DISTRACTED DRIVING AND DRIVER INTERPRETATION OF SHORT TERM CONSTRUCTION AND MAINTENANCE WORK ZONES IN URBAN ENVIRONMENTS

by

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ABSTRACT

SCOTT PHILLIP OOSTHUYSEN. Distracted driving and driver interpretation of short term construction and maintenance work zones in urban environments. (Under the direction of DR. NICHOLAS TYMVIOS)

Previous literature of distracted driving and inattention has found that secondary tasks not associated with the task of driving increase vehicular accidents and near miss accidents. Distracted drivers are comparatively different to non – distracted drivers when driving distracted, because predominant use of mobile devices such as cell phones have hazardous effects on slowed reaction time to roadway hazards, driver decision making process, and speed control. This is concerning to construction entities performing roadway construction and maintenance, because the associated hazards with performing such work becomes intuitively more dangerous for construction workers due to distracted drivers. This study compared motorist's speeds who were determined to be distracted and non – distracted, to differentiate how distracted drivers behaved differently around work zones. Observational case studies, standard safety surveys, and brief worker surveys, were conducted at four locations for specifically targeted work zones, 4,450 non – distracted, and 921 distracted drivers were observed. A statistical comparison for driver speeds, determined that there was no significant difference in non – distracted and distracted driver speeds. Additionally, North Carolina work zone accident data was statistically analyzed to determine the accident severity between work zone activity, and urban or rural location. A significant trend appeared from 2009 to 2013 for urban vs. rural work zones, accidents which occurred in rural work zones were more severe than ones which occurred in urban areas.

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CHAPTER 1: INTRODUCTION

This study investigated the research topic “Distracted driving and driver interpretation of short term construction and maintenance work zones in urban areas”, and answered the following research question: How are distracted driver speeds different compared to non-distracted speeds within work zones?

1.1: Objective of Research

The research question was based on the hypothesis that distracted drivers have a greater variability in speed compared to drivers who are not distracted around work zones. Distracted driving within a work zone is a safety concern for work zone users, because participating in distracted driving behavior increases the potential for accidents between motorists, work zone temporary traffic control (TTC) devices, construction equipment, and workers. The research question was answered by completing the following objectives:

1. Determine the frequency of distracted driving behavior.
2. Determine how distracted drivers interact with an active work zone by measuring and analyzing distracted driver speed data
3. Report the difference in driver speeds between distracted drivers, and non - distracted drivers, using supporting literature, and proposed methodologies.

1.2: Scope of Research

The research investigated urban work zones where speed information from drivers was collected; distracted drivers were identified as well as non – distracted drivers, before a comparison of driver speeds compared distracted drivers to non – distracted drivers.

Additionally, the research analyzed current North Carolina accident data by determining pertinent accident percentages for Rural, Mixed, and Urban environments. This was completed in an attempt to observe current accident trends, with the primary interest being urban environment accidents for the state.

1.3: Description of Contents

The study begun with chapter two, an investigation into pertaining literature review, which used literature of distracted driving definitions, behaviors, and impacts of distracted driving. The definition of distracted driving was not defined in this research study, as literature review suggest that distracted driving is a broad category, with vague and sometimes misinterpreted definitions between distraction and inattention (Pettitt et al. 2005). The definition of distracted driving used for the study is, simply stated as, “an act of distraction including inattention (Pettitt et al. 2005), which takes the focus of the driver away from the task of driving (NHTSA 2010). Distracted driving included sources of distraction from internal and external sources, and the listed NHTSA top ten causes of accidents on U.S roadways”. Literature review of distracted driving established a baseline for comparison, where the frequency of distracted drivers was compared to distracted drivers identified in literature.

The definition used to define the term ‘urban’ is the definition of the United States Census Bureau, which is categorized as a densely developed territory, encompassing residential, commercial, and non-residential urban land uses, of a densely settled population core of census blocks, that meet minimum population density requirements, of 50,000 people or more (U.S. Census Bureau 2015). This acceptable definition of an urban area, allowed for a clear and common understanding of the term 'urban', and allowed for relevant literature to be found for comparison. Relevant literature includes: urban area statistics on construction work zones, and accidents.

Through the use of definitions between the terms 'urban' and distracted driving, relevant literature described differences between distracted driving statistics, from impacts of work zone studies, and attempted to determine the role distraction plays in urban work zones. The impact distracted driving has on an active work zone can result in accidents of varying severity and magnitude. Accidents cause costly monetary impacts and severe health risk implications to motorists and construction workers (Bryden et al. 1998).

The methodologies, located in chapter three include the description of targeted work zones, traffic analyzer placement, used equipment, observation procedure, and used survey types. The surveys included implementing a “5 Minute Survey” which is a standard safety survey method used to measure the safety of construction and maintenance sites. The purpose of this survey method is to determine the safety of the site, when considering the actions of the workers, motorists, and the interaction between the two. An additional “Brief Worker Survey” aimed to gauge worker perceptions of safety and distracted driving, was administered to construction workers during site visits. The safety of construction and maintenance workers is important to the study, as distracted driving behavior within work zones can lead to dangerous consequences resulting in property damage, injury, and death. It is important to address the issue of distracted driving within active work zones to reduce safety risks for construction workers, and reduce the number of accidents occurring between motorist, motorists and construction equipment, and personnel.

Chapter four, reports the observations from the obtained four case study locations. Next, chapter five describes the data analysis for cleaning the obtained data, and descriptive statistics of the case study data. Chapter six includes the results from the statistical analysis of the case study data. The analysis used a two sample equivalence t-Test to obtain the result of the case study analysis. Additionally, the survey results from the “5 minute survey” and “brief worker survey” are located in this chapter. Next, chapter seven includes an analysis of NCDMV accident data for 2009 to 2013, including accidents which were fatal and non – fatal, and from urban, rural, and mixed locations. Within chapter eight are the conclusions and recommendations of the study, and the need for future research pertaining to distracted driving and urban work zones.

CHAPTER 2: LITERATURE REVIEW

This section includes literature from studies of work zones, including set up, safety concerns, accidents, and accident types found in work zones. Additional literature includes the definition of urban and rural environments, which provided statistics for urban and rural accidents, and differences in work zones, including bottle necks, and congestion for urban areas. Literature also provided the definition of distracted driving, for the purposes of the study, and additional information including, cell phone and text messaging regulations, distracted driving accidents, and work zones studies of worker perceptions of distracted driving, and work zone distractions.

2.1: Work Zones

The need for maintenance and construction on roadways occurs frequently to keep up with traffic demands, scheduled maintenance, and roadway improvements. It is beneficial for transportation departments to maintain and construct roadways as a roadway can be considered an asset. However, one of the most hazardous activities of any road work, short term construction, or maintenance is conducting a lane closure (Ibarguen 2009), and the primary function of a work zone in the form of a Temporary Traffic Control (TTC) is to allow for safe and effective movement for all road users (MUTCD 2009). Some considerations for operating a work zone should be made to keep up with traffic demands. Levine and Kabat (1984) studied the implementation of urban work zones in Houston, Texas and defined the following problems to arise:

1. Providing optimum time to perform the necessary maintenance and short term construction work.
2. Installing adequate measures to warn the public.
3. Developing alternative means to protect workers from errant motorists.

The study found that construction and maintenance needed to be completed during week days, despite trying alternative times of work zone operation to reduce traffic delays, and improve worker safety. Ultimately it was determined that maintenance and construction needs could not be ignored (Levine et al. 1984) and improvement to work zone design was needed.

The mobilization and set up of a work zone to control traffic flow through a work zone is no random act, but a plan outlined and defined by the Manual of Uniform Traffic Control Devices (MUTCD) (2009). A work zone effectively controls traffic in a TTC, which provides access to all users of the road including motorists, bicyclists, pedestrians, and persons with disabilities. TTC zones are an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents. The primary function of a TTC is to provide for the safe and effective movement of road users, while maintaining safety for construction, maintenance, utility workers, and first responders (MUTCD 2009).

Work zones are important in maintaining the function of the roadway, while producing an environment which is focused on the safety of all users. Without the use of such TTC devices the risk for safety incidents occurring rises. Work zones are not without design flaws, and are open to improvements as the MUTCD is continually updated with new versions that include design improvements. Non-engineering solutions for improving the flow of traffic and effective use of TTC plans include public relation campaigns for the duration of the project. Campaign programs have been found to result in significantly less numbers of motorists traveling through the TTC, which reduces the possible number of conflicts (MUTCD 2009).

2.1.1: Work Zone Set - Up Differences between Long and Short Projects

Differences in work zone design set up can be found between short term and long term work zone construction projects. Short term maintenance and utility type work zones are designed to be mobile and temporary, such TTC devices or equipment used will reflect this in design, and use TTC plans that are flexible to mobility. The standard durations for short – term, intermediate – term, and long – term work zones as defined by the MUTCD (2009) Part 6G.02 Work Duration are as follows:

- Short duration is considered work that occupies a location up to one hour.
- Short-term stationary is work conducted during daytime and occupies a location for more than one hour within a single daylight period.
- Intermediate-term stationary work occupies a location more than one daylight period up to three days, or nighttime work lasting more than one hour.
- Long-term stationary work occupies a location for more than three days.

In the case of short term construction and maintenance work zones, the separation of work space and travel space is accomplished by the use of cones; while in intermediate to long term construction work zones, the use of more permanent TTC devices can be observed. Intermediate to long term work zones can be identified by permanent safety devices, which are constructed or installed where possible if accessibility allows, otherwise a lane closure may still have cones separating the work space from the travel space for the duration of the construction project. Such identifiable features of intermediate to long term work zones include the use of Portable Concrete Barricades (PCB), where space allows, which separate the travel space from the work space in a single lane closure. The duration of an intermediate to long term construction project can be described as a project which has in place TTC features for more than three days (MUTCD 2009).

Below in Figure 1, a simple diagram of the difference between work zone design considerations can be found. The Intermediate/Long term work zone set up also displays an extra safety design feature known as a crash cushions system before the start of the PCB.

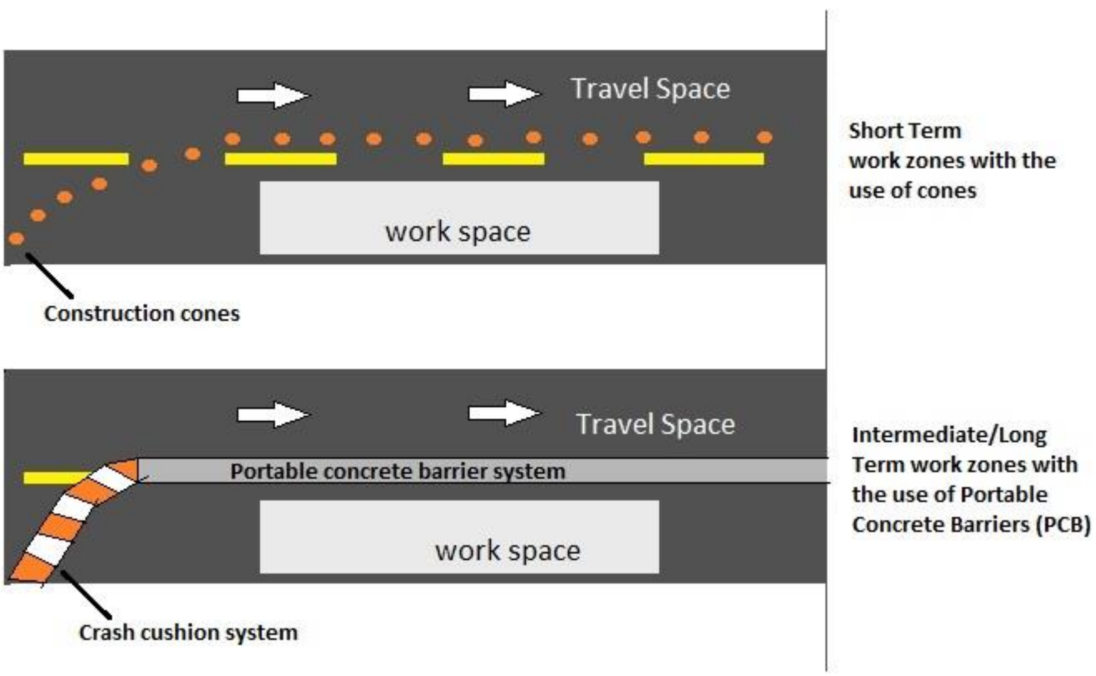

FIGURE 1: Short term vs. long term work zones

2.2: Work Zone Safety Concerns

The need for increased safety in short term work zones is not hard to comprehend since one of the most hazardous activities of any road work, including short term construction or maintenance, is conducting a lane closure (Ibarguen 2009). To improve traffic safety and mobility in work zones, the dynamic lane merging system has been introduced in several U.S. states (Harb et al. 2011). The Florida DOT has researched two potential methods to address the safety concerns of a lane closure. The two potential methods are described as an early and late merge system, for short term work zones and are ideal for work zones with durations of four to eight hours.

The early and late merging systems were studied extensively between 1997 and 2001 (Tarko et al. 1998, McCoy et al. 1999, Tarko et al. 2001). As stated the dynamic merging systems can take two forms; a dynamic early merge, and a dynamic late merge. However, implementing the dynamic merging systems for short term work zones is far too complex, because the implementation of such merging systems requires lengthy installation of merging equipment, that will be ineffective for a short term work zones (Radwan et al. 2009). The present system used by the Florida DOT is a Maintenance of Traffic (MOT) plan known as Motorist Awareness System (MAS) (Harb et al. 2011). This system is used for short term work zones and is a simplified version of the dynamic merging methods previously suggested.

