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Sharing Knowledge Across Borders

## ROAD SAFETY ANALYSIS

*Volume 5, Spring 2015*

"Better Roads. Better World."

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**EDITOR**

Sam Enmon

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International Road Federation
Madison Place
500 Montgomery Street
Alexandria, VA 22314 USA
Tel: +1 703 535 1001
Fax: +1 703 535 1007
www.IRFnews.org

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**PREVIOUS EDITIONS**

*Volume 1, Spring 2014: Road Safety Applications*
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The wealth of knowledge accumulated during the 17th IRF World Meeting & Exhibition in Riyadh was the driving force behind our decision to launch the IRF Examiner as a freely available resource for the industry. With this fourth issue, the International Road

Federation confirms its role as a leading provider of applied knowledge in areas of vital importance for the global community of road professionals.

At a time of growing motorization throughout many parts of the world, the devastating social and economic impacts of road traffic injuries can no longer be ignored. Those countries that have been most successful in improving their road safety record have done so by adopting evidence-based programs supported by a thorough understanding of the circumstances and locations of their serious and fatal crashes. This issue of the IRF Examiner provides many such illustrations of analytical approaches applied to different user groups and road networks.

*H.E. Eng. Abdullah A. Al-Mogbel*
*IRF Chairman*

Roads are the world's first "social network". They are fundamental building blocks for human and economic development whose impacts transcend national borders. The benefits of investments in roads have shown how transformative an infrastructure they can be for a wide range of beneficiary communities.

At the International Road Federation, we have tried to capture these connections with a simple slogan "Better Roads. Better World". Since we were established 1948, our primary purpose has been to transfer the latest technologies and knowledge from those who have it to those who need it, and in doing so, promote an agenda of shared prosperity that flows from accessible, affordable and sustainable road networks. The IRF Examiner is an essential vehicle to this ambitious agenda.

*C. Patrick Sankey*
*IRF President & CEO*

Reliable estimates of the incidence and burden of road injuries supported by an active research program are essential inputs to formulating strategic plans in Low and Middle Income Countries. Gearing up for the mid-term review of the UN Decade of Action, relevant stakeholders in these countries are mounting pressure on local governments to improve their injury data surveillance systems. Understandably, the lack of reliable and comprehensive data impedes the prioritization of road safety among other national development challenges and priorities. Linked to the quality of data systems is also the concern for building capacity and funding for local road safety research and foster knowledge transfer. The Global Road Safety Facility at the World Bank supports the development of key global metrics and road safety knowledge transfer in poor-information settings.

In this context, it is timely that the IRF Examiner is focusing on the important topic of road safety data analysis in developing countries. I hope this inspires more local researchers to disseminate their findings and case studies to make meaningful impact in terms of knowledge sharing and learning from best practices

*Dr. Dipan Bose*
*Global Road Safety Facility, World Bank*

# Table of Contents

# 1st IRF Europe & Central Asia Regional Congress & Exhibition

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By Professionals.

# "Corridors for Shared Prosperity"

**International Road Federation**

Better Roads. Better World.

# Integrated Road Safety Management System (IRSMS) for Indonesia

Main Author:
Paul Hambleton
Consia Consultants Denmark
Erin Consulting
paul@erin.se

Co-Authors:
Ian. J. Faulks
Consia Consultants Denmark
CARRS-Q
Queensland University of Technology, Australia
safetyandpolicy@gmail.com

Carsten Wass
Consia Consultants Denmark
wass@consia.com

## ABSTRACT

The Indonesian National Traffic Police Corps (INTPC) has a central role in achieving a reduction in Indonesia's crash fatalities in half by 2020, in accord with the UN Global Decade of Action 2011-2020. Legislation establishes Law 22 through the INTPC as the de facto lead agency for road safety.

The scope includes:

- Road policing
- Traffic management
- Traffic enforcement
- Crash investigation
- Crash reporting and analysis
- Driver licensing
- Vehicle registration
- Traffic education

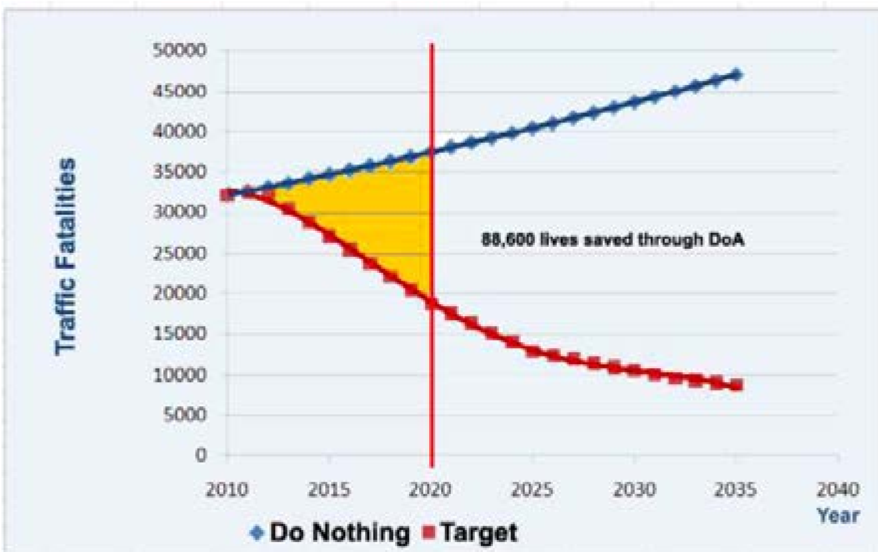
Law 22 provides the legislative framework for road safety activities. To ensure that reliable and valid road crash data are available, INTPC has – with World Bank funding – developed a web-based crash information and analysis system (CAS) and has developed media campaigns to link in with the ten highest priority safety interventions needed. The CAS, made available nationwide in 2012, uses GPS crash coordinates, tablet data input and digital maps to give a user-friendly input and outcome overview for all stakeholders.

## INTRODUCTION

The Indonesian Government put in place Law 22 in 2009 on Road Traffic and Transportation to address the main issues with road safety as the number of fatalities and serious injuries caused by road traffic crashes were, and still are, a very serious problem [1]. The law gave the newly restructured Indonesian National Traffic Police Corps (INTPC) – Korps Lalu Lintas Polri (or Korlantas) – a major mandate for road safety. Accordingly, the INTPC developed a national strategy to reflect the Indonesian Government's adoption of the Decade of Action Goals for a 50% reduction of fatalities to 18,747 by 2020 and a continued the reduction to 8,700 by 2035 as shown in Figure 1 [2].

**FIGURE 1a & 1b: Predicted Traffic Fatalities in Indonesia 2010-2035 and the Targeted Reduction Under the Decade Of Action (DOA) and the Continuation of the RUNK (from [3])**

| Year | Prediction | | | DoA Target |
|---|---|---|---|---|
| | Population | Vehicles | Fatalities | |
| 2010 | 237,000,000 | 50,000,000 | 32,192 | 32,192 |
| 2011 | 237,521,400 | 52,500,000 | 32,687 | 32,514 |
| 2012 | 238,043,947 | 55,125,000 | 33,189 | 32,189 |
| 2013 | 238,567,644 | 57,881,250 | 33,698 | 30,509 |
| 2014 | 239,092,493 | 60,775,313 | 34,216 | 28,828 |
| 2015 | 239,618,496 | 63,814,078 | 34,742 | 27,148 |
| 2016 | 240,145,657 | 67,004,782 | 35,275 | 25,468 |
| 2017 | 240,673,977 | 70,355,021 | 35,817 | 23,787 |
| 2018 | 241,203,460 | 73,872,772 | 36,367 | 22,107 |
| 2019 | 241,734,108 | 77,566,411 | 36,926 | 20,427 |
| 2020 | 242,265,923 | 81,444,731 | 37,493 | 18,747 |
| 2025 | 244,942,599 | 103,946,409 | 40,462 | 12,866 |
| 2030 | 247,648,849 | 132,664,885 | 43,667 | 10,513 |
| 2035 | 250,384,999 | 169,317,747 | 47,125 | 8,700 |




## CRASH INFORMATION AND ANALYSIS SYSTEM (CAS)

Under the Strategic Road Infrastructure Project (SRIP), the World Bank provided a loan (IBRD Loan 4834) for the development of an Integrated Road Safety Management System, which included the development of a crash database and analysis system and this was tendered. Consia Consultants, Denmark, won and adapted an "off-the-shelf" Crash Information and Analysis System (CAS) to Indonesian conditions and demands.

The aim was not only just to define the numbers of casualties and crashes set out previously, but to capture all crash details, location and information needed to develop solutions then focus on the highest priority crash locations, liaise with stakeholders, develop programmes and implement specific safety interventions then monitor the effectiveness of these evidence-based safety interventions and report on the lessons learned.

### *CAS Project Expansion*

After the pilot implementation it was found that the system was not sufficiently anchored at police district level. The crash data collection forms developed for use at the local office level were generally not used at the crash site and police staff still needed skills and motivation for using the system. It was therefore decided to extend the technical assistance to implement data input using tablets as well as to use the CAS to set priorities and initiate wider road safety interventions to realise the 'RUNK' safety strategic goals (see below) with the following services:

- Electronic data collection
- Capacity building
- Traffic safety improvement implementation
- Media campaigns
- Procurement of equipment

***Data Input***

Information can be registered in the system through a number of input screens or transferred from electronic devices such as tablets. While Android tablets were accepted as all operations could be carried out on one device remotely, mobile phones and digital cameras could also be used to input GIS location coordinates. The use of a standard tablet had many advantages of being able to record all the information needed on drop down menus and then record both videos and still photographs of the crash scene as well as record interviews with witnesses. All could be stored in a mini database on the tablet and synchronised with the main server when in range of an Internet connection.

***Validation***

After information is registered for a crash it is possible to make corrections for up to 40 days to allow for registration of seriously injured persons that die within 30 days of the crash. The client can choose the time interval for corrections.

The system also included a facility for validation of crash information. The validation for each input was carried out by another person than the one that registered data of the crash. Only after validation the crash details are included in statistics produced by the system. The identities of the operators are listed in the data forms for administrative checks.

***Output***

The system includes a wide variety of output possibilities from simple listings of crashes to advanced analytical tools.

Google Maps or Open Street Map is used to display individual crashes or clusters of crashes directly on a map (Figure 2), and they could then be drilled down and more detail could be displayed (Figure 3 & 4). When an area and time period is selected crashes will be displayed on a map. Where many crashes occur the system will show a 'balloon' with the number of crashes in the area.

**FIGURE 2: Crash Clusters on Map: By Simply Clicking on a Balloon the System will Zoom in on the Area Until the Individual Crashes are Shown as Markers**

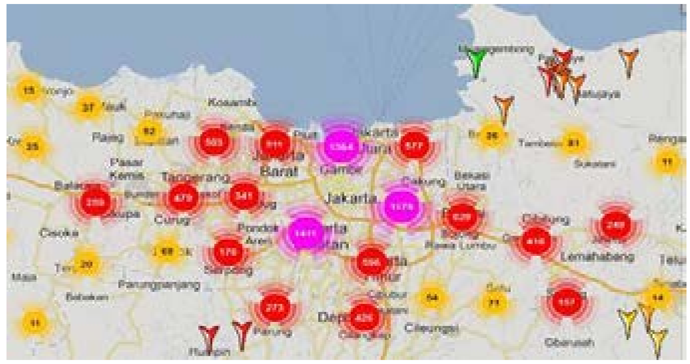



**FIGURE 3: Individual Crash Markers: Different Shaped and Colours Markers Show where the Crash Includes a Fatality, Serious Injury, Minor Injury or Material Damage Only**

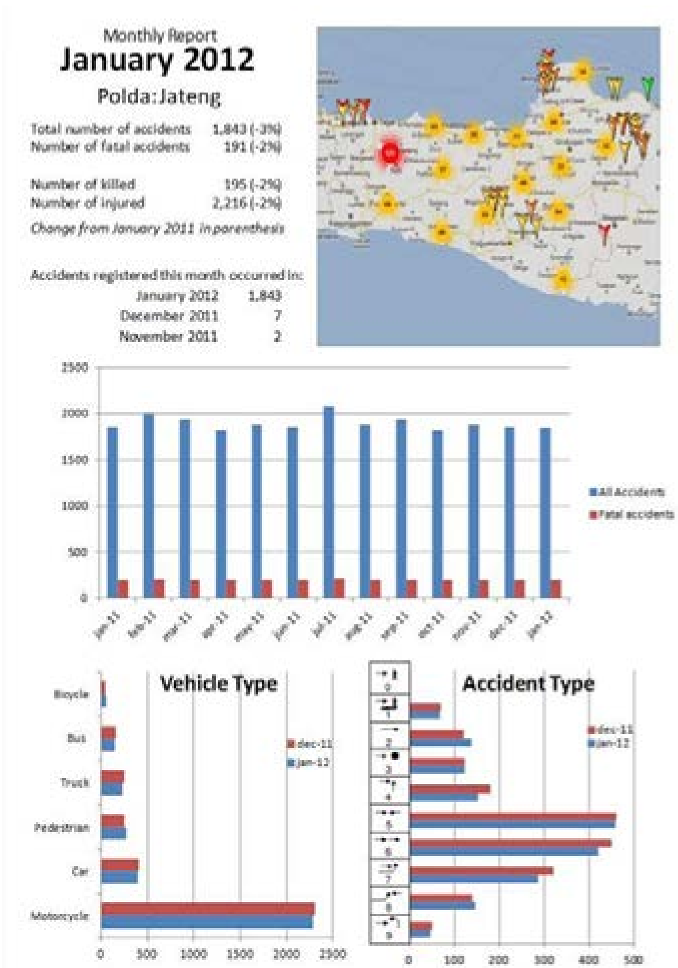

**FIGURE 4: Crash Markers Access Detailed Data (Red Pyramid for over 5 Fatalities)**

Clicking on a crash marker opens a small summary window with basic information on the crash such as identification number, day, time, types of vehicles involved, location, crash diagram and a thumbnail of one of the pictures stored (Figure 5). All pictures can be viewed by clicking the thumbnail. Clicking the Show button can access details of vehicles and persons involved.

**FIGURE 5: Detailed Crash Information**


The system includes a suite of standard reports giving daily, weekly or monthly overviews (Figure 6), which can be compared with each other to identify progress, trends and patterns of change. The reports can be matched with specific requirements and can be used to research each variable input. Reports can also be produced for any given time interval.

**FIGURE 6: Sample of Standard Monthly Report for One Province**




It is often worthwhile to analyse points or sections of road with higher density of crashes. From the map facility such locations can be identified and crashes analysed.

A cross-tabulation facility can generate tables for all pairs of parameters in the system. The facility also includes a flexible condition builder where data can be selected with any criteria for example crashes involving children riding bicycles at night on highways.

When a cross-tabulation is selected and conditions for selection of crashes established the user may save it as a personal report that can be retrieved to produce the same tabulation for example for a new time period. This has proved especially useful when periodic crash reports are needed. It is possible to export a cross-tabulation or any other data as an Excel file for further analysis outside of the crash information and analysis system.

## THE INDONESIAN NATIONAL TRAFFIC POLICE CORPS (INTPC)

The Indonesian National Traffic Police Corps (INTPC), Korps Lalu Lintas Polri (or Korlantas) is an independent traffic policing agency under the Indonesian National Police.

At present there is no official effective Lead Agency to focus efforts on road safety in Indonesia. However, because of the role of the INTPC under the current legislation and the wide scope of the organisation's functions, the INTPC serves as the only viable Lead Road Safety Agency at present. It also has control over all crash data and therefore is the "spider in the web" – or the data access controller – when it comes to any road crash information. While it has an independent and enthusiastic mandate to save lives, the main focus of the organisation has been to gather information for prosecutions rather than proactively preventing them for the future.

Under the World Bank-funded IRSMS technical assistance project, an Institutional Review was requested on the changes needed to improve the Integrated Road Safety Management System within the INTPC, which was restructured following the enactment of Law 22.

## LAW 22 OF 2009 ON ROAD TRAFFIC, TRANSPORTATION AND INTPC

The legislative framework for road safety in Indonesia is primarily provided by Law 22 of 2009, relating to Road Traffic and Transportation. Under this legislation, the primary responsibility for road safety rests with the INTPC rather than with Indonesian transport or public works agencies, although these other agencies retain road safety structures.

Under Law 22/2009, the INTPC is charged with the responsibility for road traffic and transport safety. Generally, Law 22/2009 (Article 4, 5 and 12) aims to develop and organize a secure, safe, orderly and smooth land transportation system through:

- The movement of vehicles, people and/or goods on roads
- The use of traffic and road transportation infrastructure and facilities
- Activities related to registration and identification of motor vehicles and drivers, traffic education, traffic management, engineering, and the enforcement of traffic and road transportation laws

Legislative reform is needed to make the use of rear seat belts and child seats mandatory. The mandatory wearing of seat belts in the front seats of vehicles only has been applied in Indonesia since 1993.

As well, Law 22/2009 allows minor crashes to be "resolved at scene", that is, to be negotiated between the affected parties with a signed statement including settlement. This means that an unknown number of crashes may be unreported, as they are settled between the parties and may not be recorded within the crash information system.

## DECADE OF ACTION PLAN FOR INDONESIA

Estimates of traffic casualties result in an annual social cost or what most governments would prefer not to acknowledge, as an unofficial "Death Budget" which is effectively a burden primarily born by the victims of crashes. In Indonesia this is estimated to be at least 3.7% of the Indonesian Gross Domestic Product in 2010, currently estimated to be up to 4.8 % (some US $40.6 Billion where GDP is approximately USD 846 Billion 2011). This is the author's estimate if the level of under reporting is corrected, (including corrections for local definitions where a minor injured person in Indonesia could stay up to 30 days in hospital before being classified as "Serious," compared to the international definition of a seriously injured person would have a hospital stay of more than 24 hours). The average statistical value of life (SVL) is used to value fatalities (SVL of 70 x GDP per capita) and 25% of this value is used for a Serious Injury [3]. This allows an estimate of social costs based on the one measure, which is likely to be the most accurately reported figure, the number of fatalities. In the absence of reliable data throughout the country, an estimate of 10 serious injuries per fatality can be used as an approximation assuming the international definition of a serious injury of over a 24 hour hospital stay.

## TARGETED ENFORCEMENT AND MEDIA CAMPAIGNS

The key to any crash data system is of course to use the data to target the highest priority serious injury crashes with safety interventions. The same data system can measure the effectiveness of the intervention over time. A series of 10 multi media campaigns including 5 television commercials, newspaper advertisements, billboards and Internet media were made for release in April 2013. The campaigns focused on the key priority areas of reducing casualties based on the evidence from the IRSMS crash information system, and follow and support the themes of police traffic enforcement. The target audience for the campaigns was assessed to be 15 to 25 year olds.

While we know that they are 13 times more motorbikes registered than cars, the risk of a fatality is still higher with motorbikes. While cars are over represented, motorcycles (MC) are involved in 67% of pedestrian fatalities so that overall motorbikes account for 81% of all fatalities, some 3,362 people in one province of 34 million alone.

The low proportion of Seriously (Injured) can be related to the Law 22 definitions where if an injured person spends less than 30 days in hospital the person may be registered as slightly injured or have a minor injury. This compared to an international definition where minor injuries are those where the duration in hospital is less than 24 hours. The numbers of seriously injured and slightly injured can be added together as "Serious Injuries" for International comparisons as minor injury crashes are rarely reported.

The media campaigns, linked to the same enforcement campaigns focused on what are determined to be the highest risk areas that can easily be targeted in the early stages of the road safety campaigns. Each is backed up and justified by data analysis from the CAS and each television commercial has been targeted for a minimum of 200 Target audience rating points (TARPS) to get beyond the critical viewing mass needed to have a significant effect.

The main focus areas for the television media campaign were:

- Helmets / Strap up your helmet as well as one for your child.
- Speeding / Slow down, speeding can be fatal. We want you to live, arrive alive.
- Concentration – distractions / don't let your mobile phone distract you while driving.
- Drinking and driving / be a sober driver - don't drive with alcohol in your blood.
- Lights - Be sure to be seen in the dark - wear light clothing with reflectors and make sure that the

vehicle lights are working.

