	Ashanti	3.8
16	CR-ASI-I-005	Besease to Bedum	1.3	8.9	2	2	2	1	**7**	9.7	7.6	19	Central	2.7
17	CR-AES-C-001	AwutuBereku to Obrakyire	11.6	13.6	3	0	2	0	**5**	19.1	2.0	17	Central	3.4
18	ER-BIN-C-019	Chia to Akokoaso	2.2	8.1	2	1	3	0	**6**	8.8	5.9	16	Eastern	2.7
19	ER-BIS-I-042	AkimManso to Osenase	8.8	12.3	0	5	1	0	**6**	18.1	3.5	16	Eastern	2.7
20	AR-OFF-C-045	NamongJxn to OffinsoJxn	1.7	4.8	0	4	4	0	**8**	4.8	3.1	16	Ashanti	2.0
21	AR-ASE-I-041	WiamoaseJxn to Kofiase	10.6	15.7	1	3	1	0	**5**	27.6	5.1	15	Ashanti	3.0
22	AR-ASE-C-051	BoanimJxn to AmanaseJxn	0.3	4.5	0	5	0	0	**5**	10	4.2	15	Ashanti	3.0
23	ER-BIS-I-049	AkimSwedru to ApoliNingoJxn	1.7	5.0	0	2	3	5	**10**	25.2	3.3	14	Eastern	1.4
24	CR-AGO-I-007	Duakwa to Kokoado	6.1	10.4	2	0	2	1	**5**	13.1	4.3	13	Central	2.6
25	AR-SKE-C-020	DrobonsoJxn to Drobonso	6.5	8.2	2	0	2	1	**5**	33.6	1.7	13	Ashanti	2.6
26	CR-GOM-C-048	Fawomanye to Ekotsi	14.0	14.7	2	0	1	2	**5**	16.6	0.7	13	Central	2.6
27	AR-ADW-C-032	AkrofuomJxn to Jxn	0.0	4.7	1	2	1	1	**5**	4.8	4.7	13	Ashanti	2.6
28	CR-AGO-I-007	Duakwa to Kokoado	0.2	4.5	1	1	4	0	**6**	13.1	4.3	12	Central	2.0
29	AR-AKS-C-042	MorsoJxn to Krofa	7.7	10.1	0	2	3	0	**5**	12.5	2.4	9	Ashanti	1.8

30	CR-KEE-I-015	Bando Jxn to Ekutuase	1.6	4.2	0	1	3	1	**5**	23.7	2.6	7	Central	1.4
31	AR-KWB-C-011	AhodwoJxn to Ahodwo	2.7	4.8	0	1	2	2	**5**	7.4	2.1	7	Ashanti	1.4
		Total			**53**	**76**	**69**	**32**	**230**	**433.2**	**117.4**	**594**		

4.0 ACCIDENT BLACKSPOTS ANALYSIS AND DIAGNOSIS

The main object of accident blackspot investigation and diagnosis is to carry out detailed analysis to identify patterns in crash features which may relate to associated risk factors (i.e. why the crashes occurred and why the injury outcomes are serious) for the various sites.

The philosophy underlying the approach is that the occurrence of frequent/excessive road traffic crashes can indicate safety problems which are likely to result in more injuries in the future if nothing is done. Also similarities in crash circumstances may indicate and help to diagnose a common underlying (and ideally treatable) contributory problem which is resulting in the excessive incidents.

The detailed traffic crash analysis and diagnosis has been based on:

i. Stick diagram analysis,
ii. Collision diagram analysis, and
iii. Road inspections

4.1 Stick Diagram Analysis

The iMAAP cloud software was used in carrying out the stick diagram analysis for the 14 blackspots identified (as per section 3.6 above). The stick diagram analysis provided a ready means of carrying out an in-depth analysis of the crashes characteristics at each of the identified blackspots. It greatly assisted in the identification of the nature of crashes and common patterns in the crash features and the key contributing factors to the occurrence of the crashes. The strength of the analysis is that it very clearly, visually displays selected incident factors such as the following list which can be searched by eye for patterns more easily than looking through the records and field codes:

- Crash type
- Crash severity
- Total number of crashes and casualties
- Crash location indicating route number and kilometer- post
- Crash by time of day, month and year
- Crash circumstances, lighting, road surface condition, etc.
- Total number of crashes and casualties within each severity type
- Vehicles involved and such other parameters specified

A typical stick diagram analysis showing the sticks and results is presented in Figure 6.

4.2 Summary results from stick diagram analysis

The information obtained from the analysis of the identified blackspots has been summarized and presented into Table 8. The raw data for the stick diagram analyses are presented in Appendix 4.