Drivers often try to reduce the time they spend in traffic queues and congestion by driving aggressively to the front of the line, before trying to merge at the taper. Aggressive driving and taking unnecessary driving risks were observed to occur with the current merging systems; which encourages this type of behavior. This defeats the purpose of the dynamic early merge system, and additional observations found that when one vehicle attempted to use the closed lane, a platoon of vehicles proceeded to do the same (Harb et al. 2011). This is a safety concern for construction and maintenance workers who may be working in close proximity to the taper areas in work zones. Other concerns from the use of implementing merging systems, in addition to aggressive driving, included stop and go traffic; which added driver confusion, and created driving conditions that did not exist previously.

Work zones are designed to allow for the passage of motorists in a safe and effective manner, while maintaining safety for construction workers, and other users of the work zone (MUTCD 2009). However, it is the actions of motorists that undermine the safety precautions taken to maintain safety of a work zone, therefore making the effective use of a work zone hazardous for all users.

2.3: Work Zone Accidents

In 2013, there were a total number of 30,057 fatal accidents, resulting in 32,719 fatalities on U.S. roadways. These accidents also included 527 fatalities which occurred in U.S. work zones, including 317 injury accidents, and 252 non-injury accidents to passengers, other motorists, and non-motorists involved (NHTSA 2015). Historically, work zones in the United States on average have approximately 700 traffic related fatalities, 24,000 nonfatal injury crashes, and 52,000 property damage only crashes every year (Khattak et al. 2002).

The most common accident types that occur in work zones, are rear end and side - swiping accidents (Reiprich et al. 2010). Other accidents that occur frequently in work zones include accidents with TTC devices, construction equipment, and personnel. Such accidents occur in defined work spaces, and are called intrusion accidents, which were the most frequent type of accident to occur, followed by flagger controlled sites, roadside, and buffer space collisions (Bryden et al. 1998).

Accidents which occur in work zones can come from work zone design as research has demonstrated that reduced speed limits are to be used with caution by road construction entities, and should be limited to specific portions of the TTC zone where restrictive features are present. A speed limit reduction of 10 mph should be used, except where a restrictive feature justifies a reduction greater than 10 mph, large reductions in speed limits of 30 mph, increase speed variance, and the potential for accidents to occur (MUTCD 2009).

2.3.1: Accident Types in Work Zones

Bryden, Andrew et al. (1998) determined common accident types in work zones result as vehicles make collisions with TTC devices, other design safety features, and operations. A study on New York Department of Transportation (NYDOT) projects from 1994 to 1996 recorded 496 such accidents. These accidents involved impacts with work zone traffic control devices, and safety features; construction features such as pavement bumps and joints, drainage features, excavations and materials, and construction vehicles, equipment, and workers. One third of all work zone accidents occurred between such TTC safety devices, construction features, and equipment, 37% of these accidents caused serious injuries (Bryden et al. 1998).

Channelizing devices such as, arrow panels, signs and other traffic control devices generally result in little harm when impacted. Impact attenuators, both fixed and truck mounted, also perform well in design, but cause more property damage, and accidents are slightly greater in severity to the driver and impacting vehicle. Portable concrete barriers prevent vehicle intrusions; however impacts with barriers are severe events. Barriers must be properly designed and limited to only those locations of serious hazards (Bryden et al. 1998).

Collisions that occurred with signage resulted in minor injuries, some hospitalization cases arose, but very few fatalities occurred. However, collisions with portable concrete barriers are severe accidents, which result in fatalities and injuries needing hospitalization. Severe accidents that occurred and needed hospitalization, accounted for approximately 34% of work zone accidents on NYDOT projects. Other fatalities and severe injuries resulted from secondary impacts, such as when a vehicle was redirected from an initial impact with PCB before making a secondary impact, or overturning.

The Bryden et al. (1998) study of all work zone accidents occurring on NYDOT projects, concluded that 5% of accidents were collisions with traffic control devices, and some of these resulted in serious injury. All serious injuries resulted from extremely high speeds, or secondary and avoidance impacts. Additional findings of the study supported the theory that minor collisions between devices and motorists occur more frequently but are not reported due to the minor severity of the incident. Accidents involving construction vehicles, equipment, and workers were frequent; accounting for 14% of all work zone accidents, and 20% resulted in serious injuries. An additional finding included two incidents where workers were struck by channeling equipment after a vehicle impacted with the device (Bryden et al. 1998); these incidents are less likely to occur but still are a reason for concern due to the frequency of intrusion accidents in work zones.

Reiprich, Berkjout et al. (2010) studied accidents that occurred in the vicinity of work zones in the state of South Dakota during 2006. The database of accidents consisted of 367 formal reports, which were filed by South Dakota Law Enforcement to the South Dakota Department of Transportation (SDDOT). No construction worker injuries or fatalities occurred, as a result of traffic accidents in the state during 2006. As construction workers are protected by three tiers of defense from vehicle encroachment into a typical work zone, involving a combination of signage, redirection, and isolation by physical barriers (Reiprich et al. 2010). Conclusions of the study determined that accidents with a few exceptions, would not have occurred if work zones had not been present (Reiprich et al. 2010). The following common accidents in Table 1 below occurred in South Dakota work zones in 2006.

TABLE 1: South Dakota accident study (Reiprich et. al (2010))

Accident Description	Number
Rear end collision	170
Contact with fixed object	103
Contact with another vehicle at angle	60
Side swipe - Same Direction	24
Side swipe - Reverse Direction	6
Head on with on coming traffic	4
Total	367

The findings reported by Reiprich, Berkhout et al. (2010) in Table 1 determined that, of the 170 rear end collisions, 125 of the collisions were classified as Misperceived Closure Rates (MCR), where a driver suddenly discovers contact with the vehicle in front to be inevitable (Reiprich et al. 2010). The study determined 30% of total work zone accidents were recorded on two urban highway construction projects (Reiprich et al. 2010).

2.3.2: Construction Worker Related Accidents

Accidents which occur within the defied work space of a work zone can result in injuries for those who are involved. The severity of the accident is dependent on a number of variables, and any number can influence the outcome of the accident. The variability in speed, involvement of distracted driving, number of people involved, including motorists, pedestrians, construction workers, number of vehicles involved, and what impact occurred influence the severity of an accident. With the frequency of intrusion accidents (Bryden et al. 1998) the likelihood of an accident between a motorist and a construction worker to a occur is likely.

Accidents between motor vehicles and construction workers in North Carolina occur every year on state interstates, highways, routes, and local streets. The severity of the accident type is not dependent on the type of work in progress. Accidents with fatalities occur in any type of work zone including: construction, maintenance, and utility zones. In 2013, North Carolina recorded 2,808 accidents, and 1,289 fatalities, of the recorded fatalities, 173 pedestrians were struck and killed by motor vehicles, including 3 construction workers in work zones (NHTSA 2015). Fatal accidents between motor vehicles and construction workers in North Carolina (Table 2), have seen an increase in the frequency of these accidents. Accidents between construction workers and motor vehicles have occurred almost every year from 2008 to 2013.

Table 2, below was created using queries of the NHTSA (2015) Fatality Analysis Reporting System (FARS) database of fatal accidents, it shows the percentages of accidents that occurred in North Carolina work zones, between motorists and construction workers. The following percentage of accidents were found to occur in the following work zones: 68.42 % in construction, 21.05% in maintenance, and 10.52% in utility. Of the accidents which occurred, four accidents can be noted because the accident resulted in more than one fatality or injuries to one or more construction workers.

- Accident 674, recorded two worker deaths in a maintenance work zone in 2012.
- Accidents 362, 719 recorded one fatality, and three serious injuries to maintenance workers in 2010, and 2013.
- Accident 415, recorded one fatality, one serious injury, and one suspected minor injury to maintenance workers in 2012.

The above accidents occurred inside an active work zone, and multiple fatalities or life threatening injuries resulted. The accident injury severity scale was as follows: K - Fatality, A - suspected serious injury, and B - Suspected minor injury. The accidents in Table 2 only occurred between motorists and construction workers, where only construction workers suffered injuries. However, through the FARS database query function, it is not possible to make the distinction between pedestrians and construction workers. A reporting capability where an accident between construction workers and motorists could be reported would be helpful in clarifying construction worker fatalities due to vehicle strikes. This is the significance of the column "identified as a worker”. The column of “injury severity” displays the injury severity sustained by construction workers at the scene of the accident.

TABLE 2: North Carolina construction worker fatalities (NHTSA 2015).

Accident No.	Year	Work Zone Type	Accident between Vehicle & Non-occupant	No. of Fatalities	Injury Severity	Identified as Worker
222	2004	Construction	yes	1	K	No
474	2004	Construction	yes	1	K	No
530	2004	Construction	yes	1	K	No
540	2004	Construction	yes	1	K	No
782	2004	Maintenance	yes	1	K	No
930	2004	Construction	yes	1	K	No
1254	2004	Construction	yes	1	K	No
1294	2004	Construction	yes	1	K	No
1421	2004	Utility	yes	1	K	No
491	2008	Construction	yes	1	K	No
751	2008	Construction	yes	1	K	No
1214	2008	Construction	yes	1	K	No
362	2010	Maintenance	yes	1	K	No
				3	A	No
415	2012	Construction	Yes	1	K	No
				1	A	No
				1	B	No
674	2012	Maintenance	yes	2	K	No
714	2012	Construction	yes	1	K	No
719	2013	Utility	yes	1	K	No
				1	B	No
764	2013	Construction	yes	1	K	No

The FARS database is subjective to variations in reporting errors and exclusions, because the database relies heavily on law enforcement documentation. Additionally, the database does not formally differentiate between a construction work fatality, and that of a pedestrian or bicyclist. In Table 2 (NHTSA 2015), accidents were recorded as accidents between motorists and non-motorists, however the FARS database did not report the accidents to include construction worker fatalities. The information from Table 2 was supported by workzonesafety.org who reported the Bureau of Labor Statistics (BLS) Occupational Injury and Illness Classification System (OLLICS) report (Bureau of Labor Statistics 2014). The accidents located in the OLLICS report for North Carolina construction workers were then searched for in the FARS database (NHTSA 2015) to find accidents within work zones that included a pedestrian fatality.

The BLS (2014) report included additional construction worker fatalities in work zones that were not found using the query function of the FARS database. Table 3 below, includes construction worker fatalities in work zones for 2003 to 2013 from the BLS OLLICS report are reported (Bureau of Labor Statistics 2014).

TABLE 3: NC construction worker work zone fatalities (Bureau of Labor Statistics 2014)

State	Year	No. of Deaths
North Carolina	2004	9
	2008	5
	2010	4
	2011	6
	2012	7
	2013	3

The BLS (2014) reported a number of fatal occupational injuries at road construction sites from 2003 to 2013; a total of 524 construction worker fatalities occurred in heavy and civil engineering construction from the private industry, 471 occurred on highway, street, and bridge construction, and a total of 619 construction workers were struck by motorists inside the roadway, or on the side of the road (shoulder). The role, if any, which distracted driving, had in work zone accidents which caused construction work fatalities remains unanswered. Thus, it is important to determine how many drivers are distracted, and how distracted drivers interpret an active work zone, giving this study, and future studies relating to construction worker fatalities due to distracted driving significance.

2.4: Definition of Urban and Rural Classifications

The United States Census Bureau has defined an area to be ‘rural’ or ‘urban’ based on a delineation of geographical areas, identifying both individual urban areas and rural areas of the continental U.S. and U.S. territories. An urban area represented by the Census Bureau is a densely developed territory, encompassing residential, commercial, and non-residential urban land uses. Urban areas are categorized as a densely settled core of census blocks that meet minimum population density requirements, of 50,000 people or more, urban clusters are comprised of at least 2,500 people and less than 50,000 people. Meanwhile, rural classifications encompass all population, housing, and territory that is not included in an urban area delineation (U.S. Census Bureau 2015). The Census Bureau’s description of rural and urban areas are used by a number of federal agency programs as the starting point or primary basis for implementing and determining eligibility for funding programs (FHWA 2013).

The Federal Highway Administration (FHWA), other transportation programs, and policies rely upon a clear, and well-documented distinction between urban and rural areas, which the Census Bureau has done so explicitly (FHWA 2013). However, for transportation purposes, states may adjust, in coordination with local planning partners the urban area boundaries to include areas of significant importance. The FHWA has a slightly different definition of urban areas, where an urbanized area has a population of greater than 50,000, a small urban area is 5,000 to 49,999, and an urban cluster to have at least 5,000 people (FHWA 2013). The FHWA used Federal – aid highway law (section 101 of title 33, U.S. Code) to define urban as, “an urbanized area as designated by the Bureau of the Census having a population of five thousand or more and not within any urbanized area, within boundaries fixed by responsible State and local officials in cooperation with each other, subjected to approval by the secretary. Such boundaries shall, as a minimum, encompass the entire urban place designated by the Bureau of the Census" (U.S. Code).