These TV commercials are currently being market-tested and prepared for a press launch with the enforcement campaign follow up. The TV commercials are available for public viewing on a YouTube channel – IRSMS Korlantas [4].

## CONCLUDING COMMENTS

Indonesia has moved in the right direction for road safety in that legislation is in place, there is a clear strategy moving ahead the Decade of Action themes, and a functional database is now working fully nationally across the archipelago. Some of the hindrances that corruption plays in distorting outcomes and slowing progress are being addressed (via the relatively new and very successful corruption eradication courts) and most aid agencies are funding and supporting the increase in road transportation infrastructure development that is urgently needed.

The INTPC has a major role to play, certainly as a lead agency in this early phase where massive casualty reduction gains can be made from well-targeted enforcement and clear communications that are focussed on one specific safety intervention at a time. These are needed as an interim measure while plans are in train to upgrade road infrastructure to solve the longer term issues of urban transit and safer inter urban transport.

IRSMS allows additional stakeholders (journalists, and the general public) to be able to identify specific data and to highlight where actions could be made, rather than providing crash data only to "approved" stakeholders from various government agencies, planners and road system designers. With a web-based Road Safety Management System, there is no need for proprietorial computer programs to be installed in the user's computer. It is possible to give all stakeholders access to the web-based front end of a crash information and analysis system, as envisaged by ISO 39001. Using IRSMS, with a statistical level access, such general crash data can be accessed by all stakeholders and still meet all legal privacy requirements.

The aim of IRSMS, together with the RUNK and with planned changes mandated under Law 22/2009, is to provide the practical facts that can be used to accelerate targeted crash interventions. This still needs the support of a wider, coherent process, including such elements as a road fund, a longer term 30 year country plan, trained safety champions in every province interacting with all stakeholders (especially with public works engineers) and local INTPC personnel locating the priority road segments or locations that need treatments and the priority behaviours that need to be modified through clear community information and targeted enforcement.

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# Effect of Signal Phase Sequences on Signalized Intersection Safety Performance Case Study from Abu Dhabi, U.A.E.

Main Author:
Abdulla Al Ghafli
Road and Traffic Engineer
Traffic and Patrols Directorate
Abu Dhabi Police
Abu Dhabi, UAE
abdulla522@gmail.com

Co-Authors:
Atef Garib
Road and Traffic Expert
Traffic and Patrols Directorate
Abu Dhabi Police
Abu Dhabi, UAE
agarib@eim.ae

Mohamed Sarhan
Assistant Professor
Department of Civil Engineering
Ain Shams University
Cairo, Egypt
mohamed.sarhan@gmail.com

Hussain Al-Harthei
Director
Traffic and Patrols Directorate
Abu Dhabi Police
Abu Dhabi, UAE
alharthei@saaed.ae

## ABSTRACT

In Abu Dhabi traffic signal design two types of signal design are used; split phasing and lead-lag protected phasing sequence. The main objective of this research is to examine the influence that signal changes had on the intersection safety performance. The analysis relies on before and after evaluation in relation to three factors including signal phasing, speed limit and intersection location. Results show intersection approaches that have been changed from split phasing sequence to lead lag phasing sequence experienced a significant increase 2.13 Type 1 accident compared to 0.07 for those remained split. Approaches located within the Central Business District (CBD) also experienced around 300% increases in Type 1 accidents. Approaches outside CBD that had both changes in the speed limit from 60 km/h to 80 km/h and changes to signal design have experienced an increase of 350% in Type 1 accidents. In addition, leading left turn movements were found safer than the lagging ones.

## INTRODUCTION

Safety at signalized intersections is a major issue due to the severity of accidents that result from conflict movements. In year 2012, running red signals caused 9.3% of severe accidents in Abu Dhabi, United Arab

Emirates. 89% of those accidents were right angle due to the conflict between left turn and through movements at signalized intersections and caused 13 deaths. Furthermore, few injuries from rear-end collisions occurred at signalized intersection were caused by left turn movements using through movement approach (first through lane to the left) as a shared lane. This takes place in case of lead-lag signal phase's sequence separates the through movement from the left turn movement and provides protected left turn.

In July 2009, the Department of Transport in Abu Dhabi (DOT) changed the signal design to include flashing green at the end of the green intervals to all Abu Dhabi Island traffic signals. In January 2010, it changed the signal phasing from split to lead lag left turn for 38 signalized intersections in order to maintain a green wave at certain corridors to increase the capacity because through movements considered to be majority compared to the left turning movements. In March 2011, a speed limit review study recommended changes to speed limits of three corridors in Abu Dhabi Island from 60 km/h to 80 km/h.

In term of signal operation, 15 to 20% of movements at signalized intersection for left turning movement and they are considered a critical source of conflicts at intersections (7). Traffic signals can provide for orderly movement of traffic, increase the capacity of an intersection if maintained properly, and provide safe intervals to permit vehicles to cross heavy traffic. On the other hand, improper or unjustified traffic signals can create excessive delay, excessive disobedience when drivers become impatient, and increases in the frequency of certain types of crashes (8)

Under the right circumstances, the use of a lead lag operation can be extremely beneficial. However, traffic engineers continue to be wary of implementing it due to an unreasonable fear of violating driver expectancy, which is unwarranted and it may violate driver expectations and lead to accidents (3).

Even though split phasing is much safer that lead lag phasing, left turn crashes were not fully eliminated by the protected signal phasing, even though left turn signal phasing significantly reduces conflicts for between left turning vehicles and opposing through traffic, there are other collision patterns, such as collisions between vehicles making left turns, collisions between left turning vehicles and free right turning vehicles, or collisions between left turning and crossing traffic when one of which was against signal. (4)

Three conflict elimination mechanisms were used for the left turning phasing have been defined; Protected left turn, Permissive left turn and Protected / Permissive left turn (Compound) (9). A research showed that changing from permissive to protected only phasing significantly reduces left turn crashes, because it separates left turning movements from the opposing traffic completely, and thus reduces conflicts between the left turning and opposing vehicles (4). Thus, the protected phase is safer than permissive phase and that compound signal usually has more left turn crashes than permissive phase (9).

Moreover, lagging sequence recommended where it is intended to improve intersection safety. However, drivers tend not to react as quickly to the green arrow indication (1). But Traffic Signal Timing Manual claimed that Lead-Lead left turn phasing, drivers tend to react quickly to the green arrow (6).

In term of operation, Traffic Signal Operation Handbook claimed that if traffic flow on the street has a dominant flow direction that reverses by time of day, then it may be necessary to switch the leading and lagging left turn phases by time of day. Phase sequence changes of this nature are supported by most modern controllers and can be incorporated in time of day timing plans. If the phase sequence is switched in this manner, then traffic behavior should be monitored during the initial stages of plan implementation to ensure that drivers are responding safely to the change in signal operation (2).

## METHODOLOGY

Starting with traffic signal phasing plans that had been provided from the Traffic Control Center of Abu Dhabi Department of Transport, signalized intersections with a lead lag phasing sequence have been defined. Some investigations were made to define intersections that experienced geometry change through the years 2008 to 2012 to illuminate intersections that had major geometric change. Using the severe accident data managed by Abu Dhabi Police, those caused by running on red signal phase for the years 2008 to 2012 have been identified. Four accident patterns were classified as:

- Type 1 Accidents between left turning vehicles and through opposing movement vehicles
- Type 2 Accidents between through moving vehicle with through moving vehicle
- Type 3 Accidents where pedestrian involved
- Type 4 Rear-End Accidents

In addition, because of the introduced three events that have been mentioned earlier, the before and after analysis was based on the following time periods:

- Period 1: Starts in January 2008 and ends in April

2009 (16 months)

- Period 2: Starts in September 2011 and ends on 31st of December 2012 (16 months)

## SITE CHARACTERISTICS

Out of the 38 signalized intersections that were switched to lead lag left turn phasing sequence, 2 intersections (IP1 and IP135) had mountable and raised curbs in the middle of the intersection that make them unique compared to the other intersections. Furthermore, 19 out of the 38 had major modifications in the geometry and were therefore excluded. Thus, the study focuses on only 17 signalized intersections (60 approaches) that did not have any changes in the geometry from year 2008 to 2012 (Figure 1). On the other hand, there is a variation in other factors such as speed limit, signal phasing sequence, number of lanes of the left turn movement, and location of intersection and thus, the analysis consider the approaches and not the intersections. The approaches characteristics are shown in Table 1.

**TABLE 1: Approaches Characteristics**

| | Classification | No. of Approaches | Total Approaches |
|---|---|---|---|
| Posted Speed(1) Before March 2011 | 60 kph | 60 | 60 |
| | 80 kph | 0 | |
| Posted Speed(1) After March 2011 | 60 kph | 42 | |
| | 80 kph | 18 | |
| Intersection Location related to CBD | CBD | 16 | |
| | Non CBD | 44 | |
| Control Type before 2010 | Split | 60 | |
| | Lead-lag | 0 | |
| Control Type After 2010 | Split | 28 | |
| | Lead-lag | 32 | |

(1) In United Arab Emirates, the operation speed at all road links has a 20 km/hr margin speed

**FIGURE 1: Location of Study Lead Lag Signalized Intersections**


## ANALYSIS

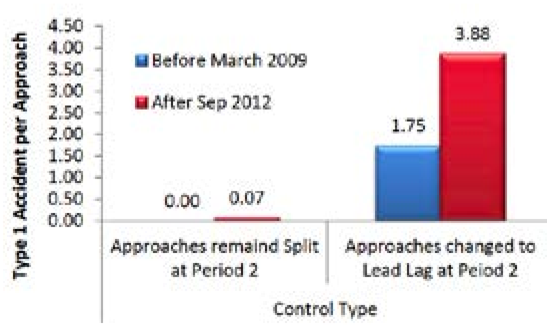
The four types of severe accidents shown in Table 2 are all types that were recorded at the 17 signalized intersections. The table shows that more than 85% of the accidents in year 2012 were Type 1. In addition, this type increased from 17 accidents in 2008 to 54 in 2012, while other accidents types had little changes. Type 1 accidents occur when a driver turns left during red left arrow signal head while the through movements signal head is green. There are two possible scenarios of this accident. The first scenario is that, when the signal head of the through movements turns green and the left turn movement signal head remain red, the driver on the left lane moves thinking that the left turn signal head is green. The second scenario may occur when the vehicle on the left lane approaches the intersections with a platoon and watching the through signal head thinking that it represent the through and the left turn head, but in fact the through signal head is green and the left turn signal head is red.

**TABLE 2: Severe Accidents at Signalized Intersections**

| | | Type 1 | Type 2 | Type 3 | Type 4 |
|---|---|---|---|---|---|
| Patterns | | | | | |
| Description | | Through Movement with Left Turn. The In fault is Left Turning movement. | Two through movement | Pedestrian Involved Collision | Rear- End Collision |
| Number of accidents | 2008 | 17 | 2 | 0 | 0 |
| | 2009 | 28 | 2 | 1 | 1 |
| | 2010 | 34 | 4 | 1 | 0 |
| | 2011 | 50 | 6 | 0 | 1 |
| | 2012 | 54 | 6 | 0 | 3 |

Analysis of severe accident records as presented in Figure 2 showed that approaches that have been changed from split phasing sequence to lead lag phasing sequence (32 approaches) experienced a significant increase of Type 1 from 1.75 accidents per approach in period 1 to 3.88 accident per approach in period 2. On the other hand, approaches that remained operating with split phasing sequence (28 approaches) did not have major change in Type 1 accidents, where the increase was just 0.07 accident per approach which can be considered insignificant.

**FIGURE 2: Influence of Control Type on Type 1 Accidents per Approach**

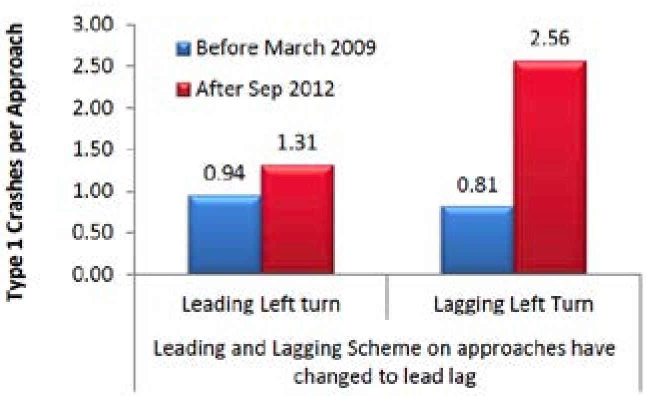


***Traffic Signal Sequence (Leading versus Lagging)***

According to lead lag signal phasing systems, there is a time period where the two through opposing movements have green signal head and the left turn movements in both approaches have red signal head. During this period, a high risk occur when a driver tends to turn left and pays attention to a signal head of the through movements thinking that it is the same as the left turn signal head. Therefore, these critical instants where the left turn signal head turns green may cause confusion to the driver and let him/her run on red signal. This period includes a leading left turn phase for one approach and lagging left turn phase to the opposing approach. Leading left turn is when the left turn traffic signal head and the through traffic signal head turns green at the same time, while lagging left turn is the time when the left turn signal head turns green after a while of the start of the through movement signal head.

Further analysis presented in Figure 3 considered only the approaches that have changed from split to lead lag, severe accidents showed that lagging left turn approaches had a significant increase in Type 1 accidents per approach from 0.81 in period 1 to 2.56 in period 2. On the other hand, leading left turn approaches had a slight increase in Type 1 accidents per approach from 0.94 in period 1 to 1.31 in period 2. This indicates that the leading left turn movements are safer than the lagging one.

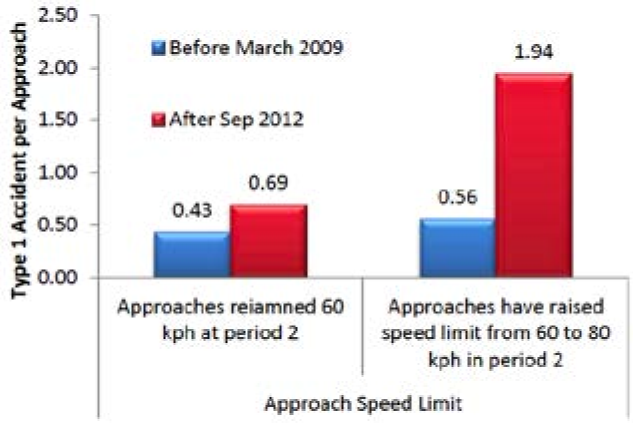
**FIGURE 3: Influence of Left-Turn Signal Phasing Sequence on Type 1 Accidents**




***Speed Limit***

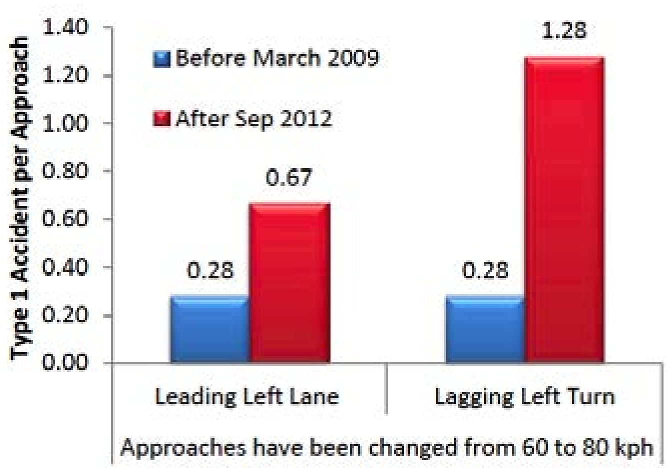
As mentioned earlier, the posted speed limit of 18 approaches has been raised from 60 km/h to 80 km/h in March 2011. Analysis of severe accidents as presented in Figure 4 shows that approaches that have been changed from 60 km/h to 80 km/h experienced a significant increase in Type 1 accidents per approach from 0.56 in period 1 to 1.94 in Period 2. However, approaches that remained operating at a speed limit of 60 km/h had not been affected much and little increase has been found for Type 1 accidents compared to those approaches that have experienced an increase in a speed limit. Those latter approaches have an increase in type 1 accidents per approach from 0.43 in period 1 to 0.69 in period 2.

**FIGURE 4: Influence of Speed Limit on Type 1 Accidents per Approach**




Due to the significant increase in type 1 accident at approaches where the speed limit has changed, further analysis was done as shown in Figure 5. By comparing both leading and lagging left turns, similar result again indicates that leading left turn movements are safer. The analysis showed that lagging left turn in Period 2 had a significant increase in Type 1 accident per approach from 0.28 in period 1 to 1.28 in Period 2. On the other hand, leading left turn approaches that remained operating at 60 km/h at period 2 did not have significant increase compared to approaches that have changed from 60 to 80 km/h.

**FIGURE 5: Leading Versus Lagging Left Turns on Approaches with 80 km/h Speed Limit**

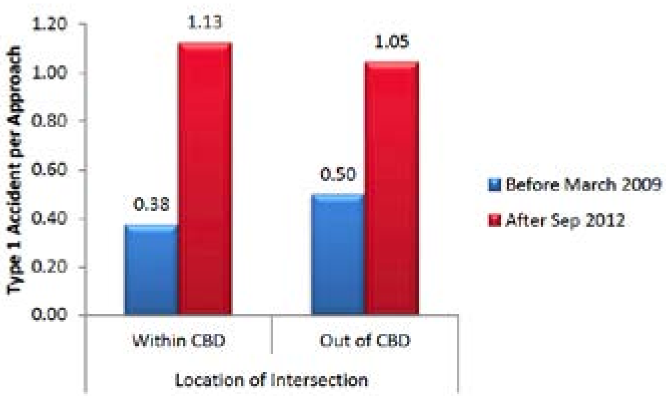


***Location of Intersection relative to CBD***

The location of signalized intersections may reflect the degree of congestion since no information is available on traffic volumes. For intersections at high density areas with high pedestrian counts, drivers tend to concentrate and to drive slow. However, most of the accidents may result in property damage only accidents. Unfortunately, these data are not available. While in areas with less population density and less congestions, speeds are higher. Therefore, the 60 approaches were divided into two groups; approaches in CBD and approaches outside the CBD. The locations of intersections by locations are presented back in Figure 1.

Study analysis of severe accident records as presented in Figure 6 proved the opposite of our assumption where the increase of Type 1 between Period 1 and Period 2 of both CBD and outside CBD was considerable. Type 1 accidents within CBD increased from 0.38 in period 1 to 1.13 in Period 2. Similarly, type 1 accident per approach outside CBD increased from 0.5 in period 1 to 1.05 in Period 2.

**FIGURE 6: Influence of Location of Intersection on Type 1 Accident per Approach**




Finally, taking the combined effect of speed limit, location of intersection and the change in signal phasing from split phasing to lead lag phasing, the results show that:

- Approaches within CBD that have changed from split phasing to lead lag phasing experienced a 300% increase in Type 1 accident
- Approaches outside CBD that have changed speed limit from 60 km/h to 80 km/h and changed from split phasing to lead lag phasing experienced an increase of 350% in Type 1 accidents

**TABLE 3: Effect of Speed Limit, Location of Intersection, and Signal Phase Design on Type 1 Accidents**

| Location | Speed | Period 1 (Jan 2008-April 2009) | | Period 2 (Sep 2011-Dec 2012) | |
|---|---|---|---|---|---|
| | | Remained Split at Period 2 | Changed to Lead Lag at Period 2 | Remained Split at Period 2 | Changed to Lead Lag at Period 2 |
| CBD | 60 km/h | 0 | 6 | 0 | 18 |
| Non CBD | 60 km/h | 0 | 12 | 2 | 9 |
| | 80 km/h | 0 | 10 | 0 | 35 |

## CONCLUSION

A total of 38 intersections in Abu Dhabi City, United Arab Emirates, have been changed from a split phasing system on all approaches to a design where two approaches are protected only lead lag and two approaches split. These changes were done in years 2009 and 2010. However, the accident history showed an increase in the number and severity of left-turn related collisions. A total of 17 intersections were used for detailed analysis. Results indicated that 88% of severe accidents at these intersections occurred between through movement and left turn movement and drivers on the left turn were at fault. This type of accidents is marked as Type 1. Intersection approaches that have been changed from split phasing sequence to lead lag phasing sequence experienced a significant increase in Type 1 accidents. In addition, there was a significant increase in Type 1 accidents for lead lag approaches where the speed limit changed from 60 to 80 km/h compared to lead lag approaches where the speed limit remained 60 km/h. Furthermore, the leading left turn approaches were safer than lagging left turns and experienced less of Type 1 accident per approach. In reference to the intersection location, little difference was observed for Type 1 accidents between CBD intersections and other intersections. Approaches within CBD that have changed from split phasing to lead lag phasing experienced a 300% increase in Type 1 accident. Approaches outside CBD that had changes in the speed limit from 60 km/h to 80 km/h and changed from split phasing to lead lag phasing experienced an increase of 350% in Type 1 accidents.