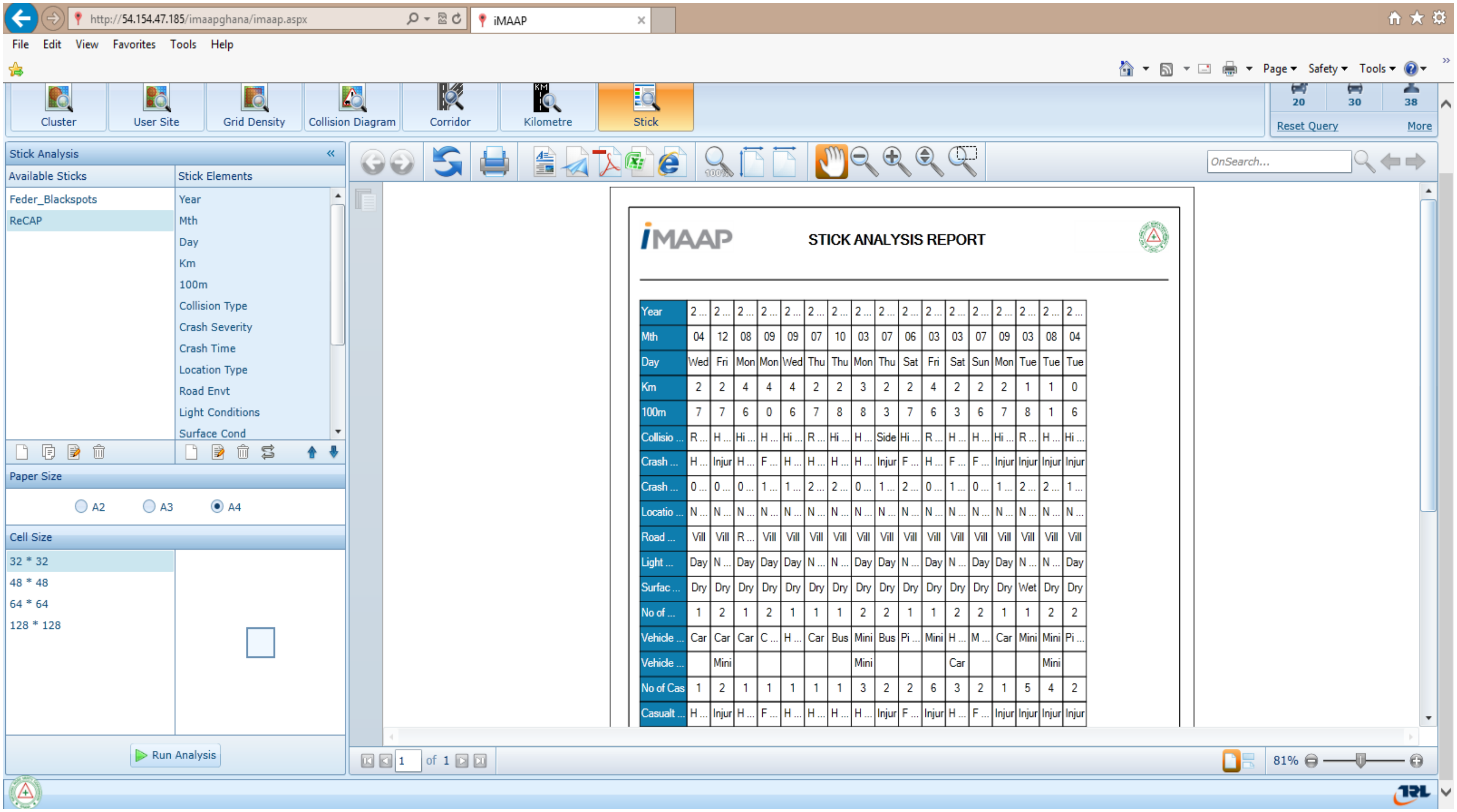


Figure 6: A typical stick diagram analysis

Table 8: Summary results from the stick diagram analysis

No.	Route Name and Code	Km Post	Total Crashes & Crash Severity	Total casualties & Casualty severity	Collision Types	Vehicles involved	Environmental Factors	Dominant Crash Types
1	Edwinase Jxn (Atimatim Jxn) to Kwamang AR-KWB-I-018	0.6-4.6	**20 Crashes** 4 Fatal, 7 Hospitalized, 6 Non-hospitalized, 3 Property damage only	**38 Casualties** 5 Killed 11 Hospitalized 22 Not-Hospitalized	8 Head on (40%) 4 Ran off (20%) 4 Hit Pedestrian (20%). 1 Hit Parked vehicle (5%) 1 Side swipe (5%) 1 Hit object (5%)	Minibus (43.4%) Car (33.3%) HGV (6.7%) Pick-ups (6.7%) Motorcycle (3.3%) Bicycle (3.3%) Bus (3.3%)	Village (100%); Day (50%), Night (50%); Dry (95%), Wet (5%).	Head on (40%) Ran- Off (20%) Hit pedestrian (20%)
2	Offinso Old Town Jxn to Oboasa Jxn AR-OFF-C-034	1.6-5.1	**9 Crashes** 4 Fatal, 4 Hospitalized, 1 Non-hospitalized	**10 Casualties** 4 killed, 4 Hospitalized, 2 Non-hospitalized.	5 Hit Pedestrian (55.5%), 2 Other (22.2%), 1 Ran off (11.1%), 1 Head on (11.1%).	4 Cars (36.4%), 3 HGV (27.3%), 2 Minibus (18.2%), 1 Pickup (9.1%), 1 Bicycle (9.1%).	Villages (100%); 6 Day (66.7%), 3 Night (33.3%); Dry (100%).	Hit Pedestrian (55.5%)
3	Akrofonso Jxn to Wioso AR-SKE-I-001	2.5-8.5	**9 Crashes** 4 Fatal, 2 Hospitalized, 3 Non-hospitalized	**32 Casualties** 4 Killed, 14 Hospitalized, 14 Non-hospitalized.	4 Ran off (44.4%), 3 Hit Pedestrian (33.3%), 1 Rear end (11.1%), 1	8 Cars (80%), 1 HGV (10%), 1 Bicycle (10%).	Village (100%); Day (100%); Dry (100%).	Ran off (44.4%), Hit Pedestrian (33.3%).

					Other (11.1%).			
4	Kade to Ofoase ER-KWA-I-025	27.6-29.7	**11 Crashes** 4 Fatal, 1 Hospitalized, 5 Non-hospitalized, 1 Property damage only	**16 Casualties** 4 Killed, 2 Hospitalized, 10 Non-hospitalized.	4 Ran off (36.4%), 2 Head on (18.2%), 2 Hit Pedestrian (18.2%), 2 Hit Parked Veh (18.2%), 1 Side swipe (9.1%).	7 Motorcycle (43.8%), 5 Cars (31.3%), 2 Minibus (12.5%), 2 HGV (12.5%).	Villages (100%); 10 Day (90.9%), 1 Night (9.1%); Dry (100%).	Ran off (36.4%), Head on (18.2%), Hit Pedestrian (18.2%), Hit Parked Vehicle (18.2%).
5	Apapam to Kyebi Low Cost ER-EAK-C-011	0.0-4.6	**11 Crashes** 1 fatal, 7 hospitalized, 2 Non-hospitalized, 1 Property damage only	**12 Casualties** 1 Killed, 8 Hospitalized, 3 Non-hospitalized.	2 Side swipe (18.2%), 2 Head on (18.2%), 2 Rear end (18.2%), 2 Hit Pedestrian (18.2%), 2 Other (18.2%), 1 Right Angle (9.1%).	9 Cars (47.4%), 3 Pickup (15.8%), 2 Motorcycle (10.5%), 2 Bicycle (10.5%), 1 HGV (5.3%), 1 Minibus (5.3%), 1 Other (5.3%).	10 Villages (90.9%), 1 Rural (9.1%); 10 Day (90.9%), 1 Night (9.1%); Dry (100%).	Sideswipe (18.2%), Head on (18.2%), Rear end (18.2%), Hit Pedestrian (18.2%), Other (18.2%).
6	Adoagyir to Oworam ER-AWS-I-001	2.9-6.9	**9 Crashes** 3 Fatal, 1 Hospitalized, 3 Non-hospitalized, 2 Property damage only	**17 Casualties** 3 Killed, 7 Hospitalized, 7 Non-hospitalized.	4 Ran off (44.4%), 2 Head on (22.2%), 1 Rear end (11.1%), 1 Side swipe	8 Cars (61.5%), 3 HGV (23.1%), 1 Pickup (7.7%), 1 Motorcycle	Village (100%); 6 Day (66.7%), 3 Night (33.3%); Dry (100%).	Ran off (44.4%), Head on (22.2%).

					(11.1%), 1 Other (11.1%).	(7.7%).		
7	Konongo to Dickson AR-AKN-I-032	0.5-3.1	**6 Crashes** 2 Fatal, 4 Hospitalized	**12 Casualties** 2 Killed, 10 Hospitalized	2 Head on (33.3%), 1 Sideswipe (16.7%), 1 Rear end (16.7%), 1 Hit Pedestrian (16.7%), 1 Other (16.7%).	3 Motorcycle (30%), 2 Bicycles (20%), 1 Pickup (10%), 1 Car (10%), 1 Minibus (10%), 1 Tractor (10%), 1 HGV (10%).	Villages (100%); Day (83.3%), 1 Night (16.7%); Day (100%).	Head on (33.3%)
8	Kade to Ofoase ER-KWA-I-025	33.1-36.5	**10 Crashes** 1 Fatal, 4 Hospitalized, 2 Non-hospitalized, 3 Property damage only	**13 Casualties** 1 Killed, 5 Hospitalized, 7 Non-hospitalized.	3 Head on (30%), 2 Hit Pedestrian (20%), 2 Ran off (20%), 1 Rear end (10%), 1 Hit Animal (10%), 1 Other (10%).	7 Motorcycle (50%), 2 Cars (14.3%), 2 HGV (14.3%), 1 Minibus (7.1%), 1 Tractor (7.1%), 1 Pickup (7.1%).	7 Villages (70%), 3 Rural (30%); Day (100%); Dry (100%).	Head on (30%), Hit Pedestrian (20%), Ran off (20%).
9	Bawdua Jxn to Takyiman ER-KWA-C-003	0.5-4.9	**7 Crashes** 2 Fatal, 3 Hospitalized,	**10 Casualties** 2 Killed, 4 Hospitalized,	4 Hit Pedestrian (57.1%), 2	4 Cars (44.4%), 2 Motorcycle	4 Villages (57.1%), 3 Rural (42.9%);	Hit Pedestrian (57.1%)