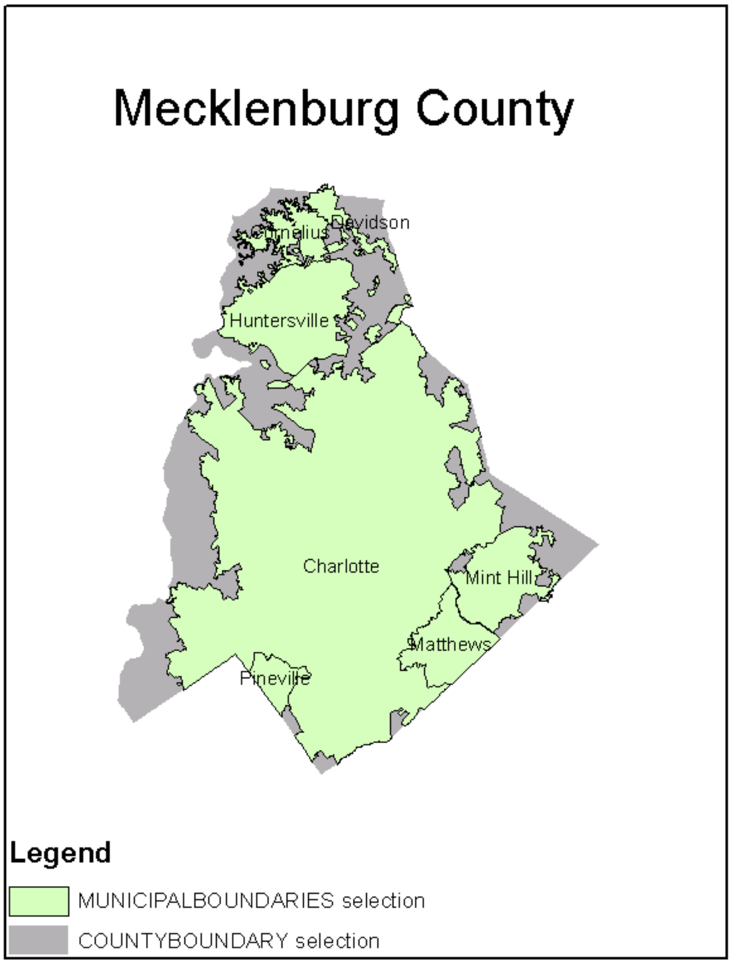

FIGURE 2: Mecklenburg County (NCDT - GIS Unit, 2015)

For the purposes of this research study the definitions defined by the Census Bureau will be used to differentiate between land delineations of 'urban' and 'rural' areas. Since the Census Bureau's definition of the term 'urban' is widely used as a clear, and well documented definition (FHWA 2013), the decision to use this definition is justified. FIGURE 2 above describes the municipal area where data collection will take place in Mecklenburg County, North Carolina. The majority of Mecklenburg County is urbanized and defined by the municipal boundaries shown. FIGURE 2 was created using ArcGIS, and databases of North Carolina county boundaries (North Carolina Geodetic Survey, 2015), and municipal boundaries (North Carolina Department of Transportation - GIS Unit, 2015).

2.4.1: Differences in Work Zone Impacts and Accident Statistics

Short term construction and maintenance zones are unlike long term work zones, because of their temporary nature and uniqueness. Short term construction or maintenance work zone projects are unique when considering their length of time, location, driver interpretation, traffic behavior and congestion of the urban environment.

Urban work zones present major differences compared to rural work zones, the MUTCD Part 6 (2009) applies to both rural and urban areas. Rural highways are normally categorized as roadways which have lower traffic volume, higher speeds, fewer turning conflicts, and fewer conflicts with pedestrians. However, an urban highway typically has lower speeds, with a wide range of traffic volumes and fluctuations, narrow travel lanes, turning conflicts in the case of intersections and driveways, and significant pedestrian activity (MUTCD 2009).

Urban areas have a considerably higher population density than rural areas, with 80.7% of the U.S. population living in urban areas (U.S. Census Bureau 2015). Due to the population density, greater traffic volumes, and fluctuations in traffic flow between rush hour commutes, and impacts to work zone design are greater in urban areas than in rural areas. Ullman and Dudek's (2003) study of traffic flow in work zones, set two parameters for consideration in the importance of design and impact on traffic flow.

1. Traffic queues stabilize upstream of the temporary work zone bottlenecks in urban areas
2. Long term work zones allow for the traffic patterns to return back to normal or equilibrium

Work zones can cause congestion in either rural or urban environments, but the congestion impacts of urban areas are much greater than those found in rural work zones. This is because of the difference in traffic volume between urban and rural areas. The primary effects on urban work zones are heavy traffic delays, and queuing above the bottleneck in urban areas (Ullman et al. 2003).

Ullman and Dudek (2003) determined that long term work zones allow for traffic conditions to revert back to normal, because drivers will take alternative routes over time to avoid work zones, where short term work zone projects do not. However, short term maintenance and construction zones do not provide ample time for the traffic conditions to return back to equilibrium, because of the work zone duration. Short term work zones used for utility and maintenance work are mobilized, set up, and demobilized in a matter of hours, classified by the MUTCD (2009) as work which lasts longer than one hour of daylight.

Some additional differences between urban and rural environments include accident statistic differences between area classifications. For motorists, the differences in area classification include, different driving perspectives, such as differences in speed limit, access, and function of roadway systems. However, regardless of urban or rural environment, accidents occur frequently. According to the U.S. Census Bureau, the 2010 Census (U.S. Census Bureau 2015) determined that 80.7% of the United States population lives in urban areas, with a 12.1% urban population growth from 2000 to 2010. In 2013, there were 32,712 fatalities recorded in the FARS (NHTSA 2015) database. However, 54% of fatalities occurred in rural areas, while 46% occurred in urban areas (NHTSA 2015) even with the population growth of urban areas. The amount of fatal rural accidents is considerably higher than urban environments, considering approximately 19% of the population lives outside of urbanized areas.

In 2013, 52% of rural fatal accidents occurred during the day, while the percentage of daytime fatalities for urban areas was 55%. A high number of these fatal accidents were related to speeding, 28% in urban areas, and 30% in rural areas, which resulted in most of the deaths at the scene of the accident (NHTSA 2015). Additionally, speeding was also identified to be a common cause of work zone accidents (Rescot et al. 2010). In 2013, the state of North Carolina recorded 1,289 fatal accidents, 67% in rural, and 33% in urban areas (NHTSA 2015). Urban accidents which occur during daylight hours and are consistent with daytime movements or commute of urban areas, have the potential to occur in urban work zones, putting the safety of work zone users at risk.

2.5: Distracted Driving

The following literature determines an acceptable definition for the broad category which is distracted driving; a definition which clarifies the difference between distraction and inattention. Also located in this sub - chapter is an exploration of current texting and driving laws, and the use of hand held devices for the United States. Additionally, literature of distracted driving behavior and the associated hazards to driver reaction time, and the concerns of distracting driver behavior for construction workers, relating to the behavior of motorists around work zones is found within. Finally, literature of how work zones are distracting, and accidents related to distracting driving behavior are located in this section.

2.5.1: Definitions of Distracted Driving

The term ‘distracted driver’ can be defined as the inattention of the operator of the vehicle because the operator is temporarily distracted by another person, object, task, or something other which is not related to driving. The National Highway Traffic Safety Administration (NHTSA) top ten causes of accidents on U.S roadways below, include distracted and inattention activities of motorists, which are considered distracted driving characteristics and behavior. Distracted driving activities are all the following terms, except drowsiness and falling asleep, which can be considered to be inattention behavior of motorists (NHTSA 2010):

- Drowsiness
- falling asleep
- operating a cell phone or other technology devices
- talking on a cell phone
- having conversation with another passenger
- reading
- turning around or reaching for an object
- eating or drinking
- adjusting radio controls
- looking at other objects

From a study performed by the NHTSA and the Virginia Tech Transportation Institute (VTTI), it was determined that approximately 80% of crashes and 65% of near crashes involved some form of involvement of inattention prior to an accident. The study defined inattention to be “motorist involvement in secondary tasks, driver drowsiness, driving related inattention to the forward roadways, and non-specific eye glance away from the forward roadway" (Klauer et al. 2006).

However, Pettitt et al. (2005) suggests that the definition of driver distraction is too broad of a definition lacking the precision necessary for scientific purposes. Since there is no compelling scientific definition, Pettitt et al. (2005) aimed to provide the scientific community with a more precise definition of the term, one where distraction should be discussed in terms of four more distinct categories. The definition of distraction is divided into the following categories:

- Visual
- Cognitive
- Biomechanical
- Auditory distraction

Pettitt et al. (2005) determined that for the act of distraction to occur, the task of driving should result in a measurable change that affects the driver's engagement in a secondary task or activity. Many sources of distracted driving confuse the definition of inattention with distraction. Distraction is an event that takes the attention of the driver away from the task of driving to another separate activity. The result of distraction is inattentive driving; however inattention is not always caused by distraction. For example, inattention may result due to driver fatigue, or non-driving activities such as day dreaming. Pettitt et al. (2005) concluded that the comprehensive definition of distracted driving should include the following: the difference between distraction and inattention, the recognition that distraction can be internal or external to the vehicle; distraction can be categorized into the four listed components above, and the effect of distraction on the driving task.

The term distracted and inattention are used interchangeably causing confusion between the true definitions of distraction. However, both distraction and inattention have been used in similar studies (Pettitt et al. 2005, Klauer et al. 2006, NHTSA 2010) to define the same driver characteristics or driver behaviors. For the purposes of this research study the definition of distracted driving will simply be stated as, an act of distraction including inattention (Pettitt et al. 2005), which takes the focus of the driver away from the task of driving (NHTSA 2010). Distracted driving will include sources of distraction from internal and external sources, and the listed NHTSA top ten causes of accidents on U.S roadways.

2.5.2: U.S Text and Phone Regulations by State

The United States has implemented state regulations; primary or secondary laws which prohibited the use of hand held devices, cell phones, and text messaging based on motorist age, or device use. A primary enforcement law is considered a law which an officer may cite a driver for using a device without any other traffic offense taking place (GHSA 2015). Secondary enforcement laws are usually enforced in the event that a primary enforcement law was broken first.

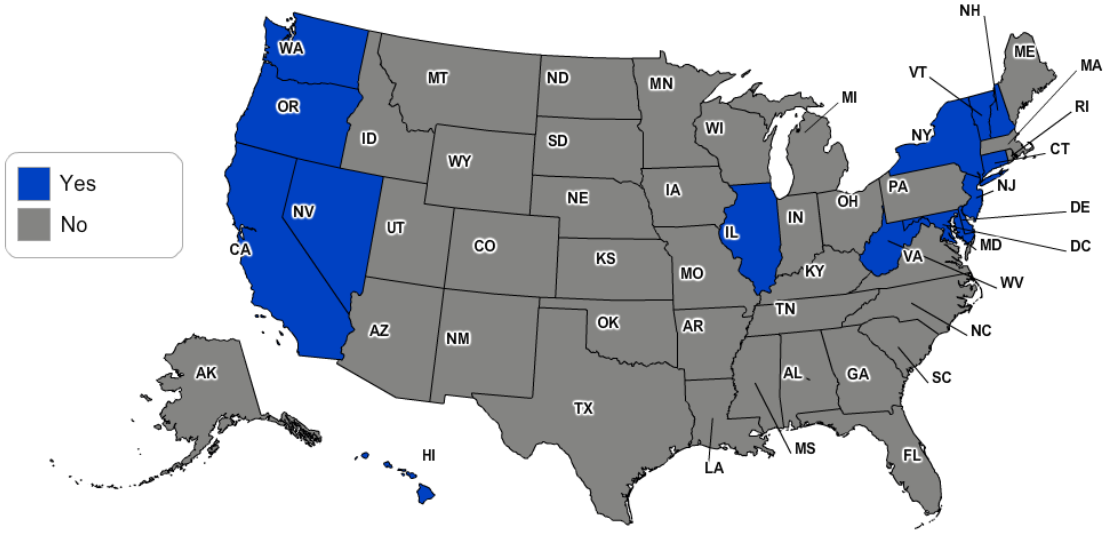

FIGURE 3: Hand held phone ban (GHSA, 2015).

Figure 3, displays a map of the United States for hand held cell phone use regulations. There are a total of 14 states, and Washington D.C. which do not permit hand held cell phones use. All of the highlighted states consider the ban on hand held phones to be a primary law (GHSA 2015). Additionally, the following states which are not highlighted also enforce hand held cell phone bands for drivers possessing learner or intermediate licenses, or under the age of 18 years of age:

- Arkansas
- Louisiana
- Oklahoma

The following states shown in Figure 4 have a primary text messaging ban (GHSA 2015), the current text messaging regulations include 46 states and Washington D.C. which ban text messaging and driving for all drivers. The four states which do not have text messaging bans are: Arizona, Missouri, Montana, and Texas. However, two states of the four listed prohibit texting by novice drivers, these are Texas and Missouri.

A novice driver is typically under the age of 18 years old, or one who possesses a learner or intermediate type license (GHSA 2015). No state has banned all uses of cell phones for all drivers, but 38 states and Washington D. C. (Figure 5) ban all cell phone use by novice drivers (GHSA 2015). An all cell phone ban would include a ban on hand held use, text messaging, and hands free use.