The research was done based on severe crash data provided by Abu Dhabi Police, which indicate the severe intersection conflicts (Type 1 Accident). To add more value to the safety performance related to the signal phase sequence, future research will include property damage accidents data, which will help to study all accident patterns. Moreover, another research will study the effect of cycle length and clearance time to the safety performance of signalized intersections as a case study in Abu Dhabi City, U.A.E.

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# Crash Deaths in the Arab World During Three Decades: Challenges and Opportunities

Main Author:
Hashim M. N. Al-Madani
Professor of Transportation
Department of Civil Engineering & Architecture
College of Engineering
University of Bahrain, Bahrain
hmnalmadani@uob.edu.bh

## ABSTRACT

Over three decades of traffic fatality related data were analyzed for 18 Arab Countries and compared against 27 European Union (EU) countries. Data collected included both death frequencies and rates per inhabitants and vehicles. Predicted fatality estimates were also analyzed for the coming decade. While traffic fatalities in the Arab world almost doubled from 22k to 38k between 1980 and 2011, EU countries dropped from 75k deaths to 30k during the same period. The EU and Arab rates were about the same at 13.25 deaths per 100k persons during the 1980's. The fatality rates for the Arab countries are now substantially higher than the EU. The rates for the EU countries dropped to 5.5 by 2011, while Arab countries were still around 11. The Arab countries' data are thought to be presented for the first time.

## OBJECTIVES AND STUDY APPROACH

Population and vehicular data are first gathered along with traffic fatalities for Arab countries, and EU countries. The data are gathered from the official reports, web sites, international databases and research literature. The data for the Arab countries required special attention since the published data is scarce. Some data was obtained through official contacts with the various Traffic Directorates. Death frequencies and rates in the GCC countries for the period from 1980 to 2011 along with future predictions are compared with those in the 15 and 27 EU countries. The considered death rates are per population and registered vehicles.

## DATA

The majority of data was gathered from official publications and web sources, as for Bahrain, Qatar, Saudi Arabia, Kuwait, Oman, UAE, Algeria, Yemen, Morocco and Tunisia, and from several well known data bases like International Road Federation, as IRF World Road Statistics (1) European Union Road Federation, as European Road Statistics (2), Economic Commission for Europe, as Statistics of Road Traffic Accidents in Europe (3), International Traffic Safety Data and Analysis, as IRTAD Group (4), World Health Organization, as the International Status Report on Road Safety Call for Action (5,6) and UK Department of Transport, as Transport Statistics for Great Britain [7]. Several Annual fact books were also used to gather the Data published through official bodies, as General Directorate of Traffic in Bahrain (8), Oman (9) and Dubai (10), Public Security in Saudi Arabia (11) and Ministries of Planning.

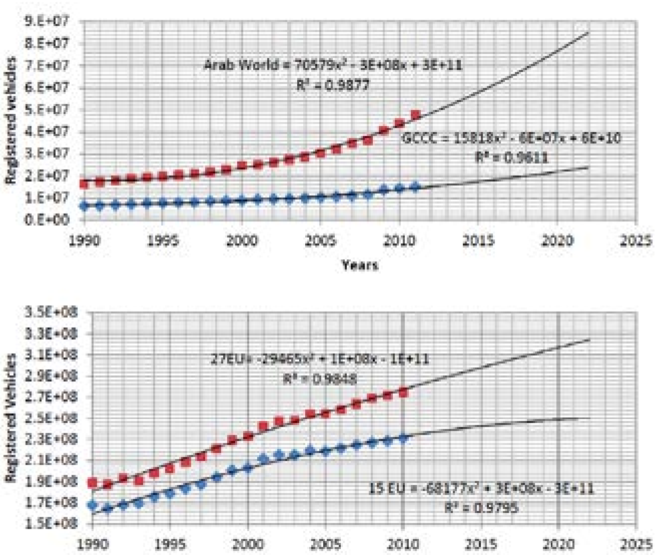
European data is well established and widely available in several European databases. The casualty and vehicle data for most of the GCC countries are gathered through official contacts involving Bahrain Directorate of Traffic with various corresponding Directorates. It took over eight months to compile the necessary data for 18 of 22 Arab countries. Data for Somalia, Djibouti, Comoros and Mauritania are not available except for few recent years. As a result, they are excluded here. However, the influence of the data from these countries on the overall analysis is minimal since the vehicle and death data from these countries, based on the most recent available data, account for only 2.4 and 1.8%, respectively, from the total 22 Arab countries.

The vehicle population in the 22 Arab countries (Table 1 and Figure 1) has increased from around 6 millions in 1978 to 48 millions in 2011, multiplying eight times in 34 years. That in 15 and 27 EU countries increased by 70 and 85%, respectively, less than doubled since 1980. The best-regressed models fitted to the vehicle data indicate a further increase in vehicle population by the year 2022 in the Arab world compared with the 2011 record. This means over 38 million extra vehicles will be added to the current 48 million's record. That in 27 EU countries is 46 million vehicles. This means that an extra 84 million vehicles will be added to the road network around the globe by the year 2022. This is almost 10% of the current 850 million vehicles worldwide, just from the Arab World and EU.

**TABLE 1: Vehicle Fleet in the GCC and Arab World (1978-2011)**

| Year | GCC (in millions) | 22 Arab Countries |
|---|---|---|
| 1978 | 2.1 | 6.1 |
| 1980 | 2.9 | 8.1 |
| 1985 | 5.4 | 13.1 |
| 1990 | 6.4 | 16.4 |
| 1995 | 7.7 | 19.7 |
| 2000 | 9.0 | 24.6 |
| 2005 | 10.3 | 30.3 |
| 2010 | 14.3 | 44.0 |
| 2011 | 15.0 | 47.7 |

**FIGURE 1: Trends of Vehicle Fleets in the GCC, Arab, and EU Countries (1990-2011)**




## RESULTS

The trends in the crash deaths show continuous increasing patterns in the vast majority of the Arab countries. These historical crash death data, along with the other coming vehicle and death rates, are probably presented for the first time in the literature. The total crash deaths in the 22 Arab world countries increased from 22,145 victims in 1980 to 37,736 in 2011. The direction of the fatality rate in the EU countries is the opposite. The crash deaths in 15 and 27 EU countries dropped from 59879 and 74,876, in respective order, during 1980 to 20,764 and 30,170 during 2011. While these are about one-third and two-fifth of the 1980 records in 15 and 27 EU countries respectively; that in the Arab world is three and a half times of the 1980 records. Two-third of the crash death in the Arab world basically occurs in four Countries; namely Saudi Arabia, Egypt, Morocco and Algeria. Such increasing and high trends in the Arab countries raises serious questions regarding the counteract safety plans and the effectiveness of the official efforts towards such serious public health problem.

The predicted traffic death rate in the Arab countries, according to the best regression fit is expected to reach 52,000 persons by the year 2022. That in the 27 EU countries, as per cubical regression model shown in Table 2 and drops to 13,800 by the same year; which is less than that for the GCC countries though the population and vehicle fleet in the GCC countries are 8% and 5% of that in the 27 EU countries. Once again, such trends in the Arab countries show serious traffic safety concerns, since the fatality trends in the developing countries show continuous dropping patterns and will continue dropping during the coming decade; and the trends in the GCC countries show continuous increasing pattern.

**TABLE 2: Fitted Models for Traffic Crash Deaths in GCC, Arab, and EU, and Prediction for 2022**

| Countries | Model type | Developed models | R2 | Prediction For Year 2022 |
|---|---|---|---|---|
| GCC | Linear | 172.894(year) -339078 | 0.84 | 10514 |
| | Quadratic | 6.5613(year)2 - 26000(year) + 3E+07 | 0.94 | 14800 |
| | Power | 2.31716626E-188(year)57.995 | 0.87 | 12127 |
| | Exponential | 3.4607499E-22e0.02909287(year) | 0.88 | 12215 |
| | Logarithmic | 344577.692ln(year)-2612390 | 0.84 | 10481 |
| Arab | Linear | 504.4739(year) - 977356 | 0.84 | 42690 |
| | Quadratic | 13.76(year)2 - 54373(year) + 5E+07 | 0.89 | 52000 |
| | Power | 7.14396E-109(year)34.122 | 0.86 | 45061 |
| | Exponential | 4.243617E-11e0.0171year | 0.86 | 44054 |
| | Logarithmic | 1005595.2568ln(year) - 7611833 | 0.83 | 425100 |
| 15 EU | Linear | -1189.3864(year) + 2416270 | 0.96 | 11331 |
| | Quadratic | -1.9686(year)2 + 6647.8(year) - 5E+06 | 0.96 | 9800 |
| | Power | 2.18990E178(year)-52.65 | 0.91 | 19545 |
| | Exponential | 3.49131E+27e-0.026464(year) | 0.91 | 20128 |
| | Logarithmic | -2367291.74526ln(year) + 18031034 | 0.96 | 11582 |
| 27 EU | Linear | -1161.6051(year) + 2375067 | 0.91 | 26301 |
| | Quadratic | -15.257(year)2 + 59575(year) - 6E+07 | 0.93 | 13,800 |
| | Power | 5.6643E136(year)-40.03 | 0.84 | 26468 |
| | Exponential | 1.48601E+22e-0.0211(year) | 0.85 | 32318 |
| | Logarithmic | -2311216.945ln(year) + 17619172 | 0.91 | 26560 |

It is worth mentioning that people in the Gulf region are more car-oriented travelers. The average annual growth rate in the vehicle fleet during the past three decades is 5.5% compared with 1.0% in 15 EU countries. That in 18 Arab countries is 7.8% compared with 1.2% in 27 EU countries. There are still no clear plans to encourage travelers to shift towards safer and more sustainable mode of transport in most of the Arab countries, though congestion in major cities is a serious problem. In exception to many Arab cities; Dubai and Cairo have succeeded in providing Mass Transit System (MTS) to their busy networks. MTS is necessary to control users exposure to accidents by shifting some of the car users towards other safer modes of transport. Murray Mackay [12] considers the latter among the important pillars of any Traffic Safety Strategies.

Though many factors lead to the earlier high number of crash deaths in the Arab World and require careful attention; Urban planning of the infrastructure in most of the Arab countries are not forgiving ones. They do not support traffic safety plans; especially ones that are related to exposure control towards accidents. Another sector requiring intensive improvement is human behavior development, since generally over half of crash fatalities in many Arab countries are related to speed, red light crossing and not obeying the rules. It is quite important to mention that while the western drivers comprehend over 74% of the posted signs; GCC drivers understand only 51.8% of them [13,14]. The comprehension of other Arab drivers of posted signs is 56.4% [15].

The crash fatality rates per 100,000 population during the past three decades in individual Arab countries did not show any encouraging decreasing trend; except that in Bahrain, UAE and Iraq. Nevertheless, the overall pattern of the 18 Arab countries considered here showed a slight declining trend in fatality rate from 14 deaths per 100,000 population during early 1980's to around 10.5 in 2011. This is more than twice that for EU countries. The rates for GCC countries showed a non-uniform pattern which might best be described as a non-uniform sinusoidal wave with rates bouncing up and down over the years. In general, the rates during early 1980's were in the range of 26 to 32 deaths per 100,000 population. It dropped slightly during late 1980's and early 1990's were towards 18 to 22 deaths per 100,000 population. The rate remained the same during the late 1990's and the new millennium. During the past eight years the rate was in the range of 22 to 25 deaths per 100,000 population. These rates are substantially higher than that for the EU.

While the overall fatality rate for 15 and 27 EU countries were in the range of 14 to 17 deaths per 100,000 population during early 80's, which were fairly close to that of the Arab countries and half that of the GCC countries. The rates in the EU countries decreased continuously during the past three decades, and will continue doing so during the coming decade as per model developed in that in the Arab world will also continue dropping gently during the coming decade. However, the gap between them will also continuously increase with the time if no proper counter action is considered. It is also important to keep in mind the difference between the European and Arab countries in the vehicle owner ship rate and average vehicle-miles travelled. While the former in the EU countries is one vehicle per 1.8 population that in the Arab countries is one per 7.4 population. That in the GCC countries is one per 2.7 population. The latter though is not yet easy to be estimated, it is surely far less than that in EU countries. As the vehicle ownership is expected to increase along with the vehicle miles travelled, the crash deaths are also expected to escalate if no clear traffic safety plans are imposed.

Currently, the overall rates for the EU countries is in the range of 5 to 6 deaths per 100,000 inhabitants, which is half that of the average Arab countries and less than a quarter of that in the GCC countries. The gap between the two is ever increasing and it is expected to be far greater than the current difference in a decade time.

While quadratic models, with very high R2 values of 0.95, show that the fatality rates per 100,000 population in EU countries will tend to be close to zero, or at least will be heading towards it, in 10 years time. A linear model for the Arab countries shows that the annual death rate will be in the range of 9.5 deaths per 100,000 population. The GCC countries will be in the range of 20 in its best scenarios. In other words, while the deaths rates per population in the various EU countries drop drastically towards zero in a decade time, the rates in the Arab countries decrease by only 25%.

The traffic crash death rates per 10,000 vehicles in the Arab countries showed a clear descending pattern from an average 27 deaths per 10,000 vehicles in 1980 to 8 in 2011. According to a regressed exponential model the rate is expected to further drop during the coming decade. The drop in the GCC countries as a whole is not as clear as that for the Arab countries in general because of low resulting R2 value. In the EU countries, the pattern is fairly similar to that earlier discussed for the fatality rates per 100,000 population. Once again, it is quite interesting to mention that while the rates in the EU countries will be approaching zero, or at least it is heading towards it, in about a decade time, as per developed linear mathematical model which are solely data dependent equations; those in the Arab countries, as well as in the GCC countries will be in the range of 6 deaths per 10,000 vehicles.

Lack of good record keeping in the past, current safety records and the expected future trends in the Arab World require careful reading, proper interpretation of the results and extensive research since many factors contribute to such high rates of traffic deaths. Such factors need to be well researched in order to be prioritized according to their importance and most likely include the following among many others:

- Lack of measurable long term traffic safety plans
- Inconsistent application of traffic safety strategies
- Poor involvement of Non-Governmental Organizations (NGOs) in traffic safety problem
- Poor coordination between various stake holders
- Poor research involvement in the traffic safety crises
- Limited post-accident rehabilitation centres
- Insufficient detailed data
- Insufficient financial support

These general weaknesses do not mean exclusion of acceptable individual safety programs, as that employed for example in Riyadh, Dubai and Bahrain. They have involved lots of effort, especially in human behaviour and enforcements, to reduce traffic fatalities. However, such plans are yet to be evaluated scientifically.

Many EU countries set long term national safety plans since the 1970's and 1980's for the traffic casualty reduction. In 1987 a target was set in UK, for example, to reduce road casualties by one-third by the year 2000 [16]. As a result, road deaths have fallen by 39% and serious injuries by 45%. The target was successfully met. In 2000, the officials set a plan to further reduce crash deaths and severe injuries by 40% by the year 2010. They have fairly succeeded in approaching the sat target [16]. There are many other similar successful stories throughout the 15 EU countries to improve the current plans and follow them up. The Swedish National Road Administration employed their "Vision Zero- from Conceptual to Action" plan [17]. The Danish Road Safety Commission employed "Every Accident is One Too Many" targeting 40% deaths reduction [18]. There are great opportunities to transfer such experience to the GCC countries through the various involved bodies as consulting offices, research institutions and contractors. Some, as TRL and Sewe-Road, are already involved in developing traffic safety plans and procedures for casualty reductions in the region. Manufacturers may also involve better vehicle high tech to suite the regional problems since an over 38 million extra vehicles are expected to be added to the current 48 million vehicles by the year 2022. Supporting traffic safety through intelligent transportation systems and administering the traffic more efficiently are also sectors requiring further investigation in the region.

## CONCLUSIONS AND RECOMMENDATIONS

Traffic crash deaths in 18 Arab countries were in the range of 22 thousand during the year 1980 compared to that in 27 EU countries were 75 thousand deaths were recorded. The death records in the Arab countries exceeded 37 thousand in 2011; which is about three and a half times that of 1980. Contrary to this, traffic death in EU countries dropped substantially with the time. The total traffic deaths in 2011 were just over 30 thousand, which is only two-fifths of the 1980 record.

The gap in the fatality records and rates between the Arab countries and the EU ones is continuously increasing with time; and are expected to do so during the coming decade unless proper counter actions are considered. The total deaths record in the Arab countries is expected to exceed 52 thousand in the year 2022. That in the EU countries is expected to further drop to less than 14 thousand. Moreover, while the death rates in EU countries will be heading towards the zero, those in the Arab countries will be dropping slightly from the current 10.5 deaths per 100,000 population and 8 deaths per 10,000 vehicles to 9 and 6.5 respectively.

Such poor safety records require careful reading, proper interpretation of the results and extensive research since there many contributing factors lead to such high rates in traffic deaths. These include, among many others, lack of measurable long-term traffic safety plans, inconsistent handling of traffic safety strategies, poor involvement of Non-Governmental Organizations in traffic safety problem, poor coordination between various stake holders, poor research involvement and poor human behaviour towards traffic regulations. Urban planning though being reasonable in many countries is yet not forgiving one and does not support Traffic Safety Strategies.

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# Driver Behavior at Signalized Intersection and Response to End-Of-Green Flash Intervals

Main Author:
Mohamed Eisa Sarhan
Assistant Professor
Department of Civil Engineering
Ain Shams University
Cairo, Egypt
mohamed.sarhan@gmail.com

## ABSTRACT

A dilemma zone is created when stopping sight distance (SSD) > (S) the distance that a vehicle requires to cross the stop line before the onset of the red interval, whereas an option zone is created when S > SSD. Because dilemma zones are more critical than option zones in the sense that vehicles in dilemma zones can neither stop nor proceed during the yellow interval, a flash green (FG) interval at the end of the green interval are sometimes used at high-speed intersections to increase S. This would in turn reduce the probability of having a dilemma zone. In Abu Dhabi City, three second FG interval has been added to around 100 intersections on roads with 60 and 80 km/h speed limits. Using the probabilistic analysis approach, the mean and standard deviation of the dilemma/option zone were formulated. Analysis indicated that the use of three seconds FG may suite roads with 80 km/h but only two second FG is more appropriate for 60 km/h roads.