			2 Non-hospitalized	4 Non-hospitalized	Right Angle (28.6%), 1 Ran off (11.1%)	(22.2%), 1 Minibus (11.1%), 1 Bicycle (11.1%), 1 HGV (11.1%).	4 Day (57.1%), 3 Night (42.9%); Dry (100%).	
10	Bawdua Jxn to Takyiman ER-KWA-C-003	5.6-9.6	**7 Crashes** 2 Fatal, 3 Hospitalized, 2 Non-hospitalized	**14 Casualties** 2 Killed, 6 Hospitalized, 6 Non-hospitalized	3 Ran off (42.9%), 2 Hit Pedestrian (28.5%), 1 Head on (14.3%), 1 Sideswipe (14.3%)	5 Cars (55.5%), 3 Motorcycle (33.3%), 1 Minibus (11.1%).	6 Villages (85.7%), 1 Rural (14.3%); 6 Day (85.7%), 1 Night (14.3%); Dry (100%)	Ran off (42.9%), Hit Pedestrian (28.5%)
11	Osenase to Apinamang ER-WAK-I-024	0.0-4.1	**15 Crashes** 1 Fatal, 1 Hospitalized, 7 Non-hospitalized, 6 Property damage only	**24 Casualties** 1 Killed, 1 Hospitalized, 22 Non-hospitalized	11 Ran off (73.3%), 2 Hit Pedestrian (13.3%), 1 Sideswipe (6.7%), 1 Hit object off road (6.7%).	9 Cars (56.25%), 4 Minibus (25%), 1 Motorcycle (6.25%), 1 Pickup (6.25%), 1 Other (6.25%)	12 Villages (80%), 3 Rural (20%); 12 Day (80%), 3 Night (20%); Dry (100%).	Ran off (73.3%)
12	Hemang to Kona AR-KWB-I-014	1.8-6.2	**6 Crashes** 3 Fatal, 1 Hospitalized, 2 non-hospitalized	**26 Casualties** 3 Killed, 7 Hospitalized, 16 Non-hospitalized	3 Ran off (50%), 1 Hit object on road (16.6%), 1 Hit Pedestrian (16.6%), 1 Hit Parked Veh	2 Cars (28.5%), 1 Pickup (14.3%), 1 Motorcycle (14.3%), 1 HGV (14.3%), 1	6 Village (100%), 3 Day (50%), 3 Night (50%), 6 Dry (100%)	Ran off (50%)

					(16.6%)	Bus (14.3%), 1 Minibus (14.3%)		
13	Sikabeng to Obawale Jxn ER-YIL-C-015	0.2-5.4	**6 Crashes** 2 Fatal, 3 Hospitalized, 1 Property damage only	**35 Casualties** 2 Killed, 9 Hospitalized, 24 Non-hospitalized	4 Ran Off (66.6%), Head on (16.7%), 1 Hit Pedestrian (16.7%)	2 Tractor (28.6%), 2 Minibus (28.6%), 1 HGV (14.3%), 1 Bus (14.3%), 1 Motorcycle (14.3%)	3 Rural 50%, 3 Village 50%, 5 Day (83.3%), 1 Night (16.7%), 6 Dry (100%).	Ran Off (66.6%)
14	Akwasiase Jxn to Mamfo AR-AAN-C-049	1.0-7.1	**6 Crashes** 1 Fatal, 5 Hospitalized	**9 Casualties** 1 Killed, 7 Hospitalized, 1 Non-hospitalized	1 Sideswipe (16.7%), 2 Head-on (33.3%), 3 Hit pedestrian (50%)	1 Tractor (11.1%), 1 Pickup (11.1%), 3 Car (33.3%), 1 Bicycle (11.1%), 3 Motorcycle (33.3%)	2 Rural 33.3%, 4 Village 66.7%, 6 Day 100%, 6 Dry 100%.	Hit Pedestrian (50%), Head-on (33.3%).

Source: GHA2076A_ReCAP Blackspots study

4.3 Collision Diagram Analysis

A collision diagram is a way to display the main crash characteristics spatially at a particular blackspot site. It gives an indication of which traffic crash situations are most frequent and may be over-represented at the hazardous road location. An over-representation of a given crash pattern can indicate that there is a safety problem with a common cause which may be treated by engineering improvement (or potentially enforcement measures or education approaches).

A typical collision diagram is as presented in Figure 7.

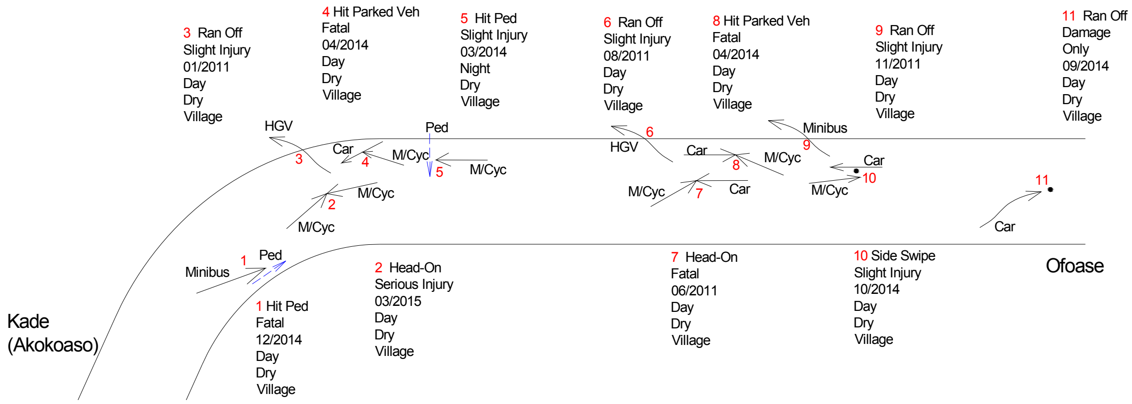


Figure 7: A typical collision diagram showing crash types and prevailing circumstances

Generally, the collision diagram presents a pictorial view indicating among other things the following:

- Collision Type
- Crash Severity
- Month/Year of crash occurrence
- Day/Night situation
- Surface Condition of road at time of the crash
- Village/Rural environment
- Vehicle Type Involved

The collision diagrams were developed based primarily on the police sketches and these were studied in combination with the stick diagrams to make an informed judgment on ***why*** and ***how*** the crashes occurred.

4.4 Road Inspections

The desk based analyses were supplemented by site inspections. This is an important process to help identify problems, which were not readily apparent from the accident analyses, including inappropriate road user behavior or interactions at the locations. The issues that can be identified by site inspection may be due to features of the road layout or road maintenance issues. A checklist was developed to assist with the site inspections.

The site inspections picked up issues such as road narrowing; particularly at bends, and poor safety resulting from inadequate routine maintenance practices were frequently observed problems. There was also the general lack of basic road safety features such as signage and pavement markings on the roads to inform, warn and guide drivers. In addition, sight distances for safe driving were frequently obstructed by overgrown vegetation. For this study, all the hazardous locations were identified to be on the paved sections of the feeder roads, albeit that these sections were sometimes poorly maintained.

5.0 PROPOSED COST-EFFECTIVE COUNTERMEASURES FOR HAZARDOUS LOCATIONS

The development of the blackspot treatment follows the detailed accident analysis stage. This stage develops proposals for specific treatments which should result in the reduction of the crashes occurring at the hazardous sites. These fixes are specified based on the patterns identified during the investigation stage and identification of common risk factors which may be contributing to the crash occurrence (Elvik, 2007). Simple low-cost or cost-effective remedial measures have been proposed to treat the blackspots taking into account the observed problems/accident patterns and the related deficiencies observed during the site inspection of the road traffic crash location for each site.

The proposed cost-effective countermeasures for each hazardous road location were selected based on their potential to improve the safety of the identified location (Hendrie, Meuleners and Fraser, 2008; SweRoad, 2001; Ogden,1994).The proposed countermeasures for each crash type were selected from Table 9.