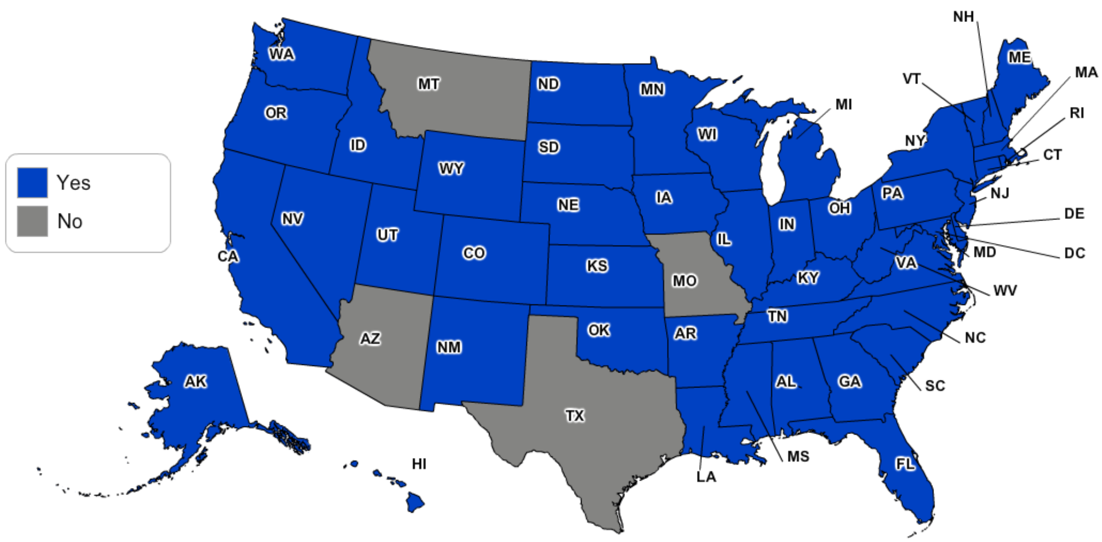

FIGURE 4: Text messaging ban on all drivers (GHSA 2015).

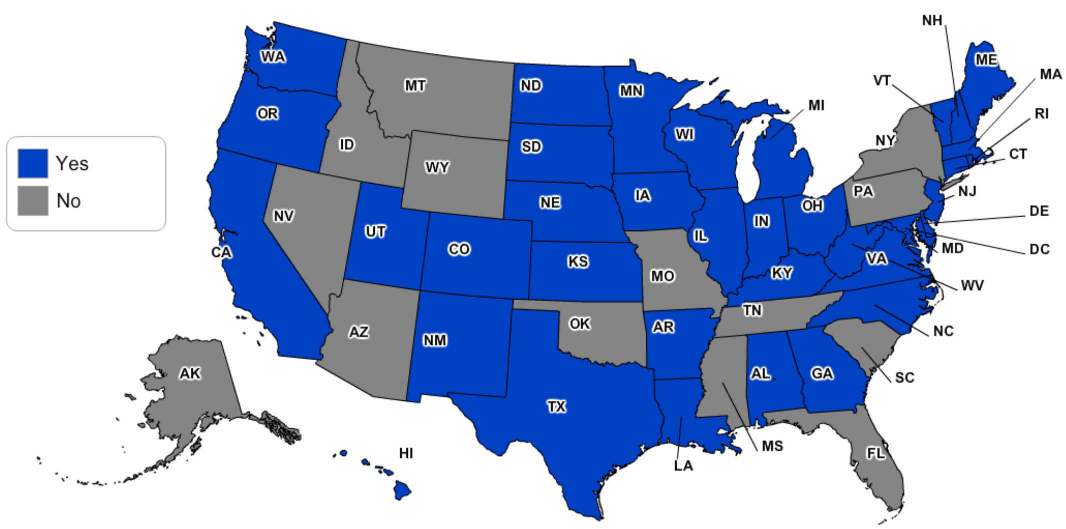

FIGURE 5: Novice driver all cell phone ban (GHSA, 2015)

2.5.2: Distracted Drivers and Accidents

Distracted driving has been the cause of as many as 80 % of vehicle crashes, and recent studies have supported the finding that distraction is a significant contributor to vehicle accidents (Hendricks et al. 2001, Klauer et al. 2006). On roadways today, drivers are engaged in secondary activities, many of which are distracting (Bellinger et al. 2009) including the wide spread use of cell phones. The concern with the use of cell phones while driving, and the effects distracted driving have on accident risk have gained interest of researchers in recent years (Stutts et al. 2001, Young et al. 2003).

The focus of many studies is centered on the use of cell phones, but distractions from secondary tasks have existed before the increased use of cell phones became a problem. It should be noted that some authors have argued banning the use of cell phones by drivers, while ignoring the risks created by other distractors may be unreasonable (Consiglio et al. 2003). Secondary tasks are distracters such as talking with an occupant of the vehicle, eating, drinking, smoking, or listening to the radio, and adjusting controls. However, analysis of distracted related crashes have shown that other distractions from secondary tasks, are even more frequent than the use of cell phones in distraction related crashes (Stutts et al. 2001). Regardless of opinion, both secondary tasks and inattention cause accidents.

Distracted driving is a behavior dangerous to drivers, passengers, and non-occupants of the vehicle alike (NHTSA 2013). As a continuing improvement process to improve data quality, the NHTSA (2013) changed the coding of the FARS database for distracted driving, to include fatal accidents relating to distracted driving for 2010 and 2011. In 2011, a total of 3,331 people were killed, and an estimated additional 387,000 were injured in motor vehicle crashes involving distracted drivers on U.S. roadways. Distraction – affected crashes were reported to cause 10% of fatal crashes and 17% of injury crashes. The use of cell phones contributed to 12% of fatalities, and 5% of injury cases, where at least one person was using a cell phone to talk, listen, dial, text, or other related cell phone activities such as email. The acts of dialing a hand held device, talking on a device, and reading the screen accounted for 3.6%, 3.6%, and 2.9% respectively for all crashes and near crashes (Klauer et al. 2006).

The use of cell phones, and other distractions around work zones was evaluated by Singh (2010) who conducted a study of distracted driving. The study defined the event of distracted driving to pertain to drivers who were distracted from at least one internal source. Common driving conditions where inattention was the cause of a crash, resulted from talking and conversing on the phone, such as instances of congested traffic, within construction work zones, or when there was no traffic flow interruption. Singh (2010) used the NHTSA National Motorist Vehicle Crash Casualty Survey (NMVCCS) data, with the goal of understanding the role of inattention in a crash occurrences. The study evaluated traffic flow conditions of six scenarios, including construction work zones, to 14 defined distracted driving behaviors. Distracted driving behaviors consisted of two categories, inattention related factors, which considered a driver's interaction with in-vehicle sources of distraction. Examples of these included operating a phone, and retrieving objects. The other was cognitive activities such as day dreaming, and thinking about personal problems. The conclusions of the NMVCCS found that within work zones 12.4% of the drivers were distracted by at least one internal source of distraction. However, when considering all internal and cognitive distractions of inattention prior to an accident, drivers were found to be engaged the most in conversing with a passenger in all traffic flow conditions. The highest recorded percentage of drivers conversing with a passenger, at 67.3%, occurred in a work zone. This study also discovered that 13.4 % of drivers were focused on internal objects in the vehicle, and a relatively smaller percentage of 9.8% reported talking on the phone within a construction work zone.

2.6: Concerns Associated with Distracted Driving

Distracted driving is an act of distraction including inattention (Pettitt et al. 2005) which takes the focus of the driver away from the task of driving (NHTSA 2010). Distracted driving includes sources of distraction from internal and external sources, and the listed NHTSA top ten causes of accidents on U.S. roadways. However, studies showed distracted and inattention to be used similarly (Pettitt et al. 2005, Klauer et al. 2006, NHTSA 2010). Research suggests that both the physical and cognitive distraction caused by using mobile phones while driving can significantly impair a driver's visual search patterns, reaction times, decision making processes and their ability to maintain speed, throttle control and lateral position on the road (Redelmeier et al. 1997, Cooper et al. 2002, Harbluk et al. 2002).

In general, there is a significant association between mobile phone use while driving and crash risk (Lam 2002). As much as 80% of car accidents, and 65% of near miss accidents involve at least some form of driver distraction within three seconds of the incident (Klauer et al. 2006). Participating in distracted driving behavior increases the risk of an accident up to as much as 23.2 times for drivers who engaged in text messaging when compared to non – distracted drivers (Klauer et al. 2006). The likelihood of an accident increases significantly based on driver distraction, and inattention such as driver drowsiness which is a significant problem; increases the risk of being involved in a collision as much as 4 times (Redelmeier et al. 1997). Although the most common distraction for drivers is the use of cell phones, the number of accidents and near accidents for dialing are nearly identical to talking or listening, which is reportedly 2.8 times more dangerous (Klauer et al. 2006). The likelihood of increased accident risk from other driver involvement in secondary tasks include: reaching for a moving object, increasing the risk of a crash or near-crash by 9 times; looking at an external object by 3.7 times; reading by 3 times; applying makeup by 3 times; dialing a hand-held device (typically a cell phone) by almost 3 times; and talking or listening on a hand-held device by 1.3 times (Klauer et al. 2006).

A concern with distracted driving specific to urban areas from the Hendricks, Freeman et al. (2001) study resulted from turning and intersection accidents; 51.8% of accidents occur at locations controlled by traffic signals, and 32.8% occurred at non – intersection locations, such as private drives, and commercial access points. The majority, 77.6% of accidents did not involve inattention, however approximately 18.0% became aware of the traffic control device 4 seconds or less before an accident, and were participating in driver inattention. Accidents occurred specifically when drivers became inattentive after noticing the traffic signal but as a result of inattention the specific traffic signal phase could not be determined. Inattentive drivers reportedly remembered the last phase of the traffic signal, such as “green” but after an extended interval between the last time the signal was checked and the intersection entry the traffic signal had changed (Hendricks et al. 2001).

Motorists engaged in distracted driving are comparatively different to non – distracted motorists when considering driver reaction times. According to Burns, Parks et al. (2002) driver reaction times to hazards are on average, 50% slower under normal driving conditions. Two studies by Cosiglio, Driscoll et al. (2003) and Bellinger, Budde et al. (2009) both researched the reaction time difference between mobile phone use and various control scenarios of young drivers. Reaction time was shown to be slower when distracted, however reaction times for the mobile phone and hands free scenarios were similar, at 465ms and 464ms (Consiglio et al. 2003). There is also evidence that phone use while driving reduces speed control, and regardless of mobile phone use or hands free phone use, both significantly impair driver performance, and represents a significant road safety danger (Burns et al. 2002). However, Bellinger, Budde et al. (2009) had similar findings in reaction time, but the study showed that distracted drivers had a faster movement time of 18ms faster than the control to hit the brakes, and applied more pressure resulting in a harder and shorter breaking distance (Bellinger, Budde et al. 2009). It was discovered by Hancock, Lesch et al. (2003) that older distracted drivers had a slower reaction time and break harder to make up for that slow reaction.

2.7: Work Zones and Distraction

Previous studies have determined construction activities, equipment, and work zone set up to be distracting to road users (Arditi et al. 2007, Trout et al. 2010). When considering the effectiveness of work zone set up, the goals of access, mobility, and safety are often competing considerations (Porter et al. 2008). Two contributing factors of work zone crashes in construction and maintenance zones are identified as driver distraction and speeding (Rescot et al. 2010). A work zone is a complex area of constricting construction activity, including equipment, lane closure procedures, and safety risks. Where there is an active work zone, speed reductions, and construction activities are expected to be present.

As stated by Rescot, Jasrotia et al.(2010), speeding is a known contributor of accidents in work zones, which raises the question of driver's interpretation of work zone signage. Trout, Finley et al. (2010) studied the enforceability and understanding of Texas Department of Transportation (TxDOT) work zone signs and electronic message boards. The study used the TxDOT standard which deems the use of short term speed reductions to be appropriate when construction, and maintenance activities take place on, or within fifteen feet of the edge of pavement (Trout et al. 2010). Additionally, the TxDOT suggests that posted speed signs should be removed or covered when workers are not present, allowing speed limits to revert back to normal; turning signs or laying signs down when workers are not present is not an acceptable method of indicating that short term construction speed limits are not in effect. The conclusions of the Trout, Finley et al. (2010) study determined that 85% of participants interpreted the signs correctly, more than 96% recognized that the type of signs, including static and electronic, indicated a work zone, and 99% of participants thought that they could receive a speeding citation for travelling over the posted temporary work zone speed limit.

The conclusions of the Trout, Finley et al. (2010) study confirm that drivers understand the meaning of work zone signage and the enforceability of the posted temporary work zone speed limits. However, motorists continue to speed through work zones, increasing the chances of having an accident, which increases the safety risks for construction workers.

According to the American Association of State Highway and Transportation Officials (AASHTO 1998) work zone fatalities occur in every functional highway classification. The Reiprich, Berkhout et. al (2010) study of accidents occurring in the vicinity of work zones in the state of South Dakota during 2006 used an accident database provided by the SDDOT of formal accident reports filed by South Dakota Law Enforcement. The study concluded rear end collisions included 125 cases of Misperceived Closure Rates (MCR). Accidents that were classified as MCR resulted in 73.52% of the recorded rear end collisions. An accident classified as an MCR occurs when a driver discovers contact with the vehicle in front to be inevitable (Reiprich et al. 2010). Accidents due to MCR within work zones could be an indication of distracted driving within the work zone, another conclusion of Reiprich, Berkhout et al. (2010) suggested that accidents would not have occurred if the work zones had not been present.