## INTRODUCTION

The risk of collisions in the vicinity of signalized intersections increases because drivers are loaded with tasks such as changes of signal intervals, maneuvers by other vehicles, searching for directions and destinations, pedestrian crossings, …etc. This suggests paying careful attention to the design of all road and traffic elements that would affect either or both the operation and safety performance near intersections. One of these elements is the traffic signal. As shown in the top part of Figure 1, for every vehicle approaching an intersection, there are two distances:

- Stopping sight distance (SSD)
- Distance (S) that a vehicle needs to proceed and cross the stop line before the onset of the red interval

The two distances are formulated as follows:

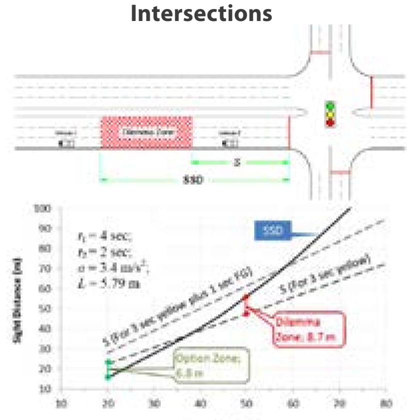
$$S = 0.278 * V * (t_1) + L \qquad (1)$$

$$SSD = 0.278 * V * t_2 + \frac{V^2}{254(a \mp G)} \qquad (2)$$

Where;

- SSD = stopping sight distance (m)
- S = travel distance (m)
- V = speed (km/h)
- t1 = amber time plus End-of-Green Flash Interval (s)
- L = vehicle length (m)
- t2 = perception and reaction time (s)
- a = deceleration rate (m/s2)
- G = percent of grade divided by 100

**FIGURE 1: Dilemma versus Option Zones at Signalized Intersections**



When SSD is greater than S, a dilemma zone is created and a vehicle in this area is neither far from the intersection to stop safely using a comfortable deceleration rate nor close to the intersection to cross the stop line in time. On the other side, when S is greater than SSD, an option zone is created where drivers have to choose to either to stop or to proceed. Both actions can be done in a safe manner. For more illustration, the bottom part of Figure 1 shows an application example that was prepared using some assumptions as shown in the graph. The chart indicates that the distance S for example is greater than SSD at a speed of 20 km/h resulting in an option zone of 6.8 m. When speeds increase to 50 km/h, a dilemma zone of 8.7 m is created. The dilemma zone increases even more as speeds increase, which sometimes reach speeds more than 80 km/h.

One common approach to close the gap between the two curves (SSD and S) and eliminate the problem of dilemma zones is the use of an end-of-green flash interval. When the flash green (FG) time is added, the S curve is shifted up. In the same graph for example, the addition of 1 second, FG is represented by another curve higher than the case of 3 second yellow-only. In such a case, the dilemma zone at the speed of 50 km/h disappears and an option zone of 5.2 m is created instead.

In the Emirate of Abu Dhabi (AD), United Arab Emirates (UAE), a 3 second FG interval has been added to around 100 intersections in Abu Dhabi City in year 2009. The overall safety performance of these intersections from year 2007 to 2012 has been evaluated by Sarhan et al. (1). Al-Harthei et al. (2) also investigated the most significant factors contributing to the occurrence of road crashes at the same Abu Dhabi intersections. The developed algorithm utilized expert opinions and employed artificial intelligence techniques to estimate a hazard index for such intersections.

### *Characteristics of Dilemma and Option Zones*

The difference between SSD and S for every vehicle decides whether a dilemma zone or an option zone is created. This distance (Z) can be formulated as follows:

$$Z=SSD-S=0.278*(t_2-t_1)*V+\frac{V^2}{254(a\mp G)}-L \qquad (3)$$

The type of analysis where a single value is used for each parameter in this equation is called deterministic approach. This approach yields only a mean value of Z. The alternative type of analysis is the probabilistic approach where a distribution is used for each random variable. Each distribution is described by a mean and standard deviation. Using the First Order Second Moment analytical method as one common type of the probabilistic analysis approach, the mean length of the dilemma/option zone can still be estimated using Equation 3 whereas the variance is estimated as follows:

$$\mathrm{var}(Z)=\left(\frac{\partial Z}{\partial V}\right)^2\delta_v^{\,2}+\left(\frac{\partial Z}{\partial a}\right)^2\delta_a^{\,2}+\left(\frac{\partial Z}{\partial t_2}\right)^2\delta_{t_2}^{\,2}$$
$$+2\left(\frac{\partial Z}{\partial V}\right)\left(\frac{\partial Z}{\partial a}\right)\delta_v\delta_a\rho_{va}+2\left(\frac{\square Z}{\partial V}\right)\left(\frac{\partial Z}{\partial t_2}\right)\delta_v\delta_t\rho_{vt_2}$$
$$+2\left(\frac{\partial Z}{\partial a}\right)\left(\frac{\partial Z}{\partial t_2}\right)\delta_a\delta_{t_2}\rho_{at_2} \qquad (4)$$

Where:

$$\frac{\partial Z}{\partial V}=0.278*(t_2-t_1)+\frac{V}{127(a\mp G)} \qquad (5)$$

$$\frac{\partial Z}{\partial a}=-\frac{V^2}{254(a\mp G)^2} \qquad (6)$$

$$\frac{\partial Z}{\partial t_2}=0.278V \qquad (7)$$

### *Data Collection*

From Equations 3 and 4, there are five factors that would affect the mean and standard deviation of the dilemma/option zones including three random variables (speed, PR time, and vehicle deceleration rate) and two factors that can be taken as constants (vehicle length and yellow plus FG interval). In the following subsections, data for the three random variables were measured on Abu Dhabi roads to assess the characteristics of these variables.

### *Operating Speed*

Portable speed radar has been used to collect operating speeds on eight different Abu Dhabi Roads. At each location, special attention was given to keep the radar hidden in order to eliminate the influence of its existence on the drivers' behavior. Posted speeds at these locations are 60 km/h except one road that has a speed limit of 80 km/h. It should be noted that all roads in Abu Dhabi City have a legal 20-km/h-speed tolerance. In other words, the enforcement speed is 20 km/h higher than the speed limit as shown in the table. All data were collected during April and May 2013 at different time of the day to cover all operational conditions as possible. Table 1 shows a summary of the data where a total of 36,507 speed records were collected. The average speed on the eight roads with 60-km/h speed limits had a range from 62.0 to 69.8 km/h (average of 66.4 km/h) whereas an average of 81.3 km/h is observed on the 80-km/h roads. The average standard deviations of speeds are 11.7 and 12.1 km/h for the 60 km/h and 80 km/h roads, respectively.

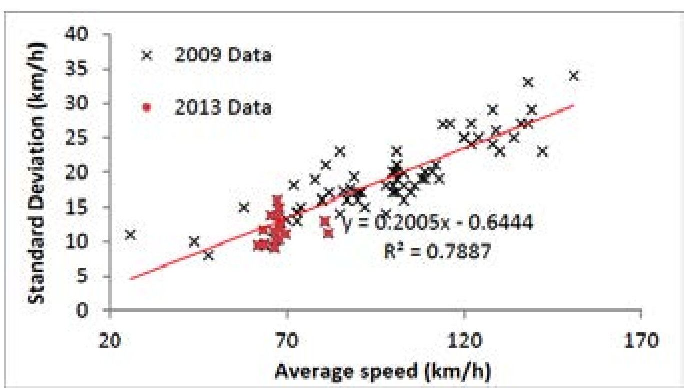
**TABLE 1: Summary of Speed Data Collected in Year 2013**

| Road | Speed Limit (km/h) | Enforcement Speed (km/h) | Date of Data Collection | | | Time | | Count | Speed (km/h) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Year | Month | Day | From | To | | Minimum | Maximum | Average | Stdandard Deviation |
| Murour St. 1 | 60 | 80 | 2013 | 4 | 18 | 7:00 PM | 11:00 PM | 5,637 | 29.0 | 120.0 | 62.0 | 9.4 |
| Murour St. 2 | 60 | 80 | 2013 | 4 | 27 | 11:00 PM | 11:00 PM | 604 | 32.0 | 119.0 | 67.8 | 10.4 |
| | | | 2013 | 4 | 28 | 12:00 AM | 1:00 AM | 526 | 38.0 | 162.0 | 69.8 | 11.1 |
| Dilma St. 1 | 60 | 80 | 2013 | 4 | 19 | 2:00 PM | 7:00 PM | 2,710 | 24.0 | 156.0 | 67.0 | 10.2 |
| | | | 2013 | 4 | 21 | 1:00 PM | 3:00 PM | 375 | 25.0 | 91.0 | 63.9 | 9.7 |
| | | | 2013 | 4 | 21 | 5:00 PM | 8:00 PM | 3,543 | 32.0 | 134.0 | 63.7 | 9.5 |
| Soltan bn Zayed St. | 60 | 80 | 2013 | 5 | 8 | 10:00 PM | 11:00 PM | 573 | 31.0 | 127.0 | 68.1 | 11.8 |
| | | | 2013 | 5 | 9 | 12:00 AM | 1:00 AM | 257 | 35.0 | 117.0 | 68.3 | 12.7 |
| | | | 2013 | 4 | 22 | 10:00 PM | 11:00 PM | 502 | 35.0 | 138.0 | 65.7 | 13.8 |
| | | | 2013 | 4 | 23 | 12:00 AM | 12:00 AM | 153 | 42.0 | 100.0 | 66.4 | 11.5 |
| Al Saada St. | 60 | 80 | 2013 | 4 | 29 | 10:00 PM | 11:00 PM | 361 | 13.0 | 136.0 | 67.4 | 13.8 |
| | | | 2013 | 4 | 30 | 12:00 AM | 12:00 AM | 78 | 36.0 | 103.0 | 67.4 | 15.9 |
| | | | 2013 | 4 | 30 | 12:00 AM | 1:00 AM | 156 | 32.0 | 113.0 | 67.9 | 14.8 |
| Al Kornesh St. | 60 | 80 | 2013 | 4 | 23 | 1:00 PM | 8:00 PM | 13,700 | 17.0 | 163.0 | 66.7 | 9.1 |
| Al Karama St. | 60 | 80 | 2013 | 5 | 3 | 2:00 PM | 8:00 PM | 4,637 | 24.0 | 130.0 | 63.5 | 11.7 |
| Rashed bn Saeed St. | 80 | 100 | 2013 | 4 | 20 | 2:00 PM | 6:00 PM | 1,522 | 37.0 | 142.0 | 80.8 | 12.9 |
| | | | 2013 | 4 | 20 | 6:00 PM | 8:00 PM | 1,173 | 44.0 | 144.0 | 81.7 | 11.2 |

In addition to this set of data, a total of 69 other locations in Abu Dhabi were used to collect speeds in year 2009. Those points were also used to discover the relationship between both average speed and standard deviation as shown in Figure 2. The chart shows a linear relationship with a coefficient of determination of 0.79 as follows:

$$\delta_v = 0.20 * V_{avg} - 0.64 \qquad (8)$$

**FIGURE 2: Relationship between Average Speed and Standard Deviation**




### *Perception and Reaction Time*

Numerous researchers have investigated the perception and reaction (PR) time of drivers at intersections. However, there was a quite variation among their findings depending on the type of their study. From the literature review, there are two main study types: simulation studies and real observation studies. The difference is that, in the first type drivers are more alerted and hence PR time may decrease compared to the real observation studies where drivers are unaware of data collection. A study by Green (8) on a large number of datasets for example indicated that, when drivers are alerted, they could detect a signal and move the foot from accelerator to the brake pedal in about 0.70 to 0.75 second. However, for unexpected events such as a lead car's brake lights, PR time may increase to 1.25 second and may even reach 1.5 second in cases such as an object suddenly moving into the driver's path. Rakia et al. (9) also found that the use of 1.0 second represents 85 % of drivers. Moreover, Gates et al. (10) found that the 50th and 85th PR time is 1.0 and 1.6 s, respectively.

### *Vehicle Deceleration Rate*

Different values for the vehicle deceleration rate were reported in numerous studies in the literature. Wang et al. (11) found that the 3.4 m/s2 deceleration rate in the Green Book (12) is applicable with 92.5% of the vehicles having deceleration rates less than 3.4 m/s2. It was also stated that no relationship was found between the average/maximum deceleration rates and approach speeds. Gates et al. (10) found that the 50th and 85th PR time is 3.02 and 3.93 m/s2, respectively. Council et al. (13) studied 54 intersection approaches and found that 3.0 m/s2 is a reasonable deceleration rate. Maura et al. (14) observed a maximum deceleration rate of 1.71 m/s2. Maura et al. (14) also summarized results published in many other studies as shown in Table 2, which indicates a wide range of deceleration rates at different speeds.

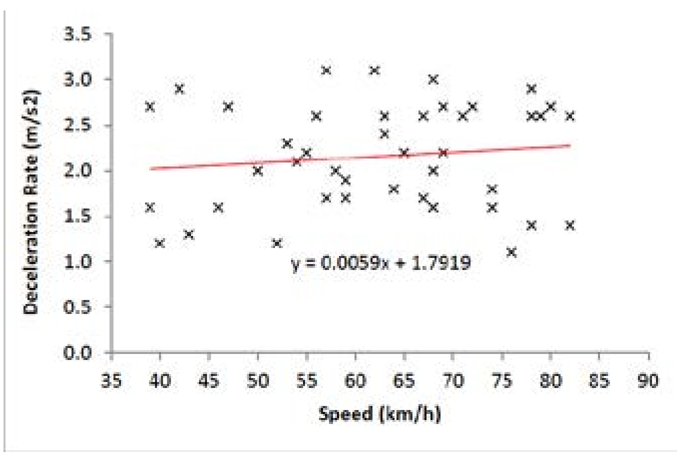
**TABLE 2: Deceleration Rates Observed by Various Researchers (14)**

| Author | Year | Speed range (km/h) | Deceleration Rate ($m/s^2$) |
|---|---|---|---|
| Gazis et al. | 1960 | 72 | 4.9 |
| St. John and Kobbet | 1978 | | 1.07 |
| Parsonson and Santiagio | 1980 | | 3 |
| Bester | 1981 | | 0.6-1.9 |
| Lee et al. | 1984 | | 0.28-0.96 |
| Wortman and Fox | 1994 | 48.3-80.5 | 2.1-4.2 |
| Wortman and Matthias | 1983 | 57.6-76.4 | 2.5-4 |
| Brodin and Carlsson | 1986 | | 0.5 |
| Watanatada et al. | 1987 | | 0.4-0.6 |
| McLean | 1991 | | 0.5-1.47 |
| Bennett and Dunn | 1995 | 60-70 | 1.39 |
| | | 70-80 | 1.78 |
| | | 80-90 | 2.22 |
| | | 90-100 | 2.34 |
| Akçelik and Besley | 2001 | 60 | 3.09 |
| Wang et al. | 2005 | 40-50 | 2.4 |
| | | 50-60 | 2.39 |
| | | 60-70 | 2.67 |
| | | 70-80 | 2.52 |
| | | 80-90 | 2.55 |

Results indicated a speed range of 39 km/h to 82 km/h. The calculated deceleration rates are from 1.1 m/s2 to 3.1 m/s2. The data also showed an average deceleration rate of 2.16 m/s2 and standard deviation of 0.58 m/s2. The 85th and 95th percentile values were found 2.70 and 3.09 m/s2, respectively. As shown in Figure 3, the relationship between speed and deceleration rate indicated a slight increase of the deceleration rate with the increase of the speed. This can be interpreted that vehicles with higher speeds are normally urged to use higher deceleration rates to be able to stop in time. Furthermore, the correlation coefficient between speed and deceleration rate is + 0.13 and the linear relationship is described as follows:

$$a = 0.0059 * V + 1.79 \qquad (9)$$

**FIGURE 3: Relationship between Speed and Deceleration Rate**




## ANALYSIS AND DISCUSSION

Using Equation 3, the mean value of the dilemma/option zone is calculated at different speeds from 40 to 100 km/h as presented in Figure 4. For the factors in this equation, the deceleration rate was estimated using Equation 9. The average PR time of 1.0 second was used based on the gathered data. The standard deviation of the speed is estimated using Equation 8. The standard deviation of both the deceleration rate and PR time are 0.58 m/s2 and 0.2 second, respectively.

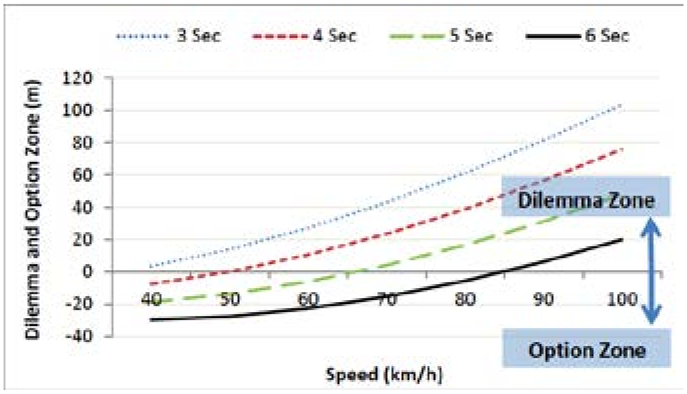
In addition, a vehicle length of 5.79 m was used as recommended in the Green Book (12) as a design passenger car. It should be noted that heavy vehicles are only allowed to take certain routes in Abu Dhabi and that no heavy vehicles are allowed to enter the city for safety purposes. For the correlation coefficients between the three input variables (i.e., speed, deceleration rate, and PR time), only the coefficient between speed and deceleration rate (+0.19) was used whereas no information was available for the other two couples of variables.

In Figure 4, a positive value indicates a dilemma zone whereas a negative value indicates an option zone. The figure shows that the use of 3 second yellow interval with no FG as the case before year 2009 in Abu Dhabi City might not suite the speeds and driver characteristics on Abu Dhabi roads. This is because the 3 second curve falls entirely in the dilemma area. With the addition of FG time, option zones start to create at low speeds and dilemma zones start to decrease. The best choice is believed to be the curve that passes the neutral axis (zero value for the dilemma/option zone) at speeds close to the operating speeds.

In this context, the use of 6 second (3 second yellow + 3 second FG interval) as the case in Abu Dhabi City after year 2009 shows that the curve indicates a zero dilemma/option zone at speeds around 85 km/h. This scenario might not suite roads with 60 km/h speed limit (80 km/h enforcement speed) since the average speeds for these roads as measured in Abu Dhabi are around 62 to 68 km/h, as presented earlier in TABLE 1. Therefore, the author believes that the use of 3 second FG should be used on roads with 80 km/h speed limit while only 2 second FG should be used on those with 60 km/h speed limit.

For the standard deviation of dilemma/option zone, the use of the input values presented in Figure 4 back in Equation 4 has resulted in values between 85 and 390 m for speeds between 40 and 100 km/h, respectively. These are very long distances that show the great impact of the variation of all input values on the standard deviation of dilemma/option zone. It is noteworthy that each approaching vehicle has its own zone type and length based on its speed and driver characteristics. This means that two approaching vehicles can have different types (i.e., dilemma and option) with different lengths.

**FIGURE 4: Dilemma and Option Zones at Different Speeds**




## CONCLUSIONS

The yellow or FG-yellow intervals are both intended to provide warning to drivers that the green interval will be terminated and that the red signal will start thereafter. Well-designed signal timing is the one that allows drivers far from the intersection to decelerate comfortably to a stop and for drivers closer to the intersection to clear the intersection before the onset of the red interval. When short warning time is given to drivers, the dilemma zone problem becomes predominant. On the other side, the option zone is experienced when more warning time is given. It should be mentioned that, although drivers can decide to stop or proceed when their cars fall in an option zone, the conflict in decisions among drivers might negatively affect safety and increase the probability of collisions.

In this paper, the characteristics of the dilemma/option zone have been assessed on Abu Dhabi roads with 60 and 80 km/h posted speeds. Data have been collected for speed, perception and reaction time, and deceleration rate and values have been substituted in formulas derived for the calculation of the mean and standard deviation dilemma/option zone based on the probabilistic analysis approach. Results indicated that the use of 3 second yellow interval plus 2 seconds FG is appropriate for roads with 60 km/h whereas the use of 3 second FG may be granted for approaches with 80-km/h speeds.

Results also indicted that the speed has the greatest impact on the standard deviation of dilemma/option zone. This could increase the probability of collision on high-speed roads compared to low-speed roads. However, one should keep in mind that the addition of flash green (FG) intervals moves such zones farther from the intersections giving drivers more time to either accelerate or start early braking for a relaxing deceleration. Moreover, the problem can be eliminated by increasing the enforcement level (speed radars and police patrolling) that normally encourages drivers to respect posted speeds and in turn reduces speed variation.

