HIGHWAY WORKZONE SAFETY: AN ASSESSMENT OF CURRENT SAFETY PRACTICES AND DRIVER'S RISK PERCEPTION FOR PAKISTAN

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Submitted By

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LIST OF ACRONYMS

WHO	World Health Organization
UN	United Nations
GNP	Gross National Product
NTRC	National Transport Research Center
RCF	Road Crash Fatalities
NSC	National Safety Council
FHWA	Federal Highway Authority
RTC	Road Traffic Crashes
PPE	Personal Protective Equipment
TTC	Temporary Traffic Control
RCI	Road Crash Injuries
MUTCD	Manual on Uniform Traffic Control Devices

ABSTRACT

Nations around the globe continue to face the challenges posed by alarming increase in number of road crash fatalities and injuries. According to the World Health Organization (WHO) "Global Status Report on Road Safety - 2013", approximately 1.24 million people around the world, die on roads every year and approximately 20 to 50 million sustain non-fatal injuries due to road traffic crashes (RTC). Pakistan has a large road network (approximately 260,760 km), serving approximately 11 million vehicles of all types. According to WHO estimates there were approximately 30,000 annual RCF in Pakistan in year 2010 (WHO, 2013). Highway workzone is the road area where highway construction, maintenance or activity related to utility maintenance takes place. Workers in highway workzone are exposed to a variety of hazards and face risk of injury and death from construction equipment as well as passing motor vehicles. Workzone crashes account for significant proportion of all traffic crashes in Pakistan due to higher crash rate as compared to other parts of the highway network. Safety measures and better understanding of risks involved while moving through the workzone have significant effects on the overall safety climate at workzones. The direct study of the safety measures taken at workzone and road user's perception of the risk can be helpful in identification of those key areas/ measures that need special attention for improving highway workzone safety in Pakistan. Present study synthesized the state of safety practices at highway workzones in Pakistan and also carried out a comparative analysis of typical highway workzones in Pakistan with international standards as recommended by Manual on Uniform Traffic Control Devices (MUTCD). Using data from eight different highway workzones across the country, analysis revealed that majority of the highway workzones in Pakistan lack proper safety measures and that they are constructed without following any established standards. Advance warning area, transition area, activity area and termination area, of majority of the highway workzones were either missing or without proper specifications. Also, driver's risk perception while driving through a typical highway workzone in Pakistan was modeled using fixed and random effect ordered probit models. Analysis revealed that education and income level, age, driving

experience, frequency of travelling through highway workzone and law enforcement significantly influence driver's risk perception of highway workzone. The study can lay foundations for improvement in safety environment at highway workzones in country through improved understanding of present safety conditions and driver's risk perception.

CHAPTER 1. INTRODUCTION

1.1. Background

Nations around the globe continue to face the challenges posed by alarming increase in number of road crash fatalities and injuries. The Global Status Report on Road Safety – 2013, published by World Health Organization (WHO) states that about 1.24 million people die each year in road traffic crashes worldwide and approximately 20 to 50 million suffer from non-fatal injuries. The report was based on the road safety data collected from 182 countries. This accounted for almost 99% of the world's population. Unluckily, only 28 countries, which make up 7% of world population, have sufficient laws to address key road crash risk factors (WHO, 2004; UN, 2014). There have been many efforts worldwide to quantify the economic effects of these fatalities and injuries. But their psychological impacts on social fiber of the society and individuals still need further research.

Although, road traffic accidents have been among the major contributors of injuries in past, studies have shown that situation is getting worse. It is expected that by 2020 it will rank as high as 3rd cause of disease or injury worldwide (WHO, 2004). This trend can be partly due to ever increasing motorization of the low-income or middle-income countries together with expansion of road networks around the globe. The problem can further aggravate due to lack of preventive measures and safety legislations. Increasing economic activity is making more and more people to travel on roads. WHO data for 2002 shows that deaths caused by road traffic injuries were "20.2 per 100,000 population in low / medium-income countries" which accounted for 90% of the total 1,183,492 road traffic related deaths in the world. Overall, 2.1% of all global deaths (ranking 11th leading cause of death) were caused by road traffic accidents, which were 23% of all injury deaths around the world (WHO, 2002).

Road traffic injuries put a huge burden on world economies. Road traffic injuries cost "approximately 1% of the Gross National Product (GNP) in poor countries, 1.5% in medium-income countries and 2% in rich countries" (Jacobs, 2000). The data collected from poor countries is not absolutely reliable, due to the lack of comprehensive data collection and incident recording procedures. Many of the injury incidents are never recorded or reported in such countries. Thus the estimates tend to present an underestimated value (Jacobs, 2000).

Pakistan has a large road network of 260,760 km of which 9,555 km are National Highways and 1,930 km are Motorways, serving approximately 11 million vehicles of all types. There has been overwhelming reliance on roads and highways in meeting transport demand with roads handling nearly 95 percent of all passenger and freight demand (NTRC, 2009). A recent study shows that in Pakistan, approximately 30,000 people die every year because of road crashes (Khan, 2013). As per WHO data, Pakistan has approximately 30,000 annual road crash fatalities (WHO, 2013). These crashes cost approximately Rs. 111.6 Billion, which amounts to be 1.5% of GNP of the country (Ahmed, 2007). Road crash fatalities (RCF) and road crash injuries (RCI) are expected to "increase by 65% in next 10 years" unless there are "new efforts" to address the prevailing state of road safety around the world (WHO, 2004).

Highway workzone is the road area where highway construction, maintenance or activity related to utility maintenance take place (Turner, 1999). It is identified by "warning signs/signals/indicators" and has marked start and end of a construction, maintenance or utility work (NSC, 2007). The American National Standards define the range of workzone from the "first warning sign, signal or flashing lights to the END ROAD WORK sign or the last traffic control device" (NSC, 2007). Workers in highway workzones are exposed to a variety of hazards and face risk of injury and death from construction equipment as well as passing motor vehicles. Regardless of task, most of the workers are exposed to dangerous conditions such as poor lighting, poor visibility, inclement weather, congested work areas, high volume traffic and over speeding vehicles. In USA alone, 87,606 crashes were caused by workzones in 2010 (FHWA, 2014). It is conceivable that workzone crash fatalities and injuries affect many families more devastatingly by the loss of working members of family and inflict a huge economic burden on the disabled persons and their families. A study carried was out on 196 km section of the Karachi-Hala Highway in Pakistan that utilized police reported crashes data from January 2006 to December 2008 to assess highway workzone crashes. The study concluded that workzone crashes accounted for as much as "15.0% of all traffic crashes" (Bhatti, 2011).

The goal of the present research is to study major highway workzone safety aspects in Pakistan. The study carried out a comparative analysis of typical highway workzones in Pakistan with international standards as recommended by Manual on Uniform Traffic Control Devices (MUTCD). Also, the study explored the driver's understanding of workzone conditions, through modelling of driver's risk perception while driving through a typical highway workzone in Pakistan. The study can lay foundations for improvement in the safety environment at highway workzones in country through better understanding of present safety conditions and hazards presented by moving traffic. It can also provide basic understanding of the subject for future research in relevant field.

1.2. Problem Statement

Highway workzones are major contributor to Road Traffic Crashes (RTCs) across Pakistan. At present, not much work has been done to understand safety requirements of such workzones and there is a pressing need to study the subject in detail. There are two parties to any external interaction at a highway workzone namely the safety conditions at site and the road user's (driver's) risk perception. Highway workzone safety involves both.

- The safety conditions here mean the measures which dictate workers and/or road user's safety at work site in an event of their mutual interaction (e.g. safety markings, traffic management). The better safety assurance measures will render a workzone safer for workers as well as for the road users. These physical measures are easy to adopt and are well rehearsed around the world. Their emphasis is on controlling and guiding traffic in such a way that ensures safe and efficient traffic flow (Li and Bai, 2009).
- Simultaneously, road user's better understanding of risks involved and safety measures required will have equal effects on the overall safety climate at site. A realistic risk perception will dictate a reasonable reaction by the driver and thus lead to a safe event of driving through a workzone. Hence safety of workzone can be ensured by carefully studying the driver's risk perception according to local conditions. Such an understanding can prove beneficial in order to improve/readjust safety measures for a pragmatically safe highway workzone.

There is a need to carryout in depth study of both the factors, being equally important for improving the highway workzone safety in Pakistan. The direct study of the safety measures taken at work site and road user's perception of the risk can be helpful in improvement of highway workzone safety in Pakistan. The present study aims at the same.

1.3. Research Objectives

In order to overcome safety problems at highway workzones in Pakistan, there is a need to develop a clear understanding of extent of the problem. This is only possible if the existing highway workzones are compared with a benchmark. Also, there is a need to understand the user's perception of the risk associated with travelling through a highway workzone. Therefore, the objectives set forth for present study are;

- Synthesize the international and national literature on highway workzone safety to understand Pakistan specific issues.
- Synthesize the state of safety practices at highway workzone in Pakistan.
- Comparison of highway workzone safety situation in Pakistan with the state of the art highway workzone.
- Development of a model to understand driver's risk perceptions while driving through a highway workzone in Pakistan.

1.4. Overview of Study Approach

In order to achieve the objectives set for the research, a detailed methodology (Figure 1.1) was worked out and the following research tasks were identified;

- Literature review of the previous relevant research works at national/international level.
- Identification of detailed design of a safe highway workzone, as per recommended standards.
- Collection of highway workzone data from selected projects across the country.
- Comparison of safety practices at selected highway workzones (selected projects) vis-à-vis a safe highway workzone.
- Development of road user's risk perception model, using data collected through interviews of selected sample of drivers.
- Analysis and discussions.
- Conclusion and Recommendations.

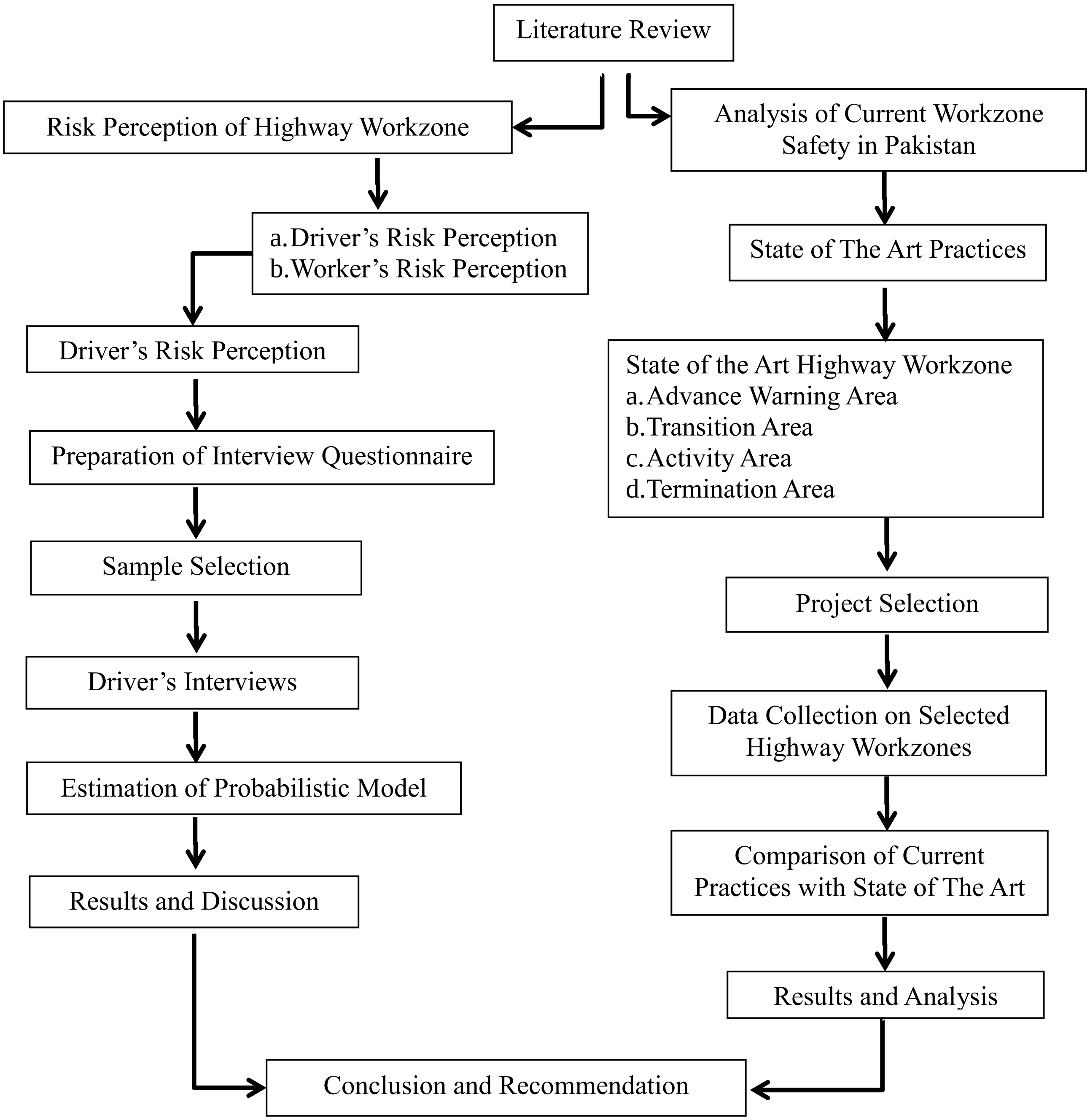

Figure 1.1 Overview of Study Approach

1.5 Thesis Organization

This research is organized into five chapters. The basic introduction along with problem statement, research objectives and research overview is given in Chapter 1. Chapter 2 provides a literature review on highway workzone safety and risk perception. In Chapter 3 the current state of safety at highway workzones in Pakistan is evaluated. Selected highway workzones across Pakistan are compared against standard guidelines and an overall safety picture is drawn. Chapter 4 covers the estimation of ordered probit model for driver's risk perception while driving through a typical highway workzone in Pakistan. Lastly, the research synopsis, conclusions, and recommendations are presented in Chapter 5.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This chapter summarizes several previous highway workzone safety studies carried out either internationally or in Pakistan. The chapter initially covers the different relevant research works done by some international researchers in the fields of highway workzone safety analysis and risk perception. The study highlights the severity of crash frequencies at highways in general and highway workzones in particular. The chapter further discusses the studies carried out to evaluate safety measures adopted on highway workzones. Some studies discussed the effectiveness of individual safety measures like wearing of Personal Protective Equipment (PPE) and different Temporary Traffic Control (TTC) devices.

Literature review revealed that although some significant research efforts have been made by Pakistani researchers in the field of worker and workzone safety, but not much work has been done specifically related to highway workzone safety. The country owns a large highway network which continues to grow amid pressing population demands. Every year thousands of people lose their lives due to road traffic accidents, major part of which is contributed by the highway workzones.

Later, the literature review explores the understanding of road user's risk perception. Driver's behavior while passing through a workzone is a direct outcome of his/her risk perception. This subsequently affects the overall safety conditions at workzone. Any unsafe behavior can present a hazard for workers as well as other road users inside workzone. The literature search highlights the need to study the subject in detail, as no such work has been done in Pakistan.

2.2. Highway Workzone

The term Highway Workzone is used worldwide to refer to the part of highway where construction work is taking place (Huebshman et al., 2003). A common understanding of workzone is the part of highway on which construction, rehabilitation or repair work is underway. The "limits of workzone" is a much debated topic. A common man may tend to define these limits as mere extents of work area. Whereas, some experts like to add some adjacent area, where traffic often queues up due to the undergoing work and traffic restrictions (Turner, 1999). In such a situation the workzone will be ever changing as the queues of traffic will always be fluctuating.

Another way of defining the workzone is that it extends from the first upstream warning sign till the last downstream warning sign. This may not be constant throughout the construction period as many times the warning signs used are temporary or mobile. Also the queue of traffic may extend beyond the warning signs or it may merge with another queue caused by another independent workzone. Federal Highway Administration (FHWA) defines Workzone as "an area of a highway with construction, maintenance, or utility work activities" (MUTCD, 2009). A workzone is "typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles". It starts from the first "warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle" to the "END ROAD WORK" sign or the last TTC device at workzone (MUTCD, 2009).

In United States of America (USA), drivers encounter a workzone every 40-50 miles while driving on any interstate or highway (Wolff, 2004). The same study also finds that the highway construction is one of the most hazardous occupations in USA. Workzones present a significant challenge to the operational safety of the highway. A study shows that 23% of all the on-foot highway worker fatalities are caused by the moving traffic vehicles (Reising, 2012).