Debnath, Blackman et al.(2015) used a qualitative methodology in the form of semi-structured interviews to examine the perceptions of road construction. These interviews aided the study to determine the perceptions of road construction and maintenance workers regarding work zone hazards. Workers of varying experience were interviewed; including supervisors, operators, and general laborers, most had experience in rural and urban construction. There was a total of 66 study participants who participated in interviews, the experience of those interviewed are as follows:

- 9 (less than 2 years)
- 35 (2-10 years)
- 22 (greater than 10 years)

General laborers working adjacent to the travel space in active work zones experienced the most hazardous work type. Construction workers located adjacent to the travel space identified excessive speeds, aggressive driving behavior, driver frustration, and distracted driving to all be hazards (Debnath et al. 2015). According to construction workers drivers directed aggressive driving behavior towards them, and witnessed driver frustration as a result of work zone activities.

Distracted driving consisted of mobile phone use and was determined to result in motorists disobeying or not noticing signage and traffic lights, which was a major concern to roadway workers. As for high speeds through the travel space of the work zone, it was determined that approximately 60% of motorists were speeding in the absence of law enforcement (Debnath et al. 2015). A work zone study pertaining to the use of law enforcement in Houston, TX concluded that active police presence and enforcement may improve speed limit compliance, but other beneficial influences on driver behavior have resulted in discouraging driver inattention and aggressive behavior (Levine et al. 1984).

Debnath, Blackman et al. (2015) concluded that the perceived hazards at active work sites arise from a range of driver, environmental, worker and equipment factors. Driver factors include speeding, distraction, confusion, frustration, aggression, impairment, fatigue, and general noncompliance with traffic controls. Based on construction worker perceptions of hazards within active work zones featuring a lane closure, driver predictability has been determined to be the most hazardous concern, one with no engineering solution other than work zone set up and safety features (Debnath et al. 2015). Driver predictability is something that can not be determined, and has been identified as a hazardous concern for construction workers. Distracted driving may influence driver predictability to the extent that drivers are unpredictable and greater knowledge is needed to provide a solution that may support engineering solutions.

CHAPTER 3: METHODOLOGY

3.1: Research Data Collection

Both quantitative and qualitative data was collected for this study. Quantitative data consisted of speed data collected by traffic analyzers placed adjacent to the work zones in each case study. However, qualitative data consisted of data collected from brief worker surveys, observational safety site surveys, and video data from each work zone case study. Quantitative data was collected using the NC – 200 Portable Traffic Analyzer and retrieved with a laptop. The traffic analyzers were placed prior to the work zone observation, leaving approximately 30 minutes for the traffic analyzers to acclimatize before initiating data collection. The traffic analyzers remained in place for the duration of the work zone observation, and were retrieved at the end of the case study observation. The work zone layout determined the number and spacing of the traffic analyzers, ideally two to three traffic sensors would be placed in the work zone.

Initially, it was thought that a traffic analyzer could be placed before the construction taper, adjacent to the construction taper, and in the work zone as shown in Figure 6. However, the observed work zones which made up the four case studies did not allow for this placement of traffic analyzers. This was due to the observed work zone layout, which did not have a defined construction taper at case study locations. The observed work zone locations were part of a larger work zone, where case studies occurred at temporary lane closures within. Only traffic analyzer locations adjacent to the construction taper and in the work zone were used. The traffic analyzer which was placed in the work zone was always placed next to construction activities as shown in Figure 6 as the work space.

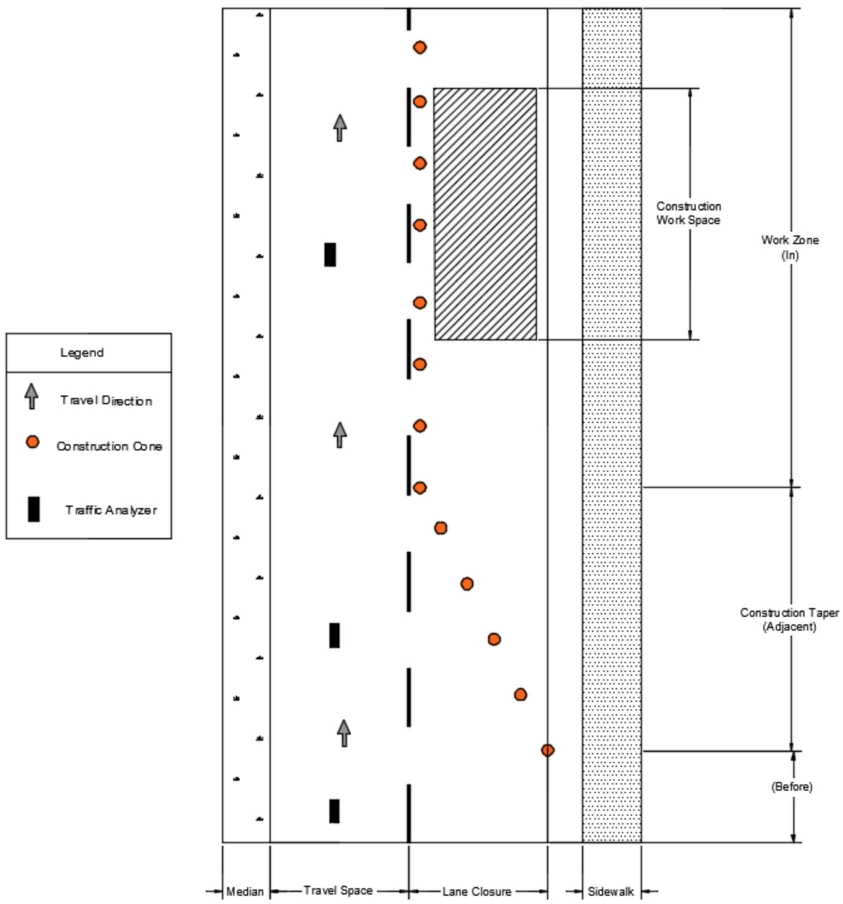

FIGURE 6: Traffic analyzer location

3:1.2: Observation Procedure

1. Place the Portable Traffic Analyzers

Once the research team arrived on site, the cooperation of a construction employee was required to stop traffic one researcher was a spotter, while the other was placing the traffic analyzer on the roadway surface. One traffic analyzer was placed adjacent to the construction taper and one in the work zone next to construction activities. The Portable Traffic Analyzers were placed flat on the roadway surface, covered with a durable cover, and secured to the roadway with asphalt tape.

2. Place Video Camera

The video camera was placed appropriately in the median, shoulder, or lane closure where space allowed. The video camera was always located in close proximity to the traffic analyzer in the work zone, and recorded motorists that were traveling through the travel space (Figure 6) passing over that traffic analyzer. Often the video camera recorded motorists passing the traffic analyzer with construction activities happening in the background, so real time video footage of the relationship between motorists and the work zone activities was captured. Typically, the video camera was started five minutes prior to when the traffic analyzers were programmed to start.

3. Create a Site Sketch

Work zones were sketched upon arrival by the observers for each of the case studies, identifying the geographical features, layout, any apparent weather conditions, and any other safety concerns. These were used to describe the site for each case study location and help to identifying challenges, and limitations of data collection at each case study location. Other documentation procedures of the site included taking pictures of the lane closure, equipment, and work processes. The site sketch required some measurements to be taken, measurements were taken using a measurement wheel. Measurements which were taken included the distance between traffic analyzers, and other measurements of importance that were unique to the site.

4. Conduct “5 - Minute Surveys”

Periodically throughout the site observation a “5 - Minute Survey” was performed. This data collection method is a standard safety survey to collect data on the safety of a site. The researchers would at random choose times to conduct the surveys and focused solely on the site during that time. The researchers alternated taking the survey and performed one at least every hour for the duration of the case study.

5. Conduct Brief Worker Surveys

Where the opportunity presented itself, the researchers administered a brief worker survey to construction employees of the heavy civil contractor working within the work zones. However, these surveys were very limited because the opportunity rarely presented itself, as construction workers were very busy or separated from the researchers and it would have been dangerous to administer a survey in the lane closure due to heavy equipment operating in the site and traffic conditions.

6. Observation Procedure

Once the traffic analyzers started recording traffic data points at the set program start time, the researchers stood next to the video camera and announced observed distractions from a code reference sheet shown in Figure 7. When a distracted driver was observed passing over the traffic analyzer, the researcher would call out the color of the vehicle and the action of the driver from the reference sheet. In some cases, distractions were not on the reference sheet but were so obvious that the researchers could not ignore them, such as applying makeup while driving and counting money. The researchers alternated, taking shifts to perform this duty of announcing distractions of motorists. The purpose of rotating between researchers was to reduce fatigue, because it was visually demanding, and to ensure the accuracy of the data collection process.

CODE REFERENCE SHEET

ADJ. CONTROLS – INCLUDES ADJUSTING OF CONTROLS WHILE DRIVING **EX. ADJUSTING THE RADIO, MIRRORS, ETC**
FOOD – INCLUDES EATING AND DRINKING WHILE DRIVING
PHONE – INCLUDES TALKING WHILE DRIVING ON THE MOBILE PHONE
REACH – INCLUDES REACHING FOR OBJECTS WHILE DRIVING **EX. REACHING, AND TURNING AROUND MOVEMENTS OF THE DRIVER**
READ – INCLUDES READING, OTHER APPLICATIONS OF READING IN PAPER FORM **EX. LOOKING AT MAPS, READING NEWSPAPER, ETC.**
TALKING – INCLUDES TALKING AND ACTIONS OF THE DRIVER WHILE THERE IS A PASSANGER IN THE VEHICLE **EX. TALKING TO A PASSENGER, ROUGH HOUSING**
TEXT – INCLUDES TEXTING, AND OTHER USEAGES OF THE MOBILE PHONE WHILE DRIVING **EX. TEXTING, TWEETING, EMAIL.**

NOTE: The color of the vehicle will be said, followed by the **underlined** code reference word

FIGURE 7: Code reference sheet

The second researcher relieved the first and announced observed distractions from the code reference sheet to the camera, roughly every 15 minutes. The presence of the second researcher decreased the potential for bias to occur, which would result if one individual only completed the entire study. If the study was completed solely by an individual it would be subjected to one sided, opinionated based data collection, and could affect the potential conclusions of the study.

7. Traffic Analyzer Removal

With the cooperation of a construction employee to stop traffic, the traffic analyzers were retrieved from the roadway. The case studies lasted just over four hours on average; rush hour times were avoided, but sometimes the start of rush hour traffic would begin early, signaling the end of good data collection and the end of the work zone observation.

8. Download Recorded Data

Once the portable traffic analyzers had been retrieved, the information stored was downloaded using the appropriate software. The traffic analyzers were programed to collect the vehicle count, speed, and length. Additional parameters were collected such as, the headway between vehicles, and gap in time.

3.2: Targeted Work Zones

The researchers targeted specific days to collect data, with appropriate weather, traffic and work zone characteristics. Week days were selected for observations to avoid weekend traffic which would have higher traffic volumes for special events and recreational activities. The weather conditions for site observations were targeted to be clear or have dry roadways. Dry conditions were also targeted as a safety concern for the equipment, and ensure the asphalt tape remained in place to prevent damage to the NC - 200 Portable Traffic Analyzer if it were to become dislodged.

The type of work zones that was specifically targeted by the researchers were work zones that are set up in that location for the first time. Typically, construction work zones with work shifts of four to eight hours were targeted for the case studies. An example of a targeted work zone would be one located on a two lane arterial road, or divided highway within an urban environment. The work zone TTC measures included a single lane closure, closed for construction activities with the use of cones or a temporary barricade system. Work zones with permanent barricade systems such as Portable Concrete Barricades (PCB) were not an interest of the study, because work zones of this nature are in place for longer durations than desired by the researchers.

Figure 8 below, shows the TTC implemented in a typical short term construction or maintenance lane closure described by the MUTCD Part 6 (2009). After the advanced warning area, other TTC measures for a single lane closure include: a transition area, activity area, and termination area. The transition area is the portion of the TTC where road users are redirected from two lanes of travel to one, with the use of a construction taper. The activity area is more complex, and is composed of three additional zones/spaces; the buffer space (optional), work space, and travel space. This is the portion of the work zone where construction workers work in close proximity to open travel lanes, which is the designated travel space of the TTC. In the case of short term construction and maintenance work zones the separation of work space and travel space is accomplished by the use of cones. The termination area is the region used for redirection of traffic with the use of a taper at the end of a work zone (MUTCD 2009).