It is also suggested that the FG interval is deactivated during rush hours when speeds decrease to values of 30 or 40 km/h. This would mitigate the option zone problem and prevent drivers from speeding up at the onset of FG in an attempt to catch the yellow signal. Other measures also can play a significant impact in improving operational and safety performance at signalized intersections such as the implementation of digital countdown signals. This may increase the time during which drivers should chose the appropriate decision and, in the same time, it eliminates the probability of sudden actions and maneuvers that some drivers may take when the signal changes suddenly from green to FG.

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# Whiteroads EU Project: A Positive Approach To Road Safety

Main Author:
Elena de la Peña
Spanish Road Association
Madrid, Spain
edelapena@aecarretera.com

Co-Author:
José Díez
European Union Road Federation
Brussels, Belgium
j.diez@erf.be

## ABSTRACT

Road accidents have negative social, economic and health consequences, proving to be a challenge for 21st century roads. Road safety is becoming a policy priority not only for the European Union and its Road Safety Programmes but also at international level for United Nations with the launching of the Decade of Action for Road Safety [1] [2]. WhiteRoads EU Project is a European initiative developed by the European Road Federation (ERF) and the Spanish Road Association (AEC), which are two major actors in the field of road safety and infrastructure. The Project has located road sections of the Trans-European Road Network (TEN-T) that despite the same density of traffic flow and similar road infrastructure register fewer accidents. Those road sections are called "white spots" in clear opposition to the so-called "black-spots" [3].

## DATA COLLECTION AND ANALYSIS

The main challenge for the consortium was the collection and analysis of statistics from 27 member states. This information has been critical to develop the Project. During initial phases of WhiteRoads, the ERF and AEC maintained regular contact with more than 100 experts in road safety from National Road Agencies, Ministries of Transport, Home Affairs, Traffic Police, or National Statistics Bodies.

In particular, with the support of the European Commission, the following (TEN-T) data have been requested to all EU members:

- List of roads in each member state
- Road sections where no injury accidents have happened in the period 2004-2009
- Road sections where no injury accidents involving motorcyclists have happened in the period 2004-2009
- Road sections where no fatal accidents have happened in the period 2004-2009
- Road sections where no fatal accidents involving motorcyclists have happened in the period 2004-2009
- Traffic volumes data

The need of very specific information about accidents has represented a major challenge. There is no homogenous data in the European Union due to national divergences in references (kilometers or coordinates "X, Y"), periods of data collection, systems of data publications, content or collection methods.

In addition, some countries have not even been allowed to provide any data due to strict privacy regulations. Frequently, data was incomplete and consequently requiring further analysis and in some cases, even the use of special software tools to locate where the accident happened exactly. The lack of statistics or the existence of incomplete information has always a very negative impact on road safety as it was stressed during the presentation of the WhiteRoads results by road safety experts, representatives from European Parliament and Commission, OECD and industry.

The Project has shown that the lack of clear information, statistics and correlation between accidents and road sections remains a serious obstacle to improve road safety, not only for the WhiteRoads consortium but also for black spot management works or other research studies.

## EUROPEAN WHITE SPOT DEFINITION AND CRITERIA

Following extensive statistical analysis of road accidents in almost all EU countries, the next step in the development of the Project was the definition of European White Spot (EUWS). The concept brings together three parameters including time, section length and type of accidents to be considered.

The EUWS is defined as road section of the TEN-T of at least 15 consecutive kilometers (km) long where no fatality accidents have happened during the last 5 years considered for the study. A time parameter of 5 years was set as practices for road safety statistical analysis commonly consider 3 or 5 years, so the longest period would be the best to identify those white sections.

As regards the length of 15 km, the consortium had the possibility to follow other practices for the black spot identification and management, which normally consider a distance of 1 km long. However, this distance is too short and cannot be representative of a good behaviour from the accident point of view so a new study should be more exigent in the length of the road. The length of 10 kilometres long is usually considered for the analysis of itineraries, but the consortium decided to be even more restrictive. It would have been desirable to consider a higher length (i.e. 25 km) for the definition of EUWS, but the consortium decided to consider 15 km as it ensured the existence of EUWS in all countries analysed.

In addition, TEN-T roads are mainly motorways but also there are single carriageway conventional roads located mostly in new member states.

The third parameter refers to the typology of the accident. WhiteRoads only consider fatal accidents and not serious injuries because there is only a common definition in Europe for fatalities (dead caused within the 30 days after the accident) while there are divergences for the concept injury depending on the member state.

Consequently, the WhiteRoads consortium has identified 982 EUWS, which represent 40% of the total TEN-T road network after analysing 85,418 km and 248,158 accidents in the EU.

**FIGURE 1: Number of EUWS per Country**

| COUNTRY | NUMBER OF EUWS |
|---|---|
| Austria | 16 |
| Belgium (Flanders) | 8 |
| Belgium (Walonia) | 7 |
| Bulgaria | 40 |
| Cyprus | 3 |
| Czech Republic | 22 |
| Denmark | 16 |
| Estonia | 11 |
| Finland | 79 |
| France | 242 |
| Greece | 4 |
| Hungary | 18 |
| Ireland | 42 |
| Ireland | 42 |
| Italy | 45 |
| Latvia | 23 |
| Lithuania | 1 |
| Luxembourg | 1 |
| Poland | 9 |
| Portugal | 46 |
| Romania | 7 |
| Slovakia | 5 |
| Slovenia | 5 |
| Spain | 150 |
| Sweden | 106 |
| The Netherlands | 59 |
| United Kingdom | 17 |

**FIGURE 2: Number of White Kilometers per Country**


## ON-SITE FIELD WORK INSPECTIONS

Another important milestone of WhiteRoads has been the onsite analysis of EUWS in eight member states with different infrastructure characteristics.

In order to complete a more detailed analysis, each EUWS have been divided into sub-sections of 3 km long (for example, a white road of 20 km has been divided into six sub-sections of 3 km and one of 2 km). Inspections were carried out between April and October 2013 under relatively good weather conditions recording and collecting information about conditions and existence of different infrastructure elements. Figure 3 illustrates the countries where the field work has been conducted and the number of km inspected.

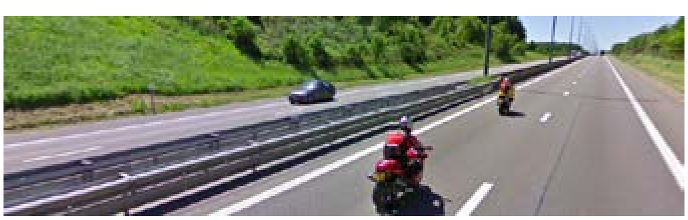
**FIGURE 3: Countries and km Analyzed in the Fieldwork**


The fieldwork concluded that these particular road sections present in general a good standard of design, appropriate road equipment, as well as a good level of maintenance. However, the presence of pedestrian crossing or lack of protection for other vulnerable users such as motorcyclists represents a real risk for road safety in some countries.

Most of the white sections are located on dual carriageway motorways although there are also some single carriageways especially in new member states where road network is currently being upgraded through the investment of EU funds. Lanes are wider than 3.5 m with paved hard-shoulders between 0.5-1.5 m width. In case of conventional roads hard-shoulders are narrower being most of them half-paved although keeping enough safety distance to avoid crashes with obstacles as houses or trees.

EUWS are designed avoiding dangerous curves and permitting good visibility ensuring safety for all road users including motorcyclists.

**FIGURE 4: Detail of EUWS on Motorway A26 with Special Protection for Motorcyclists (Belgium)**



The average daily traffic for most of the roads is normal to high, ranging from 10.000 to 35.000 vehicles a day. The percentage of heavy vehicles varies depending on the country and its location in Europe. For instance a peripheral country like Spain has a percentage between 13-26% depending on the road while in central Europe like Poland percentage rises up to 43%.

As regards equipment, common characteristic for all the EUWS is the good maintenance level of road equipment. Good maintenance of markings and signs reduce accident risks. During the inspections of the EUWS, the consortium has checked different elements in this aspect as consistency between markings and signs, condition and visibility.

**FIGURE 5: Detail of EUWS on Single Carriageway R1 with Good Markings and Signs (Estonia)**

Existence of additional traffic guidance equipment has been also considered as profiled road markings, directional sign in curves, road studs, side posts, posts or cushions on exists and variable message panels.

**FIGURE 6: Profiled Road Markings**

FIGURE 7: Directional Signs in Curves

FIGURE 8: Road Studs

FIGURE 9: Side Posts

FIGURE 10: Posts or Cushions on Exits

Another important element characterising safety is lighting specially in specific spots as crossings, accesses to fuel stations or urban areas. All the EUWS have at least one point lighted ensuring a minimum of safety during the night. Different studies have shown a direct link between no lighting and increase of accident risk.

FIGURE 11: Lighting in Exits Improves Visibility for Users

As regards pavement, EUWS are constructed either using concrete or asphalt being the last the most common element. Inspections have considered the existence of potholes and cracking. Pavement condition also varies depending of its construction or latest upgrade date. The majority of EUWS have a pavement in normal to good condition. Again, a good level of maintenance plays always an important role for safety.

FIGURE 12: Good Maintenance and Upgrades Always Reduce Accident Risks

## DEVELOPMENT OF COMPARATIVE CHECKLIST

One of the final objectives of the consortium has been the development of a checklist of positive safety elements in road infrastructure common to the European White Spots (EUWS).

The checklist provides a set of general aspects to be considered in order to design and build in the safest conditions from the infrastructural and equipment perspective, consequently generating the so-called "White Roads".

Although the WhiteRoads Project has been developed for the TEN-T, it could be easily applied to other road networks. In this context, and provided that tools included in Road Infrastructure Safety Directive 2008/96 for the design, maintenance and management of roads without accidents (safety impact assessment, safety audit, safety inspection and safety management of the network) are only compulsory for the TEN-T, at least a road safety audit or a road safety inspection should be conducted.

The WhiteRoads checklist should be considered as a new and complementary tool after the road safety audit (new road design) or inspection (existing road) has been done. Consequently, in regional or local road networks, it is particularly important to carefully consider safety requirements of vulnerable road users, such as pedestrians, cyclists or motorcyclists. While pedestrians and cyclists are not so common in the TEN-T in some EU Member States, motorcyclist's traffic is representative in all road networks.

The checklist focuses on key aspects such as width of lanes and shoulders, traffic volumes, road surroundings, road margins, road signs, road markings guidance equipment, road restrain systems or traffic management technology.

The consortium has elaborated two compatible checklists to be applied on new construction and existing roads.

**FIGURE 13: WhiteRoads Checklist for Designing New Infrastructure**

| Chapter | Aspect | Checked | | Comment |
|---|---|---|---|---|
| | | Yes | No | |
| Previous road safety treatment | Was a safety impact assessment conducted in the planning stage? | | | |
| | Has a road safety audit been conducted during this stage? | | | |
| Functionality of road | Check that the road, expected type of traffic and equipment are suitable for the functionality of the TEN-T. | | | |
| Connection with the network | Check safety conditions of the connection with other roads, although not part of the TERN. | | | |
| Tunnels | Conduct a road safety audit in the road section included in the tunnel. | | | |
| Alignment | Ensure proper consistency of the alignment. | | | |
| Cross section | Check suitability of lane width and shoulder width, which should be paved. | | | |
| Traffic | Carefully analyze the expected traffic; if a high volume of heavy traffic is expected, a decrease in the speed limit should be valued; variable speed limits are advisable. | | | |
| Pavement | Carefully analyze pavement layer and road foundation and its suitability to expected traffic, in order to avoid structural damage causing bad maintenance condition in the road surface. | | | |
| Traffic signs | Are traffic signs credible with the alignment and surroundings of the road? | | | |
| | Ensure that directional traffic sings area easily and undoubtedly perceived by foreign users. | | | |
| | Are traffic signs homogeneous along the itinerary? | | | |
| Variable message signs | Provide variable message signs. | | | |
| Vehicle restraint systems | Ensure that containment level of vehicle restraint systems fulfills with safety requirements of all expected users, including motorcyclists and heavy vehicles along the whole road. | | | |
| Road lighting | Provide lighting to all singular road sections (interchanges, crossroads, etc). | | | |
| Vulnerable road users | Pedestrians should not be allowed; check that they are clearly informed by signs and physical barriers are provided, in order to avoid their entrance to the road area. | | | |
| | If cyclists are allowed, is their safety guaranteed? If not, it is reasonable to prohibit their access to the infrastructure, in order to preserve their safety. | | | |
| | Check that motorcyclist's protection systems are installed in safety barriers in road sections with high risk for this type of users. | | | |
| Public transport | If there are bus stops along the road, check not only the right placing and safety conditions, but also the existence of a "safe way" for pedestrians getting in and off the bus. Otherwise, bus stops should be placed in the service road. | | | |
| Others | Is the road expected to be self-explaining from the road user perspective? | | | |
| | Value and limit work load of the road section, considering frequent users point of view and also elderly drivers. | | | |
| | Ensure legibility of the road. | | | |
| | Consider a strategy for variable speed limits depending on traffic and weather conditions. | | | |

**FIGURE 14: Checklist for Operating White Roads**

| Chapter | Aspect | Checked | | Comment |
|---|---|---|---|---|
| | | Yes | No | |
| | Was a road safety inspection conducted recently? | | | |
| | Are black spots (or high accident rate road sections) identified periodically? | | | |
| Functionality of road | Check that the road, expected type of traffic and equipment are suitable for the functionality of TEN-T. If functionality has changed, new safety measures should be implemented (e.g. avoid the presence of pedestrians). | | | |
| Safety management | Check safety of the entire itinerary once a black spot (or high accident rate road section) has been identified and sorted out; in case that some infrastructural problem has been identified, check that similar problems do not appear along the itinerary. | | | |
| Pavement | Ensure proper periodical maintenance programs, according to the traffic volumes, in order to guarantee adequate quality of service. | | | |
| | Establish an emergency program for repairing road surface damages in a short time. | | | |
| Traffic signs | Are traffic signs credible with the alignment and surroundings of the road? | | | |
| | Ensure that directional traffic sings area easily and undoubtedly perceived by foreign users. | | | |
| | Ensure proper periodical maintenance programs, in order to guarantee adequate quality of service. | | | |
| | Establish an emergency program for repairing damaged traffic signs in a short time. | | | |
| | Are traffic signs homogeneous along the itinerary? | | | |
| | Variable message signs | | | |
| Variable message signs | Check correct performance of variable message signs and that the information provided is useful, updated and oriented to improve quality of service and users' safety. | | | |
| Road markings | Are road markings credible with the alignment and surroundings of the road and coherent with traffic sings? | | | |
| | Ensure proper periodical maintenance programs, in order to guarantee adequate quality of service. | | | |
| | Establish an emergency program for repainting road markings in a short time. | | | |
| Traffic guidance equipment | Ensure proper periodical maintenance programs, in order to guarantee adequate quality of service. | | | |
| | Establish an emergency program for repairing damaged guidance equipment in a short time. | | | |
| | Are traffic signs homogeneous along the itinerary? | | | |
| Road lighting | Provide lighting to all singular road sections (interchanges, crossroads, etc). | | | |
| | Establish an emergency program for repairing lighting in a short time. | | | |
| | Value and limit work load of the road section, considering frequent users point of view and also elderly drivers. | | | |
| | Ensure legibility of the road. | | | |
| | Consider a strategy for variable speed limits depending on traffic and weather conditions. | | | |

## CONCLUSION

After three years of analysis and the inspections of white roads, the consortium can conclude that there are indeed road sections experiencing a "positive behavior" from the accident perspective. Those white sections share similar characteristics in terms of safety. Some of the features included in the WhiteRoads checklist are the following:

- Suitability of road, traffic and equipment to the functionality of the TEN-T
- Correct and safe connection with other roads although not part of the TEN-T
- Adaption of pavement and speed limits to high traffic flow of heavy vehicles
- Correct installation of homogeneous traffic signs well located and visible to all the users considering the increase of cross-border traffic
- Installation of variable message panels improving road management when any unexpected situation happens (traffic accident, bad weather condition, congestion, etc)
- Ensure that containment level of barriers adapts to all users, especially motorcyclists and heavy vehicles
- Ensure special protection to vulnerable users such as pedestrians or cyclists with separated and protected lanes or crossings
- Provision of lighting in special areas as crossings, exits, etc
- WhiteRoad sections represent stretches in the main European roads, which have received proper funding for maintenance. However, although the project can contribute to the creation of safer roads, ultimately it is necessary an integral approach between users, vehicle, infrastructure, enforcement and governments.

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# Comprehensive Analysis of the Severity and Nature of Traffic Crashes Occurring on Rural Roads in the Kingdom of Saudi Arabia

Main Author:
Hany M. Hassan
King Saud University
Prince Mohamed Bin Naif Chair for Traffic Safety Research
Riyadh, Saudi Arabia
hhassan@knights.ucf.edu

Co-Authors:
Hesham Al-Faleh
Director of Traffic Safety Department
General Department of Traffic
Riyadh, Saudi Arabia
h.alfaleh@hotmail.com

Ali Al-Rashidi
Ain Shams University
Faculty of Engineering
Department of Civil Engineering
Public Works Division
Cairo, Egypt
dlrashidi@gmail.com

## ABSTRACT

Traffic crashes are among the greatest sources of external costs in the Kingdom of Saudi Arabia (KSA) in terms of fatalities, injuries, property damage, and congestion effects. This paper aims at thoroughly examining the nature, causes of traffic crashes occurring on rural roads in the KSA so that countermeasures and future studies could be suggested. An objective is to identify the significant factors affecting the severity of those crashes. The results indicated that sudden lane change, distraction, speeding, failed to yield right of way and defects in tires were the main reasons for involvement in traffic crashes on rural roads. Passenger cars were the most frequent vehicles involved in crashes at 64% followed by trucks at 28%. The findings of the ordered probit model revealed that crash location, aggressive driving behavior and size of crash were the significant variables that increase the severity of traffic crashes on rural roads.

## BACKGROUND

Prior Studies that addressed traffic safety in Saudi Arabia

Few studies have been conducted to examine traffic safety problems in KSA. For instance, Koushki and Al-Ghadeer (1) examined driver compliance with traffic regulations in Riyadh and the results indicated that drivers do not comply with traffic regulations.

Al-Ghamdi (2) investigated the factors affecting pedestrian related crashes in Riyadh. Data reported by the police, from 638 pedestrian related crashes reported during the period 1997–1999 were used. The findings showed that about 77% of pedestrians involved in these crashes were struck while crossing a road where no crosswalk existed. In addition, it was found that about 34% of the fatal injuries were located on the head and chest.

In addition, Al-Ghamdi (3) evaluated ambulance response time in Riyadh and compared it with the corresponding times in other countries. The results revealed that the mean response time was 10.2 min, which is below the acceptable standards in developed countries like the UK and the US. Also, the time to serve one call takes on average 61.2 min with an 85th-percentile time of 66 min.

Moreover, Al-Ghamdi and AlGadhi (4) assessed the effectiveness of using warning signs as countermeasures to camel–vehicle collisions in Saudi Arabia. The mean speed reduction of motorists passing these warning signs was the measure of effectiveness used in that study. The results indicated that after using such signs, the speed reduction ranged from 3 to 7 km/h.

Furthermore, Bendak (5) investigated driver behavior, personal characteristics and their relationship with respect to using seat belts using a questionnaire survey. The results showed that the rate of using seat belt in two Riyadh suburbs for drivers were 33% and 87%, respectively. However, for the front-seat passengers, the rates of using seat belt were only 4% and 41%.

***Prior studies that addressed severity of traffic crashes worldwide***

Gray et al. (7) performed an injury severity analysis of accidents involving young male drivers in Great Britain using ordered probit models. It was found that the characteristics predicted to lead to serious and fatal injuries include driving in darkness, between Friday and Sunday, on roads with a speed limit of 60 mph, on single carriageways, overtaking, skidding, hitting an object off the carriageway, and when passing the site of a previous accident.

Haleem and Abdel-Aty (11) examined the factors associated with traffic crash injury severity at unsignalized intersections in Florida using three approaches: ordered probit model, binary probit model, and nested logit model. It was found that traffic volume on the major approach, and the number of through lanes on the minor approach, the upstream and downstream distance to the nearest signalized intersection, left and right shoulder width, number of left turn movements on the minor approach, and number of right and left turn lanes on the major approach were the significant variables affecting crash severity at unsignalized intersections.