2.3. Summary of International Research Efforts

Road traffic Injuries (RTIs) were the 9th largest contributor of worldwide injuries in 1990 (WHO, 2004). The trend is on the rise and according to same WHO report, RTIs are expected to be the 3rd largest cause of disease or injury in the world by year 2020. A major portion of RTIs occur on highway workzones. For example in USA alone 87,606 road crashes were reported in workzones in 2010 (FHWA, 2014). These crashes caused 37,476 injuries in workzones. In other words one workzone injury every 14 minutes. Out of 37,476 more than 20,000 were construction workers. Additionally, above quoted crashes caused 576 fatalities which equate to one fatality at workzone every 15 hours. Even then safety is dealt as secondary priority (Ng et al., 2005).

There are several ways to evaluate safety performance of a construction workzone including study of Accident Rate, Incidence Rate, Experience Modification Rating, Score Card etc (Ng et al., 2005). The same study developed a "framework for evaluating the safety performance of construction contractors”. The study established the factors affecting safety performance according to their priority. The factors were divided into two categories, namely organization related factors and project related factors. The study concluded that most important organization related safety factor is implementation of safety regulations. Whereas, “provision of safe working environment” is most important project related safety factor.

A study carried out detailed analyses of 29 reported highway workzone accidents cases across USA. The study concluded the reasons for these accidents according to respective work scenarios and made recommendations for the improvement of safety conditions which are effectively applicable to all highway workzones. The study emphasized on adoption of simple measures like wearing of high visibility safety apparel, working in non-peak hours, use of flaggers and flashers to improve overall safety environment at workzones (Pratt et al., 2001).

A recent study by Chen and Tarko (2014) attempted to model the safety of highway workzones using data from 72 workzones in USA. The study observed that crash frequency is proportional to length of workzone at decreasing rate. Also wider workzone right of way reduces the crash frequency. The study found that presence of detour sign served to reduce crashes in workzone (Chen and Tarko, 2014).

A study carried out to study driver’s response to workzone conditions highlights the fact that decision regarding the safety of workzone is normally made in tight cost-conscious environment (Morgan et al., 2009). The study further establishes that safety conditions within workzone can be managed through effective traffic control measures. Traffic control measures through a workzone are achieved through establishment of a TTC zone.

Different TTC methods and their effectiveness have been widely studied by different researchers. These methods include use of TTC devices for the safety of workers and road users at same time. Use of TTC devices can prevent some of the most common human errors while driving which may include, “disregarding traffic control measures”, “inattentive or distracted driving”, “following other vehicle too closely” and “exceeding allowable speed limit”. Thus many severe crashes can be avoided (Li and Bai 2009).

The most effective combination of TTC devices for multilane highway workzones is cones, arrows and flaggers (Garber and Woo, 1990). Whereas, another study verified that 1/3 of truck drivers found it hard to see flaggers and 1/2 considered their directions as confusing (Benekohal et al., 1995). In same study, 50% of truck drivers recommended the advance warning area as long as 3-5 miles.

Safety conditions of a highway workzone effect workers as well as the road users. Thus any attempt to evaluate a highway workzone must cover all the relevant aspects. Shi et al. (2009) for their study divided safety evaluation process into following aspects; “Overall Workzone Management and Coordination, Transportation Operations Management Plans, Public Information Plans, Temporary Traffic Control Plans, Construction Worker Safety and Monitoring Workzone Safety and Mobility Impacts during Construction” (Shi et al., 2009). The research provided guidelines safety audit of highway during its construction stage.

A research carried out to study the workzones with specific reference to accommodating pedestrian, found that a large number of workzones did not pay any attention to pedestrian requirements (Morelli et al., 2006). The researchers witnessed pedestrians in every workzone but none of them addressed the pedestrian accommodation perfectly. The study also highlighted the presence of a good number of unnecessary equipment at site which created additional hazards. Highway workzone presents a complex situation where hasty action to ensure safety may itself put safety of other workers or road users at risk.

Almost every organization attempts to employs some kind of safety measure at site (whether good or otherwise). The effectiveness of these measures is dictated by the response by the road user. A study carried out to study road user’s response to safety measures at workzone, concluded that TTC measures recommended in MUTCD correspond very well to the safety requirements. These TTC measures effectively reduce vehicle speed and ensure smooth transition (Tsyganov et al., 2003).

There has been extensive research being carried out on traffic safety. The researchers have been looking for the ways to improve safety by introducing improvements in design and technology. On social level, efforts are made to avoid accidents by introducing rules and regulations. An important aspect is to understand the relation between an accident and drivers behaviour. Workzones are interruption in the smooth flow of the traffic. A workzone presents a violation to the driver’s expectations. This is due to the fact that workzones do not occur frequently or at regular intervals. On encountering a workzone, driver’s first feeling is a surprise and discomfort followed by a desire to avoid it (Wretstrand, 2008). Driver’s immediate perception of hazard and risk involved plays vital role in outcome of the incident.

A good understanding of risk by driver can result in no accident and vice-versa. A safe behaviour could improve traffic safety

Presence of a highway workzone presents a major distraction for the road user. It presents a surprise to driver's expectations (Morgan et al., 2009). How a driver manages the distraction varies significantly from person to person and may also change from day-to-day depending on his/her state of mind, level of stress, fatigue and other distractions (Regan et al., 2009). The whole process elevates the level of risk for the driver and worker on site (Wang et al., 1996).

Generally workzone related traffic accidents are less discussed as a separate topic. Mostly they are included in the studies for traffic accidents. In USA, during 1995-2002, 844 highway workers were killed at road construction workzones (Pegula, 2004). In 1999, 872 people were killed due to vehicle crashes into the workzone. This number rose to 1028 in 2003 (Li and Bai, 2009). According to a study, the risk of accident at a highway workzone is 2.5 times higher than any other traffic accident (Mohan and Zech, 2005). The workers at any highway workzone are subjected to higher risk of getting injured not only by work activity but additionally by hazard traffic also. Working at highway workzone at night-time has a risk level as high as five times as compared to working at daytime (Arditi et al., 2007). In 2006, U.S. National Highway Safety Administration recorded more than 1000 fatal workzone. The crash rate at workzone can be as high as 21.5% than pre-work time (Morgan et al., 2009). Another study shows that longer workzone duration increases the crash frequency at workzone (Khattak et al., 2002). Higher risk level suggests much extensive study of the safety issues at highway workzones, both for day and night work. Also there is a need for much elaborate measures for safety of highway workers and travellers.

The element of risk perception is central to traffic safety. Most of the studies carried out around the world discuss risk perception of road users in relation to whole traffic system. Risk perception means the understanding (which is subjective in nature) of risk in traffic condition that carries potential hazards (Deery, 1999). Driver's ability to process the information available to him is utmost important in order to make a rapid and rational decision. Any misjudgement of risk will lead to flawed decision and hence unsafe behaviour (Krallis and Csontos, 2013). The heuristic concept of bounded rationality suggests that some drivers may tend to focus on some elements of information more than others (Sivak, 2002).

Such instances can lead to undesirable or unexpected behaviour by driver. This concept also suggests that too much of varying kind of information can prove counter-productive. Unnecessary information may mask the important one and thus confuse the driver.

The drivers response to any information depends upon how he perceives the risk (Englund et al., 1988). A better or higher perception will lead to much safer behaviour. In order to improve safety, one important measure would be to increase risk perception of road user. Aberg suggests that risk perception can be enhanced by “introducing new risks in the form of efficient traffic rules” (Englund et al., 1988). Well-crafted and better enforced rules and regulations can enhance the level of risk perception and lead to a safer behaviour. The higher perception of risk of getting seen or caught by law enforcement officials will ensure better compliance. On the contrary, absence of rules and regulations or weak or no enforcement can lead to careless/hazardous behaviour.

Risk perception is closely related to perceived safety. Social characteristics of driver can have significant influence on his/her level of perceived safety and hence risk perception. For example; age and gender differences can be easily detected. Young drivers prove to be more critical in assessment (Wretstrand, 2008). At the same time young and inexperienced drivers are more likely to be involved in accidents than older ones (Warner, 2006).

Drivers response is based on a quick mental calculation that creates a balance between his/her risk perception and level of risk that he/she is willing to take (Wilde, 2014). Thus driver’s response is an individual characteristic and likely to vary from one another. It may also vary according to mental state of driver. The Risk Homeostasis Theory also suggests that some safety measures that tend to decrease the risk perception (e.g. wearing of seat-belts) might result in more risky behaviors (e.g. driver will drive faster). Hence such measures will not necessarily result in safer traffic. Traffic conditions and driver’s behavior are the major contributory factors in safety conditions at a workzone (Chen and Tarko, 2014). The study for highway safety must be two pronged, safety conditions at work site and drivers behavior through risk perception. Besides making safety measures at workzone through rules and regulations there is need to understand the level of risk perception of a common road user. Only then measures can be taken to improve upon the safe driving habits and hence safety.

Table 2.1. Summary of International Research Efforts – Highway Workzone Safety

Author	Year	Details
Englund et al.	1988	Review of traffic safety knowledge
Garber et. al.	1990	Study of the effectiveness of different combinations of TTC devices
Benekohal and Shim	1995	Study of the effectiveness of different TTC methods
Wang et al.	1996	Analysis of crash data at highway workzones
Deery et. al	1999	Study of the risk perception of young drivers
Pratt and Marsh	2001	Analyses of 29 reported highway workzone accidents across USA
Khattak et. al.	2002	Study of traffic crashes with reference to workzones
Sivak	2002	Study of the contribution of bounded rationality to traffic fatalities
Tsyganov et. al.	2003	Study of road user’s response to safety measures at workzone
Pegula	2004	Study of fatal injuries at highway workzones
Ng et. al.	2005	Analysis of factors affecting safety performance according to their priority
Mohan et. al.	2005	Study of causes of accidents
Morelli et. al.	2006	Safety of pedestrian related issues in workzones
Warner	2006	Study of driver's speeding behavior
Arditi et. al.	2007	Effect of night and daytime workzone on crashes
Wretstrand	2008	Driver’s response to workzone conditions
Morgan et. al.	2009	Driver’s response to workzone conditions
Li and Bai	2009	Different TTC methods and their effectiveness
Shi et al.	2009	Safety audit of highway during its construction stage
Regan and Young	2009	Study of distractions during driving
Krallis et. al.	2013	Effect of risk perception on behavior
Chen and Tarko	2014	Modeling safety of highway workzones
Wilde	2014	Study of theory of homeostasis

2.4. Summary of National Research Efforts

According to WHO report on Global Burdon of Disease Project issued in 2002, 90% of global RTIs are contributed by the low or medium income countries. WHO estimated 30,131 RCFs annually in Pakistan (WHO, 2013). The situation gets even more alarming due to the fact that need for safety has not been one of the top priorities in Pakistani construction industry. Khan (2012) studied the safety conditions in Pakistani Construction industry and established that safety related training is given least attention (Khan, 2012). The study also highlighted the fact that workers are not much forthcoming in adopting safety measures themselves, especially once not being supervised. Most of the construction companies do not have formal safety policy. At the same time most of the clients don't allocate any funds for the safety. Resultantly, the emphasis is only given to quality, cost and time.

Another study concluded that worker's behaviour at workzone is closely influenced by the overall culture (Tauha and Sherif, 2009). The study found that workers had good safety awareness and relatively good risk perception. Workers working in a collective and less uncertain environment displayed safer behaviour. The study also found significant relationship between workers behaviour and management practices. Better management results in better and safer behaviour by the workers collectively.

Bhatti et al. (2011) studied highway workzone crashes using police reported data (2006-2008) from 196 km long section of the Karachi-Hala Highway. The study concluded that workzone crashes accounted for 15.0% of all traffic crashes on the test section. The rate of crashes was found higher in the workzone than on other segments of the same road. The study emphasized the need to improve safety conditions at highway workzones across Pakistan.

A study by Farooqui et al. (2008) has shown that Personal Protective Equipment (PPE) is not being effectively used on workzones in Pakistan. The study concluded that construction workers are either unaware of importance of PPE or they consider it hindrance in their work. Also the management was not found interested in emphasizing the need for PPE. The study also found that approximately 58% of the construction companies fall in the category of extremely unsafe to moderately unsafe. Where ever safety practices are followed, they are not standardized.

Safety at workzone can be enhanced, if it is embraced as a wholesome. The process hinges on the efforts of an organization to implement the principle of health and safety from within (Choudhry et al., 2014). Subsequently the process of safety management must engulf all the aspect organization in the form of a deliberate and efficient plan. The study discusses the factors affecting the safety management system within an organization.

Farooqui et al. (2008) while studying the performance of Pakistani construction industry concluded, that there is need for change of mind-set of all stakeholders in order to improve the performance in all aspects of industry including safety. The study emphasized on the importance of management staff to change their approach to bring about constructive changes in safety environment. The research found that one of the main impediments to improvement in performance is the rigidness of concerned management staff.

Khan (2011) investigated the relation between driver’s comfort level and length of taper in transition area of workzone and found that driver’s comfort level lowers with decrease in taper length. The study also concluded that age and driving experience are significant factors in driver’s response to level of comfort while traversing through a taper of transition area.

Unluckily, reliable crash data required for study of effectiveness of safety measures at workzones is not readily available in Pakistan. Also there is no formal organization responsible for collecting such for research purposes. OSHA in USA, HSE in UK, Safe Work Australia, EU-OSHA in European Countries etc. are some of the organizations which carry out research along with ensuring safety at work sites in their respective countries. Establishment of occupational safety and health governing body in Pakistan is indeed a must requirement. In the absence of relevant data, a more direct approach was adopted in this research to evaluate the level of safety situation at our highway workzones. Usefulness of MUTCD in making workzone safer has already been highlighted. This research utilizes the same for the evaluation of safety conditions at Pakistani workzones.

Table 2.2 shows the summary of national level research on highway workzone safety.

Table 2.2. Summary of National Research Efforts – Highway Workzone Safety

Author	Year	Details
Farooqui et. al.	2008	Level of safety performance in construction industry of Pakistan
Farooqui, et al.	2008	Analysis of current state and directions for improvement of Pakistani construction industry
Tauha and Sherif	2009	Influence of culture on safe work behavior
Bhatti et al.	2011	Highway workzone crashes on a section of the Karachi–Hala Road, Pakistan
Riaz A. K.	2011	Case study for workzone conditions in Pakistan
Khan H.Z.A.	2012	Evaluation of current safety practices in construction industry of Pakistan
Choudhry et al.	2014	Factors affecting the safety management system

2.5. Manual on Uniform Traffic Control Devices (MUTCD)

MUTCD is a comprehensive document published by FHWA. The document gives standards for all traffic control devices installed on any street or highway around the country. The first edition of MUTCD was published in 1935 with subsequent revisions. The millennium edition was adopted by OSHA in December 2002. Every state can use either the national MUTCD in entirety or with its respective supplement. It is noteworthy that provisions of manual employ the concept that an "effective traffic control depends upon both appropriate application of the devices and reasonable enforcement of the regulations" (MUTCD, 2009).

According to MUTCD (2009), traffic control devices are "signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, bikeway or private road open to public travel". The purpose of traffic control devices is to "promote highway safety and efficiency" through orderly movement of traffic (MUTCD, 2009).

In 2009 edition, there are 9 distinct parts in MUTCD. Part-6 deals with TTC in case of workzone or any incident on highway. Safety of road users as well as personnel in workzone is integral and high priority element of any phase of any project (MUTCD, 2009). Establishment of TTC zone is essential part of any highway construction, work related to any utility, maintenance work and for management of any kind of traffic incident. The basic function of TTC is to provide "safe and effective" traffic movement while ensuring safety of travellers, workers and equipment. At the same time it provides an efficient road user flow (MUTCD, 2009). TTC planning starts with the planning phase and continues throughout all the phases of the project. As the work on the project progresses, the site conditions keep changing, resultantly the TTC must also be modified as soon as required.

Coordination with relevant authorities like railways, canals, bridges, police, emergency responders, transport agencies and other adjacent projects etc. are part and parcel of a good TTC. Good public relation plays an important role for the success of a TTC. Public relations can be maintained through advance notices, news media and public awareness campaigns. TTC must be in place before the road is opened for the traffic and it should be removed as soon as it is no longer required.

The standard guidelines laid down in MUTCD are taken as benchmark for comparison and subsequent evaluation of highway workzones in Pakistan under actual field conditions. The relative details of these standards will be covered in relevant part of this document.