Table 9: Possible low-cost countermeasures for treatment of given crash types

General Safety Problem	Low-cost countermeasures for paved rural roads	Low-cost countermeasures for unpaved rural roads
Head on	Mark centreline; provide curve ahead signs; Repair potholes; Trim overgrown vegetation to improve sight lines; Speed controls in settlements	Provide curve ahead signs; Trim overgrown vegetation to improve sight lines; Speed control in settlement areas; Repair erosion gullies and failed local spots
Skidding/slipperiness	Restore surface texture; Resurfacing; Improve drainage	Improve earth drains; Restore surface texture; maintain failed local sections
Collision with roadside objects	Remove objects; Better delineation; Install crash barrier or fencing	Remove objects from road; install crash barrier or fencing with delineators at sharp bends
Side swipe	Mark centreline; Repair potholes and road edge failures; Trim overgrown vegetation to improve sight lines	Trim overgrown vegetation to improve sight lines/distance; Maintain failed sections
Pedestrian- vehicular crashes	Speed controls (speed humps) in settlement areas; Signing and marking of pedestrian crossing areas; Walkways; Pedestrian guardrails	Speed control (speed hump made of earth) in settlement areas; signing of critical pedestrian crossing points
Loss of Control (run - off road)	Speed controls; Crash barriers; Chevron signs; curve ahead signs; Install delineators; Improve alignments; Superelevation; Trim vegetations	Crash barriers; Chevron signs; curve ahead signs; Improve alignments and critical sections; Trim vegetations to improve sight lines
Night-time crashes	Better delineation; Reflective road markings and signage; Street lighting; Improved sight lines	Better delineation; street lighting; Improved sight lines and signage
Poor visibility	Trim or remove vegetation; realignment; improved sight lines.	Trim or remove vegetation; realignment; improved sight lines.

Adapted from Hendrie, Meuleners and Fraser (2008); SweRoad (2001); Ogden (1994)

6.0 APPRAISAL OF COUNTERMEASURES AND PRIORITISATION OF SITES FOR TREATMENTS

6.1 Economic appraisal of proposed countermeasures

The proposed countermeasures are expected to reduce both the crash number and injury severity at the hazardous locations once implemented. The economic appraisal of the countermeasures requires that estimations of the expected costs and potential benefits of the proposed safety measures are known. The benefits are the savings (in monetary value) expected from the reduction in the number and severity of traffic crashes. Typically, these are calculated by using the Crash Reduction Factor or Crash Modification Factor which is the average percentage or proportion reduction in crashes (accidents) achieved by applying the particular measure (see Appendix 5). The costs for the safety measures are primarily the capital cost of initial implementation and maintenance costs for following years which is required for some appraisal approaches.

Multiplying the number of crashes which are estimated to be saved by the monetary value of the crash prevention gives the benefits expected from implementing the measure. Appraisal compares the scale of the costs of implementation of the treatment with the expected savings from the anticipated crash reductions. This gives the First Year Rate of Return (FYRR).

The FYRR was computed as follows:

$$\text{FYRR} = \frac{\textit{expected savings gained from proposed countermeasures}}{\textit{estimated total implementation costs}}$$

6.2 Prioritisation of hazardous locations for treatment

The restricted funding available for the program for improving hazardous locations limits the number of sites that may be treated at any time. Therefore, it is imperative to prioritise between sites and safety measures in order to use the limited funds as effectively as possible.

Prioritisation of the identified blackspots for treatment was based on their expected First Year Rate of Return. This is an economic indicator that is simple to use. If the FYRR is positive then benefits in the very short term (i.e. even in the first year after implementation) are expected. The higher the FYRR, the better and greater the economic savings predicted. For the study, only the top 14 worst hazardous locations were further ranked in the order of their FYRRs.

For computing the FYRR, the physical costs of the proposed interventions were obtained from the Ghana Highway Authority (GHA) Road Safety Unit at their Head Office, Accra, and the expected savings from anticipated crash reductions were derived from current international best practices (SweRoad, 2001; Bahar, et al., 2008; Jateikiene, et al., 2016) and research works locally done by BRRI on the national cost of accidents where crash costs by severities had been developed (Afukaar, et al, 2006). The accident cost figures were adjusted to current monetary values for the computations.

A Microsoft Excel spreadsheet was used for the computation of the FYRR as a prioritisation tool for the ranking of the hazardous road locations for treatment. The prioritised list is as shown in Table 10.

Table 10: Prioritised list of hazardous locations for treatment based on the FYRR

No.	Hazardous Location			Dominant Crash Type	Recommended Countermeasures	Accident Savings (GH₵)	Construction Cost (GH₵)	FYRR (%)
	Route Name	Route Code	Km Post					
1	Kade to Ofoase	ER-KWA-I-025	27.6 -29.7	Head On	Advance Warning Signs and Centreline Markings	90,513.11	6,200.00	1,460
2	Konongo to Dickson	AR-AKN-I-032	0.5 - 3.1	Head On	Advance Warning Signs and Centreline Markings	58,630.40	6,200.00	946
3	EdwinaseJxn (AtimatimJxn) to Kwamang	AR-KWB-I-018	0.6 - 4.6	Hit Pedestrian	Traffic Calming (Speed humps) and Signage	122,416.79	15,693.50	780
				Head On	Advance Warning Signs and Centreline Markings			
4	Offinso Old Town Jxn to OboasaJxn	AR-OFF-C-034	1.5 - 5.9	Hit Pedestrian	Traffic Calming (Speed humps) and Signage	109,204.25	14,240.25	767
5	BawduaJxn to Takyiman	ER-KWA-C-003	5.6 - 9.6	Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings	67,961.40	12,346.75	550
				Hit Pedestrian	Traffic Calming (Speed humps) and Signage			
6	AkrofonsoJxn to Wioso	AR-SKE-I-001	2.5 - 8.5	Hit Pedestrian	Traffic Calming (Speed humps) and Signage	91,779.07	17,093.50	537
				Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings			
7	Adoagyir to Oworam	ER-AWS-I-001	2.9 - 6.9	Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings	55,267.47	10,700.00	517
				Head On	Advance Warning Signs and Centreline Markings			

8	AkwasiaseJxn to Mamfo	AR-AAN-C-049	1.0 - 7.1	Hit Pedestrian	Traffic Calming (Speed humps) and Signage	48,433.66	12,593.50	385
				Head On	Advance Warning Signs and Centreline Markings			
9	Hemang to Kona	AR-KWB-I-014	1.8 - 6.2	Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings	77,332.02	22,800.00	339
10	Osenase to Apinamang	ER-WAK-I-024	0.0 - 4.1	Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings	24,217.38	7,600.00	319
11	Kade to Ofoase	ER-KWA-I-025	33.1 -36.5	Head On	Advance Warning Signs and Centreline Markings	45,137.47	15,693.50	288
				Hit Pedestrian	Traffic Calming (Speed humps) and Signage			
12	BawduaJxn to Takyiman	ER-KWA-C-003	0.5 - 4.9	Hit Pedestrian	Traffic Calming (Speed humps) and Signage	40,957.16	14,240.25	288
13	Apapam to Kyebi Low Cost	ER-EAK-C-011	0.0 - 4.6	Head On	Advance Warning Signs and Centreline Markings	17,203.17	12,593.50	137
				Hit Pedestrian	Traffic Calming (Speed humps) and Signage			
14	Sikabeng to ObawaleJxn	ER-YIL-C-015	0.2 - 5.4	Ran Off	Advance Curve Signs, Chevron Signs, Centreline Markings	14,649.11	15,200.00	96
	Average					**61,693.03**	**13,085.34**	**471**

Source: GHA2076A_ReCAP Blackspots study FYRR - First Year Rate of Return 1US$=GHS4.00 (Nov.2016)

6.3 Summary results of the economic analysis

Table 10, shows that the total estimated accident savings for just the first year if all the 14 hazardous locations are treated is about GHȻ863,700 compared to the total construction costs of about GHȻ173,200. The average FYRR is 471% making implementation of the whole blackspot improvement programme highly viable.