Yang et al. (12) explored the impacts of contributing factors related to crash injury severity at freeway diverge areas using ordered probit model. The results revealed that the mainline lane number, length of ramp, difference of speed limits between mainline and ramp, light condition, weather condition, surrounding land type, driver impairment, road surface condition, shoulder width, and crash types of rear-end and sideswipe were the factors significantly influencing crash severity at freeway diverge areas.

Castro et al. (14) proposed a spatial generalized ordered response model to examine the severity of traffic collisions occurring on highway road segments in Austin, Texas. The findings from this study showed that the most important determinants of injury severity on highways were:

- Seat belt usage
- Involvement of a truck
- Point of collision (head-on)
- Whether passengers were ejected
- Whether a vehicle overturned

Considering these prior studies, an issue that has not been explicitly addressed in any prior studies is the detailed exploration of the characteristics and main causes of traffic crashes occurring on rural roads in the KSA. Therefore, this paper aims at thoroughly examining the nature, causes of traffic crashes occurring on rural roads in the KSA so that countermeasures and future studies could be suggested. Another objective is to identify the significant factors affecting the severity of those crashes.

***Data Source and Description***

According to the Saudi crash report, crash severity is classified into four levels:

- Fatalities
- Severe injury
- Slight injury
- Property damage only (PDO)

In Saudi Arabia crash reports are filed by the traffic departments if the crash resulted in injury or fatal crashes. However, if the crash resulted in PDO, the crash report is filled by a private insurance company (Najm) and in this case a short form of the Saudi crash report is filled.

To achieve the objectives of this study, about 500 crash reports that occurred on rural roads in the Eastern Region of the KSA in 2012 were obtained from the general department of traffic of the KSA. These crash reports were in hard copies format and hence the research team has made substantial effort to prepare and process the data (i.e., transferring the data to electronic format) to make it ready for the statistical analysis.

***Preliminary Analysis***

Table 1 shows the distributions of the dataset used in this study. As shown in Table 1, about 45% of the crashes' sample was PDO crashes while approximately 10% of them were fatal crashes. It can be noted from the table that about 56% of these crashes were single vehicle crashes. It was found also that about 26% of the crashes' sample resulted in two injuries or more while about 10% of them resulted in one fatality or more.

Regarding the type of the first vehicle at-fault involved in those crashes, it was found that approximately two-third of the sample (64.5%) occurred by passengers' cars and about 28% of the sample occurred by trucks. In addition, Table 1 revealed that approximately 47% of the drivers' at-fault in those crashes was Saudi while about 32% and 19% of those drivers were Asians and Arabs, respectively.

With respect to damages in public and private properties resulted from the sample of traffic crashes that occurred on rural roads in the KSA, it was found that about 97% of those crashes resulted in damages in vehicles while approximately 11% of them resulted in damages in metal fences that surround most of the rural roads in the KSA (i.e., to prevent camels from the sudden crossing of the roads).

Concerning crash time, the results presented in Table 1 indicated that the largest percentage of the sample (20.2%) occurred on Saturday (first working day of the week) while the smallest percentage of the sample (6.5%) occurred on Friday (Thursday and Friday are the weekend). These results are logical considering the increase in traffic volumes that exist during working days compared to the weekend. It was found also that about 44% of those crashes occurred during the day times while approximately 56% of them occurred during the night times.

In addition, the results showed that most of the sample (97.6%) occurred on dry roads' surfaces while only 2.4% of the sample occurred on wet roads' surfaces. Regarding roads' lighting conditions, more than two-third of the sample (about 69%) occurred on rural roads with lighting while approximately 31% occurred on rural roads without lighting. With respect to weather, it was found that the majority of the sample (95.2%) occurred in clear weather conditions while only 4.8% of the sample occurred in reduced visibility conditions. Concerning point of collision, the findings revealed that more than half of the sample (about 55%) was sideswipe crashes while about 27%, 15%, 2% of those crashes were rear-end, head-on, and angle crashes, respectively.

One objective of this study was to identify the main reasons for involving in traffic crashes that occur on rural roads. As shown in Figure 1, the driver factors was the main reason for those crashes followed by the vehicle factors. It was found that about 88% of those crashes occurred due to driver factors while only 12% of them occurred due to vehicle factors. Figure 1 shows that sudden lane change, distraction, speeding and failed to yield right of way were the main driver factors that led to those crashes while defects in tires was the main vehicle factors that led to those crashes.

**TABLE 1: Distributions of the dataset (N=124)**

| No. | Variables | Categories | Frequency | Percentage |
|---|---|---|---|---|
| 1 | Crash Severity | Fatal | 12 | 9.7 |
| | | Severe injury | 24 | 19.3 |
| | | Slight injury | 32 | 25.8 |
| | | PDO | 56 | 45.2 |
| 2 | No. of vehicles involved | 1 | 69 | 55.7 |
| | | 2 | 50 | 40.3 |
| | | 3 or more | 5 | 4.0 |
| 3 | No. of injuries | 0 | 56 | 45.2 |
| | | 1 | 36 | 29.0 |
| | | 2 | 20 | 16.1 |
| | | 3 or more | 12 | 9.7 |
| 4 | No. of fatalities | 0 | 112 | 90.3 |
| | | 1 | 10 | 8.1 |
| | | 2 or more | 2 | 1.6 |
| 5 | Vehicle Type | Passenger car | 80 | 64.5 |
| | | Pick-up trucks | 35 | 28.2 |
| | | Others | 9 | 7.3 |
| 6 | Nationality of driver at fault | Saudi | 58 | 46.8 |
| | | Arab | 24 | 19.3 |
| | | Asian | 40 | 32.3 |
| | | Others | 2 | 1.6 |
| 7 | Private damages | None | 3 | 2.4 |
| | | vehicles | 120 | 96.8 |
| | | others | 1 | 0.8 |
| 8 | Public damages | None | 103 | 83.1 |
| | | Metal fences | 14 | 11.3 |
| | | others | 7 | 5.6 |
| 9 | Day of the week | Saturday | 25 | 20.2 |
| | | Sunday | 15 | 12.1 |
| | | Monday | 15 | 12.1 |
| | | Tuesday | 20 | 16.1 |
| | | Wednesday | 21 | 16.9 |
| | | Thursday | 20 | 16.1 |
| | | Friday | 8 | 6.5 |
| 10 | Crash time | Day | 54 | 43.6 |
| | | Night | 70 | 56.4 |
| 11 | Crash Location | Not at Intersections | 7 | 5.6 |
| | | At intersections | 105 | 84.7 |
| | | At exists or entrances | 12 | 9.7 |
| 12 | Road surface condition | Dry | 121 | 97.6 |
| | | Wet / others | 3 | 2.4 |
| 13 | Road Lighting conditions | With lighting | 86 | 69.3 |
| | | without lighting | 38 | 30.7 |
| 14 | Weather | clear | 118 | 95.2 |
| | | Others (cloudy, rainy, dust) | 6 | 4.8 |
| 15 | Collision point | Head-on | 18 | 14.5 |
| | | Rear end | 33 | 26.6 |
| | | Angle | 2 | 1.6 |
| | | Sideswipe | 68 | 54.9 |
| | | Others / unknown | 3 | 2.4 |

Figure 2 shows the distribution of the sample of traffic crashes by the crash type. The results presented in the figure indicate that the largest percentage of the sample of traffic crashes (37.9%) that occurred on rural roads resulted due to hitting moving vehicles, 29% due to vehicles' turnover, 14.5% due to hitting fixed objects, 4.8% due to hitting stopped vehicles, 4% due to hitting pedestrians.

**FIGURE 1: Distribution of the sample of traffic crashes by the crash reason**

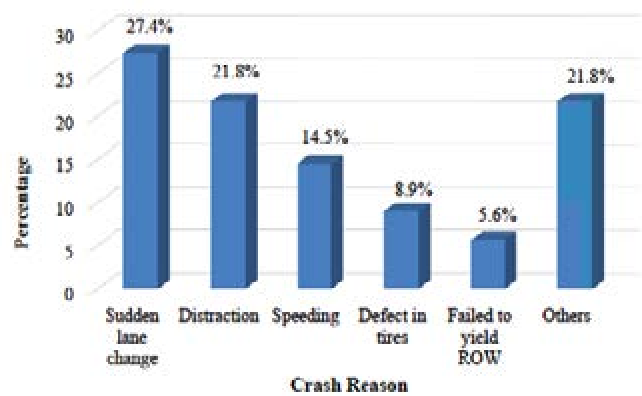
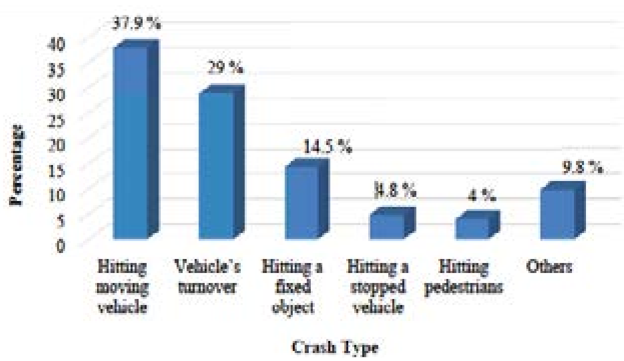



**FIGURE 2: Distribution of the sample of traffic crashes by the crash type**




Prior to modeling the severity of traffic crashes occurred on rural roads, two-way analyses were conducted. Pearson's chi-square test was used to examine the independence of every pair of nominal variables, whereas a Cochran–Mantel–Haenszel (CMH) test was used to analyze the association between every pair of ordinal variables or between ordinal and nominal variables. A summary of the factors that have a significant association with the response variable (severity of traffic crashes) is provided in Table 2. As indicated in Table 1, crash severity is an ordinal variable with four levels: (1) fatalities, (2) severe injury, (3) slight injury, and (4) property damage only (PDO) and hence the ordered probit model approach was estimated.

As shown in Table 2, the results of the two-way analysis indicated that number of injuries and fatalities resulted from the crash, crash location, crash reason and day of the week when the crash occurred were the variables that showed significant association with the ordinal target variable crash severity (fatal, severe injury, slight injury and PDO).

**TABLE 2: Summary of the factors associated with the severity of traffic crashes**

| Factors | Value | P Value |
|---|---|---|
| Number of injuries resulted from the crash | CMH = 68.6158 | <0.0001* |
| Number of fatalities resulted from the crash | CMH = 98.3251 | <0.0001* |
| Crash Location | CMH = 13.6365 | 0.0034* |
| Crash Reason | CMH = 3.2816 | 0.0701** |
| Crash Type | CMH = 3.4126 | 0.0647** |
| Day of the week when the crash occurred | CMH = 3.2108 | 0.0732** |

## RESULTS AND DISCUSSION

In this study, the ordered probit model was estimated using the SAS software package, procedure QLIM. As indicated earlier in Table 2, the factors that have significant association with the response variable crash severity were carefully identified using the two-way analysis. Table 3 shows the estimation results of the fitted ordered probit model. Crash location, number of injuries resulted from the crash, and speeding were the three significant variables affecting the severity of traffic crashes occurring on rural roads. It is worth mentioning that a positive coefficient of a variable implies that the increase of the variable would increase the severity of crashes.

The results presented in Table 3 indicate that traffic crashes that occur at intersections tend to increase the probability of severer crash injuries at rural roads. The findings point out also that crashes resulted due to speeding tend to increase the likelihood of severer crash injuries. In addition, as expected, the more number of injuries resulted from traffic crashes tend to increase the severity of traffic crashes on rural roads. Other variables presented in Table 1 were not found to be significantly related to crash severity on rural roads and hence they were excluded from the model. Table 4 presents model fit summary of the fitted OP model and Table 5 shows that Goodness-of-Fit Measures of the OP model.

**TABLE 3: Ordered Probit Model Estimation Results**

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| Parameter | DF | Estimate | Standard Error | t Value | Approx |
| Intercept | 1 | -3.070592 | 0.394148 | -7.79 | <.0001 |
| Intercept 2 | 1 | -0.917632 | 0.168334 | -5.45 | <.0001 |
| Intercept 3 | 1 | -1.943392 | 0.216621 | -8.97 | <.0001 |
| Crash Location | 1 | 0.615620 | 0.347872 | 1.77 | 0.0768 |
| Number of injuries resulted from the crash | 1 | 0.724572 | 0.097198 | 7.45 | <.0001 |
| Speeding | 1 | 0.483613 | 0.301299 | 1.61 | 0.1085 |

**TABLE 4: Goodness-of-Fit Measures of the OP model**

| Model Fit Summary | |
|---|---|
| Number of Endogenous Variables | 1 |
| Endogenous Variable | Acc_Sev |
| Number of Observations | 124 |
| Log Likelihood | -121.43273 |
| Maximum Absolute Gradient | 3.8683E-6 |
| Number of Iterations | 8 |
| Optimization Method | Quasi-Newton |
| AIC | 254.86545 |
| Schwarz Criterion | 271.78714 |

**TABLE 5: Goodness-of-Fit Measures of the OP model**

| Goodness-of-Fit Measures | | |
|---|---|---|
| Measure | Value | Formula |
| Likelihood Ratio (R) | 67.734 | 2 * (LogL - LogL0) |
| Upper Bound of R (U) | 310.6 | - 2 * LogL0 |
| Aldrich-Nelson | 0.3533 | R / (R+N) |
| Cragg-Uhler 1 | 0.4209 | 1 - exp(-R/N) |
| Cragg-Uhler 2 | 0.4583 | (1-exp(-R/N)) / (1-exp(-U/N)) |
| Estrella | 0.46 | 1 - (1-R/U)^(U/N) |
| Adjusted Estrella | 0.3907 | 1 - ((LogL-K)/LogL0)^(-2/N*LogL0) |
| McFadden's LRI | 0.2181 | R / U |
| Veall-Zimmermann | 0.4943 | (R * (U+N)) / (U * (R+N)) |
| McKelvey-Zavoina | 0.4632 | |
| **N = # of observations, K = # of regressors** | | |

Prior studies (e.g., 14) indicated that the coefficients of explanatory variables estimated in the OP model do not directly reflect the impacts of contributing factors on each level of the response variable (i.e., crash severity). Therefore, the marginal effects of the significant variables identified in OP model presented in Table 3 were estimated.

The marginal coefficients illustrate the change of occurrence probability of injury severity by one unit increase of the input variable, keeping other factors at their mean values. A positive marginal coefficient of a variable for a particular injury severity level means that the probability of this severity level will increase by a value equals the coefficient, as the one unit increase of this input variable, and vice versa. Table 6 presents the marginal effects of the OP Model.

It can be concluded that the occurrence of traffic crashes at intersections will increase the probabilities of fatalities by 6.8%, severe injuries by also 6.7% and slight injuries by 4.9%. In addition, increasing the number of injuries resulted from traffic crashes on rural roads of the KSA increase the likelihoods of fatalities and severe injuries by about 8% and slight injuries by 5.7%. Finally, speeding will increase the probabilities of fatalities by 6%, severe injuries by 5% and slight injuries by about 4%.

**TABLE 6: Marginal Effects of the Ordered Probit Model**

| Variable | Crash Severity | | | |
|---|---|---|---|---|
| | Level 1 (PDO) | Level 2 (Slight injuries) | Level 3 (Severe injuries) | Level 4 (Fatalities) |
| Crash Location | -0.1854 | 0.0486 | 0.0674 | 0.0684 |
| Number of injuries resulted from the crash | -0.2183 | 0.0572 | 0.0805 | 0.0825 |
| Speeding | 0.0145 | 0.0381 | 0.0537 | 0.0617 |

## CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to explore the characteristics of traffic crashes that occurred on rural roads of the KSA. Also, this paper examined the impacts of contributing factors on crash injury severity at rural roads. A total of 124 crash reports for traffic crashes that occurred on rural roads in the Eastern Region were obtained and used in the analysis presented in this paper.

To achieve the objectives of this study, conditional distributions, two-way analyses and ordered probit (OP) model were performed. The results indicated that about 88% of the crashes' sample occurred due to driver factors while only 12% of them occurred due to vehicle factors. Sudden lane change, distraction, speeding and failed to yield right of way were the main driver factors that led to those crashes while defects in tires was the main vehicle factors that led to those crashes.

It was found also that the majority of the sample (84.7%) occurred at intersections while 5.6% and 9.7% occurred at straight segments and exists/entrances, respectively. Regarding the type of the first vehicle at-fault involved in these crashes, it was found that approximately two-third of the sample (64.5%) occurred by passengers' cars and about 28% of the sample occurred by trucks.

Considering the results of the two-way analysis, the findings revealed that the number of injuries and fatalities resulted from those crashes, crash location, crash reason and day of the week when the crash occurred were the variables that showed significant association with the ordinal target variable crash severity

In addition, the results of the OP model indicated that crash location, aggressive driving behavior and size of crash were the significant variables that increase the severity of traffic crashes on rural roads.

Considering the results of this study, traffic safety agencies in Saudi Arabia are advised to focus their efforts on intersection locations with rural rods (e.g., about 85% of the crash sample occurred at intersection locations). It is recommended that future education course and campaigns should emphasize the negative effects of committing speeding, sudden lane change and distraction while driving and the strong association between these aberrant driving behaviors and increasing the crash risk and severity.

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# Utilization of Traffic Accident Countermeasure Database Towards Effective Road Safety Projects in Japan

Main Author:
Azuma Taekemoto
Researcher
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure, Transport and Tourism
takemoto-a92ta@nilim.go.jp

Co-Authors:
Yuta Ozaki
Researcher
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure, Transport and Tourism
ozaki-y82ac@nilim.go.jp

Sho Kamiya
Guest Research Engineer
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure, Transport and Tourism
kamiya-s924a@nilim.go.jp

Masayuki Yabu
Head
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure, Transport and Tourism
yabu-m92ta@nilim.go.jp

## ABSTRACT

The Hazardous Spot Countermeasure Project has been conducted as part of road safety project for arterial roads in Japan. The project is an effort to take countermeasures effectively and efficiently by concentrating countermeasures at specific hazardous locations. The traffic accident countermeasure database was constructed to accumulate the knowledge about countermeasure implementation in all hazardous spots. By constructing the database, it becomes possible that road administrator key in information about road structure, traffic situation, type of countermeasure, traffic accident data, photos, drawings, etc. for each hazardous spots. It also enabled input the data about contents for discussion of countermeasure planning. The function which can search the countermeasure cases from various conditions was added to the database. Moreover, the digest version which can review the main information about countermeasure implementation in each hazardous spots was created in the database. About 8,000 countermeasure cases conducted at hazardous spots are now accumulated in the database.

## INTRODUCTION

Traffic accident fatalities and injuries in Japan peaked at 1.191 million in 2004, then began declining reaching 829,807 in 2012. Traffic accident fatalities peaked at 11,452 in 1992 then began to fall, reaching 4,411 in 2012. The number of victims of traffic accidents continues to fall in this way, but many people continue to become victims of traffic accidents, so road administrators throughout Japan must strengthen their efforts to reduce traffic accidents.

In Japan, the hazardous spot countermeasure project has been conducted as part of road safety projects for arterial roads. This project is an effort to take countermeasures effectively and efficiently by, based on the characteristic of traffic accidents on arterial roads that they are concentrated at certain specified locations, concentrating countermeasures at these hazardous spots.

To implementation the project more effectively, it is important that knowledge obtained through each countermeasure implementation is accumulated and shared. It is also important to utilize knowledge based on the analysis of the accumulated data. Therefore, the traffic accident countermeasure database was constructed to accumulate knowledge about countermeasure implementation at all hazardous spots. Additionally, this study analyzed the effect of countermeasures using the data in the database.

## CONSTRUCTION OF THE TRAFFIC ACCIDENT COUNTERMEASURE DATABASE

The traffic accident countermeasure database was constructed in order to support the management of traffic safety projects and to accumulate and share experiences gained through projects at individual locations, in order to more effectively conduct traffic safety projects.