2.6. Chapter Summary

Safety at highway workzone is a multidimensional issue. It involves a variety of stakeholders. Road work is such an activity that influences hundreds of people from variety of backgrounds. In a highway workzone, not only lives of workers are at risk, but drivers, travellers and bystanders also face a hazardous environment. Besides being unavoidable, such work activities can be made safe for human lives and property by incorporating health and safety at every stage of work. Apropos of above, requirement of safety must be realized at all levels from legislators to governing bodies to constructors to common man.

Thousands of people lose their lives worldwide due to incidents at highway workzones that could be avoided. Additionally many more suffer severe injuries and thousands of families bear the aftermath of un-repairable losses. The matter can be dealt with careful and thorough study of subject and making required changes in legislation, rules, regulations and above all “attitudes”.

Unluckily Pakistan doesn’t have formal infrastructure for study of workzone safety unlike other countries. Similarly reliable accident data are not available. Thus the formal method of studying health and safety through accident data is not much reliable. While addressing highway workzone, there is requirement of formulation of relevant rules and regulations and their subsequent enforcement. MUTCD is a comprehensive guide that provides standards to ensure safety of workers and road users. The manual can be modified to fit with our regional or national requirements. Also better understanding of the risk involved can influence a safer driving attitude and hence safer highway workzones.

CHAPTER 3. ANALYSIS OF CURRENT HIGHWAY WORKZONE SAFETY PRACTICES IN PAKISTAN

3.1. Introduction

In order to reduce RTCs at highway workzones, there is dire need to uplift safety conditions. Better safety conditions can be ensured by physically improving the safety measures at workzones. Thus reducing the safety hazards and minimizing possibilities of crashes due to in-sufficient safety measures. The required improvement in safety measures can be best affected if these measures are taken after deliberate study of road environment. The study of effectiveness of existing safety practices can give an insight about quantum of effort required in this regard. The most obvious requirements for any effort to improve safety conditions at highway workzones is, to evaluate the current state of adherence to safe practices. One of the objectives laid down for current study was to study the existing highway workzones safety practices in Pakistan for their adherence to safety measures prescribed by literature. This chapter discusses the same aspect.

3.2. State of The Art Highway Workzone

The first requirement for the assessment of any highway workzone is the identification of state of the art highway workzone to be used as bench mark. A thorough literature search along with practices being followed worldwide, were studied in order to enlist standard safety performance measures of highway workzones. These performance measures are used to compare the existing practices at selected workzones around the country. The performance measures contain TTC measures which are required to regulate traffic in safest and most efficient manner possible (Li and Bai, 2009). The standard TTC provisions given in MUTCD-2009 were the basic guide for development of required set of performance measures. The MUTCD is a guideline document that is issued by the Federal Highway Administration (FHWA). It specifies the standards by which road markings, traffic signals and signs are designed, installed on road, and used to regulate traffic on road and in a TTC zone.

3.3. Components of Highway Workzone

There is no standard size for a highway workzone. Its size varies from situation to situation. It can be as small as few hundred feet and as long as several hundred meters. Thus exact size of workzone or any of its components cannot be given. Secondly the components of a workzone are not separate entities. Each component is linked with and merges with the next component. There are no physical boundaries of components and at the most a warning sign can specify end of one component and start of the next. For ease of understanding, a highway workzone can be divided into four components (MUTCD, 2009);

a. Advance warning area
b. Transition area
c. Activity area
d. Termination area

A discussion on components of a highway workzone is provided in ensuing paragraphs;

a. Advance Warning Area

Advance Warning Area (AWA) is the section of highway before the actual start of highway work area, where road users are warned about the upcoming hazards (MUTCD, 2009). The purpose of AWA is to prepare the road user about the subsequent workzone conditions. The road user gets mentally prepare for possible differing conditions at workzone. Traveller may adjust travelling speed, lane etc. before actually entering into workzone. While driving through a workzone speed of vehicle is crucial. Reducing vehicle speed prior to its entry in the workzone is one of the most suitable methods to avoid collision (Morgan et al., 2009).

An AWA may consist of a single sign or as series of signs but normally it consists of three signs that advise, warn and instruct the road user about the upcoming workzone (Wolff 2004). Size of AWA may not be fixed and vary according to situation. A study has revealed that truck drivers desired to see warning signs “3-5 miles in advance of the workzone” (Li and Bai, 2009). According to MUTCD-2009, the length of AWA may vary according to type of road e.g. length of AWA for freeways and expressways should be longer than urban streets, and can be as long as 0.5 mile or more. For urban streets the AWA (in feet) must be

"4-8 times the speed limit in miles per hour" (mph). For rural highways the size of AWA (in feet) must be 8-12 times the speed limit in mph. Thus in open highway conditions the distance can be extended to 1500 feet or more. Table 3.1 gives the minimum recommended spacing of advance warning signs for different types of roads.

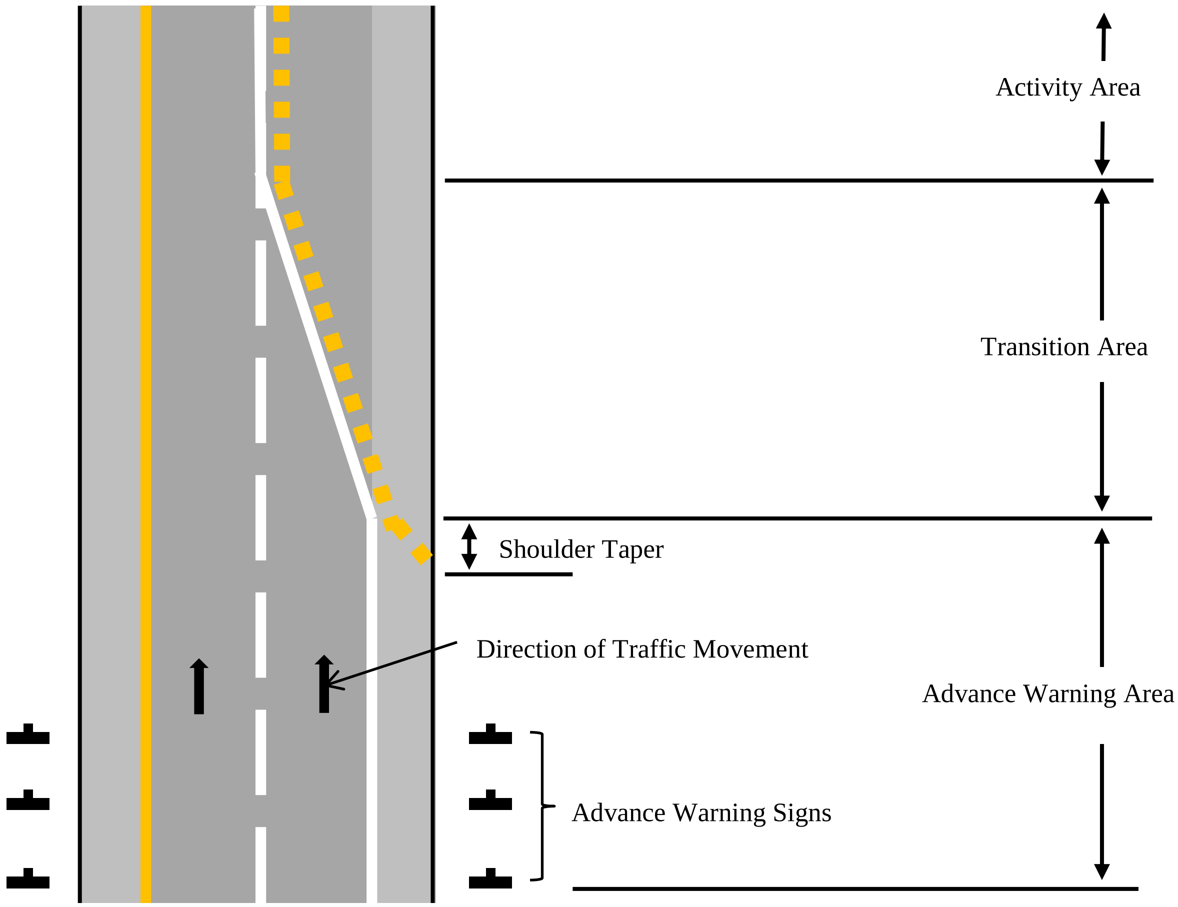

Figure 3.1. Advance Warning Area (MUTCD, 2009)

Table 3.1. Recommended Minimum Spacing of Advance Warning Sign

Road Type	Distance Between Signs (feet)		
	A	B	C
Urban (low speed)	100	100	100
Urban (high speed)	350	350	350
Rural	500	500	500
Expressway / Freeway	1,000	1,500	2,640

Where: A= Closest to workzone, B = Intermediate, C = Farthest from workzone (MUTCD, 2009)

b. Transition Area

Transition Area is portion of highway that directs the road users out of their normal path (MUTCD, 2009). Transition Area serves to shift the traffic from hazardous lane to safer

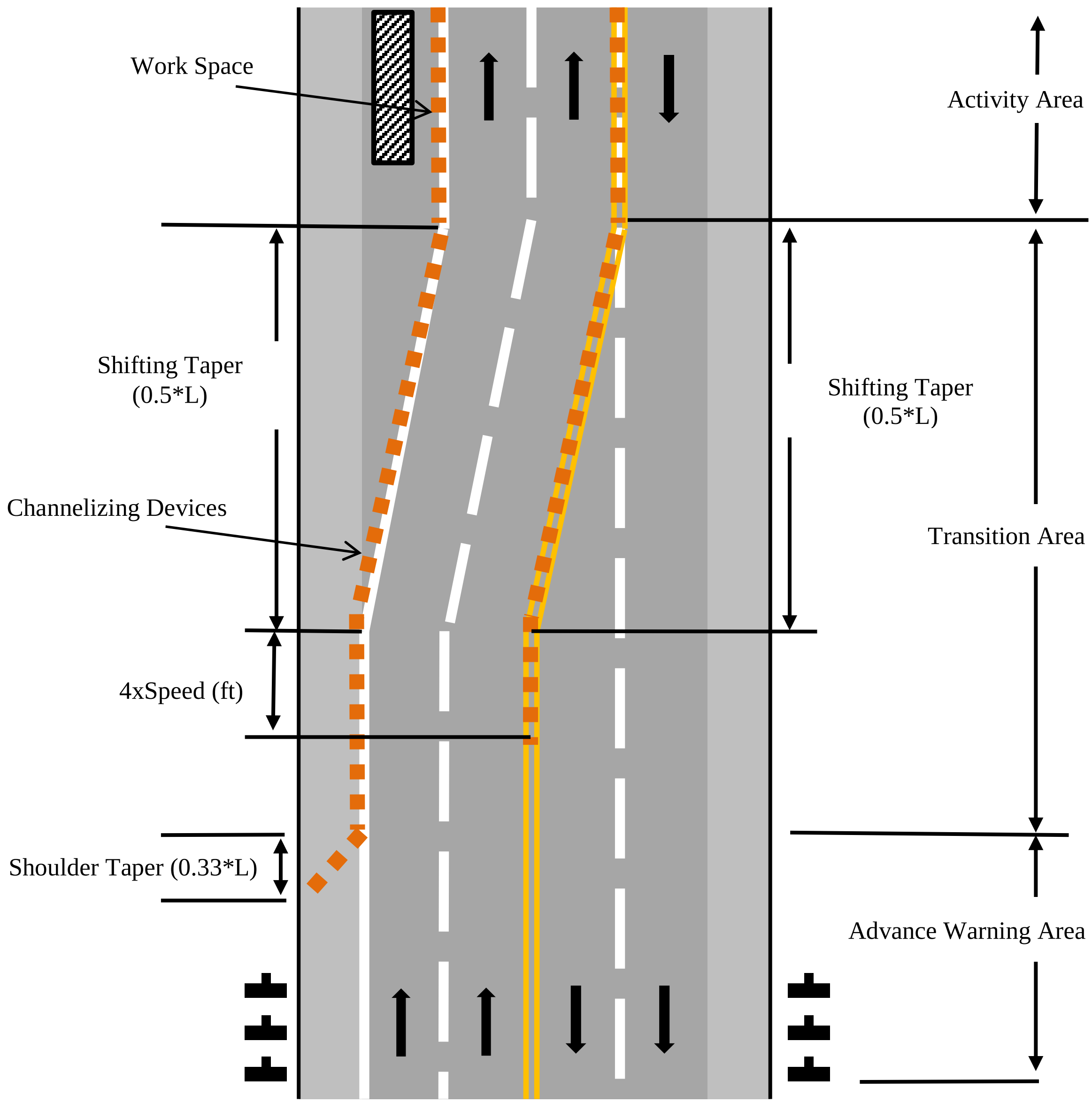

Figure 3.2. Transition Area (MUTCD, 2009)

lane. Transition area must provide a predictable transition for the driver. A safe and predictable transition area serves as a useful and practicable measure to improve workzone safety (Morgan et al., 2009). Transition area of a highway workzone is shown in Figure 3.2.

The shifting is materialized with the use of tapers. Normally tapers are created by employing a series of channelizing devices and/or by use of pavement markings. Tapers can be used in termination areas also. Different types of tapers and buffer spaces for a typical highway workzone are given in Annexure-B. The length of taper may vary according to the situation. “Longer tapers are not necessarily better than shorter ones” (Morgan et al., 2009). Longer taper length may cause slow response from drivers and they tend to delay shifting of lanes. The same study shows that too short taper length can result in unsafe condition where driver has less reaction time available. The situation may get even worse in the presence of a lead vehicle. Table 3.2 and 3.3 give the criteria for the calculation of taper lengths. It is evident that merging taper requires the longest distance. Flaggers may also be used in transition area to control the traffic. Flaggers are particularly useful on one-lane, two-way tapers. Number of flaggers is subjected to length of section and the visibility at site. They must have a reliable mode of communication (Wolff, 2004).

Table 3.2. Taper Length Criteria for Highway Workzones

Type of Taper	Taper Length
Merging Taper	at least L
Shifting Taper	at least 0.5 L
Shoulder Taper	at least 0.33 L
One-Lane, Two-Way Traffic Taper	50 feet minimum, 100 feet maximum
Downstream Taper	50 feet minimum, 100 feet maximum

(MUTCD, 2009)

Table 3.3. Formulae for Determining Taper Length

Speed (S)	Taper Length (L) in feet
40 mph or less	$L = WS^2/60$
45 mph or more	$L = WS$

(MUTCD, 2009)

Where: L = Taper length in feet, W = Width of lane in feet,
S = Posted speed limit, or off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed in mph

c. Activity Area

Activity area is part of the road where work actually takes place. Figure 3.3 represents activity area in relation to other components of highway workzone. The major components of activity area of a highway workzone are discussed as follows (MUTCD, 2009).