This ReCAP programme has clearly demonstrated that huge savings to be derived, if low-cost remedial measures are carried out, far outweigh the construction costs of implementation, yielding on average FYRR which is more than 450%. This implies that the estimated savings in crash reduction for the first year are predicted to be over four and half times the costs of construction of the proposed countermeasures. Indeed, the benefits and economic returns can be extremely significant if similar safety improvements can be applied across the rural roads nationwide.

This ReCAP study has also brought to the fore how research and its application can provide major economic returns and savings to the country. Thus, adoption of a scientific approach applied for the identification, ranking (based on the crash severity score criterion) and recommendation of appropriate low-cost remedial measures is the most desirable path to ensuring a successful accident blackspot improvement programme in Ghana. The clearly defined ABMS which is now in place at the DFR puts the Department in a good position for effectively tackling road traffic crashes on the rural road networks in Ghana.

7.0 SUMMARY OF USER MANUAL GUIDELINES FOR THE iMAAP

This is a summary of the user manual guidelines for the iMAAP. The complete manual has been made available to the project.

This iMAAP User Guideline has been provided with detailed description of various features of the iMAAP Accident Database Management System (ADMS). This document serves as a guide for its users for understanding the purpose and usage of the features.

The User Manual/Guidelines basically provides detailed information on the ADMS and it covers:

- The System Administration of the Database
- Accident Record Form
- Query system
- Map
- Analysis
- Reports
- Dashboards and Auditing

System Administration

Information on access to the system where iMAAP is implemented has been provided under this module in the User Manual. The Department configuration represents the various organizational units which access the system controlling general user permissions. Administrators are given the opportunity to setup organizational units for different departments which stakeholders work in as well as creating user accounts with password protection.

Also, information on the Application Settings of the iMAAP ADMS which is used to configure the various important parameters such as Date and Time Format, Maximum Number of Query Results, Display of Record Validity etc. have been provided.

Accident Record Form

The manual gives information on the accident record form built in the iMAAP ADMS and it includes information on:

- Viewing accident forms– used to view/search crash details captured in the iMAAP system.
- Accident data list search panel – This enables users to search for crashes based on Report number, Police Station, Region, Severity, ‘From Date’ and ‘To Date’ etc.
- Entry of New/Edit/Delete Accident Records – This is where a user can enter, edit or delete any crash record details.

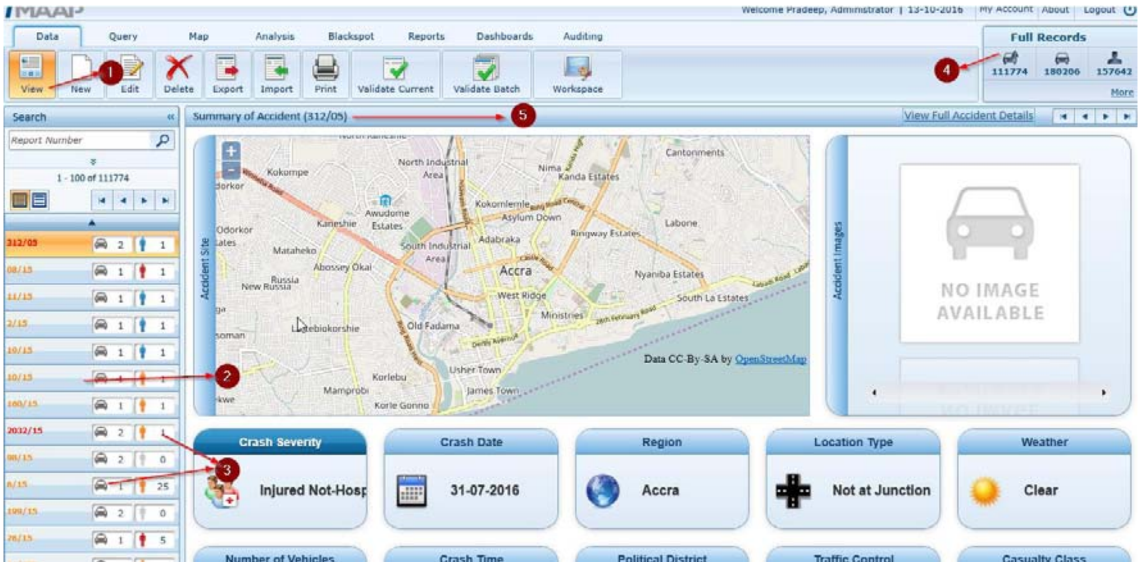


Figure 8: View Screen of iMAAP

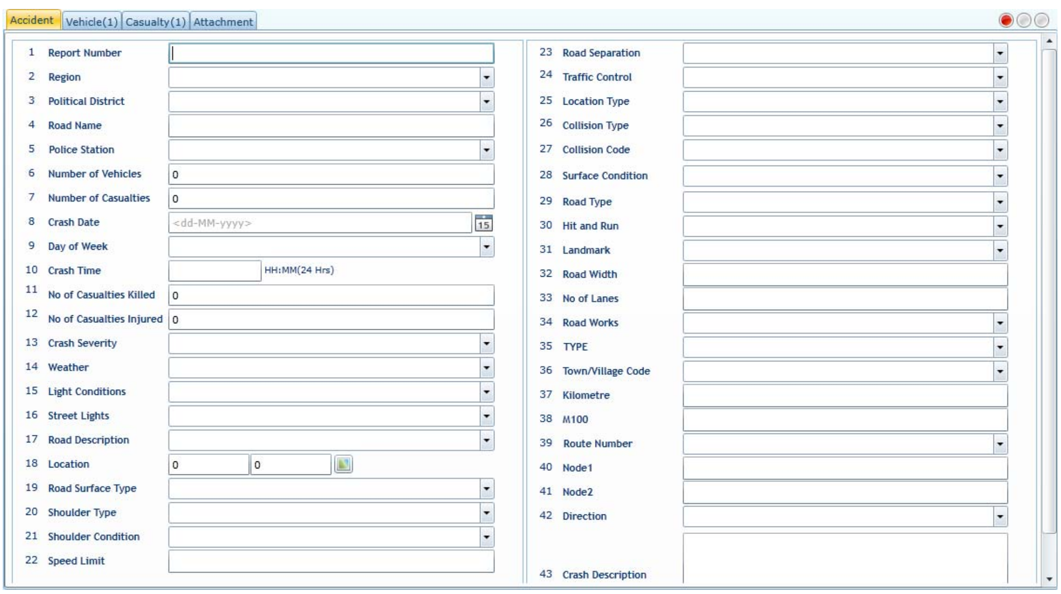


Figure 9: Accident Form

Figure 10: Vehicle Form

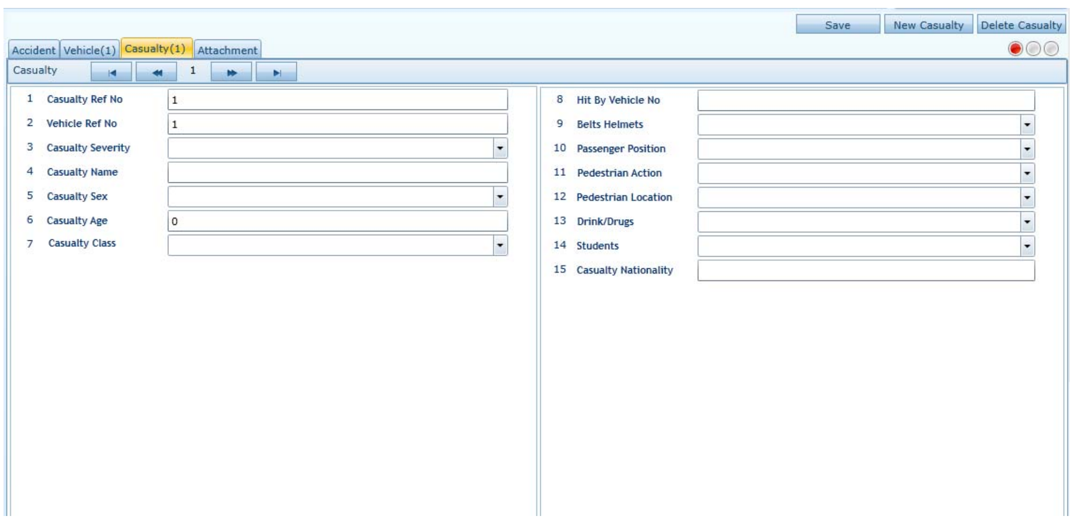


Figure 11: Casualty Form

- Exporting Accident Records – The iMAAP system has the functionality to export all fields from the accident/vehicle/casualty records. The export interface enables the user to export accident records in a number of predefined formats as shown in Figure 12 below.