This database is a system, which can be used to input, reference, and output data from the web. Traffic safety officials (road administrators) of the Ministry of Land, Infrastructure, Transport and Tourism, prefectures, and government-ordinance-designated cities can each input and update information about locations they manage, enabling them to use the database as a progress management tool. And each road administrator can refer to nationwide information that has been input and can output this data.

Road administrators can input and reference information about road structure, traffic situations, countermeasures taken, traffic accident data before and after the countermeasure, photos, drawings, etc. of countermeasure locations (Table 1). And in order to accumulate concepts applied when analyzing the causes of accidents and planning countermeasures for each location as experience, information about the process of accident occurrence, causes of accidents and countermeasure policies, which have been hypothesized, based on the accident data can also be accumulated in the database.

A search function that can be used to abstract cases matched to conditions when referring to a specific location has been provided. This function was included to permit users to refer to experiences at similar locations in the past when analyzing causes of traffic accidents or planning new countermeasures. In order to let them find cases they wish to reference more easily, a digest version permitting reference to major data concerning each case has been prepared. About 8,000 countermeasure cases conducted at hazardous spots throughout Japan are now accumulated in the database.

**TABLE 1: Input Item and Examples of Input Contents of Database**

| Input items | Examples of input contents |
|---|---|
| Location | Address, road number, kilo-post, etc. |
| Road structure | Radius of curvature, longitudinal gradient, intersection or uninterrupted road section, number of lanes, lane configuration, etc. |
| Traffic conditions | Traffic volume, speed limit, roadside conditions etc. |
| Traffic accidents | Date of, type of, etc. of each accident before and after countermeasure |
| Road conditions | Photos, drawings |
| Concept guiding countermeasure planning | Type of accident to be reduced, hypothetical cause of accidents, process of accident occurrence, countermeasure policies |
| Countermeasure executed | Year of countermeasure, type of countermeasure, number executed, photograph after countermeasure, etc. |

## UTILIZING THE TRAFFIC ACCIDENT COUNTERMEASURE DATABASE

In order to more effectively carry out traffic safety projects, it is important to use knowledge obtained by analyzing national data accumulated in the database. Each of the following were analyzed:

- Effectiveness of overall traffic safety projects
- Effectiveness for types of accidents to be reduced by the countermeasures
- Effectiveness of major types of countermeasures by type of accident

### *Analysis of the Effectiveness of Overall Traffic Safety Countermeasures*

Analysis to clarify the effectiveness of implementation of countermeasures at hazardous spots was performed for 3,174 spots selected by omitting countermeasure spots where accident data is not clear from 3,271 spots where countermeasures were completed by 2007. The periods, which were the objects of the analyses, were from 1996 to 1999 as the period before countermeasures, and from the year after the year of completion of each countermeasure until 2010 as the period after each countermeasure.

The annual average number of traffic accidents on arterial roads nationwide were calculated. As a result, during the two periods accidents causing injury and death increased 7% and fatal accidents fell 36% (Figure 3). In contrast, at hazardous spots, after the countermeasure, accidents causing injury or death fell 25% and fatal accidents fell 59% (Figure 4).

The deterrence rates were used as indices to clarify the effectiveness of countermeasures at hazardous spots. A deterrence rate is an index, which shows by what percentage accidents were, deterred at hazardous spots in comparison with changing traffic accidents on all arterial roads in Japan. The deterrence rate calculation method is shown below. Deterrence rate of accidents at hazardous spots was, in the case of accidents causing injury or death, about 30%, and in the case of fatal accidents, about 36%.

$$\mathbf{D = (a - h) / a} \quad (1)$$

D: deterrence rates

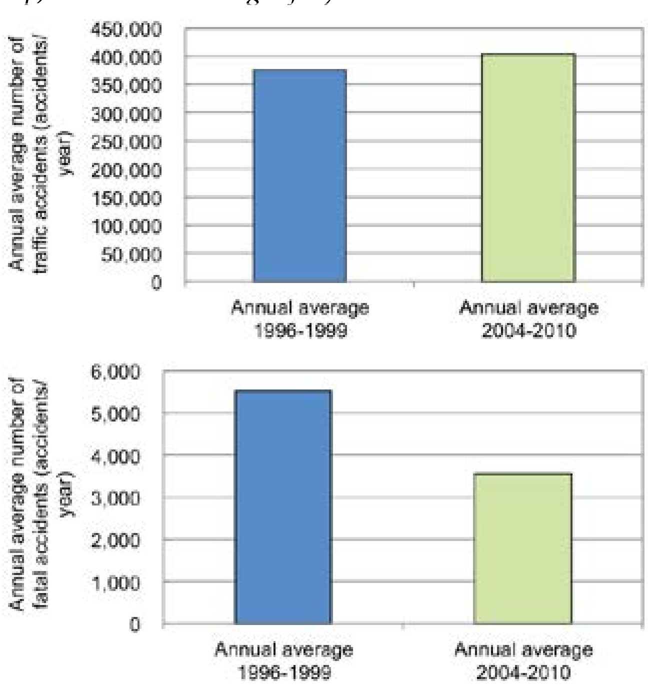
a: Rate of change* of accidents on all arterial roads

h: Rate of change* of accidents at hazardous spots

*Rate of change is a value calculated with the number of accidents during the period after the countermeasure as the numerator and the number of accidents in the period before the countermeasure as the denominator.

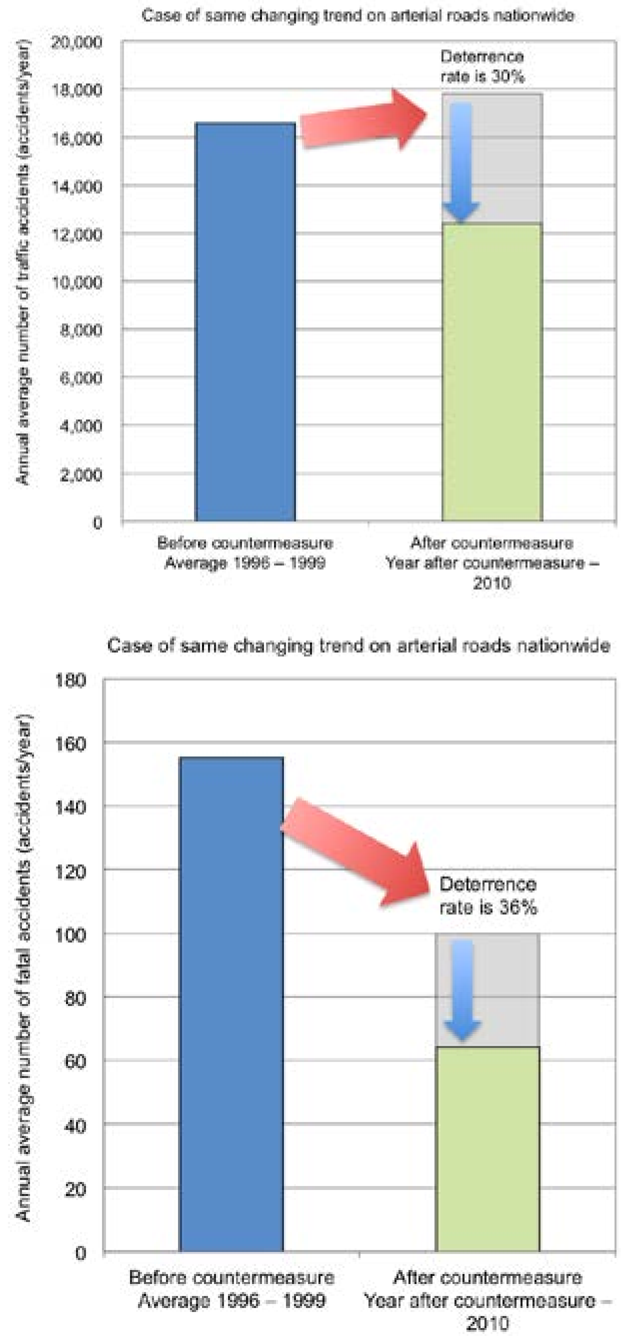
**FIGURE 3: Changes of Numbers of Traffic Accidents on Arterial Roads Nationwide**

*(Top) Accidents causing injury or death*




*(Bottom) Fatal accidents*

**FIGURE 4: Changes and Deterrence Rates of Numbers of Traffic Accidents at Hazardous Spots**



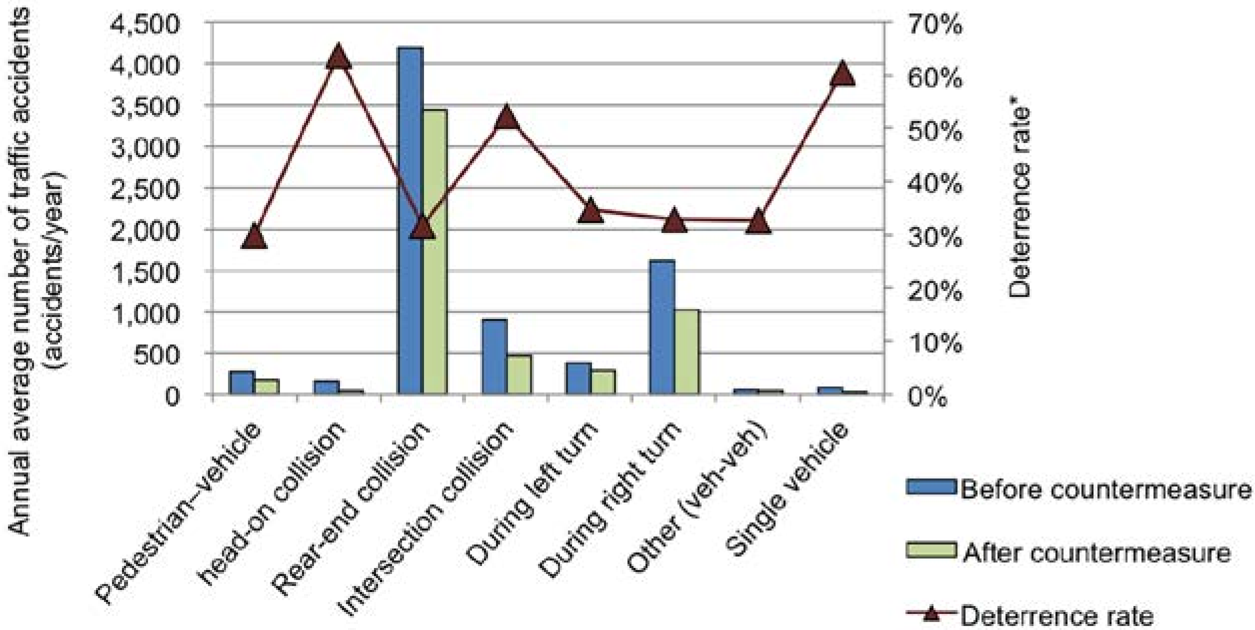

*(Top) Accidents causing injury or death*
*(Bottom) Fatal accidents*

### *Analysis of Effectiveness for Types of Accidents to be Reduced by the Countermeasures*

The effectiveness for types of accidents to be reduced by the countermeasures was analyzed. This analysis calculated the change of the annual average number of accidents before and after countermeasures and the deterrence rate.

First, obtaining the change of the annual average number of accidents before and after countermeasures has shown that accidents of all kinds causing injury or death fell after the execution of countermeasures (Figure 5). Among these, the deterrence rate was particularly high for head-on collisions and single vehicle accidents. It is assumed that countermeasures based on the road traffic environment are effective in deterring these types of accidents. On the other hand, for pedestrian – vehicle accidents that easily become serious accidents; the deterrence rates were relatively low.

**FIGURE 5: Effectiveness for Types of Accidents to be Reduced by Countermeasures**




***Analysis of Effectiveness of Major Types of Countermeasures by Type of Accident***

It was focused the analysis on types of countermeasures often executed to deal with head-on collisions, for which the deterrence rate was high, and pedestrian – vehicle accidents, for which the deterrence rate was relatively low.

First, as head-on collision countermeasures, four kinds of countermeasures—delineators, road surface markings (clarifying traveling position), signboards, and center median strips— often implemented in Japan were analyzed. All countermeasures marked high deterrence rate almost equally (Table 2).

Next, four kinds of pedestrian – vehicle accident countermeasures—road lighting, guard fences, signboards, and sidewalk improvements— often implemented in Japan were analyzed. The deterrence rate of road lighting was high, followed by the deterrence rates of sidewalk improvements and signboards (Table 2(b)). However, the deterrence rate of guard fences was low. Guard fences were intended to prevent vehicles from entering sidewalk space, to prevent pedestrians from crossing the road where drivers do not expect them and to guide pedestrians to crosswalks. For example, at locations where guard fences were constructed continuously to intersection crosswalks as shown in Figure 6(a), the numbers of pedestrian – vehicle accidents were reduced. However, at locations where guard fences were constructed discontinuously on the sidewalk on one side considering access to roadside facilities by vehicles as shown in Figure 6(b), pedestrian – vehicle accidents were not reduced. At such locations, roadside conditions must be considered, but it presumed to be necessary to take measures to prevent people from crossing outside of crosswalks; installing continuous guard fences, new guard fences on sidewalks without guard fences, or guard fences on median strips.

**TABLE 2a & 2b: Deterrence Rate of Accidents Causing Injury or Death by Type of Countermeasure**
**(a) Head on Collision Accident Countermeatures**

| | Before counter-measure | After counter-measure | Increase-decrease rate | Increase-decrease rate of head-on collision on all arterial roads | Deterrence rate |
|---|---|---|---|---|---|
| Delineators | 51.3 | 12.4 | 75.8% | 32.9% | 64.0% |
| Road markings (clarifying traveling location) | 33.8 | 7.1 | 78.9% | 32.9% | 68.5% |
| Signboards | 26.3 | 6.2 | 76.6% | 32.9% | 65.1% |
| Center median strips | 29.3 | 8.2 | 72.0% | 32.9% | 58.3% |

**(b) Pedestrian – Vehicle Accident Countermeasures**

| | Before countermeasure | After countermeasure | Increase-decrease rate | Increase-decrease rate of pedestrian vehicle accident on all arterial roads | Deterrence rate |
|---|---|---|---|---|---|
| Road lighting | 45.0 | 22.2 | 50.8% | 12.9% | 43.5% |
| Guard fences | 22.5 | 16.9 | 24.7% | 12.9% | 13.6% |
| Signboards | 21.8 | 13.4 | 38.6% | 12.9% | 29.6% |
| Sidewalk improvements | 12.5 | 7.5 | 39.8% | 12.9% | 30.9% |

**FIGURE 6: Examples of Implementation of Pedestrian – Vehicle Accident Countermeasures**

*(Top) Example of the installation of a continuous guard fence at an intersection*
*(Bottom) Example of the installation of a discontinuous guard fence at straight road section*

## CONCLUSION

Through this research, we have constructed the traffic accident countermeasure database in order to more effectively carry out traffic safety projects on arterial roads. It is expected that road administrators will use this as a tool to manage the progress of traffic safety projects at individual locations. And this database can accumulate concepts guiding the analysis of causes of traffic accidents and planning of countermeasures at individual locations, so in the future, when road administrators are studying new countermeasures, they will be able to refer to past experience of countermeasures at similar locations.

Analysis of countermeasure effectiveness has been done using data accumulated in the database. The results have clarified the effectiveness of overall traffic accident projects in Japan, and the effectiveness for traffic accidents to be reduced by taking the countermeasures. And based on the results of analysis of effectiveness by countermeasure type, causes and effective installation methods, etc., in which scattering has appeared in countermeasure effectiveness, have been organized.

In the future, knowledge about locations where traffic safety projects have been newly implemented will be accumulated in the database. And based on data that has been accumulated, technical documents concerning the effectiveness of each countermeasure type and effective installation methods, etc., will be prepared.

# Road User Perception Toward Safety at Pedestrian Crossings in Abu Dhabi, UAE

Main Author:
Mohamed Shawky Ahmed
Assistant Professor
Department of Public Works
Ain Shams University
Cairo, Egypt
m_shawky132@hotmail.com

Co-Authors:
Atef M. Garib
Traffic Expert
Traffic and Patrols Directorate
Abu Dhabi Police
Abu Dhabi, United Arab Emirates
agarib@eim.ae

Hussain Al-Harthei
Director
Traffic and Patrols Directorate
Abu Dhabi Police
Abu Dhabi, United Arab Emirates
alharthei@saaed.ae

## ABSTRACT

In the Emirate of Abu Dhabi (AD) UAE, pedestrian accidents represent about 21% of total traffic accidents, which lead to 26% of total fatalities. The majority of pedestrian causalities occurred when the pedestrians try to cross roads (65%). Vehicle-pedestrian crashes usually occur due to an improper behavior of pedestrians and/or motorists. Better understanding of pedestrian and motorist behavior, perception and attitude are a key for developing more effective countermeasures for pedestrian crashes.

This paper aims to explore the pedestrian and motorist behavior, perception, and attitude with respect to safety issues at pedestrian crossings in AD. In general, the results indicated that the presence of legal, comfortable, well designed, close pedestrian crossing facility, awareness, and enforcement effort will significantly affect pedestrian behavior. The results showed that the majority of the pedestrians and motorists are satisfied with existing conditions of crosswalks in many aspects.

## INTRODUCTION

In Emirate of Abu Dhabi (AD) UAE, pedestrian accidents represent about 21% of total traffic accidents, which lead to 26% of total fatalities. The majority of pedestrian causalities occurred when pedestrians try to cross roads (65%). Recently, several actions and countermeasures have been applied to improve pedestrian safety in AD. These actions included the three main approaches of road safety: engineering, enforcement, and education. For example, a number of zebra crossing and pedestrian crossovers were constructed at black-spot locations of pedestrian accidents. In addition, comprehensive programs for public awareness (by lectures, interviews, and websites) and for law enforcement was conducted. As a result, the pedestrian safety aspects have been significantly improved over the recent years in AD as shown in Table 1.

**TABLE 1: Key Performance Indicators of Pedestrian Safety in AD**

| Key performance indicator | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| No. of pedestrian accident (with casualties) | 663 | 640 | 532 | 486 | 402 |
| No. of serious injury in pedestrians | 76 | 93 | 76 | 63 | 78 |
| No. of death in pedestrian | 110 | 118 | 101 | 81 | 70 |
| Death rate per 100,000 inhabitants | 3.9 | 3.8 | 3.3 | 2.6 | 2.2 |
| Death + serious injury rate per 100,000 inhabitants | 6.7 | 6.9 | 5.8 | 4.6 | 4.7 |
| Death rate per 10,000 vehicle | 21.0 | 19.6 | 14.5 | 10.3 | 8.4 |
| Death + serious injury rate per 10,000 vehicles | 35.5 | 35.1 | 25.4 | 18.4 | 17.8 |

Vehicle-pedestrian crash type at pedestrian crosswalks is usually associated with non-compliant behavior of the motorists and/or pedestrians. Proper understanding of pedestrian and driver behavior, attitude and perception at crosswalk is a key parameter for improving pedestrian safety. Thus, the main objective of this study is to investigate the pedestrian and motorist behavior and the perceived risk on road safety at pedestrian crosswalk. Also, this study addresses the evaluation, preferences, opinion, and suggestions regarding the existing systems and facilities of pedestrian crossing.

## DATA COLLECTION METHODOLOGY

The employed data for this study was collected by using physical interviews with pedestrians and motorists in AD. Two different questionnaire forms were used; one was prepared for pedestrians and the other for motorists. These questionnaire forms were designed into different parts and group of questions. The pedestrians' questionnaire form included 42 questions and the motorists' questionnaire form included 31 questions. About 1,500 questionnaire forms were distributed in three different languages: Arabic, English, and Urdu.

The pedestrians' survey was conducted in January 2013 and the motorists' survey was conducted in March 2013. The physical interviews were conducted in several locations in the main cities of Abu Dhabi Emirate; mainly on streets at black-spot points of pedestrian accidents. Around 20% of the physical interviews were done with the public at traffic police departments of main cities. The non-complete forms were rejected (i.e., the forms have more than 10 missing questions, the forms have missing personal information of the interviewed person, and the non-seriously filled-down forms). Based on these criteria, about 668 completed questionnaires of pedestrian and 872 questionnaires of motorists were used in this study.