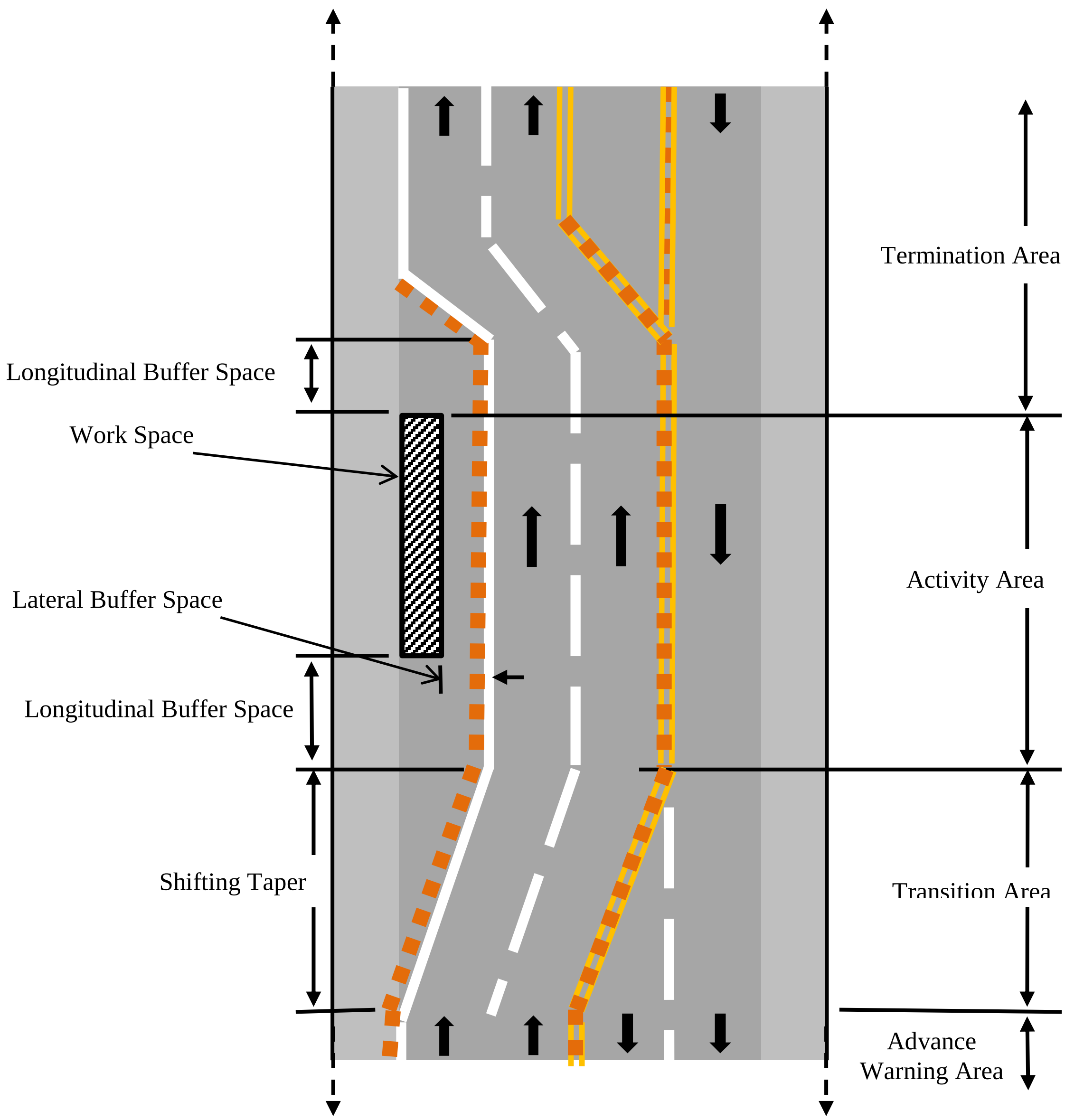

Figure 3.3. Activity Area (MUTCD, 2009)

(1) Work Space. It is the part of road closed for the traffic and dedicated to workers, equipment and materials etc. Work space is separated from traffic with the use of channelizing devices and barriers. Work space may remain stationary or move with progress of work.

(2) Traffic Space. Traffic Space is part of the road where road users are guided through activity area. These are in fact open lanes for traffic movement in a workzone. Traffic space provides least interrupted flow to the traffic without interfering activity within work space.

(3) Buffer Space. Buffer Space is longitudinal space left between work space and the flow of traffic and/or lateral space left between work space and traffic space. Buffer space serves to protect workers and work activity from traffic hazard and vice versa. The aim of buffer space is to provide some recovery space to an intruding vehicle. The required size of the buffer space depends on the speed of the vehicle. Table 3.4 shows the longitudinal buffer space required as a function of the speed of vehicle. The lateral buffer space must be set by "engineering judgment" (MUTCD, 2009) .

Table 3.4. Requirement of Longitudinal Buffer Space

Speed*(mph)	Distance (feet)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820

(MUTCD, 2009)

*Posted speed / off-peak 85th-percentile speed

d. Termination Area

Termination Area is the part of road that provides road users a clear path to return to their normal path from where they were diverted. It starts from the "downstream end of the activity area" and ends at the "last TTC device" at the downstream end of workzone. The last TTC device can be an "END ROAD WORK" sign or a speed limit sign that allows the road users to return to their normal speed.

The termination area may consist of a downstream taper and/or longitudinal buffer space. Figure 3.4 shows the standard layout of a termination area on a highway workzone.

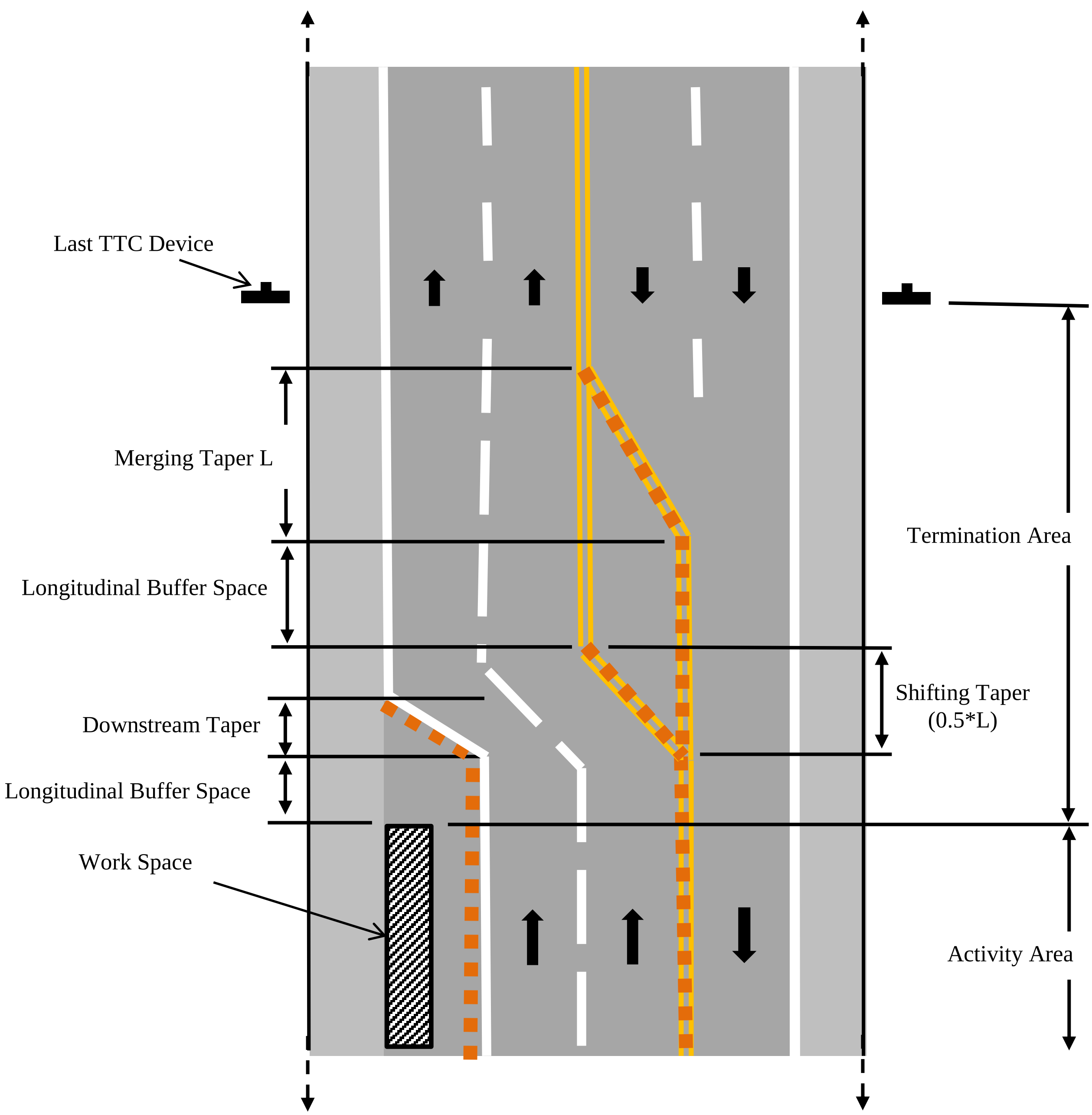

Figure 3.4. Termination Area (MUTCD, 2009)

3.4. Performa for Evaluation of Highway Workzone

A set of performance measures based on standards given in MUTCD was prepared, in order to record the safety measures taken at different highway workzones. The performance measures selected for evaluation were covered under seven major attribute groups, which were further sub-divided into 60 sub-attributes. The performa used to record performance measures is provided in Appendix-A. Different attribute and their details are discussed as follows;

a. Project Information. The basic information recorded about the selected projects includes;

(1) Project name.
(2) Project location.
(3) Contractor.
(4) Client.
(5) Type of highway.
(6) Type of traffic.
(7) Permissible speed limits.

b. Workzone Characteristics. This section records the general information about the under consideration workzone of the respective project. These are the overall characteristics of the workzone that cannot be attributed to any single component. This section includes seven workzone characteristics, that are;

(1) Type of workzone.
(2) Length of the workzone.
(3) Permissible speed limit through workzone.
(4) Nature of work.
(5) Cross movement through workzone.
(6) Presence of intersection within the limits of workzone.
(7) Detour/diversion provided for workzone.

c. Advance Warning Area. This group records the characteristics of advance warning area of the workzone, if provided. All the necessary safety characteristics of advance warning area, as highlighted through literature study (Wolff, 2004; MUTCD, 2009), are checked for adherence on selected workzones. Relevant distances are measured to check against the minimum safety requirements as discussed earlier. The advance warning area is measured from first warning sign placed on road till start of transition area. The information recorded here includes;

(1) Provision of advance warning area or otherwise.

(2) Length of advance warning area.

(3) Number of advance warning signs in advance warning area.

(4) Spacing between advance warning signs in advance warning area.

(5) Presence of retro-reflective warning signs in advance warning area.

d. Transition Area and Tapers. This section records attributes of the transition areas and tapers in both upstream transition and termination area. The upstream transition area serves to guide the traffic out of the normal flow and into a safer lane. Whereas, the termination area safely guides the traffic back to its normal flow. The information recorded includes;

(1) Presence of transition areas.

(2) Length of transition areas.

(3) Presence of warning signs in transition areas.

(4) Presence of retro-reflective warning signs in transition areas.

(5) Use of channelizing devices in transition areas.

(6) Spacing between channelizing devices.

(7) Required buffer spaces.

e. Activity Area. Activity area is the part of workzone where workers, equipment and material is actually engaged in work activity. This area offers maximum risk to the workers and hence is very important from safety point of view. Characteristics recorded in this section include;

(1) Length of work space.

(2) Marking of work space.

(3) Restriction of work space for public.

(4) Marking of isolated hazards, storage areas, parking areas and staging areas for incident response.

(5) Retro-reflective markings.

(6) Presence of required buffer spaces.

(7) Use of retro-reflective safety apparels by workers.

f. Traffic Control Measures. Effective traffic control measures are necessary for safety of workers and road users at workzone. This section records measures as adopted for overall workzone. Some attributes required in this section are;

(1) Measure to regulate traffic.

(2) Speed control measures.

(3) Safety measures for pedestrian.

g. Public Relations. An effective public relation policy can help in reducing incidents at workzone by preparing road users beforehand about the expected conditions.

3.5. Data Collection of Highway Workzones in Pakistan

After development of data collection sheet/proforma, workzones were visited and data were collected through video recordings and actual field observations. Video clips were recorded with a special focus on safety attributes of selected workzones. Eight projects were shortlisted for the survey. The selected projects represented four each of urban and rural highways. One project, namely Indus Highway - 2, (Khairpur-Ratodero Section) was an undivided two-way highway, whereas, rest of the projects were divided highways. Kashmir Highway, Islamabad had partial access control (restricted for rickshaws and animal driven carts). Rest of the highways had no access control. Table 3.5 provides the basic characteristics of the shortlisted projects. Selected projects presented a variety of data across the urban and rural parts of the country. All data recordings were verified through careful analysis of respective video clips.

a. Selected Project Workzones

(1) Clifton Flyover, Karachi. Clifton flyover is an urban highway project being undertaken by Karachi Metropolitan Corporation on a six lane divided highway. It is located in busy urban neighbourhood of Clifton beach, shrine of Abdullah Shah Ghazi and Behria Icon. There were multiple lane closures and at places cross movement of traffic was also observed.

Table 3.5. Project Information

Project	Clifton Flyover	Clifton Underpass	Indus Highway - 1	Islamabad-Rawalpindi Metro-Bus Project	Kashmir Highway	Indus Highway - 2	Sialkot-Daska Road	Sialkot-Wazirabad Road
Location (District)	Karachi	Karachi	Dadu	Rawalpindi	Islamabad	Ratodero	Daska	Sambrial
Highway Type (Urban/Rural)	Urban	Urban	Rural	Urban	Urban	Rural	Rural	Rural
Divided/Undivided Highway	Divided	Divided	Divided	Divided	Divided	Undivided	Divided	Divided
Total Number of Lanes	6	6	6	6	4	4	4	4
Posted Speed Limit								
• LTV (Kmph)	50	50	80	50	80	80	100	100
• HTV (Kmph)	45	45	70	00	65	70	80	80
Police Enforcement in Workzone	Nil	Nil	Nil	Nil	Yes (Partial)	Nil	Nil	Nil
Speed Limit Signs (Regulatory Signs)	No	No	No	No	Yes	No	No	No
Approx. Length of Workzone (km)	1.0	0.6	8.0	8.6	12.0	6.0	8.0	2.0
Lane Closure	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple
Cross Movement of Traffic/Pedestrians	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Provision of diversion	No	No	No	No	No	No	No	No
Marked Start/End of Workzone	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Designated/Marked Pedestrians Path	No	No	No	No	No	No	No	No
Provision of Flaggers	No	No	No	No	No	No	No	No

(2) Clifton Underpass. Clifton underpass is also an urban highway project being undertaken by Karachi Metropolitan Corporation. It is located in the vicinity of Clifton flyover project on a six lane divided highway. The movement of traffic on the old highway is completely stopped and massive excavation has been done. There is no cross movement of traffic through workzone.

(3) Indus Highway – Dadu District. Indus Highway is part of national highway system and is also known as N-55. It is a 1,264 km long highway that runs along the Indus River. This highway was first constructed in 1985. Presently it is being rehabilitated/improved in different sections. The section of Indus highway surveyed for this research is located in rural area of Dadu District of Sindh province. There are multiple lane closures on this project and no arrangements for workzone safety.

(4) Islamabad-Rawalpindi Metro Bus Project. It is an urban Rapid Transit Project connecting the two cities. The project is simultaneously being undertaken by Rawalpindi Development Authority and Capital Development Authority. The total length of project is 23 KM, including an 8.6 KM elevated track and 24 bus stops. It is a fast track project with planned completion time of 11 months. Almost complete length of the project is an active workzone. The workzone is located within the roadway of Murree Road, Rawalpindi and 9th Avenue and Jinnah Avenue, Islamabad with numerous cross movement locations.

(5) Kashmir Highway. Kashmir highway is an urban highway project located in Islamabad city. The project aims at widening and improvement of existing Kashmir Highway. The project will provide fast and easy entrance and exit from Islamabad for Motorway, National Highway and New Islamabad Airport. The project was started in 2007 but due to some issues it was delayed. The project length is 11 km, which has been an active workzone.

(6) Indus highway - Khairpur-Ratodero section. This project is part of Indus Highway at Khairpur-Ratodero section. The project is being undertaken by NHA. The project passes through rural areas of Ratodero. It is an undivided two-way highway. The length of workzone is approximately 6 km. Work on one carriageway is being carried out and both-way traffic is using the existing carriageway. Unrestricted cross movement is possible through workzone.

(7) Sialkot-Daska road. The construction of additional carriageway project of Sialkot-Daska road is undertaken by Punjab Highway Department. It connects the two industrial

towns through a thickly populated area. The existing workzone is located on Sialkot bound carriageway. The length of workzone is 8 km. Frequent cross movement locations are available and Daska bound carriageway is being used for two-way traffic movement.

(8) Sialkot-Wazirabad Road. It is a rural highway project being undertaken by Punjab Highway Department. The length of workzone is approximately 2 km. The workzone comprised of shoulder and slow lane of the road. Work is being carried out besides heavy traffic. A huge number of pedestrians also use the road at numerous locations besides being an active workzone.

3.6. Safety Analysis of Selected Workzone in Pakistan

The site survey data provided with a comprehensive data set to evaluate individual workzones against the standard design template. The data were recorded using a simple and easily comprehendible form. All observations were video tapped as well, so that data can be verified. Some key observations about the selected workzones are listed as follows;

a. General Observations. General characteristics of selected workzones are presented in Table 3.5. Surveyed highways allowed varying permissible/posted speed limits. Workzones were established in different configurations e.g. four of the surveyed projects had single workzones while four had multiple workzones. None of the projects had an explicitly marked speed limit for driving through workzone. In almost all the projects, there were multiple lane closures. Less project-2 (Clifton Underpass), all other projects allowed cross movement of travellers through the workzone. None of the projects included construction of diversion to avoid workzone. Three (38%) project workzones used barricades to restrict the traffic from interfering into workzone and vice versa. Police was available on one project (12%) to regulate traffic. Four (50%) of the projects did not employ any mean to regulate traffic. Interestingly all these four projects were rural highways. Flaggers were not used on any of the project to regulate the traffic. Only one (12%) project namely Kashmir Highway, Islamabad had some (although insufficient) regulatory signs in place. Rest no other project had employed any mean to control traffic speed through workzone.