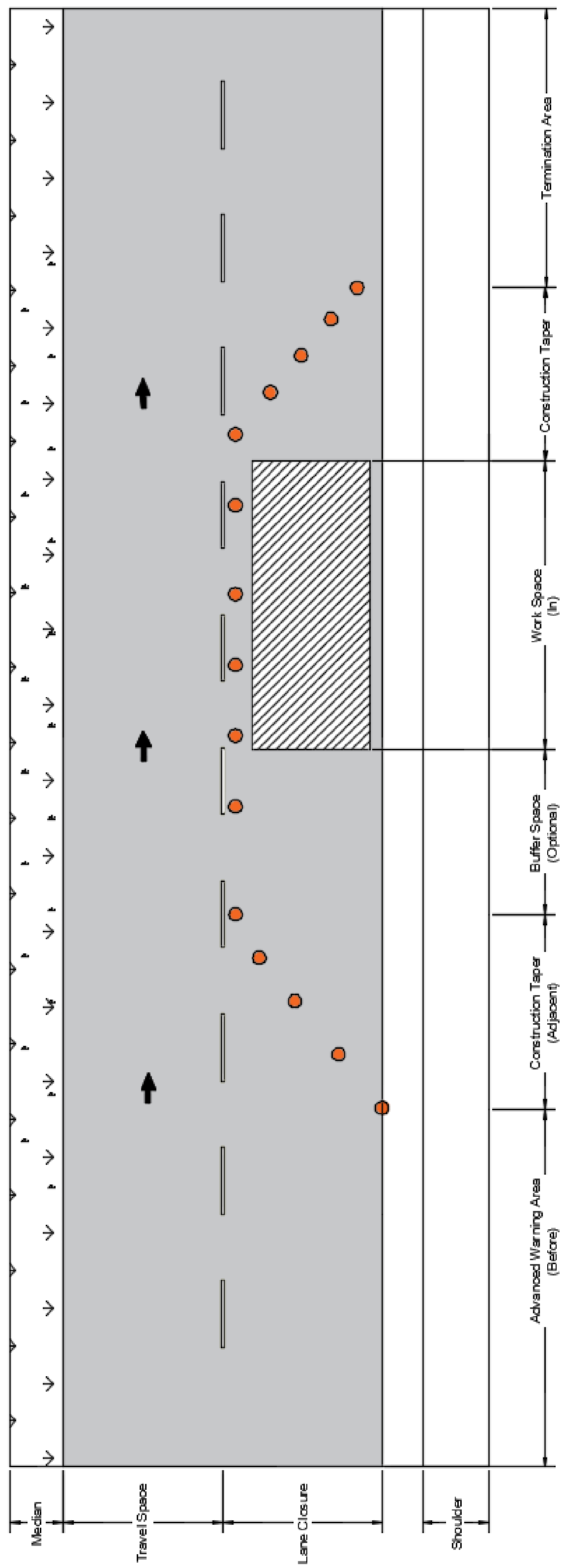

FIGURE 8: TTC lane closure

3.3: Equipment

The study used specialized equipment, and software; and other measurement tools such as surveys, which produced useable data to be used in the data analysis. To gather the needed data for this investigation, the following equipment, and tools were used. The surveys were used as a tool to obtain the qualitative data, while quantitative data was obtained through the use of special equipment, the NC - 200 Portable Traffic Analyzers.

3.3.1: Portable Traffic Analyzer

The portable traffic analyzer consisted of a manufactured unit called the NC - 200, which can be purchased from Vaisala. The NC - 200 is made up of primarily two parts, a durable aluminum housing and sensor with internal hardware as shown in Figure 9. The NC - 200 Portable Traffic Analyzer is designed to provide accurate count, speed, and length data (Vaisala, 2010). The recorded speed data was paired with the video data to match all drivers, including distracted drivers with corresponding speed values.

FIGURE 9: NC - 200 Portable Traffic Analyzer

TABLE 4: Manufacture specifications NC 200 Portable Traffic Analyzer

NC 200 Portable Traffic Analyzer	
Housing Material	Extruded / Anodized Aluminum
Ultimate Bearing Stress	88,000 psi (607 Mpa)
Dimensions	7.125 x 4.625 x 0.5 inches
Weight	1.3 lbs.
Operating Temperature	-4 ^{0} F to +140 ^{0} F
Sensor	GMR magnetic chip for Vehicle Magnetic Imaging
Memory	Micro Serial Flash: 3MB
Battery	Lithium - ion rechargeable
Capacity	≥300,000 or 21 days per study
Vehicle Direction	Speeds of 8 mph - 120 mph
Accuracy Length Classification	± 4 ft.
Accuracy Speed Classification	± 4 mph
Accuracy Vehicle Count Determination	± 1 %

The traffic analyzers utilized Vehicle Magnetic Imaging (VMI) technology to detect vehicle count, speed and length. The data was then easily transferred to a software program called Highway Data Management (HDM) where the data was sorted into reports, charts, and graphs (Vaisala 2010). Above in Table 4 additional manufacturer specifications can be referenced.99

3.3.2: Surveys

The study used two survey methods which aided in improving the quality of the observation findings from the case study locations, and assessed worker perceptions. The observation of each case study was completed by two researchers, as it was important to have two researchers to reduce the potential for bias.

The first survey was called the “5 Minute Survey”, it is a standard safety survey used by the construction industry and trades to evaluate the overall performance safety of a site. The one used for this research study is located in Appendix A and was tailored from the traditional freeway survey to fit the parameters of the study to include distracted driving. This survey was completed by one of the researchers at least once every hour that the case study observation lasted; it was structured to be completed within 5 minutes, and the time for completing the survey was chosen at random. It was purposely administered in a way that the researchers would alternate completing this survey to eliminate observations from only one researcher. During the allotted time the researcher completing the survey was intentionally looking for safety concerns associated with the work zone; which included worker safety, motorist safety, pedestrian safety, and environmental safety hazards. The observers looked for safety issues such as how many times a construction worker crossed the open travel lane, or how many times a passing vehicle veered, entered, or struck an object or person within the closed lane.

The second type of survey was a brief survey designed to be given to the construction workers, present at the work zone being observed. This survey method was aimed to target every construction worker on site in an attempt to gather a survey sample called a "sample of convenience". This would have aided the research study in reaching suggestions for the conclusions of the study. The sample of convenience eliminates the potential for bias or discrimination to be identified, because the whole work crew was to be surveyed. The survey can be administered in the following ways:

1. Verbally by the observer to the construction worker
2. The construction worker completes the survey by himself/herself

The brief worker survey is located in Appendix B and focused on open ended questions of personal worker safety with the associated tasks of road construction. Additional open ended questions regarding distracted driving observations, and features of urban construction were also asked. The questions are open ended to reduce bias, and to obtain the true measurement without asking persuasive questions to obtain an answer that is for or against the study. After a discussion with the research board it was determined that this survey would not need IRB approval.

However, this survey experienced limitations and could not sample everyone, only a total of four individuals were surveyed. Limitations of this survey came from the fact that some of the construction workers were equipment operators, and to prevent a loss in production the researchers did not stop these employees to administer the survey. Other construction workers were engaged in demanding construction activities in the median of the roadway or lane closure, and a time did not present itself to administer the survey. It could have been potentially dangerous to administer this survey in the middle of the lane closure where construction activities occurred in close proximity to motorists. Therefore, the findings will be reported but not used to support the suggestions of the study.

CHAPTER 4: CASE STUDIES

The study successfully completed four case studies, and the corresponding locations for each of the respective studies are shown in Figure 10. There were a total of four case studies that were acceptable to use in the analysis of the study. However, two additional preliminary case studies were also completed, but were determined to be unusable in the study because of poor video quality. The preliminary case studies prevented the behaviors of motorists to be determined and were therefore not used. The case studies are located in the northern city limit of Charlotte, North Carolina and in close proximity to the University of North Carolina at Charlotte. The description of the case studies, and work zone layout of the sites are described as if driving in the direction of traffic flow, indicated by the arrows in Figures 11, 17, 23, 25; all the information presented in the case studies was obtained from the "5 minute survey", video analysis, and personal observations from the researchers.

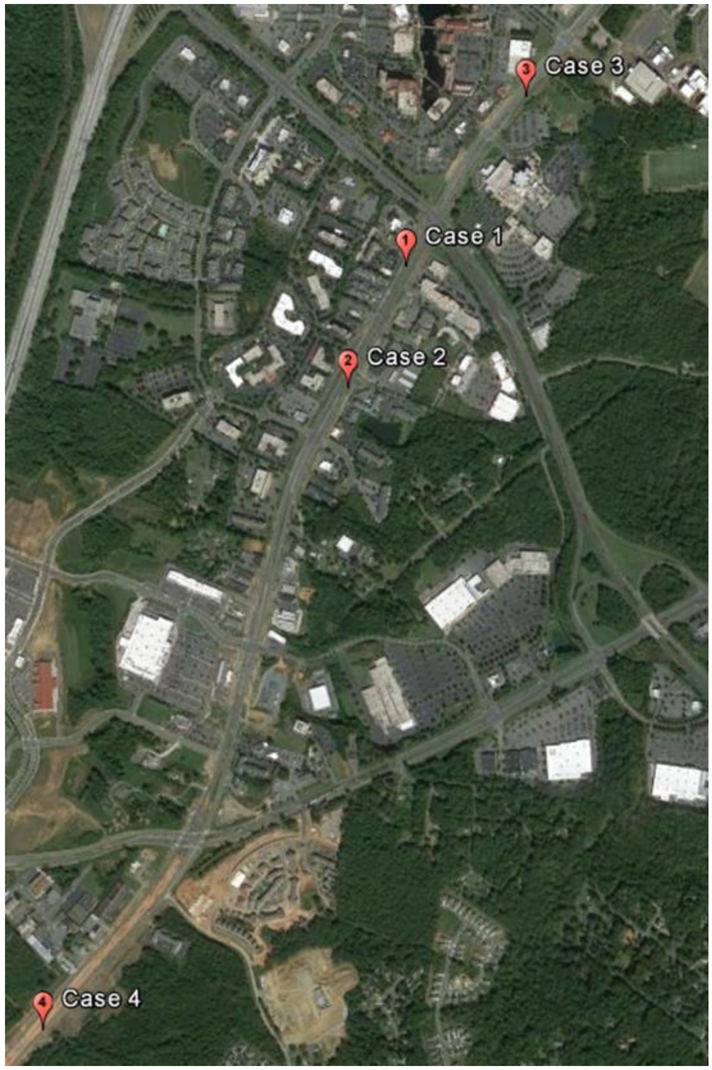

FIGURE 10: Case study locations

4.1: Case Study 1 – North Tryon and W.T Harris Intersection

This investigation of North Tryon St. occurred just south of the intersection of W.T Harris Blvd on May 20, 2015. The investigation took place between 2:30 pm and 4:30 pm and a total of 950 usable data points were collected from motorists traveling in the south bound lanes. As shown in Figure 11, the traffic observation was of a single lane closure in the left hand lane, while the right hand lane remained open. The site originally had three south bound lanes, two lanes were for through traffic, while the third started and terminated between intersections and was used for turning traffic. However, construction activities had permanently closed one lane of through traffic for a temporary side walk, and were in the process of reconfiguring the alignment of the roadway. A small work crew (Figure 12) was working in the median of the roadway where asphalt was being laid and subsequently being compacted. In addition to the equipment operators there was a small cleanup crew of general laborers also in the median. A flagging crew was located in the lane closure between the two adjacent parking lot intersections and was directing dump trucks for construction activities. In addition to the temporary sidewalk, there was a bus stop located close to the second parking lot intersection. As the duration of the observation progressed a traffic control crew picked up the temporary lane closure in the median at the end of the study.

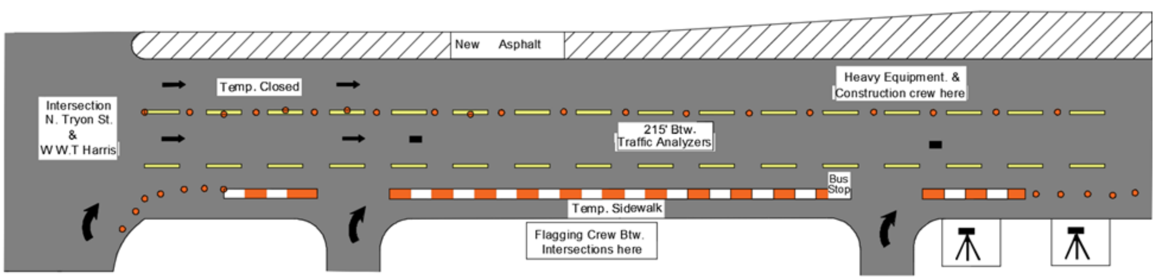

FIGURE 11: Case Study 1 - N. Tryon & W.T Harris

FIGURE 12: Construction workers in the median at Case Study 1

The work zone displayed an electronic message board (Figure 13) at the intersection of N. Tryon St. and W.T Harris Blvd. and had the posted speed limit of 35 MPH. The site allowed for the placement of two traffic analyzers, the first was approximately 150 ft. south of the intersection of W.T Harris Blvd. and the second was located 215 ft. from the first. The second traffic analyzer was placed before the downstream traffic signal to prevent capturing data that was stopped or backed up from the traffic signal. The video camera was placed on the right shoulder of the roadway, and recorded the activities of motorist passing over the second traffic analyzer. However, as construction activities on the shoulder progressed, an excavator got too close to the camera setup, which had to be moved approximately 50 ft. away, as shown in Figure 11 which has two symbols for the camera. The researchers moved the camera to the second location when there was a break in traffic to avoid missing any passing vehicles.

FIGURE 13: Permanent lane closure at Case Study 1

The associated challenges with collecting valid data for this site came from the bus stop and the two small intersections from parking lots adjacent to the site. The two adjacent intersections caused turning conflicts, motorists were observed to drive inside the lane closure, and in some instances drivers completely ignored the lane closure to drive through the work zone and merge into the north bound lanes. Other drivers entered the lane closure from the turning lanes of W. T Harris, and displayed some driver confusion.