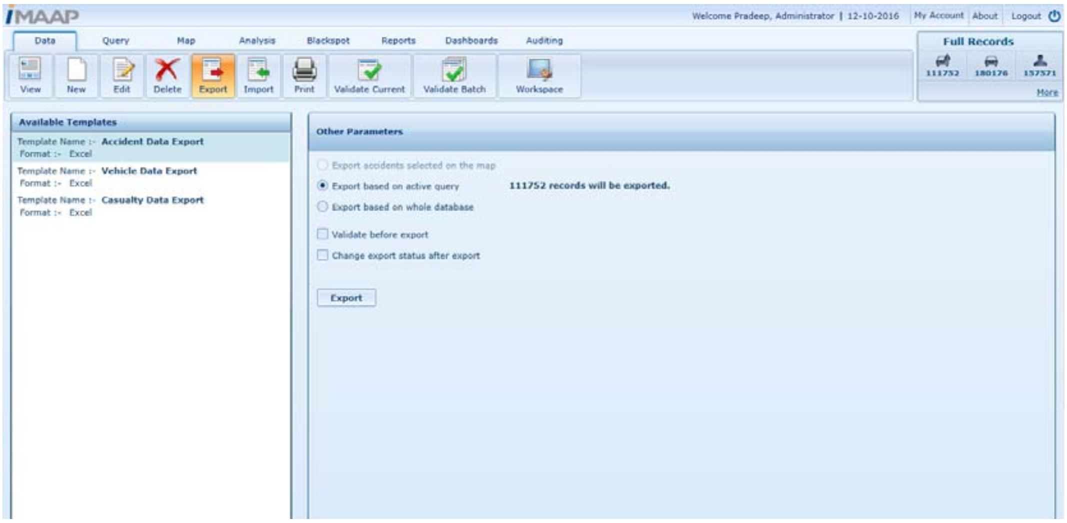


Figure 12: Exporting Accident Records

- Importing – The application allows users to import crash records from a file in a predefined template format into database.

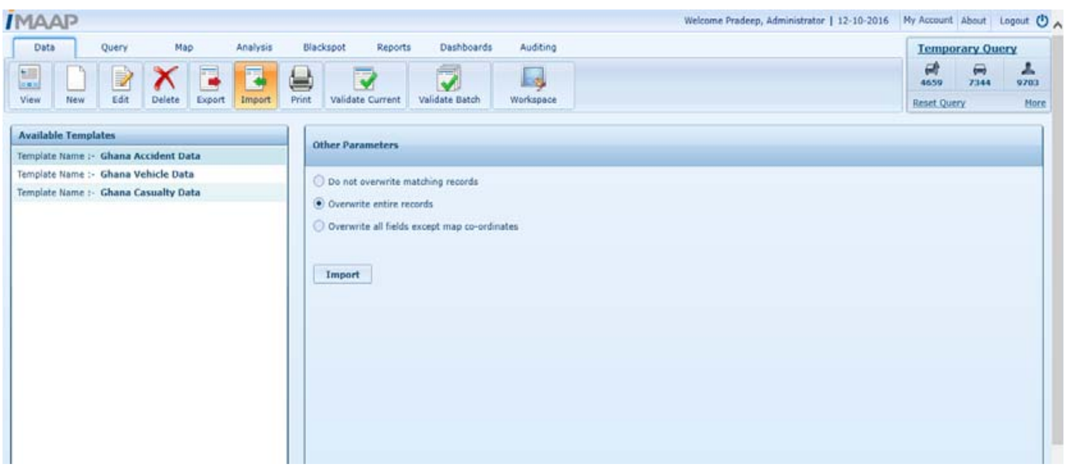


Figure 13: Importing Records

- Printing Accident Records – The user can export, zoom and print selected crash records using the print functionality. Exports to RTF, XPS, PDF, Excel or Html are the options available to the user.

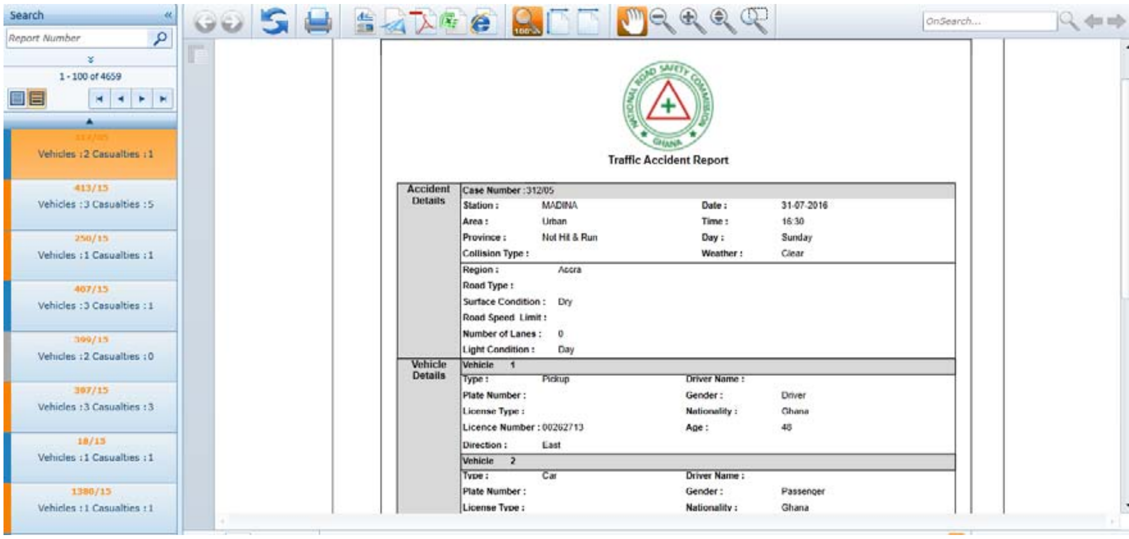


Figure 14: Print Screen

- Validating Current Record – In the View/Edit Mode, the Validate Current has been provided to validate the quality of the crash data against the set of predefined validation rules configured in the administration section.