Less one (12%) project namely Sialkot-Wazirabad Road all projects had start and end of workzones explicitly marked. None of the project workzones had any marked or dedicated safe passage for pedestrians. Two (25%) of projects had issued public notices to inform the public. Interestingly both of these projects are located in Karachi city and are undertaken by same client. One (12%) project, namely Islamabad-Rawalpindi Metro Bus project had employed warning signs and notice boards.

b. Advance Warning Area. The details of advance warning area of selected workzones are provided in Table 3.8. In three of the workzones under study, no advance warning area was provided. At least one advance warning sign was required to mark the start of advance warning area. In above mentioned three workzones, no warning signs were placed and first warning sign, if provided was placed either in transition area or the activity area. Where provided average length of advance warning area was found to be 280 meters (918 feet), including one project that provided an exaggerated distance of 500 meters (1640 feet). Table 3.6 shows the minimum required length of advance warning areas as a function of posted speed for respective projects.

Table 3.6. Minimum Recommended Length of Advance Warning Area

Project	Posted Speed Limit (S) (in kmph)	Factor (F)*	Length of Advance Warning Area (SxF/1.6)* (in feet)
1	50	6	190
2	50	6	190
3	80	10	500
4	50	6	190
5	80	6	300
6	80	10	500
7	100	10	625
8	100	10	625

* MUTCD, 2009

Once provided, all the projects had more than the minimum required advance warning area (as recommended by MUTCD-2009). Thus no formal standards were followed to set the minimum required advance warning area and mostly the approximate judgment was adopted by site staff. The minimum requirement for number of advance warning signs was never adhered. None of the projects provided successive advance warning signs, thus violating the standard of 100 feet (urban) 500 feet (rural) spacing between successive advance warning signs as recommended by MUTCD. Once provided, the advance warning signs were found in satisfactory condition. Two out of the five projects, that provided advance warning signs, were found not using retro-reflective material. Thus compromising visibility at night or during poor visibility conditions.

c. Transition Area / Tapers. The details of transition area for selected projects are provided in Table 3.9. Only one workzone (Kashmir Highway project) had upstream shifting taper for transition. In rest of the projects, the traffic either had to find its own way through workzone or make some kind of transition by itself. Also the length of shifting taper was not sufficient and the transition area was marked by a single warning sign. Table 3.7 provides the required length of upstream shifting taper in transition areas as a function of posted speed for respective projects. The spacing (in feet) between transition devices (e.g. cones) in taper should not be more than posted speed limit (in miles per hour) (MUTCD, 2009).

Table 3.7. Minimum Recommended Length of Shifting Taper in Transition Area

Project	Posted Speed Limit (S) (in kmph)	Width of Offset (W) (in feet)	Factor (L)	Length of Shifting Taper (L/2) (in feet)
1	50	12	$WS^2/60$	95
2	50	12	$WS^2/60$	95
3	80	12	WS	290
4	50	12	$WS^2/60$	95
5	80	12	WS	290
6	80	12	WS	290
7	100	12	WS	360
8	100	12	WS	360

(MUTCD, 2009)

Once used, the condition of warning sign was just satisfactory. Only one project had used retro-reflective warning signs. Also in one project (Kashmir Highway, Islamabad), channelizing devices were used in transition area. Although retro-reflective channelizing devices were provided, but they were less in number and were inappropriately spaced.

d. Activity Area. The details of activity area for selected projects are provided in Table 3.10. There was no uniform size for the work space. Size of work space ranged from few hundred meters several kilometres. Only in one workzone, (Islamabad-Rawalpindi Metro Bus Project) had explicitly marked work space. None of the projects effectively restricted public from entering into workzone. Road users were seen routinely travelling or crossing through workzone. None of the projects had explicitly marked or cordoned isolated hazards like excavations, material dumping sites, sharp edges, dowels, equipment etc. None of the projects had all its markings of activity area made in retro-reflective material. Workers on two projects (Indus Highway, Dadu and Islamabad-Rawalpindi Metro Bus Project) workzones were wearing retro-reflective safety apparels. On remaining projects safety apparels were either not being worn at all or few of the workers were wearing them. None of the workzone had explicitly marked storage area. Mostly materials were either stored within workzone or on shoulder. Many a times it was observed that dumped materials were occupying some part of road way. Thus presenting additional hazard for road users. Longitudinal buffer spaces for activity area were never provided except Islamabad-Rawalpindi Metro Bus project. No buffer space was provided for storage areas.

Table 3.8. Advance Warning Area Characteristic of Selected Projects

Details	Project-1 A	Project-1 R	Project-2 A	Project-2 R	Project-3 A	Project-3 R	Project-4 A	Project-4 R	Project-5 A	Project-5 R	Project-6 A	Project-6 R	Project-7 A	Project-7 R	Project-8 A	Project-8 R
Whether Advance Warning Area is provided or not?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes
Length of Advance Warning Area (feet)	656	190	656	190	984	500	1640	190	-	300	656	500	-	625	-	625
Number of Advance Warning Signs	1	3	1	3	1	2	1	3	-	4	1	2	-	2	-	2
Spacing between Advance Warning Signs* (feet)	656	100	656	100	984	500	1640	100	-	100	656	500	-	500	-	500
Condition of Advance Warning Signs*	G		G		S		G		#		G		#		#	
Are Advance Warning Signs* retro-reflective?	Yes		Yes		No		Yes		#		No		#		#	

Where: *If Provided, A = Actual, R = Recommended by MUTCD, G = Good, S = Satisfactory, # = Not Provided.

Table 3.9. Transition Area / Tapers Characteristic of Selected Projects

Details	Project-1 A	Project-1 R	Project-2 A	Project-2 R	Project-3 A	Project-3 R	Project-4 A	Project-4 R	Project-5 A	Project-5 R	Project-6 A	Project-6 R	Project-7 A	Project-7 R	Project-8 A	Project-8 R
Whether Transition Area provided or not?	No	-	No	-	No	-	No	-	Yes	-	No	-	No	-	No	-
Length of Upstream Shifting Taper* (feet)	0	95	0	95	0	290	0	95	164	290	0	290	0	360	0	360
Number of Warning Signs placed*	0	1	0	1	1	1	0	1	1	1	0	1	0	1	0	1
Are Warning Signs* retro-reflective?	NA	-	NA	-	Yes	-	NA	-	No	-	NA	-	NA	-	NA	-
No. of Channelizing devices (cones)*	0	4	0	4	0	7	0	4	2	7	0	7	0	7	0	7
Spacing between Channelizing Devices* (feet)	0	31	0	31	0	50	0	31	20	50	0	50	0	63	0	63
Are Channelizing Devices* retro-reflective?	NA	-	NA	-	NA	-	NA	-	Yes	-	NA	-	NA	-	NA	-

Where: *If Provided, A = Actual, R = Recommended by MUTCD, G = Good, Sat = Satisfactory, NA = Not Applicable

Table 3.10. Activity Area Characteristics of Selected Projects

Details	Project-1		Project-2		Project-3		Project-4		Project-5		Project-6		Project-7		Project-8	
	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R
Explicitly marked Work Space	No	-	No	-	No	-	Yes	-	No	-	No	-	No	-	No	-
Work Space effectively restricted for public	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Marked or cordoned isolated hazard	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Marked Storage Area*	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Marked Parking Area* for Construction Machinery	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Retro-reflective markings and signs	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Workers within right-of-way of Workzone, wearing high-visibility retro-reflective safety apparel	No	-	No	-	Yes	-	Yes	-	No	-	No	-	No	-	No	-
Storage/Staging Space for Incident Response or Emergency	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-
Length of Buffer Space for Storage Area* (ft)	0	250	0	250	0	425	0	250	0	425	0	425	0	645	0	645
Length of Longitudinal Buffer Space* (ft)	0	250	0	250	0	425	82	250	0	425	0	425	0	645	0	645
Lateral Buffer Space*	No	-	No	-	No	-	No	-	No	-	No	-	No	-	No	-

Where: *If Provided, A = Actual, R = Recommended by MUTCD, NA = Not Applicable

No marked space was provided on any of the projects for parking of construction machinery. No buffer space was provided to any construction machinery parked at work site. None of the projects had storage/staging space for incident response or emergency. Only in one of the projects (Islamabad-Rawalpindi Metro Bus Project) longitudinal buffer spaces were provided. Although, there is no standard provision for lateral buffer space in MUTCD. Lateral buffer space is to be governed by engineering judgment. None of the understudy workzones had a formal lateral buffer space. Thus at places it was observed that road users were travelling dangerously close to workers and equipment.

e. Termination Area. The details of termination areas of selected projects are provided in Table 3.11. Only one workzone (Indus Highway, Dadu) had transition taper in termination area, but no shifting taper at upstream of workzone. In rest of the projects, the traffic either had to find its own way out of the workzone or make some kind of transition by itself. But once provided (as in case of Indus Highway, Dadu) the length of shifting taper was not sufficient (against the recommendations of MUTCD and as provided in Table 3.7). Also the transition area was marked by a single warning sign. The spacing (in feet) between transition devices in taper in a termination area should not be more than posted speed limit (in miles per hour) (MUTCD, 2009). Once used, the condition of warning signs was just satisfactory. Only in one project (Islamabad-Rawalpindi Metro Bus Project) longitudinal buffer spaces were provided on downstream end of activity area. In three of the understudy projects, opposing traffic was flowing dangerously close and there was requirement for downstream longitudinal buffer space for opposing traffic. But none of the workzones had any. None of the workzones provided downstream merging taper for opposing traffic.

Table 3.11. Termination Area Characteristics of Selected Projects

Details	Project-1		Project-2		Project-3		Project-4		Project-5		Project-6		Project-7		Project-8	
	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R
Downstream Shifting Taper provided	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Length of Downstream Shifting Taper* (feet)	0	95	0	95	65	290	0	95	0	290	0	290	0	360	0	360
No. of Channelizing Devices in Termination Area*	0	3	0	3	0	6	0	3	0	6	0	6	0	6	0	6
Spacing between Channelizing Devices in Termination Area*	0	31	0	31	0	50	0	31	0	50	0	50	0	63	0	63
Downstream Longitudinal Buffer Space provided	No		No		No		No		No		No		No		No	
Length of Downstream Longitudinal Buffer Space* (feet) (Refer Table 3.4)	0	250	0	250	0	425	82	250	0	425	0	425	0	645	0	645

Where: *If Provided, A = Actual, R = Recommended by MUTCD, NA = Not Applicable

3.7. Workzone Safety Assessment Results

a. Comparison with MUTCD

As discussed in previous section (section 3.6), the workzone data were collected by physical inspection of selected workzones and video recordings. The data thus collected were tabulated on a spread sheet. Also the standard guidelines recommended by MUTCD were tabulated on same spread sheet. MUTCD recommendations were selected as per their applicability in respective cases under study. For example, required size of advance warning area was selected as recommended by MUTCD under the specific allowable speed limit of the highway under study. Further the requirement of TTC devices, buffer spaces and distances were included based upon MUTCD recommendations. The collected data were then compared with recommended standards and short comings were highlighted. All the eight workzones were compared individually. The comparison results of the data in terms of percentage difference from standards are provided in Table 3.12. The values shown in Table 3.12 represent the average values of all eight workzones. Since the workzones were located in different parts of the country and projects were being executed by different contractors and clients, the results shown represent a fair analysis of overall safety conditions of workzones across the country.

b. Summary Highway Workzone Safety Assessment Results

The summary of highway workzone safety assessment results at selected highway workzones in Pakistan is provided in Table 3.12. The results suggest that speed limit signs were never used within workzone boundaries (0% agreement with recommended standards). On 88% of the occasions there was significant cross movement through the workzone whereas, 63% of the workzones were located near an intersection. None of the understudy workzone was provided with dedicated diversion or detour. 63% of workzones provided advance warning area and interestingly all of them had it for longer distance than required. Once provided, the advance warning area had utilized only 28% of the required number of advance warning signs. These warning signs were never found placed as per the required spacing. Additionally, use of retro-reflective material in advance warning signs was not a routine. A formal transition area with required distance and markings was never provided on workzones. Only on 25% of occasions, warning signs of transition area were used out of which 50% were retro-reflective but their condition was poor. Only 28% of workzones utilized channelizing devices in upstream transition area but they were never as per recommended number and spacing. No channelizing devices were used in downstream transition area. Only one project had upstream and downstream longitudinal buffer space, rest no other type of buffer space was observed on any of the workzones. Only one workzone explicitly marked the work space. Work space was never fully cordoned or restricted and cross movement was possible. Only 25% of times, high visibility safety apparels were worn by the workers in workzone. Only in one project police enforcement was observed within workzone limits. Also in one of the selected projects regulatory signs were placed within workzone. Separate passage for pedestrians was never provided; also no effective measure was utilized to avoid traffic congestion.

Table 3.12. Summary of Workzone Safety Measures Meeting Recommended Standards

Workzone Safety Measures	% Meeting Recommended Safety Standards
1. General	
a. Marked speed limit through workzone	0%
b. Diversion or detour provided	0%
c. Measures taken to regulate traffic	50%
d. Measures taken to enforce speed in workzone	12%
e. Marking of start and end of workzone	88%
f. Separate passage for pedestrians	0%
2. Advance Warning Area	
a. Provision of advance warning area	63%
b. Minimum sufficient length of advance warning area*	100%
c. Required number of advance warning signs*	28%
d. Sufficient spacing between advance warning signs*	0%
e. Retro-reflective advance warning signs*	0%
3. Transition Area / Tapers	
a. Provision of transition area / taper	0%
b. Sufficient length of upstream shifting taper*	0%
c. Provision of warning signs in transition area	25%
d. Retro-reflective warning signs of transition area*	50%
e. Required number of channelizing devices in upstream transition area*	28%
f. Sufficient spacing between channelizing devices in upstream transition area*	0%
4. Activity Area	
a. Explicitly marked work space	12%
b. Work space restricted for general public	0%
c. Marked/cordoned isolated hazard	0%
d. Retro-reflective markings and signs	0%
e. Use of high-visibility retro-reflective safety apparel by all workers within right-of-way of workzone	25%
f. Sufficient length of upstream longitudinal buffer space*	12%
g. Sufficient width of lateral buffer space*	0%
h. Marked storage area	0%
i. Sufficient length of buffer space for storage area*	0%
j. Marked parking area for construction machinery	0%
k. Sufficient length of buffer space for parking area*	0%

Where: *If Provided

Table 3.12. Summary of Workzone Safety Measures Meeting Recommended Standards (Continue)

Workzone Safety Measures	% Meeting Recommended Safety Standards
5. Termination Area	
a. Sufficient length of downstream shifting taper*	0%
b. Provision of required number of channelizing devices in downstream transition area*	0%
c. Sufficient spacing between channelizing devices in downstream transition area*	0%
d. Sufficient length of downstream longitudinal buffer space*	12%
e. Sufficient length of downstream longitudinal buffer space for opposing traffic*	0%
f. Sufficient length of downstream merging taper for opposing traffic*	0%

Where: *If Provided

3.8. Chapter Summary

The research results show a clear picture of level of safety measures in a typical workzone in Pakistan in comparison with MUTCD standards. The research results show that sufficient safety measures are not taken at highway workzones in Pakistan. Warning and transition areas are not routinely provided. Even if warning and transition areas are provided, their sizes and markings are not sufficient to effectively prevent the vehicles from crashing into workzones. A comfortable and smooth traffic flow along with safety of workers and drivers is not ensured.

Drivers are not provided with sufficient information to ensure safe and smooth navigation through workzone. Mostly the drivers are left to their personal judgment and skills. Additionally, not much effort is done to regulate traffic through workzones and often cross movement mixing of different types of traffic is observed. Construction of formal diversions is not preferred and many a time drivers try to create their own diversions by travelling off the road paths. All these issues result into frequent traffic congestions, which itself is not addressed properly.