## QUESTIONNAIRES DESIGN

Both forms of questionnaires were structured into six parts including personal information, behavior during crossing roads, vehicle-pedestrian crash history, opinions and evaluation, preferences regarding pedestrian crosswalk facilities, awareness check and decisions about improving their future behavior. Table 2 shows descriptions of the main questions of each part in the two questionnaire forms.

**TABLE 2: Questionnaire Description**

| | Questionnaire Part | Pedestrian Questionnaire | Drivers Questionnaire |
|---|---|---|---|
| I | Personal information | • Sex, Age, Nationality, Education level, Occupation | |
| II | Trip information & behavior at crosswalk | • No. of road crossing during last week, trip purpose, area type, etc.<br>• Illegal crossing during last week, pedestrian, fine ticket history, reasons of illegal crossing, main problems facing road crossing, behavior and actions during crossing at legal and illegal places, maximum acceptable walking distance to the crosswalk | • Visibility of pedestrian crosswalk, and pedestrian waiting to cross, warning signs<br>• Action at pedestrian crosswalk sites<br>• Action when see a person cross roads at a far distance<br>• Desired running speed at crosswalk and the maximum speed limit value to implement zebra crossing |
| III | Pedestrian crash history | • Vehicle-pedestrian crash history, the fault of whom, .. etc.<br>• Locations and movements that feel high risk of pedestrian accidents | |
| IV | Awareness evaluation | • Questions in some knowledge about pedestrian safety facts<br>• Questions about pedestrian rules, priorities and fines<br>• Questions about the received awareness in pedestrian safety before and how | |
| V | Preferences & Opinions | • The preferable crossing facility in CBD area and out of city center.<br>• Opinion about current crosswalk facilities type, design, locations, etc.<br>• Opinion regarding countdown pedestrian traffic signals, warning signs.<br>• The most effective awareness methods | |
| VI | Benefits and future behavior | • Is the questionnaire useful<br>• The intention to change their road crossing behavior | |

**TABLE 3: Characteristics of the Interviewed People**

| Category | | Pedestrians | | Motorists | |
|---|---|---|---|---|---|
| | | Number | Percentage | Number | Percentage |
| Sex | Male | 478 | 72% | 742 | 85% |
| | Female | 190 | 28% | 130 | 15% |
| Age | < 18 | 40 | 6% | 0 | 0% |
| | 18-30 | 301 | 45% | 431 | 49% |
| | 31-45 | 266 | 40% | 301 | 35% |
| | > 45 | 63 | 9% | 140 | 16% |
| Nationality | Locals | 176 | 26% | 326 | 37% |
| | Arabian | 292 | 44% | 302 | 35% |
| | Asian | 147 | 22% | 207 | 24% |
| | Other | 52 | 8% | 37 | 4% |
| Education level | Low | 127 | 19% | 106 | 12% |
| | Medium | 303 | 45% | 362 | 42% |
| | High | 237 | 36% | 404 | 46% |

## FINDINGS

### *Road User Behavior at Pedestrian Crossing*

#### *Pedestrian behavior*

The survey showed that the average rate of road crossing of the interviewed pedestrians during the last week was about 5.1 times. The majority of road crossing events are located in the residential areas (42%) followed by CBD area (26%). The trip purpose survey showed that 47% was for work trips, 26% for shopping trips, and 27% for recreation and other purposes trips. Regarding the illegal crossing behavior, 37% of pedestrians crossed roads at illegal locations. Men were reported to frequently commit violations of road crossing (40%) more than women do (24%). The age group between 18 and 30 years old has the highest frequency illegal crossing (48%) followed by the age group between 31 and 45 years old (36%), and age over 46 years old reported the lowest frequency illegal crossing (7%). This means that the pedestrian tend to cross at designated locations as their age increases. Table 4 shows the percentage distribution by the reason of the illegal road crossing. It shows that the main reasons are the lack of crosswalk facilities or that they are fare away.

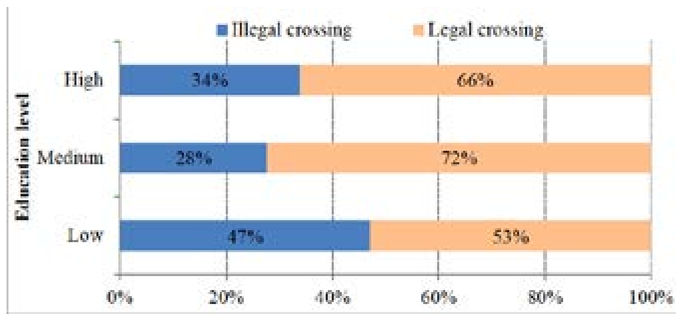
**TABLE 4: Referred Reasons of the Illegal Crossing**

| Reasons | Percentage |
|---|---|
| No legal crosswalk exist | 33% |
| The legal crosswalk is quit far | 30% |
| Unawareness of traffic rules | 16% |
| Easy crossing and no physical barriers exist | 11% |
| There is no deterrent enforcement | 10% |

Regarding taken caution at zebra crossing, 61% of pedestrians are more careful during crossing at legal locations as if they crossing at illegal locations, 23% take caution but not as if they cross at illegal locations, and 16% cross roads relying on the fact that he/she cross at legal place and the motorists will be forced to reduce the speed or completely stop. The survey also showed that 35% of pedestrian prefer to cross road by the shortest and easiest way when possible, regardless of the traffic rules, 49% prefer to walk to the closest crosswalk facility when available at a fair distance, and 16% prefer to look for a designated crosswalk even if it is located at a far distance.

Figure 1 shows the pedestrian behavior for deciding to cross legally by their education level. It shows that the high-educated pedestrians have low frequency of illegal crossing than the low-educated pedestrians.

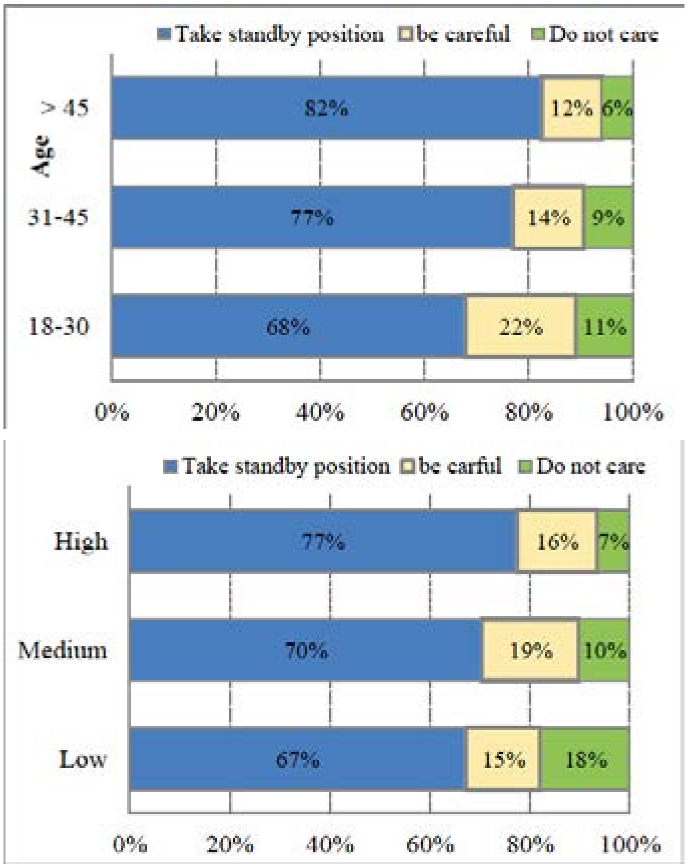
**FIGURE 1: Illegal Cross Road Distribution by the Pedestrian Education Level**




#### *Motorist Behavior*

About 70% of motorists pay attention when they drive at pedestrian crosswalk location even if they not recognize any pedestrians waiting to cross the road, 17% of them not always pay attention, and 13% do not care about the pedestrian crosswalk locations during driving. Regarding the taken actions at pedestrian crosswalk locations, 72% takes the standby position for calming speed, 18% take careful and drive normally, and 10% do not care. The survey results show that no significant differences in the behavior between male and female motorists regarding actions and taking caution at pedestrian crossing. Figure 2 shows the percentage distribution of motorists by their reactions at pedestrian crossing in terms of the pedestrian age and education level. It shows that the motorists are more careful and ready for any unexpected event at pedestrians' crosswalk as their ages and education levels increase.

**FIGURE 2: Motorists' Reaction at Pedestrian Crosswalks by Age and Education Level**




*Vehicle-Pedestrian Crash History*

***Pedestrian Accident History***

About 27% of the interviewed pedestrians involved in a vehicle-pedestrian crash before. 20% of them admitted that it was their faults, 37% said it was the fault of the motorists, 20% mentioned that it was a shared fault, and 23% said do not know who was at fault. The majority of the pedestrian crashes occurred during work trips (47%) followed by shopping and recreational trips (26% for each). About 52% of the crashes occurred at residential areas, and 40% at CBD area and 9% on external roads. 59% of the pedestrians see that the motorists somewhat give priority to pedestrians, 14% said the motorists always give priority to the pedestrian, and 27% of pedestrian though that motorists do not pay any attention to the pedestrians.

***Motorist Accident History***

The motorists' survey showed that 19% involved in a pedestrian accident before. About 18% of them admitted that it was their faults, 32% said it was the fault of the pedestrians, 17% said it was a shared fault, and 34% said they do not know who was at fault.

Motorists consider that the most prominent places where the pedestrian's possibility of being hit is at CBD area (30%) followed by residential area (24%), at schools zones (18%) , in front of big malls (12%), on highways (11%), and at bus stops (5%). The common situation where the motorists feel high risk of potential pedestrian accidents is at intersections (75%) with a breakdown of 41% during right turn, 20% during left turn, and 14% during through movements.

***Awareness Evaluation***

***Pedestrian Awareness***

About 44% of pedestrians know that quarter of the traffic accident fatalities in AD are pedestrians. 73% can easy find and recognize the location of the legal crosswalk facilities. 58% of pedestrians know that there is a fine for illegal road crossing against 42% does not know that. 49% of the interviewed pedestrians have received education and information regarding the safety of road crossing. The highest percentage of received information was by radio (31%), followed by lectures (26%), television (24%), physical interviews (10%), and by others (9%) such as newspapers, websites, while issuing driving license, etc.

***Motorist Awareness***

About 55% of motorists know that quarter of the traffic accident fatalities in AD are pedestrians, 86% knows well the priority rules of pedestrian, 83% knows that the motorists is considered the responsible party in case of pedestrian accidents, and 71% know that the severity of pedestrian accident increases 10 times with an increased value of 10 kph in vehicle speed. About 64% of the interviewed motorists have received education and information regarding the pedestrian safety. The majority received this information by Radio (37%), followed by television (34%), by lectures (21%), and finally by physical interviews (8%).

***Evaluation Results of Existing Pedestrian Crossing Facilities***

***Pedestrian Evaluation***

Table 5 summarizes the result of the evaluation process of the existing crosswalk facilities based on pedestrians' perception. It indicates that the majority are satisfied with the current conditions. However, 60% of the pedestrians said the locations of the pedestrian tunnels are not easy to find. About 54% thought that the existing crosswalk facilities are not convenient for peoples with especial needs.

**TABLE 5: Evaluation of Existing Crosswalk Facilities in AD**

| Crossing Facility | Evaluation | | | |
|---|---|---|---|---|
| | Excellent | Good | Fair | Bad |
| Zebra crossing | 3% | 22% | 41% | 34% |
| Pedestrian tunnels / crossover | 2% | 13% | 40% | 46% |
| Waiting area to cross | 4% | 14% | 39% | 43% |

### *Motorist Evaluation*

Regarding the visibility of zebra crossing locations and pedestrians waiting to cross road on the sidewalk, 60% of the motorists mentioned that they clearly see them, while 34% said they see them in most cases, and 6% said do not see them in many sites. About 61% of motorists are satisfied with the existing traffic warning signs for pedestrian in terms of its location and design, 37% said not at all sites, and 2% said not satisfied. About 73% of motorists clearly see the traffic signals of pedestrian, 25% said they were not clear at some places. Regarding the design of zebra crossing, 67% are satisfied, 30% are somewhat satisfied, 3% are not satisfied. Regarding the illumination at crosswalks, 63% thought that it is enough, 33% see that it is not enough at all sites and 4% said not well in many sites.

## *Preferences Towards Crosswalk Facilities*

### *Pedestrian Preferences and Opinions*

Table 6 summarizes the main problems that face pedestrians during road crossing from their point of view. It clearly shows that the majority believes that the main problems refer to the lack of the designated crosswalk or its inappropriate walking distances to them.

**TABLE 6: Main Problems Facing Pedestrian Crossing**

| Problem | Percentage |
|---|---|
| Non-existence of the pedestrian crossing facility | 25% |
| Crosswalk facilities are often quit far | 24% |
| Vehicles' driver do not give priorities for pedestrian | 18% |
| Uncomfortable of the existing crossing facility | 13% |
| Do not feel safe during crossing at zebra crosswalk | 13% |
| Lack of visibility for vehicles | 7% |

**TABLE 7: Desired Distance for Walking to Pedestrian Crosswalk**

| Desired Distance | Percentage |
|---|---|
| < 50 m | 22% |
| 50-100 | 40% |
| 100-150m | 28% |
| 150-200m | 6% |
| > 200 m | 4% |

The preferable crossing facility by area type is shown in Table 8. It shows that zebra crossing is the most preferable facility in CBD area followed by pedestrian tunnels. However, pedestrian tunnel is the most preferable facility out of CBD area followed by pedestrian crossover (i.e., grade separated facilities). In addition, the percentage distribution by the effective education methods for pedestrian safety is shown in Table 9. The proposed other methods are mainly concentrated in the usage of the new social communication tools such as internet and mobile phones as well as the usage of the variable message signs (VMS), advertising through newspapers and road-side boards.

**TABLE 8: Preferable Crossing Facility by Area Type**

| Crossing Facility | At city center | Out of city center |
|---|---|---|
| Zebra crossing | 37% | 21% |
| Zebra crossing with speed humps | 14% | 7% |
| Pedestrian Tunnels | 32% | 39% |
| Pedestrian crossover | 17% | 33% |

**TABLE 9: Effective Education and Awareness Methods**

| Education method | Pedestrian opinion | Drivers opinion | Average |
|---|---|---|---|
| Radio | 18% | 31% | 25% |
| Television | 38% | 34% | 36% |
| Lectures | 23% | 19% | 21% |
| Interviews | 16% | 12% | 14% |
| Other | 6% | 4% | 5% |

Regarding the usage of the countdown timing pedestrian signals, 75% thought that it is efficient and helpful, 17% thought that it is somewhat helpful, while 8% does not care about it. About 43% of pedestrians said the allowed time for pedestrian at traffic signals are always sufficient, 46% said it is not sufficient in some places, and 11% thought it is not sufficient at all.

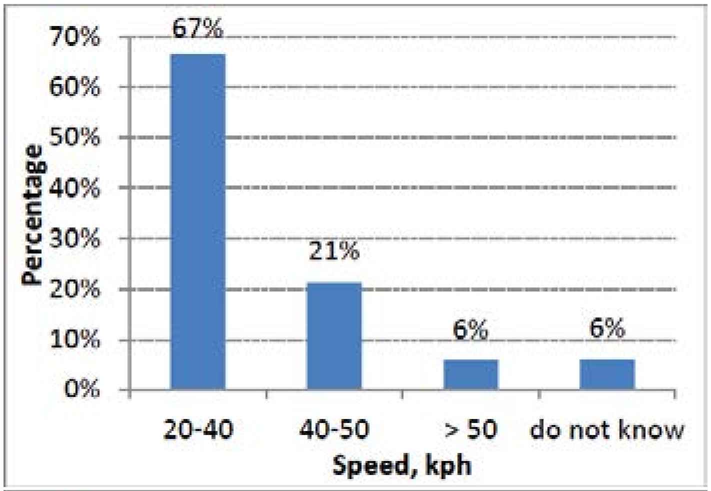
### *Motorists' Preferences and Opinions*

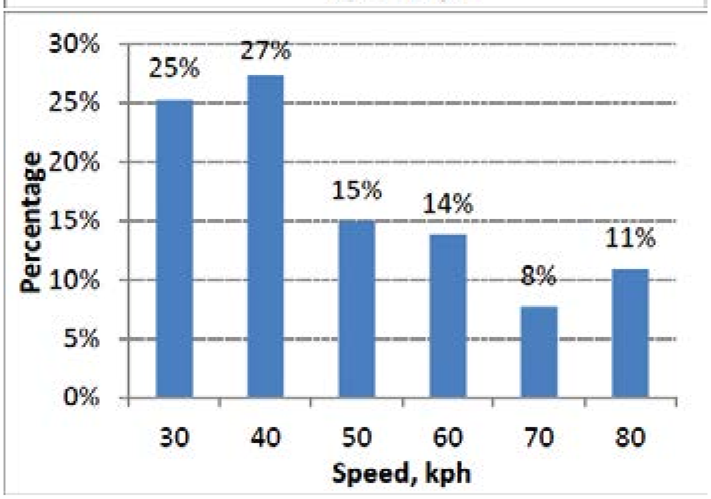
Questions have been asked regarding the preferred running speed at pedestrian zebra crossing sites and the maximum speed limit that a grade-separated pedestrian crossing should be constructed above it (i.e., the maximum acceptable speed limit for zebra crossing). The results of these two questions are shown in Figures 3 (a) and (b), respectively. The calculated average preferable value of speed at zebra crossing is 37 kph. The average maximum acceptable speed limit is 48 kph. This means that the grade separated pedestrian crossing facilities should be applied at midblock of the roads that have speed limit 50 kph and above in AD, based on the road users' point of view.

### The Intention to Change Behavior

About 92% of pedestrian see that this questionnaire was useful for them and 89% will change their road cross behavior in the future. Regarding the motorists, 95% said the questionnaire was useful and gave them new information and 91% intends to change their behavior based on this knowledge.

**FIGURE 3: Preferred Speeds at Pedestrian Crossing based on the Motorists' Perception**




*(Top) Preferred speed at zebra crossing*
*(Bottom) Maximum acceptable speed limit that is considered safe for zebra crossing*

## CONCLUSION AND RECOMMENDATIONS

The main findings of this study can be summarized as follows:

- Comfortable and close-distance road crossing facilities is the main factors that affect the pedestrian choice to cross at legal or illegal locations
- About 37% of road crossing occurred at illegal locations and men reported frequently cross road illegally more than women
- The majority of illegal crossing occurred in residential areas (42%) followed by CBD area (26%). In addition, 47% of them occurred during work trips
- Aged and well educated pedestrians were more eager to cross the roads at designated locations
- 42% of pedestrians do not know that there is a fine for illegal road crossing
- 61% of pedestrian take extra cautions when they cross at legal sites as if they cross at illegal locations
- 72% of motorists pay more attention when they approach pedestrian crosswalk even if they do not see pedestrian waiting to cross the road
- About 27% of the interviewed pedestrians were involved in vehicle accident before. 20% of them said it was their fault, 37% mentioned it was the fault of the motorists, 23% indicated it was shared fault
- About 19% of motorists were involved in pedestrian accident before. 18% said it was their fault, 32% mentioned it was the fault of the motorists, 17% indicated it was shared fault
- Motorists consider that CBD area is the highest area where they possibility could hit a pedestrian. Also, they consider that the highest risk movements are mostly at intersections, especially during right turn
- 64% of motorists have been educated about pedestrian safety before. Radio scored the highest percentage as an education method followed by television
- In general, pedestrians and motorists are satisfied by the existing condition of the pedestrian crossing facilities
- Pedestrians preferred to have maximum walk-distance to the crosswalk of 115 m (as an average accepted distance)
- Motorists thought that grade-separated pedestrian crossing should be used on the roads of speed limit 50kph and above
- More than 90% of pedestrians and motorists mentioned that the questionnaire was useful for them and 89% of pedestrians and 91% of motorists said they will change their future behavior

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