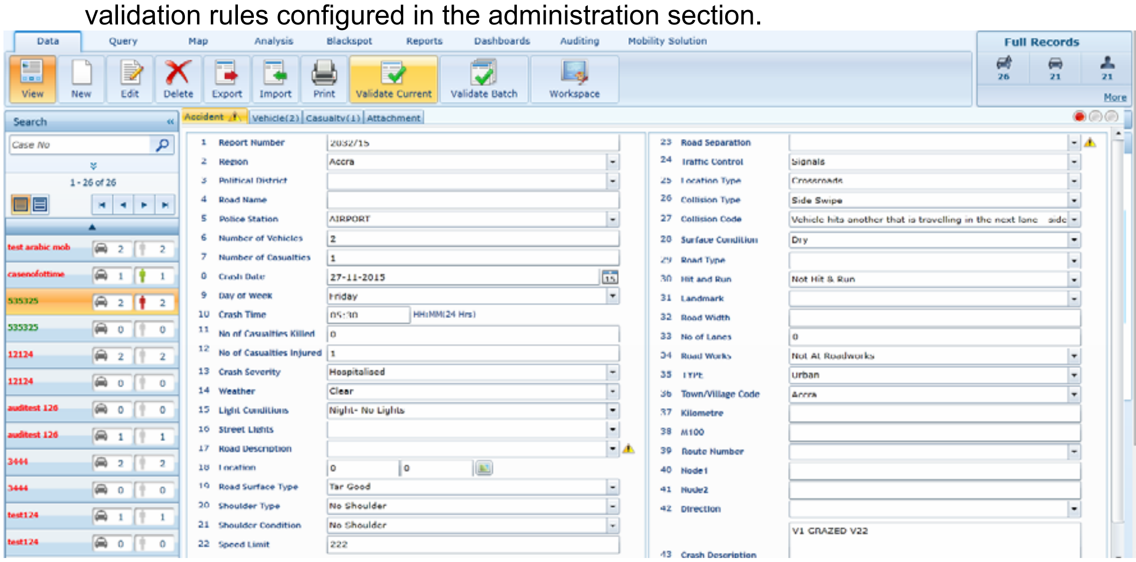


Figure 15: Validate Current Button

- Validating a group of Accident Records – The Validate Batch performs validation of a group of crash records current from a query.
- Workspace – The workspace under the data tab consists of different dashboard charts configured during the localisation of iMAAP.
- Workspace – The workspace under the data tab consists of different dashboard charts configured during the localisation of iMAAP.

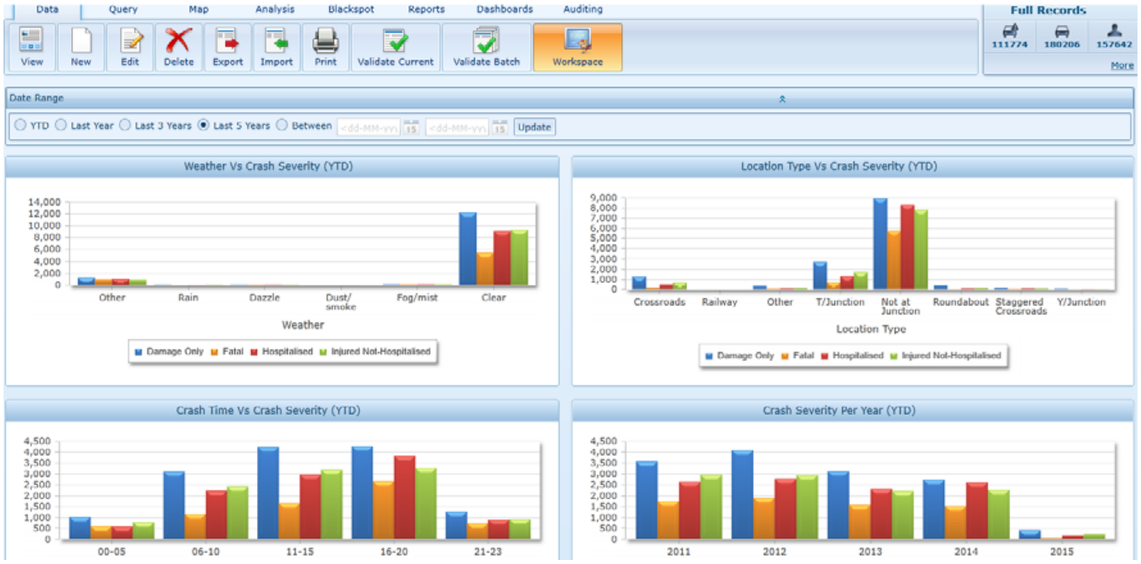


Figure 16: Workspace

Query(s)

The Query Builder allows the user to build more complex queries using the form and from field values. The system provides an option to the users to build their own queries to filter the data based on field values. The field values could be year of crash occurrence, specific police station, and fatal crashes only etc.

A query is the combination of various conditions. The user will be able to perform the following in the Query Builder module:

- Creating a query
- Saving queries
- Executing or running queries
- Deleting queries
- Executing saved queries
- Deleting saved queries
- Reset Query and
- Browse including searching of crash records

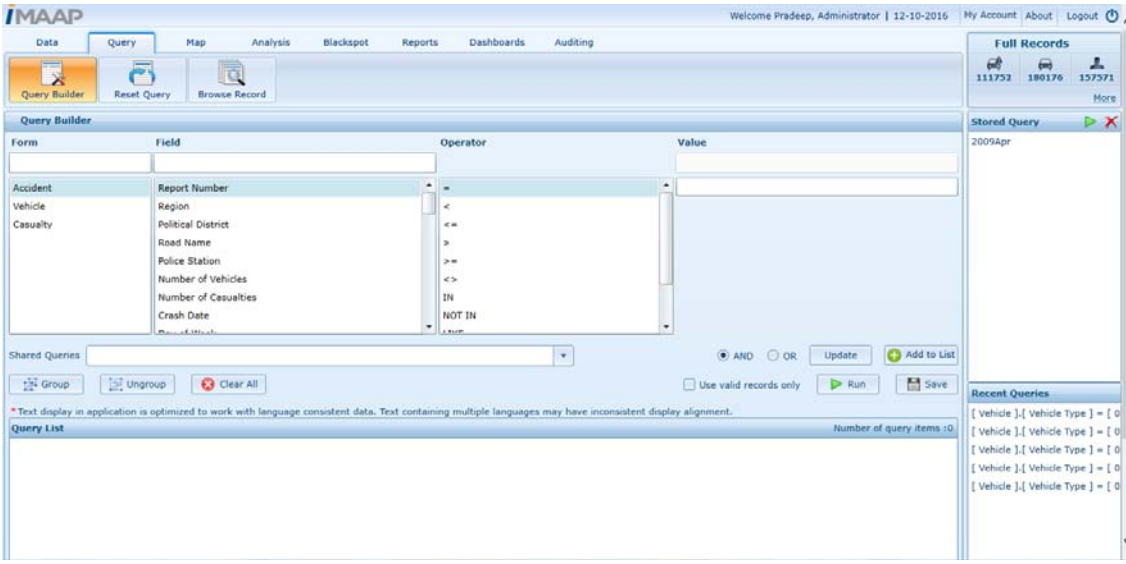


Figure 17: Query Builder

Map

Show Map

The Map Viewer interface is used to show the map and the user can perform GIS related analysis of the accident records using this tool. The controls in the Map Viewer Screen includes

- Dragging
- Zooming
- Viewing Crash History
- Showing Crash Information
- Measuring Distance and Area
- Select Feature
- Plotting of Current/All Crashes in the Map
- Selection of Crashes by either rectangle, polygon or circle controls

Functionalities such as print, export are incorporated in the map viewer.