Buffer spaces act as an additional measure to avoid damage to life and property in case of a driver losing control of his/her vehicle due to any reason. Sufficient buffer spaces are not provided as per the requirements based on allowable speed limit. Isolated hazards in the form of material storage space, parked equipment and weak structures etc. are never sufficiently marked or illuminated. Generally necessary workzone related information is not effectively communicated to public. Such information can help road users to mentally prepare for the expected conditions at workzone beforehand. Also this may help them consider other options in better way e.g. changing route or time of travel.

In short, the recommended TTC safety measures are not sufficiently adopted by Pakistani highway construction industry. Although some efforts are done on almost all the workzones to enhance safety conditions to some level and to avoid damages to life and property, but their effectiveness is questionable. Following well tested practices can pay dividend by reducing number of crashes at workzones. This may also improve efficiency of work being carried out at site besides saving valuable time of road users.

CHAPTER 4. DRIVER'S RISK PERCEPTION OF HIGHWAY WORKZONE - AN ORDERED PROBIT MODEL APPROACH

4.1. Introduction

Road users are the primary stakeholder for any road construction, maintenance or rehabilitation project. In fact the primary aim of any highway project is to provide comfortable travelling experience to its users. When a driver/road user sees a roadwork sign, he/she reacts to navigate through the workzone. The reaction may vary from individual to individual. It may range from feeling of anger (negative) to professional/academic (positive) interest (Wolff, 2004). Thus how one reacts to a workzone depends upon his/her personal behavior. There can be many factors that dictate the selection of this reaction. One of the most suitable approaches can be to consider work activity as pre-requisite for comfort and ease in future. In other words the road user accepts the temporary discomfort with a hope for much comfortable experience in future. Road user's perceptions will guide his/her subsequent actions while passing through a workzone. A much cautious and careful approach while passing through a workzone will render the event safer and minimize the risks for workers and other road users at site.

Traffic conditions and driver's behavior are the major contributory factors in safety conditions at a workzone (Chen and Tarko, 2014). Thus a comprehensive study for highway workzone safety must be two pronged, safety conditions at work site and drivers behavior through risk perception. Besides making safety measures at workzone through regulations and their enforcement, there is need to understand the level of risk perception of a common road user. Only then measures can be taken to improve upon the safe driving habits and hence safety.

4.2. What is Risk Perception?

The risk is the possibility of an occurrence that affects something that humans ascribe value. Such occurrence can be due to some event, action or situation (Renn and Rohrmann, 2000). The dictionary meanings of "Risk Perception" are "the immediate or intuitive recognition or appreciation of exposure to the chance of injury or loss; or a hazard or dangerous chance by human mind" (Dictionary, 2014). In another way risk perception can be defined as; "the belief (rational or irrational) held by an individual, group, or society about the chance of occurrence of a risk or about the extent, magnitude, and timing of its effect(s)" (Businessdictionary, 2014). Risk perception is an assessment made about the probability of occurrence of an accident. This assessment is subjective in nature (Sjoberg et al., 2004). Sjoberg et al. (2004) argues that the risk perception includes the consequences of accident. The perception is shaped through social and cultural experiences. Risk perception is associated with future events and is based on previous similar events (Smet, 2008).

Driver's risk perception is of particular importance once he/she is driving through a workzone. Workzones are often presented with advance warnings, lane transitions, signals, signs and other TTC measures. The purpose of such measures is to provide driver with advance warning and other such conditions to safely and efficiently drive through the workzone (Li and Bai, 2009). A driver's response to these conditions depends on how he perceives the risk associated with the event (Wretstrand, 2008). TTC measures at highway workzone influence a driver's risk perception by providing information, minimizing driver's aggressive behavior and assisting in movement through workzone (OSHA, 2014).

Studies have shown that normally risk is generated as a result of several factors including "human error within the traffic system" (WHO, 2004). A road user once travelling on a road segment maintains maximum interaction with the traffic system. His/her actions become part of the safety environment in the system. Although safety measures are built in the traffic system through design and operation, the resulting safety conditions are hugely impacted by the road user's adherence to these measures. Since actions are influenced by perceptions, a road user's adherence to safety measures at a workzone will be dictated by his/her risk perception. A common understanding from day to day life suggests a more cautious and safe behavior while passing through workzone, if a driver understands the risks involved. Thus driver's risk perceptions play a vital role in ensuring safety of workers and travellers at a highway workzone.

This chapter aims at understanding risk perception of a driver while passing through a typical highway workzone in Pakistan. Understanding the driver's risk perception can provide a basic knowledge to make highway workzones safe for workers and other road users. Since individual behaviors and thus actions depend upon a number of factors such as educational background, social norms and customs, changes in current safe practices at workzones must be made, that suite the local conditions and environment. The estimated ordered probit model of driver’s risk perception while passing through a highway workzone in Pakistan is discussed in ensuing paragraphs.

4.3. Data Collection

Driver’s risk perception during driving is influenced by markings and signage along the road (Rothenberg, 2004; Beca, 2014; OSHA, 2014). Through properly planned and objective marking, driver’s risk perception can be raised and thus safer behaviour while driving through workzone can be expected.

Pakistan is a mid-income country and safety is given low priority (Ng et al., 2005). Workzones are not properly marked and cause many crashes across the country (Bhatti et al., 2011). With such a back ground it is prudent to investigate the driver’s understanding of the situation while driving through workzone. Therefore, this study is designed to model driver’s risk perception while driving through a typical highway workzone in Pakistan. The study investigates, which category of drivers have what risk perception and how it is influenced by different socio-economic and other factors. A questionnaire survey was designed in which drivers were asked about their risk perception and their experience of driving through a highway workzone.

The data used for this research was collected through interviews at Kashmir Highway, Islamabad. The highway is an 11 km stretch that connects the Motorways with the city centre. The project started in 2010 and a number of workzones were established over the years. A sample of drivers travelling through this workzone and coming to main campus, National University of Sciences and Technologies (NUST) at sector H-12, were interviewed (110 drivers).

The interviewed drivers presented a mix of private, public and commercial transport vehicles. A significant number of respondents (24%) were professional drivers. 90% of the respondents were male drivers, whereas 10% were female drivers. Figure 4.1 through 4.4 show the distribution of interviewees according to their marital status, education level, type of vehicle driven and age group.

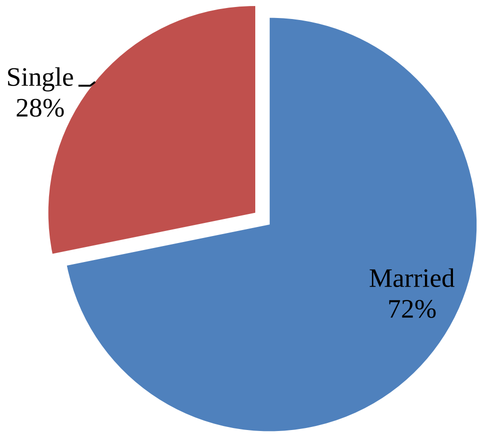

Figure 4.1 Marital status of driver

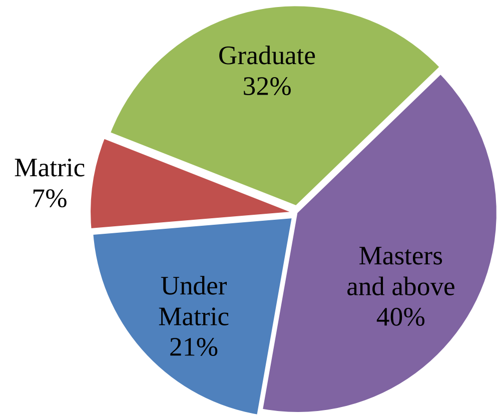

Figure 4.2 Driver's education level

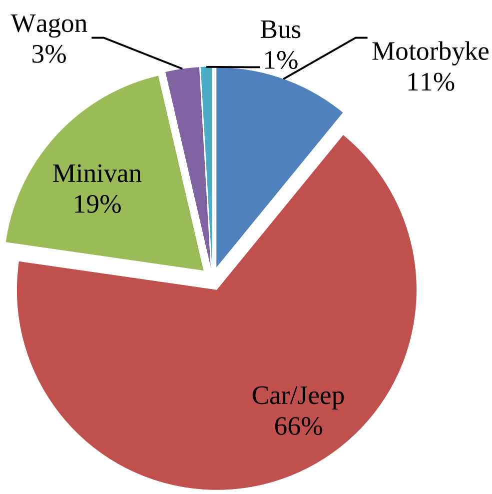

Figure 4.3 Type of vehicle owned

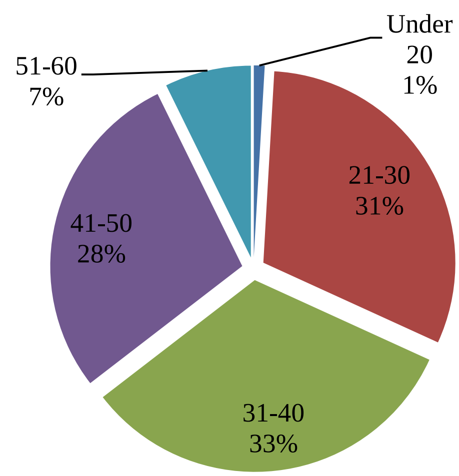

Figure 4.4 Driver's age groups

64% of the drivers included in research owned their vehicles, whereas, rest were driving office, rented or other type of vehicles. An interesting fact observed during the research was that as much as 72% of interviewees started driving under the age of 20 years. About 98% of interviewees had been using Kashmir Highway for more than 3 months but ironically 32% of them didn't know the permissible speed limit through Kashmir Highway workzone.

A comprehensive interview questionnaire was designed for the survey. The questionnaire comprised of carefully framed yet easy to comprehend questions (33 in number). The questionnaire used for the survey is attached as Appendix-B. The interview questionnaire was distributed in two major parts. Distribution of questions is as shown in Table 4.1. A Major part of questions (13 in number) were designed to explore driver's personal experience of driving through a typical workzone in Pakistan. Two questions were aimed at investigating categorical risk perception of road user. All the questions had close ended multiple choice answer options.

Table 4.1. Distribution of Interview Questions

Question Category	Number of Questions	Running Total
Personal information	6	6
Vehicle information	2	8
Driving experience	3	11
Experience of travelling through Kashmir Highway workzone	3	14
General experience regarding typical workzones	13	27
Opinion about other drivers travelling through workzone	2	29
Law enforcement through workzone	2	31
Personal risk perception	2	33

Table 4.2. Summary Statistics of Selected Variables

Variables	Mean	Std. Dev.	Min	Max
Age (years)	36.05	9.48	20	55
Average monthly income (Rupees)	58772.73	47863.46	10000	225000
Age when first started driving (years)	21	5.2	15	35
Time since in possession of driving license (years)	8.06	4.75	1	35
Usual speed on Kashmir Highway during up gradation phase (kmph) (workzone speed)	34.18	7.08	20	90
Normal speed on urban highway like Kashmir Highway (kmph)	63.63	8.26	40	100
Usual speed through a workzone (kmph)	20.73	7.70	10	80

The summary statistics of selected variables is provided in Table 4.2. Mean age of the drivers was found to be 36 years with standard deviation of 9.48. The drivers represented a variety of social and financial backgrounds. Mostly the drivers had enough experience of driving (average experience is more than 8 years) to give reliable data input for the survey. Some of the drivers agreed to be driving as fast as 80-90 kmph through workzone, displaying low risk perception. Present study attempts to understand the same risk perception through an ordered probit model.

The frequency distribution of road user's (irrespective of category) reported risk perception, while driving through a typical highway workzone in Pakistan is shown in Figure 4.5. Drivers were asked to report his/her perception regarding risk to themselves, other drivers and workers safety while driving through a highway workzone. The perception was collected through direct response and drivers were asked to give answer as per their overall past experience of travelling through highway workzones throughout Pakistan. Approximately 70% of the drivers graded their experience as high or very high safety risk, while 30% responded as moderate or low safety risk while driving through a highway workzone in Pakistan.

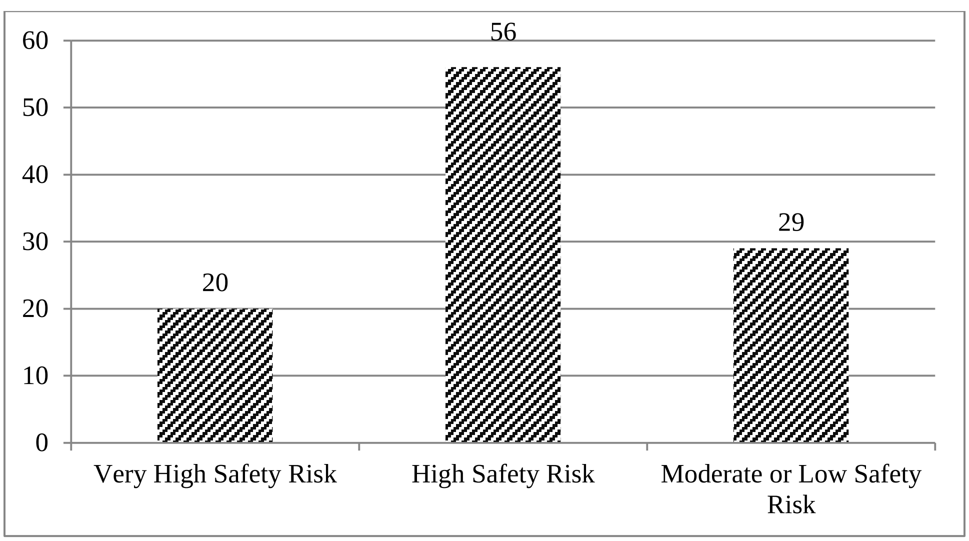

Figure 4.5 Frequency Distribution of Safety Risk Perception While Driving Through a Typical Highway Workzone in Pakistan

A detailed study of this particular response of respondents revealed that risk perception is higher among well educated (graduate and above) drivers. Also 84% car/jeep drivers graded it as high or very high safety risk, more than any other category under consideration. Whereas, 48% of minivan drivers considered moderate or low risk in driving through a workzone. 100% of female drivers graded their experience as high or very high safety risk, whereas, 72% of male drivers agreed to these grading. 46% of the respondents from the age group of professional drivers perceived driving through a highway workzone as high or very high safety risk.

4.4. Methodology

Multivariate modelling is used as an effective tool for research in number of fields. Same can be useful in predicting road user's risk perception of a highway workzone, once there are number of contributing factors. In order to study which factors are related with driver's risk perception, an ordered probit model was estimated in present study. The model explains the relationship between different explanatory variables and dependent variable. The dependent variable here is the ordered response against the question "In your opinion, how much is the risk while driving through a highway workzone in Pakistan?" (i.e. driver's risk perception of highway workzone). Dependent variable is modelled in terms of ordinal data (i.e. Very high risk perception, High risk perception, Moderate/Low risk perception). Following Duncan et al. (1998), Anastasopoulos and Mannering (2009), Hasan et al. (2011) and Sadri et al. (2013), the model structure for ordered probit model is expressed as follows;

$$Y^* = \beta X + \varepsilon \qquad \text{---} \ (1)$$

Where Y^* is the dependent variable which is coded as 0, 1, 2; β represents the model estimated parameter vector. X is the explanatory variable and ε represents the error term. Error term is assumed to be distributed normally (with zero mean and unit variance). The cumulative distribution is given by Φ(.) and density function given by φ(.). Given a specific risk perception, a driver is assigned a category 'n' if $\mu_{n-1} < y < \mu_n$. The risk perception data y, are related to underlying latent variable y*, through thresholds μ_n and where n=1,2,3. We get the probabilities as follows;

$$\text{Prob}(y = n) = \Phi(\mu_n - \beta X) - \Phi(\mu_{n-1} - \beta X) \ \text{-----------------------------} \ (2)$$

Where, $\mu_0 = 0$ and $\mu_2 = +\infty$ and also $\mu_1 < \mu_2$, (defined threshold). Driver's responses are estimated between threshold values. The threshold μ covers the range of specific values of dependent variable, which are normally distributed. The parameter β shows the effects of changes in the predictor variables. Threshold μ and parameter β were estimated using LIMDEP econometric software (Greene, 2011).