The bus stop within the lane closure, affected the quality of the obtained data, as traffic backed up behind a stopped bus. Speed readings after such occurrences, and when traffic came to a standstill had to be consequently removed, and were not used for analysis because of extreme slow speeds. During periods of slow or stopped traffic drivers were observed to be using cell phones to text and make phone calls, and partake in other distracting behavior in slower moving traffic behind busses. An additional safety hazard associated with the bus stop was observed when pedestrians were entering the lane closure to get to the bus. Figure 14 is an example of a pedestrian within the work zone; pedestrians were primarily traveling to and from the bus stop crossing through the work zone instead of using the cross walk and sidewalk from the light at the intersection at W. T. Harris.

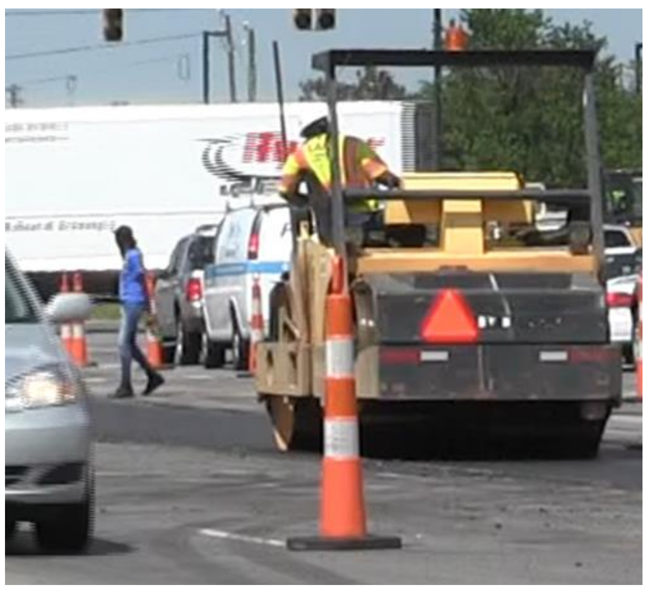

FIGURE 14: Pedestrian in the work zone example

Drivers were observed entering the work zone on multiple occasions, one vehicle (Figure 15) made a collision with a construction cone which got stuck under the front bumper of the vehicle, and the driver is seen to be removing the construction cone. Figure

16 shows two examples of work zone intrusion incidents, both occurred in close proximity to construction workers.

The motorist in the white vehicle in Figure 16 turned onto North Tryon St. and entered the work zone in close proximity to some construction workers working within the median. The motorist then proceeded to travel down the lane closure before moving to the travel lane and driving over the sensor where the motorist was identified to be having a conversation on the phone by the researchers. Meanwhile the driver of the black vehicle was traveling in the northbound direction and intentionally crossed directly behind a construction worker.

FIGURE 15: Turning collision with TTC at Case Study 1

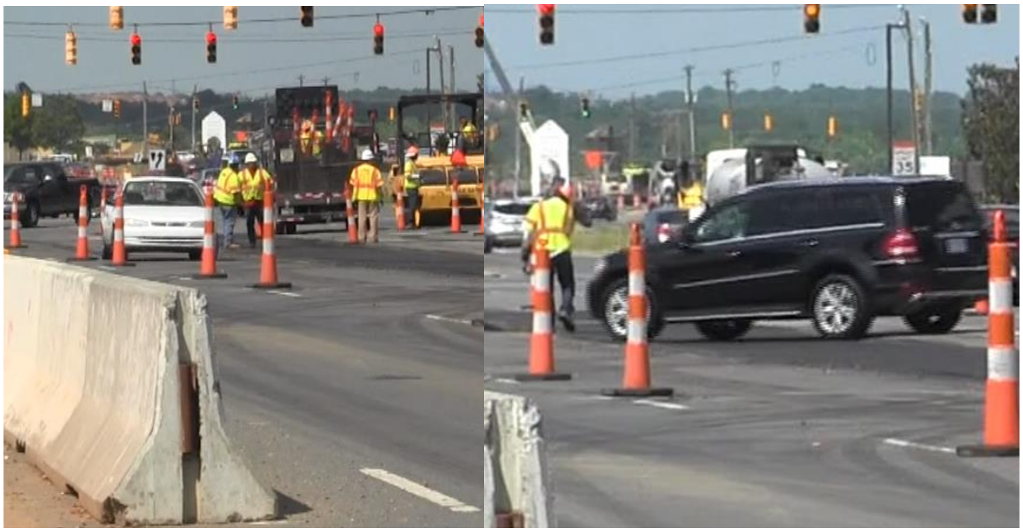

FIGURE 16: Motorist intrusion examples

4.2: CASE STUDY 2 – North Tryon North of McCullough Dr.

This investigation of North Tryon St. occurred north of McCullough Dr. on June 12, 2015. The investigation took place between 11:00 am and 1:00 pm and a total of 1800 usable data points were collected from motorists traveling in the north bound lanes. At this location North Tryon St. is a two lane divided highway separated by a concrete median. The site shown in Figure 17 featured a single lane closure of the left hand lane, where a construction taper was located to direct U-turn and turning traffic. An additional construction taper was located on the right hand side of the roadway to direct turning traffic as well. The work crew (Figure 18) consisted mainly of drivers and operators of heavy earth moving equipment, along with several laborers. The type of work performed by the work crew was consistent with the following activities, removal of the concrete median, and preparation of the sub soil, compaction of the sub soil, and subsequent placement and asphalt compaction.

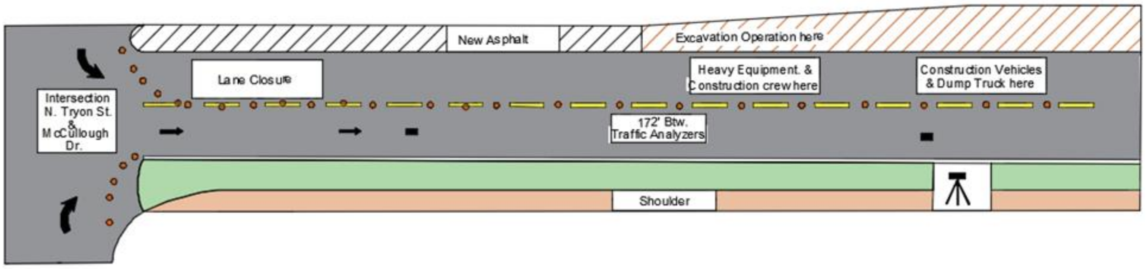

FIGURE 17: Case Study 2 - N. Tryon at McCullough Dr.

FIGURE 18: Location of work crew Case Study 2

The researchers were able to place two portable traffic analyzers within the lane closure between traffic signals at a distance of 172 ft. apart. The traffic analyzers were strategically placed to avoid the queuing and back up of traffic from the upstream traffic light. The first traffic analyzer was placed approximately 100 to 120 ft. away from the intersection of McCullough Dr. so traffic would have the needed time to accelerate to a cruising speed. The video camera was placed within view of the second traffic analyzer, and recorded motorists passing between the researchers and the work crew. Figure 19 shows the camera view of the second traffic analyzer and the work crew placing and compacting an asphalt pavement section. The posted work zone speed was 35 MPH, but motorists were observed to be distracted, and driving in excess of this speed limit in some instances. There were two instances where a motorist passed very close to the researchers while driving at high speeds. The workers were observed to cross lanes and move into lanes of traffic from the lane closure, as well as be distracted by using cell phones, in close proximity to heavy equipment.

FIGURE 19: Camera view Case Study 2

FIGURE 20: Progression of work Case Study 2

Figure 20 shows the work crew waiting on the arrival of the hot mix asphalt; a construction supervisor is overseeing the work activities of the equipment operators and laborers. A safety concern which was observed in the “5 minute survey” showed distraction at the work place where a construction worker was using a cell phone, this is a potentially dangerous activity in a lane closure, due the frequency of intrusion accidents into work zones. As seen in Case Study 1, multiple vehicles entered the work zone; some may have been accidental intrusions because of confusion of the work zone but others where intentional where drivers completely disregarded the work zone. This is very dangerous behavior displayed by the motorists, because construction workers are focused on work related tasks, and an intrusion of any kind increases the likely hood of an accident between a vehicle and a construction worker to increase.

4.3: Case Study 3 – North Tryon St. and JW Clay Intersection

This investigation of North Tryon St. occurred between the intersections of J.M. Keynes Dr. and J.W. Clay Blvd. on June 26, 2015. The researchers investigated the site between 11:00 am and 2:00 pm and a total of 1600 usable data points were collected from motorists traveling in the north bound lanes. At this location, North Tryon St. is a two lane divided highway separated by a concrete median, with a double turning lane to J.W. Clay Blvd. The site featured a single lane closure of the right hand lane, which was used as a buffer space for grading and earthwork activities on the right shoulder. A construction crew which consisted mainly of equipment operators was using heavy civil earth moving equipment on the shoulder of the roadway. Periodically throughout the site observation dump trucks would enter the lane closure and dump fill material for grading and compaction activities. Along with the dump trucks construction vehicles entered the lane closure periodically. Examples of earthwork activities are shown in Figures 21 and 22.

FIGURE 21: Equipment operating at Case Study 3

FIGURE 22: Earth work operation Case Study 3

The site allowed for two traffic analyzers to be placed, the first was approximately 250 ft. from the traffic signal at J. M Keynes Dr. and the second was just south of the intersection of J.W Clay, which was located 377 ft. away from the first. Once again the second sensor was placed at a strategic distance away from the downstream traffic signal to avoid capturing data of stopped vehicles backed up from the traffic light. The camera was placed inside the buffer space on the right hand side of the roadway, and was aimed at the second traffic analyzer, as shown in Figure 23.

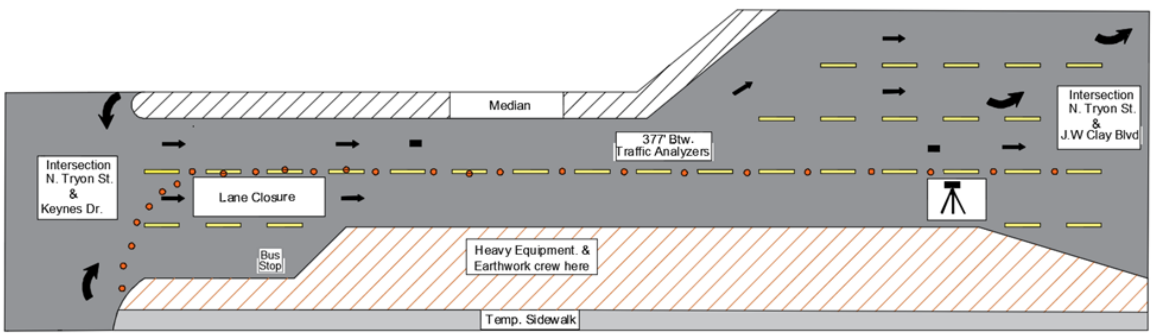

FIGURE 23: Case Study 3 - N. Tryon at J.W. Clay Blvd.

This site was challenging to obtain usable data because distracted drivers were observed to be using the turning lanes, and sometimes avoided the traffic analyzer because space allowed for traffic to merge slightly over avoiding work zone activities. Again, there was a bus stop within the lane closure, which affected the quality of the obtained data, as traffic backed up behind a stopped bus. The slow moving traffic data obtained by the traffic analyzers after a bus stopped in the roadway were omitted from the study. However, similar to Case Study 1 drivers were observed to be using cell phones, in slow and stopped traffic behind buses.

Two additional observations that affected the quality of the data from this site came from a minor accident at the intersection of J.W. Clay Blvd. (Figure 24) and blasting activities downstream of the site observation for a tunnel excavation. Due to the blasting activities downstream of the site observation traffic was stopped completely for a period of 25 to 35 minutes.

FIGURE 24: Observed accident at Case Study 3

Similarly with previous case studies pedestrians were seen to be moving into lanes of traffic and walking through the lane closure. Pedestrians were primarily traveling to and from the bus stop crossing through the work zone instead of using the cross walk and sidewalk from the light at the intersection.

4.4: Case Study 4 – North Tryon St. north of Sandy Ave.

This investigation of North Tryon St. occurred north of the intersection of Sandy Ave. on June 30, 2015. The researchers investigated the site between 11:00 am and 1:30 pm and a total of 2600 usable data points were collected from motorists traveling in the north bound lanes. As shown in Figure 25, North Tryon St. is a two lane divided highway separated by a grass median.

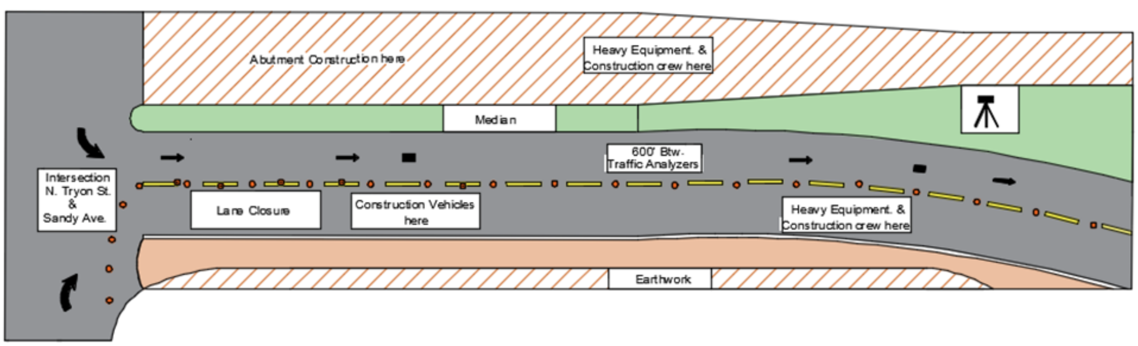

FIGURE 25: Case Study 4 - N. Tryon St. North of Sandy Ave.