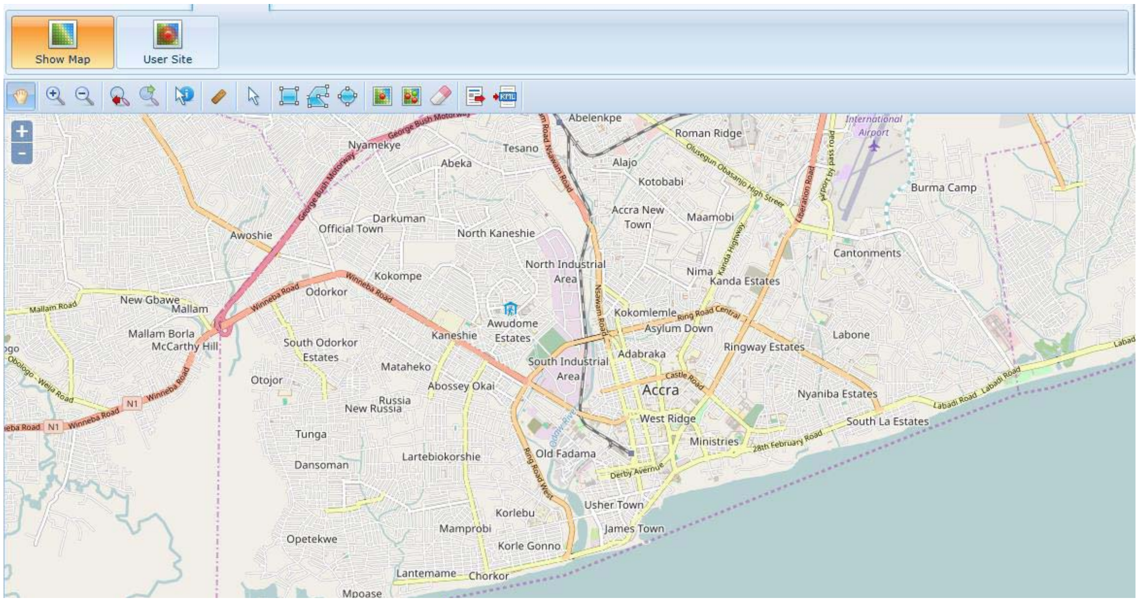


Figure 18: Show Map Screen

Monitor Site/User Site

Monitor site is a feature where the user can create a polygon or shape selection site and save it for future uses. A site is an area on the map marked by the user. The commands in the monitor site interface include creating layer, creating site and deleting layer and site.

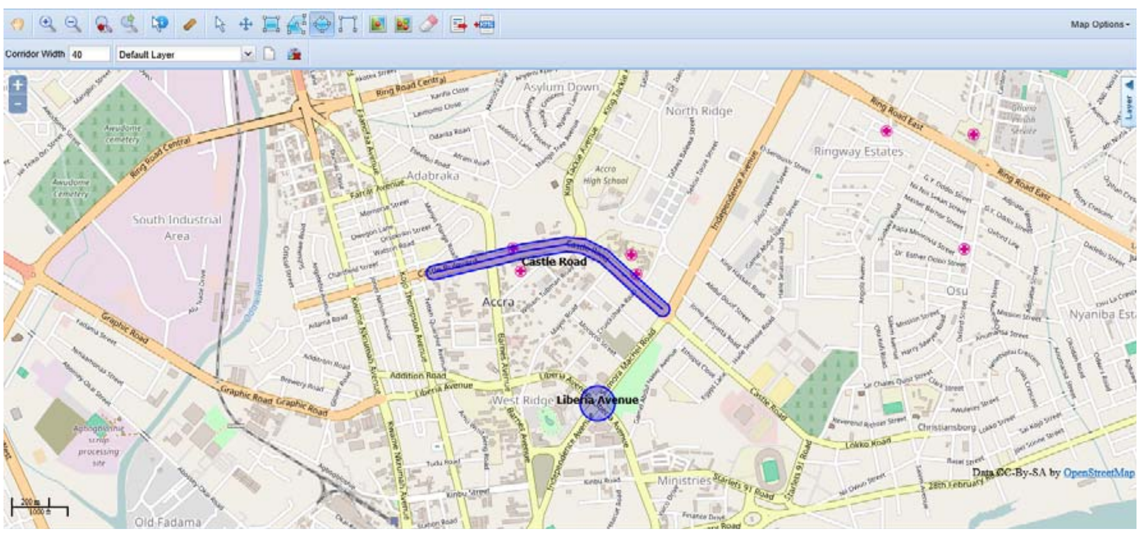


Figure 19: Monitor Site Screen

Analysis

The iMAAP application package has several modules and functions for analysing crashes. It Includes:

- Cluster Analysis
- Collision Diagram

- Kilometer Analysis
- Grid Density Analysis
- User Site Analysis
- Stick Analysis
- Corridor Analysis

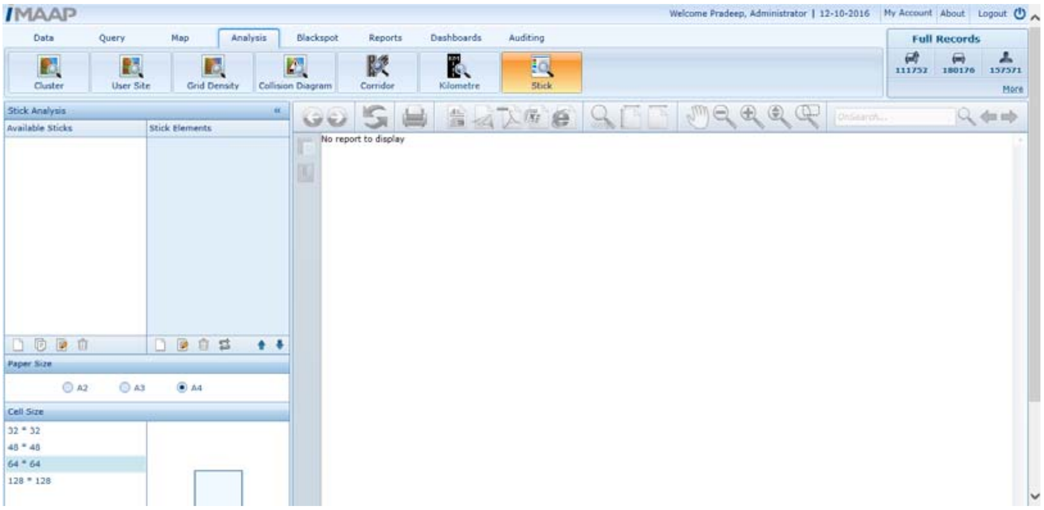


Figure 20: Stick Analysis Screen

Reports

The System provides a screen named 'Standard Reports' with a list of pre-defined templates which can be accessed from the 'Reports' menu. Examples are:

- Crashes by Year
- Crash Distribution for Day of Week
- Crash Distribution for Month of Year
- Casualties by Age Group

There is also a 'User Defined Report' facility which allows the users to create dynamic reports with a matrix of multiple sets of fields. Users are able to save and export dynamic reports to standard formats.

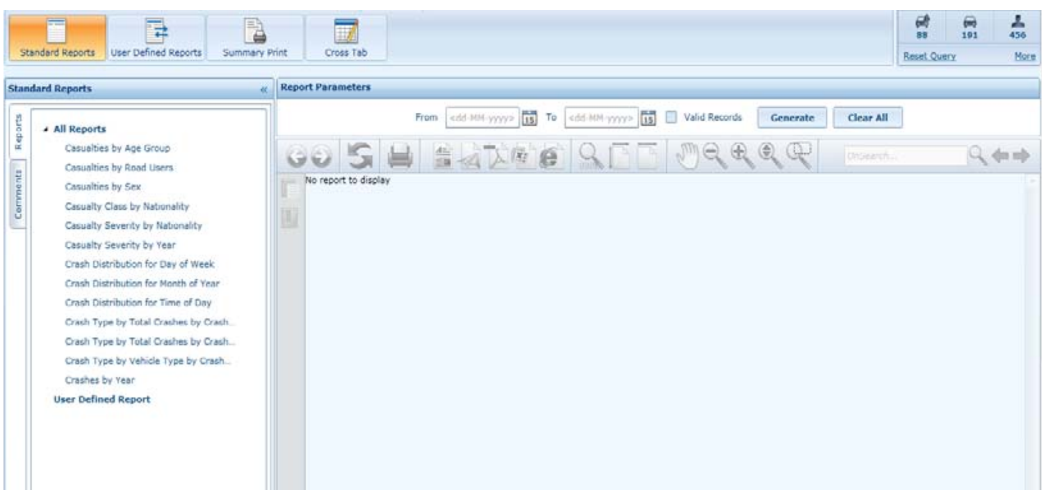


Figure 21: Standard Reports Screen