Marginal effect represents the effect of marginal change in the explanatory variables. It estimates the change in the value of dependent variable, which is associated with a specific change in value of independent/predictor variable. The marginal effect of the factor X is given as follows;

$$\delta Prob(y = n) / \delta X = [\phi(\mu_n - \beta X) - \phi(\mu_{n-1} - \beta X)]\beta', \qquad n = 0,1,2 \text{ ------ } (3)$$

4.5. Model Estimation Results

Several combinations of variable interactions were considered and tested to find the best possible ordered probit model. Both fixed parameter model and random parameter model were developed and compared. The model results for fixed and random parameters are provided in Table 4.3.

Likelihood ratio test is employed to test the "significance of random parameter model over fixed parameter model". The likelihood ratio test is a test which statistically compares the two models for their goodness of fit. One of these models (also called null model) is in fact a special case of the other model under consideration. This test employs the log-likelihood of both models and expresses the results in terms of "how many times the data under one model is more likely than the other". The likelihood ratio is given as follows (Washington et al., 2011);

$$LR = -2[LL(\beta_{random}) - LL(\beta_{fixed})] \text{ -- } (4)$$

Where, $LL(\beta_{random})$ is "log-likelihood at convergence for random parameter ordered probit model", and $LL(\beta_{fixed})$ is "log-likelihood at convergence of the fixed parameter ordered probit model" (Washington et al., 2011).

Table 4.3. Model Estimation Results – Ordered Probit Model

Variable Description	Fixed Parameter		Random Parameter	
	Coefficient	t-stats.	Coefficient	t-stats.
Constant	-1.155	-1.984	-6.377	-4.062
Indicator variable for feeling of comfort while driving through workzone (1 if very uncomfortable / not comfortable, 0 otherwise)	1.002	3.301	3.958	4.255
Indicator variable for avoidance of workzone (1 if driver tries to avoid workzone, 0 otherwise)	1.978	3.537	7.205	4.440
Indicator variable for police enforcement (1 if there is sufficient police enforcement, 0 otherwise)	-1.485	-2.464	-4.879	-3.261
Indicator variable for income and education (1 if individual income > 40000 and minimum qualification is graduate, 0 otherwise)	0.797	3.052	2.843	4.202
Indicator variable for driving through same workzone (1 if driver has driven through same workzone more than once in recent past, 0 otherwise)	-0.559	-1.959	-2.290	-3.502
Indicator variable for age (1 if age of driver > 40 years, 0 otherwise)	0.768	2.637	2.210	3.488
Indicator variable for speed reduction (1 if driver reduces speed while passing through workzone, 0 otherwise)	1.649	1.908	10.022	2.632
Indicator variable for speed (1 if vehicle speed through workzone > 40 kmph, 0 otherwise)	-0.546	-2.117	-0.939	-1.917
Indicator variable for valid driving license and driving experience (1 if driver holds valid driving license and driving experience > 5 years, 0 otherwise)	-0.846	-2.491	-1.647	-2.438
Threshold 1	2.074	8.438	6.425	5.233
Number of observations	105		105	
Log likelihood at convergence	-79.034		-76.331	

Table 4.4. Likelihood Ratio Test (Random vs Fixed Parameter Ordered Probit Model)

	Random Parameter	Fixed Parameter
Number of Parameters	15	11
Log Likelihood at convergence, LL(β)	-76.33	-79.034
LR= -2[LL(βrandom) – LL(βfixed)]	5.4	
Degrees of freedom	4	
Critical χ^2 0.050,4 (95% level of confidence)	9.488	
Number of Observations	105	

Model estimation results for random and fixed parameter ordered probit model are provided in Table 4.3. All the variables included in this ordered probit model are found to be statistically significant. There are eight variables that are significantly associated with level of risk perception of drivers. These variables include age of driver, level of comfort that driver feels while driving through highway workzone, avoidance of highway workzone by the driver, speed of vehicle, level of police enforcement at workzone, driving experience of the driver, education and monthly income of driver and reduction in speed while encountering a highway workzone.

Likelihood ratio test for random vs fixed parameter ordered probit model is provided in Table 4.4. The value of LR was 5.4, whereas, the critical value of $\chi^2_{0.050,4}$ is 9.488 (at 95% level of confidence, 5% level of significance and 4 degrees of freedom). The test fails to establish the appropriateness of random parameters ordered probit model over fixed parameters ordered probit model. Thus we accept a fixed parameter ordered probit model to best explain the relationship between dependent and independent variables.

Table 4.5. Marginal Effects

Variable Description	Marginal Effects		
	Very High Safety Risk	High Safety Risk	Moderate or Low Safety Risk
Indicator variable for feeling of comfort while driving through workzone (1 if very uncomfortable / not comfortable, 0 otherwise)	0.129	0.13	-0.26
Indicator variable for avoidance of workzone (1 if driver tries to avoid workzone, 0 otherwise)	0.149	0.424	-0.573
Indicator variable for police enforcement (1 if there is sufficient police enforcement, 0 otherwise)	-0.12	-0.31	0.432
Indicator variable for income and education (1 if individual income > 40000 and minimum qualification is graduate, 0 otherwise)	0.16	0.098	-0.258
Indicator variable for driving through same workzone (1 if driver has driven through same workzone more than once in recent past, 0 otherwise)	-0.15	-0.19	0.23
Indicator variable for age (1 if age of driver > 40 years, 0 otherwise)	0.168	0.033	-0.201
Indicator variable for speed reduction (1 if driver reduces speed while passing through workzone, 0 otherwise)	0.16	0.11	-0.25
Indicator variable for speed (1 if vehicle speed through workzone > 40 kmph, 0 otherwise)	-0.12	-0.03	0.159
Indicator variable for valid driving license and driving experience (1 if driver holds valid driving license and driving experience > 5 years, 0 otherwise)	-0.19	-0.01	0.205

Besides the combined effect of explanatory variables, marginal effects of respective dependent variables were also estimated. Marginal effects appropriately demonstrate the "difference in the estimated probabilities while the indicator variable takes the values from 0 to 1, keeping all other variables at their respective mean values" (Sadri et al., 2013). Marginal effects are important in the study of ordered probit model, as these explain any ambiguities in effect of independent variables on the intermediate categories in the estimation (Duncan et al., 1998). Marginal effects of the explanatory variables for fixed parameter ordered probit model are provided in Table 4.5.

Model results revealed that drivers who feel uncomfortable while driving through a workzone will have higher risk perception. This observation suggests that feeling of discomfort leads to more cautious behaviour. Conversely, a comfortable drive through workzone lowers the risk perception and hence will prove hazardous for the workers and other road users inside the workzone. Respective marginal effect shows that every unit rise in discomfort decreases the low risk perception by 0.26 and raises the very high risk perception by 0.129.

Those drivers who opt to avoid workzone, when an alternate route is available, have higher risk perception of highway workzone. A higher risk perception regarding highway workzone is displayed by avoiding it altogether. A driver, who considers travelling through a workzone a very high risk, tries to avoid it. He/she chooses to travel through an alternate route, provided such option is available. Also a driver who opts to travel through the workzone, once a safe alternate was available, shows lower perception of risk.

Those drivers, who consider that there is sufficient level of police enforcement in highway workzone, have low risk perception. This observation is consistent with past studies. Risk Homeostasis Theory suggests that some safety measures tend to lower the risk perception (Wilde, 2014).

The model results also revealed the impact of socio-economic variables on driver's risk perception. The indicator variable for driver's income and educational qualification indicates that those drivers whose monthly income is more than Rs.40,000 and are graduates have higher risk perception. This finding is intuitive as higher educational qualification raises risk perception and careful behaviour while driving through a highway workzone. A further investigation into the data collected reveals that 54% of the professional drivers show moderate or lower risk perception. All these drivers had monthly income in the range of

Rs.10,000 to Rs.20,000. Also, 85% of the drivers whose monthly income was Rs.100,000 or more showed very high or high risk perception. Thus, a higher risk perception can be associated with better education and financial condition of the driver.

The drivers risk perception of a workzone varies with his experience of travelling through a workzone. The model results revealed that frequent travelling through workzone lowers the risk perception of driver. If a driver drives through same workzone for a number of times, a sense of safety sets in that leads to lower risk perception and driver may tend to disregard the hazards and grow in confidence to get away with. This is an important finding, applicable particularly in driving environments of Pakistan.

Model also indicated that older drivers (older than 40 years) have higher risk perception than young drivers (younger than 40 years). This finding is also supported by the previous studies (Warner, 2006). Young drivers are more expected to under-rate the risk involved in driving through a workzone and hence display less cautious or unsafe behaviour. This will result in more workzone crashes involving young drivers. Once a driver ages above 40 years, the high risk perception rises by a factor of 0.168 with every 10 years increase in age.

Vehicle speed has close relationship with the risk perception of the driver. A driver accustomed to driving fast through workzone has low risk perception. This finding is intuitive as higher risk perception drives the driver to check his speed while passing through workzone. Model estimates show plausible sign of this relationship. It indicates that a driver driving at speed higher than 40 kmph through workzone shows drop in his/her very high risk perception by a factor of 0.12. This finding is also supported by the estimated indicator variable for speed reduction while passing through workzone. A driver who slows down while passing through a workzone has a higher risk perception.

The model results revealed that experienced drivers have low risk perception of highway workzone. A driver who is driving for more than 5 years shows lower risk perception. A logical conclusion of this observation can be that a number of exposures to workzones tend to lower driver’s risk perception. A further investigation into this finding revealed that a driver driving safely through workzones for more than 5 years, develops a lower risk perception. This conclusion is in accordance with previous studies on risk perception (Rundmo and Torbjorn, 1995), (Krallis and Csontos, 2013), (Wilde, 2014).

The above findings of model provide some logical inferences with regards to driver's risk perception of highway workzone. With the help of developed model, one can predict the risk perception under particular conditions specified in terms of explanatory variables. Efforts can be made to modify, regulate and enforce laws accordingly. Also layout of workzones and driving conditions can be improved to cater for the conditions signified by the model in terms of drivers risk perception.

4.6. Chapter Summary

Good understanding of driver's risk perception is vital to predict his/her response to highway workzone conditions. Driver's response in such an event establishes the overall safety environment and hence affects the safety of workers as well as other road users. Besides its importance, the subject remains unexplored in Pakistan. This study modelled driver's risk perception while encountering a typical highway workzone in Pakistan, through an ordered probit model. The required data was collected through driver's interviews in vicinity of an active highway workzone. The interview questionnaire contained questions regarding driver's fresh as well as his/her past experience of highway workzone. Model results reveal that risk perception is significantly related to age of driver, level of comfort that driver feels while driving through highway workzone, avoidance of highway workzone by the driver, speed of vehicle, level of police enforcement at workzone, driving experience of the driver, education and monthly income of driver and reduction in speed while encountering a highway workzone.

Law enforcement through highway workzone can significantly change risk perception of the driver. Repeated travelling through workzone lowers driver's perception of risks involved in driving through highway workzone. It was observed that drivers display low risk perception in young age. Over speeding is one of the indicators of low risk perception. It has also been found that drivers driving behaviour is significantly influenced by his/her socio-economic characteristics (education level and average monthly income). These findings are particularly important for the policy makers and law enforcement agencies.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Synopsis of the Research

In this research an attempt has been made to increase understanding of current level of safety conditions at highway workzones in Pakistan. The study started with extensive literature search from international and local studies. The international literature search provided an insight about the subject as it is dealt with around the world. It also provided a view of current practices followed in different countries along with latest improvements being introduced. The MUTCD provides an easy to follow and well tested design for highway workzones. Such a design ensures safe and efficient flow of traffic through workzone. Besides, local literatures search provided the knowledge of work already carried out on the subject in Pakistan. Detailed literature search helped in clear identification of research objectives and kept the research effort focused. Based on the intended objectives, detailed research methodology was worked out. It covered all the required steps and landmarks along with a reasonable and realistic work schedule.

The study continued on two distinct but simultaneous thrust lines. The first one explored the present safety conditions at highway workzones in Pakistan by comparing selected highway workzones with state of the art highway workzone as recommended by MUTCD. For this purpose a detailed performa was developed after going through relevant literature. Eight highway workzones across Pakistan were selected for the study. Being from different parts of country, these workzones presented a variety to research effort. Highway workzone safety data were collected through site visits and video recordings. Video clips of each workzone were later analysed in light of respective filled performa/data collection form. The results were summarized to develop a clear understanding of safety conditions at highway workzones in Pakistan. It was observed that overall there is no formal/systematic approach for highway workzone safety management in Pakistan. Safety measures taken by different contractors at workzones were minimal and there was no uniformity in effort.

In second part of this research, an ordered probit model was estimated to understand driver’s risk perception of highway workzone. With this regard, a detailed interview questionnaire was developed. The questionnaire comprised of simple and easily comprehendible questions for a common driver. The interviews were carried out in vicinity of an active workzone to record respondent’s experience of driving through a typical

Pakistani highway workzone. The data collected through interviews were used to develop random as well as a fixed parameter ordered probit models, out of which fixed parameter model was finally selected. The model provided a useful insight into Pakistani drivers risk perception while he/she drives through a highway workzone. The model revealed that driver's age, income, education, driving experience, frequent travelling through work zone and level of enforcement significantly influence driver's risk perception of highway work zone.

5.2. Research Findings

This study found that highway workzones in Pakistan are not setup according to the recommended guidelines/minimum standards. The comparison of state of the art and current practices revealed that start and end of workzones is commonly marked Pakistan. Most highway workzones do not have advance warning area and majority of workzones do not provide smooth transitions. Activity areas are not properly marked and often road users travel dangerously close to working men and machinery. Majority of highway workzones do not have termination areas for smooth transition of traffic back to normal flow. Driver's age, income, education, driving experience, frequent travelling through work zone and level of enforcement significantly influence driver's risk perception of highway work zone.

5.3. Recommendations and Direction for Future Research

Apropos of research findings it is recommended that highway workzones must be established according to well-tested recommendations of MUTCD. Sufficient funds be allocated in project estimates for proper temporary traffic control measures. In this regards a comprehensive study be carried out to analyse safety measures at highway workzones viz-a-viz contractual and legal bindings. Efforts must be made to raise the risk perception of a common driver through conventional education and public campaigns.

LIST OF REFRENCES

Ahmed, A. (2007). Road Safety Audit: A Promising Aproach for Pakistan. National Road Safety Conference Karachi, Pakistan.

Alexei Tsyganov, R. M., Rob Harrison (2003). Complex Workzone Safety. Traffic Control for Complex Workzones. Austin, TX, USA, Center for Transportation Research, The University of Texas at Austin: 84.

Arif Mohaimin Sadri, S. U., Pamela Murray-Tuite (2013). "A random parameter ordered probit model to understand the mobilization time during hurricane evacuation." Transportation Research 32: 21-30.

Asad J. Khattak, A. J. K., Forrest M. Council (2002). "Effects of workzone presence on injury and non-injury crashes." Accident Analysis and Prevention.

C S Duncan, A. J. K., F M Council (1998). "Applying The Ordered Probit Model to Injury Severity in Truck-Passenger Car Rear-End Collisions." Transportation Research Record(1635): 63-71.

Christopher Ryan Huebshman, C. G., Darcy M. Bullock, Dulcy M. Abraham (2003). Construction Workzone Safety. JTRP Technical Reports. Indiana, USA, Purdue University.

Claude J. Morelli, J. D. B., Jerome W. Hall (2006). Accommodating Pedestrians in Workzones. Transportation Research Board Annual Meeting

David Arditi, D.-E. L., Gul Polat (2007). "Fatal accidents in nighttime vs. daytime highway construction workzones." Journal of Safety Research.

Deery, H. A. (1999). "Hazard and Risk Perception among Young Novice Drivers." Journal of Safety Research 30(4): 225–236.

Dennis Krallis, A. C. (2013) From Risk Perception to Safe Behaviour. Safety Risk

Englund, G., Aberg (1988). "Traffic Safety: a review of knowledge."

Erdong Chen, A. P. T. (2014). "Modelling safety of highway workzones with random parameters and random effect models." Analytic Methods in Accident Research.

FHWA (2014). Facts and Statistics - Workzone Injuries and Fatalities. Workzone Mobility and Safety Program, FHWA.

Greene, W. H. (2011). LIMDEP; Student Reference Guide. Econometric Software, Inc. I. Econometric Software. Plainview, NY, USA, Econometric Software, Inc. 9.

J.F. Morgan, A. R. D., P.A. Hancock (2009). "Driver responses to differing urban workzone configurations." Accident Analysis and Prevention.

Jacobs G, A.-T. A., Astrop A. (2000). Estimating global road fatalities, Crowthorne, Transport Research Laboratory.

Jonathan Shi, Z. L., Mark Snyder (2009). Highway Workzone Safety Audits at the Construction Stage. 88th Annual Transportation Research Board Meeting, Transportation Research Board.

Jun Wang, W. E. H., Forrest M. Council, Jeffrey F. Paniati (1996). "Investigation of Highway Workzone Crashes: What We Know and What We Don't Know." Transportation Research Record 1529: 54-62.

Junaid Ahmad Bhatti, J. A. R., Emmanuel Lagarde, L. Rachid Salmi (2011). "Burden and Factors Associated with Highway Work-Zone Crashes, on a Section of the Karachi–Hala Road, Pakistan." Injury Prevention 17(2): 79-83.

Khan, B. A. (2013). Prediction of road crash fatalities for Pakistan using aggregat data. Transportation Engineering. Islamabad, Pakistan, National University of Sciences and Engineering, Pakistan. MS thesis.

Khan, H. Z. A. (2012). Benchmarking The Current State of Construction Safety Practices in Pakistan. Department of Construction Engineering and Management. Islamabad, National University of Sciences and Technology, Islamabad, Pakistan. MS thesis 106.

Khan, R. A. (2011). Driver’s Comfort Level in Construction Zones With Reduced Transition Taper Length: Case Study For Pakistani Conditions. Civil & Environmental Engineering. Urbana, Illinois, University of Illinois at Urbana-Champaign. MS thesis: 108.

Mannering, P. C. A. F. L. (2009). "A note on modeling vehicle accident frequencies with random-parameters count models." Accident Analysis & Prevention 41(1): 153-159.

Michael A. Regan, J. D. L., Kristie Young (2009). Driver Distraction: Theory, Effect and Mitigation. USA, CRC Press.

MUTCD (2009). Manual on Uniform Traffic Control Devices. F. H. Administration.

National Safety Council, U. (2007). American National Standard: Manual on Classification of Motor Vehicle Traffic Accidents N. S. Council. Spring Lake Drive, Itasca, Illinois, National Safety Council.

NJ Garber, T. H. W. (1990). "Accident Characteristics at Construction and Maintenance Zones in Urban Areas." Virginia Transportation Research Council 90-R12.

Özlem Şimşekoğlua, T. N., Torbjørn Rundmo (2012). "Traffic risk perception, road safety attitudes, and behaviors among road users: a comparison of Turkey and Norway." Journal of Risk Research 15(7): 787–800.

Pegula, S. (2004). "Fatal occupational injuries at road construction sites."

Rafiq M. Choudhry, D. F., Steve Rowlinson (2014). "Challenging and Enforcing Safety Management in Developing Countries: A Strategy." International Journal of Construction Management 8(1): 87-101.

Rahim F. Benekohal, P. T. V. R., Eunjae Shim (1995). Analysis of Truck Driver's Opinions on Safety and Traffic Control on Highway Workzones. Transportation Engineering Series. Urbana, IL, Department of Civil Engineering, University of Illinois at Urbana Champaign.

Reising, M. (2012). Transportation/Traffic Safety. 22nd Annual NARPM Training Program. U. S. E. P. Agency.

Rizwan U. Farooqui, F. A., S.F.A. Rafeeqi (2008). Safety Performance in Construction Industry of Pakistan. First International Conference on Construction in Developing Countries. Karachi, Pakistan.

Rizwan U. Farooqui, S. M. A., Sarosh H. Lodi, (2008). "Assessment of Pakistani Construction Industry – Current Performance and the Way Forward." Journal for The Advancement of Performance Information & Value 1(1): 51-72.

Rundmo, T. (1995). "Perceived risk, safety status, and job stress among injured and noninjured employees on offshore petroleum installations." Journal of Safety Research 26(2): 87–97.

S. Thomas Ng, Kam Pong Cheng, R. Martin Skitmore (2005). "A framework for evaluating the safety performance of construction contractors." Building and Environment 40: 1347–1355.

Samiul Hasan, S. U., Hugh Gladwin, Pamela Murray-Tuite (2011). "A Behavioral Model to Understand Household Level Hurricane Evacuation Decision Making." Journal of Transportation Engineering 137(5): 341-348.

Satish Mohan, W. C. Z. (2005). "Characteristics of worker accidents on NYSDOT construction projects." Elsevier.

Simon P. Washington, M. G. K., Fred L. Mannering (2011). Statistical and Econometric Methods for Transportation Data Analysis. USA, Chapman and Hall/CRC.

Sivak, M. (2002). "How common sense fails us on the road: contribution of bounded rationality to the annual worldwide toll of one million traffic fatalities." elsevier.

Stephanie G. Pratt, D. E. F., Suzanne M. Marsh (2001). Building Safer Highway Workzones: Measures to Prevent Worker Injuries from Vehicles and Equipment. DHHS (NIOSH) Publication. Cincinnati, Ohio, USA, National Institute for Occupational Safety and Health. 2001-128.

Tauha Hussain Ali, S. M. (2009). "National culture and safe work behaviour of construction workers in Pakistan." Safety Science 47(1): 29–35.

Turner, J. D. (1999) What's a Workzone? Public Roads 62, 27-10

UNGeneralAssembly (2014). Draft UN General Assembly resolution on improving global road safety. U. G. Assembly. UN General Assembly, UN General Assembly.

Warner, H. W. (2006). Factors Influencing Drivers' Speeding Behaviour. Department of Psychology. Sweden, Uppsala University. PhD dissertation.

WHO (2004). World report on road traffic injury prevention. R. S. Margie Peden, D. M. David Sleet, E. J. Adnan A. Hyder and a. C. Mathers. Geneva, WHO.

WHO (2013). Global status report on road safety. Geneva, Switzerland, World Health Organization.

Wilde, G. J. S. (2014) Risk Homeostasis in Everyday Life. Target Risk

Wolff, G. (2004). Workzone Safety Traffic Control. Construction Safety Management and Engineering. C. Darryl C. Hill. Illinois, USA, American Society of Safety Engineers.

Wretstrand, A. (2008). "Analyzing Self-Reported Accidents and Percieved Safety in Public Transit."

Yingfeng Li, Y. B. (2009). "Effectiveness of temporary traffic control measures in highway workzones." Safety Science.

APPENDICES

Appendix-A. Workzone Survey Performa

Project Information						
1	**Project Name**					
2	**Site**					
3	**Contractor**					
4	**Client**					
5	**Type of Road**					
	Motorway		Urban Highway		Rural Highway	
	Urban Street					
6	**Traffic Movement**					
	One Way		Two Way			
7	**No of Lanes**					
	One Lane		Two Lane		Three Lane	
8	**Normal Permissible Speed Limit for LTV on Road**					
9	**Normal Permissible Speed Limit for HTV on Road**					
10	**Type of Traffic**					
	Bicycle		Motorcycle		Rickshaw	
	Car/Jeep		Van		Mini Bus	
	Bus		Truck		Trailer	
	Animal Driven Vehicle		Padestrian			
Work Zone Characteristics						
11	**Length of Work Zone**					
12	**Type of Work Zone**					
	Single Piece		Multiple Piece			
13	**Permissible Speed Limit through Work Zone**					
14	**Location of Work Zone**					
	Outside the shoulder		Shoulder with no encroachment		Shoulder with minor encroachment	
	Within the median		Within the traveled way			
15	**In case of Lane Closure, which lane is closed for traffic ?**					
	Shoulder		Lane 1 (Slow Speed Lane)		Lane 2	
	Lane 3		Lane 4		Not Applicable	
16	**Is there any Cross Movement of traffic through the Work Zone ?**					
	Yes		No			
17	**Does Work Zone Pass through an Intersection ?**					
	Yes		No			
18	**Is there any Diversion or Detour provided ?**					
	Yes		No			

Appendix-A. Workzone Survey Performa (Continue)

Advance Warning Area										
19	**Is Advance Warning Area provided ?**									
	Yes		No		Not Applicable					
20	**What is the Length of Advance Warning Area ?**									
21	**How many Advance Warning Signs have been placed in Advance Warning Area?**									
22	**What is the spacing between Advance Warning Signs in Advance Warning Area?**									
23	**What is the Condition of Advance Warning Signs in Advance Warning Area?**									
	Very Good		Good		Satisfactory		Bad		Very Bad	
24	**Are Advance Warning Signs visible at night ?**									
	Yes		No							
Transition Area / Tapers										
25	**Is Transition Area / Taper provided ?**									
	Yes		No		Not Applicable					
26	**What is the Length of Upstream Shifting Taper ?**									
27	**What is the Length of Downstream Shifting Taper ?**									
28	**How many Warning Signs have been placed in Transition Area?**									
29	**What is the Condition of Warning Signs in Transition Area ?**									
	Very Good		Good		Satisfactory		Bad		Very Bad	
30	**Are the Warning Signs of Transition Area visible at night ?**									
	Yes		No							
31	**How many Channelizing Devices have been placed in Transition Area?**									
32	**What is the spacing between Channelizing Devices in Transition Area?**									
33	**What is the Condition of Channelizing Devices in Transition Area ?**									
	Very Good		Good		Satisfactory		Bad		Very Bad	
34	**Are Channelizing Devices of Transition Area visible at night ?**									
	Yes		No							
35	**What is the length of Upstream Longitudinal Buffer Space ?**									
36	**What is the length of downstream Longitudinal Buffer Space ?**									
37	**What is the Width of Lateral Buffer Space ?**									
38	**What is the length of Downstream Longitudinal Buffer Space for Opposing traffic?**									
39	**What is the length of Downstream Merging Taper for Opposing traffic ?**									
40	**Is Storage Area separately marked ?**									
	Yes		No							
41	**What is the Length of Buffer Space provided for Storage Area ?**									
42	**Is Parking Area separately marked ?**									
	Yes		No							
43	**What is the Length of Buffer Space provided for Parking Area ?**									
44	**Is there any Storage / Staging Space provided for Incident Response or Emergency ?**									
	Yes		No							

Appendix-A. Workzone Survey Performa (Continue)

Work Space								
45	**What is the length of Work Space ?**							
46	**What is the Type of Work Space ?**							
	Single Piece		Multi Piece		No of Pieces			
47	**Is the Work Space sufficiently Illuminated at night ?**							
	Yes		No		Not Applicable			
48	**Are Flash Lights being used for any Isolated Hazard ?**							
	Yes		No		Not Applicable			
49	**Are all the markings and signs retroreflective or illuminated at night ?**							
	Yes		No		Not Applicable			
50	**Are Workers within right-of-way of Work Zone, wearing high-visibility retroreflective safety appare**							
	Yes		No					
Traffic Control Measures								
51	**What Measures are taken to Regulate Traffic ?**							
	Police		Flaggers		Lights/Signals		Gates/Barricades	
	No measures		Not Applicable					
52	**In case of Flaggers, what is the mode of communication being used ?**							
	Flags		Tokens		Word of mouth		Wireless Communication	
	Flash Light		Electronic Devices		No Communication			
53	**What measures are taken to control Speed through Work Zone ?**							
	Speed Limit Signs		Regulatory Signs		Speed Hump/Bump		Speed Dip	
	No Measures		Not Applicable					
54	**Is Start and End of Work Zone explicitly marked ?**							
	Yes		No					
55	**Is there a separate passage provided for Padestrians ?**							
	Yes		No					
56	**What measures are taken to avoid Traffic Congestion ?**							
	Detour		Alternate Route		Managed Lane		Traffic Scheduling	
	Night Work		Selective Exclusion					
Environmental Aspects								
57	**Are measures taken to guide traffic during Adverse Environmental Conditions ?**							
	Yes		No		Not Applicable			
58	**What Measures are taken to avoid Dust Polution ?**							
	Water Sprinkling		Paving		Dust Extractor/Filter		No Measures	
	Any Other Measure							
59	**Is there any Measure taken to avoid Smoke Polution ?**							
	Yes		No		Type of Measure			
Public Relations								
60	**What measures are taken for Public Awareness of Work Zone Safety Measures ?**							
	Public Notice		Electronic Media		Warning Signs			

Appendix-B. Driver's Interview Questionnaire

User Information						
1	**Name (Coded)**					
2	**Gender**					
	Male		Female			
3	**Marital Status**					
	Married		Single		Others	
4	**Age**					
	Under 20		21-30		31-40	
	41-50		51-60		Above 60	
5	**Highest Qualification**					
	Primary		Under Matric		Matric	
	Intermediate		Graduate		Masters	
	Doctorate		No Education		Other	
6	**Average Monthly Income**					
	Under Rs. 10,000		Rs.10,000-Rs.20,000		Rs.20,000-40,000	
	Rs.40,000-Rs.60,000		Rs.60,000-Rs.80,000		Rs.80,000-Rs.100,000	
	Rs.100,000-Rs.150,000		Rs.150,000-Rs.200,000		More than Rs.200,000	
7	**Type of Vehicle**					
	Motorcycle		Car/Jeep		Suzuki Van	
	Hiace Wagon		Bus		Truck	
	Rickshaw		Animal Driven Vehicle			
8	**Status of Vehicle**					
	Self Owned		Official		Rented	
	Others					
User Safety Awareness						
9	**At what age you started driving ?**					
	Under 20		21-30		31-40	
	41-50		51-60		Above 60	
10	**Do you have a valid driving license ?**					
	Yes		No		Learner	
11	**For how long you have driving license ?**					
	Less than 1 year		1-5 years		5-10 years	
	More than 10 years					
12	**Have you frequently travelled on Kashmir Highway in last 3 Months to 1 Year ?**					
	Yes		No			
13	**Do you know the Speed Limit on Kashmir Highway ?**					
	Yes		No			
14	**What is your usual Speed on Kashmir Highway during expansion phase ?**					
	Under 20 Kmph		20-40 Kmph		40-60 Kmph	
	60-80 Kmph		80-100 Kmph		Above 100 Kmph	
15	**How fast do you normally drive on Urban highway like Kashmir Highway ?**					
	Under 20 Kmph		20-40 Kmph		40-60 Kmph	
	60-80 Kmph		80-100 Kmph		Above 100 Kmph	
16	**Do you know the Speed Limit through a Typical Work Zone in Pakistan ?**					
	Yes		No			

Appendix-B. Driver’s Interview Questionnaire (Continue)

17	**How fast do you usually drive through a Work zone ?**					
	Under 10 Kmph		10-20 Kmph		20-40 Kmph	
	40-60 Kmph		60-80 Kmph		Above 80 Kmph	
	Continue at same speed					
18	**How comfortable you feel while driving through a Work Zone ?**					
	Very Comfortable		Comfortable		Just Satisfactory	
	Not Comfortable		Very Uncomfortable			
19	**In your opinion, how much is the Safety Risk while driving through a typical Work Zone in Pakista**					
	Very High Safety Risk		High Safety Risk		Moderate Safety Risk	
	Low Safety Risk		No Risk			
20	**Do you try to avoid driving through Work Zone , if possible ?**					
	Yes		No			
21	**How good is your understanding of Work Zone markings ?**					
	Very Good		Good		Satisfactory	
	Bad		Very Bad			
22	**How do you rate the marking of a typical Work Zone in Pakistan ?**					
	Very Good		Good		Satisfactory	
	Bad		Very Bad			
23	**In your opinion, who should be responsible for Work Zone marking ?**					
	Contractor		Client		Police	
24	**Do you consider need to have Advance Warning Signs/Markings in Work Zone vicinity?**					
	Yes		No		Doesn't matter	
25	**While you drive through a Work Zone do you think the Markings are easily visible in day light ?**					
	Yes		No		No Idea	
26	**While you drive through a Work Zone do you think the Markings are easily visible during night ?**					
	Yes		No		No Idea	
27	**Have you or any of your dear one ever met an accident while driving through a Work Zone ?**					
	Yes		No		More than once	
28	**Have you ever witnessed an accident in a Work Zone ?**					
	Yes		No		More than once	
29	**Do you consider other drivers drive recklessly through a Work Zone ?**					
	Yes		No			
30	**In your opinion, which category of drivers drive in Unsafe/Reckless manner through Work Zone?**					
	(you can select more than one category)					
	Motorcycle		Car/Jeep		Suzuki Van	
	Hiace Wagon		Bus		Truck	
	Rickshaw		Animal Driven Vehicle			
31	**Do you think there is sufficient level of enforcement (Police employed) in a typical Work Zone in**					
	Yes		No			
32	**Have you ever been stopped/fined for over-speeding through a Work Zone ?**					
	Yes		No		More than once	
33	**Do you normally slow down while driving through a work Zone or keep travelling at same speed?**					
	Yes		No		More than once	