However, construction has transformed what used to be a grass median into an abutment for the construction of the light rail system. The site featured a single lane closure of the right hand lane, which was used as a buffer space for grading and earthwork activities on the right shoulder. A construction crew which consisted mainly of heavy civil equipment operators and a cleanup crew were located in this area. Within the median construction workers and equipment were working within the retaining wall, compacting fill material. Dump trucks were entering the median just north of the camera location in Figure 25, and delivering fill material. Periodically in addition to dump trucks, construction vehicles were entering the lane closure on the right hand side of the roadway where earth work operations were located.

Figure 26 shows an excavator relocating a sewer line, and the work operations of the site with relation to the travel space where a motorist is seen to be travelling past an excavator and dump truck. The first traffic analyzer was placed 145 feet north from the intersection of Sandy Ave. and was 600 ft. from the second traffic analyzer. The camera was placed in the median, as shown in Figure 25. However, there was an observed adverse effect of having the camera in this location. The drivers passing over the second traffic analyzer had a clear view of the camera which may have affected the number of observed motorists who were distracted in this location.

FIGURE 26: Description of work Case Study 4

Figure 27 shows the view of the roadway from the camera location, the traffic analyzer can just be made out in the foreground of the figure in the roadway. The work zone speed limit of 35 MPH was posted near to the intersection of Sandy Ave. but drivers were observed to be speeding, in excess to the posted speed limit, displaying high speeds close to the work zone. Additionally, drivers were observed to be displaying distracted driving behavior, while passing through the lane closure. Also, workers were observed to be distracted by using cell phones while heavy equipment was operating in close proximity. As described earlier, this site had a number of dump trucks entering the median for fill operations, which slowed traffic behind, sometimes making traffic come to a complete stop. A large number of drivers were observed to be using cell phones in stopped traffic or slow moving traffic behind dump trucks. Again, data measurements that were of slow or stopped traffic were omitted and not used in the speed comparisons.

FIGURE 27: Camera view Case Study 4

CHAPTER 5: ANALYSIS

5.1: Data Cleaning

Once the data was retrieved using the Highway Data Management program, it was exported into Microsoft Excel for analysis. As shown in Table 5, the raw data included the Time, Traffic Count, Vehicle Speed, Length, Headway, Gap between vehicles, and an Advice Code. The column of Time came from the traffic analyzer, and the Video Time was calculated to be the difference in Time and the Constant. This column was added to the Microsoft Excel spreadsheet so that the video time stamp could be matched precisely to the time of the data point from the traffic analyzer. The constant was typically the difference in time from when the video camera was started, and the time from the traffic analyzer. Usually the video camera was started a few minutes prior to the programed start time of the traffic analyzer as a precaution. Other columns that were added to the original data included Distraction, Type, Remark, and Approve. The distraction column was for yes or no answers from the video analysis where 0 = no, and 1 = yes. The Type column was for the identified distraction from the code reference sheet, examples of distraction are phone, text, and read from the code reference sheet. The remark column was used to note observations from the video, such as start time and end time, reasons for advice codes, and comments of aggressive driving behavior or other observations from video. The approved column was for binary numbers to keep or reject data points for the data analysis, 1 = accept, and 0 = reject.

TABLE 5: Data cleaning Example

Time	Gap	Constant	Video Time	Advice Code	Speed	Length	Headway	Distracted	Type	Remarks	Approve
11:00:02 AM	0	11:55:22 AM	11:04:40 PM	2	24	17	0	0			1
11:00:04 AM	2	11:55:22 PM	11:04:42 AM	2	23	16	67	0			1
11:00:05 AM	1	11:55:22 AM	11:04:43 PM	2	25	14	37	1	Phone		1
11:00:08 AM	3	11:55:22 PM	11:04:46 AM	2	25	19	110	0			1
11:00:10 AM	2	11:55:22 AM	11:04:48 PM	2	22	21	65	0			1
11:00:37 AM	27	11:55:22 PM	11:05:15 AM	2	48	16	1901	0			1
11:00:41 AM	4	11:55:22 AM	11:05:19 PM	2	49	24	287	0			1
11:00:43 AM	2	11:55:22 PM	11:05:21 AM	2	44	18	129	0			1
11:00:49 AM	6	11:55:22 AM	11:05:27 PM	2	43	15	378	0			1
11:00:58 AM	9	11:55:22 PM	11:05:36 AM	2	31	65	409	0			1
11:01:03 AM	5	11:55:22 AM	11:05:41 PM	2	34	18	249	0			1
11:01:21 AM	18	11:55:22 PM	11:05:59 AM	2	22	14	581	1	Phone		1
11:01:33 AM	12	11:55:22 AM	11:06:11 PM	2	39	17	686	1	Phone		1
11:01:34 AM	1	11:55:22 PM	11:06:12 AM	2	36	16	53	0			1

For the data analysis of each case study, every vehicle recorded on video was matched to the corresponding data point from the traffic analyzer. It was necessary to match each speed data point from the traffic analyzer, to not only determine which vehicles had distracted drivers, but also to target free flowing traffic.

Each data point included an advice code from the traffic analyzer of 2, 4, or 128. The meaning of the advice codes from the manufacture were sometimes contradictory compared to what was observed on video. The advice code of 2 is for a good data reading; advice code 4 was for a data point where the traffic analyzer detected the vehicle going in the opposite or backward direction, this was never the case; and advice code 128 was determined to be unreadable. From the obtained video data, vehicles which were lifted and had a taller clearance from the roadway surface produced an advice code of 4. Other instances of this advice code arose when a vehicle hit with a wheel or passed close to the traffic analyzer instead of passing over the center. Instances when the traffic analyzer produced an advice code of 128 were observed to occur when the traffic analyzer could not determine the vehicle length, or gap time. The obtained video data showed that the advice code of 128 was produced when a pick-up truck was pulling a trailer, or when the gap time was zero. Instances where the gap time was zero, occurred when the following vehicle was driving extremely close to the vehicle in front of it, or for large truck and trailers such as eighteen wheelers, and when traffic was at a standstill.

Once the data obtained from the traffic sensors was paired with the video data, the researcher was able to identify which vehicles were distracted, what the speed of the motorist was, and what distracted behavior the driver was performing. The data was then cleaned to exclude all data points that had the advice code of 128, and were given a binary number of “0” to be removed. Additional screening of the data filtered the vehicles with the largest speeds, and slowest speeds, which was cross referenced back to the video. The data points were then compared back to the video to determine if the vehicle speed matched the recorded speed, and to the other vehicles, data points around it to determine if the recorded data point had a reasonable speed. If the data point was unacceptable it would receive a binary number of “0” and was also removed. Data points which were accepted were given a binary number of “1” and were kept for the analysis. Data points with the advice code of 2 were given a binary number of “1” unless proved to be unreasonable in the cross checking process of the video. Data points with the advice code of 4 were also given a binary number of “1” because no vehicles were traveling in the opposite direction of traffic, and the reasons for these codes were explained by the video analysis. Data points that were determined to be unreasonable for excessive speed or lack of speed compared to data points around the one in question were again given a binary number of “0” and removed.

5.2: Initial Comparison of Data

The study consisted of four case studies which collected numerous driver speeds, typically a range from 600 to 2000 useable data points were collected at each location. The statistical software program Minitab 17 was used for the data analysis of the study, which had the capability of separating and pooling distracted and non - distracted drivers. This allowed for a comparison of the data to be performed on an individual case study basis and by driver behavior.

TABLE 6: Initial comparison of speeds

N. Tryon St. Charlotte NC	Case Study 1		Case Study 2		Case Study 3		Case Study 4	
	Non - Dist.	Dist.	Non - Dist.	Dist.	Non - Dist.	Dist.	Non - Dist.	Dist.
Mean	22.13	22.07	30.68	30.14	31.64	31.45	31.02	30.65
S.D	4.96	4.86	6.84	7.1	6.07	6.3	6.59	6.54
D.F	212		429		362		329	
Est. Difference	0.064		0.543		0.199		0.373	
95% CI for Difference	(-0.866, 0.995)		(-0.353, 1.440)		(-0.692,1.089)		(-0.495, 1.242)	
T - Value	0.14		1.19		0.44		0.85	
P - Value	0.892		0.234		0.661		0.398	

Using descriptive statistics an initial comparison of the case studies, provided as Table 6, was developed to describe the data. The columns of “Non – Dist.” refers to non – distracted drivers, while “Dist.” refers to drivers who were identified to be distracted. The percentages of observed distracted drivers were roughly 20% for the first three case studies. This finding can be compared to Singh’s (2010) conclusions of the NMVCCS which found that work zones experienced 12.4% of the drivers to be distracted by at least one internal source of distraction. This is almost identical with Case Study 4 where the observed number of distracted drivers was 12.6%. However, the average of observed distracted drivers is considerably less than the previous three case studies. This was determined to be the cause of the video camera location. Case Study 4 required the placement of the video camera to be in the median, and was slightly elevated above the roadway. It is suspected that drivers observed the video camera and did not continue in distracted driving behaviors which may have been the case prior to spotting the video camera.

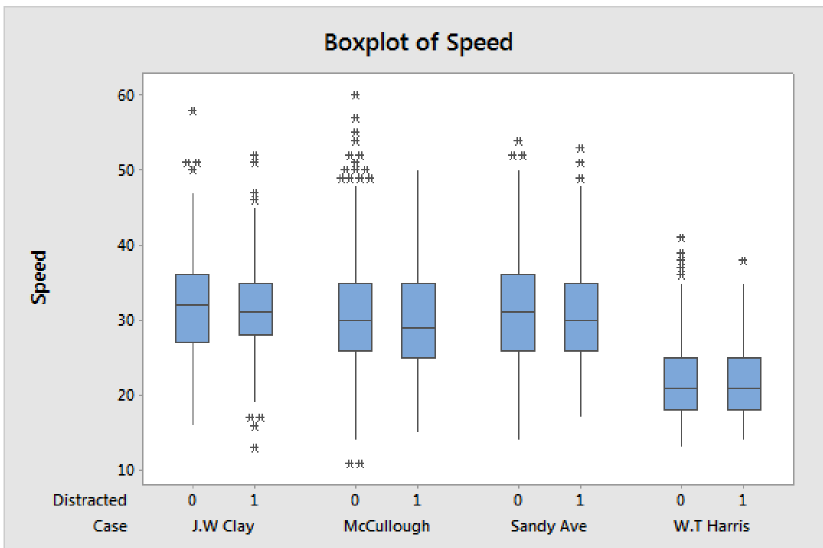

FIGURE 28: Description of Case Study data box plots

The observed speed data from each of the case study locations can be referenced in the box plot of Figure 28. All of the studies for distracted (1) and non – distracted (0) drivers have a number of outliers; these outliers were identified by video analysis to be accurate, and accepted in the cross referencing process between the video and data points around the point in question. These points should not be treated as outliers, errors in the data, or discarded because each point shows a driver driving well above, or below the speed limit for either (Distracted = 1) or (Non – distracted = 0). Unfortunately, there were not enough observed speeding incidents to significantly prove that distracted driver speeds were different than the speeds of non – distracted drivers. Distracted driver speeds showed minor differences in standard deviation as is observed in Table 6.

5.3: Statistical Analysis

After the data had been cleaned the individual case studies were evaluated separately using the statistical software Minitab 17 to analyze the data. The data was separated to pool drivers who were distracted and drivers who were non-distracted. This made eight groups of observed speeds for analysis, two for each of the four case studies.

TABLE 7: Descriptive Statistics for Case Study data

Case Study	Distraction	N	S.D	Variance	95% CI for S.D	Ratio of S.D	Ratio of Variances
1	Non - Distracted	509	4.959	24.591	(4.654, 5.304)	1.025	1.052
	Distracted	134	4.836	23.386	(4.267, 5.562)		
2	Non - Distracted	1272	6.842	46.82	(6.559, 7.149)	0.963	0.928
	Distracted	295	7.104	50.474	(6.625, 7.670)		
3	Non - Distracted	928	6.071	36.859	(5.805, 6.363)	0.964	0.929
	Distracted	240	6.3	39.687	(5.724, 6.991)		
4	Non - Distracted	1741	6.595	43.493	(6.401, 6.803)	1.008	1.016
	Distracted	252	6.543	42.81	(5.994, 7.198)		

Descriptive statistics provided as Table 7, for the datasets of observed speed data allowed for the visualization and quality of the data set to be determined, which included standard deviation, and a 95% confidence interval for the individual datasets. Ultimately, a two sample t- test and confidence interval was determined; the case study data did in fact not need to be normal based on the central limit theorem. Primarily, the case study data was skewed from a range of observed driver speeds, however the central limit theorem allows large sample sizes to be tested using methods that are typically for normally distributed data. (Devore, 2012).

CHAPTER 6: CASE STUDY RESULTS

A comparison of observed speed values between the pooled drivers of distracted and non – distracted resulted in an unexpected result. It was hypothesized that distracted drivers would have a greater variability in speeds compared to non – distracted drivers, due to the substantial amount of distracted driving accident statistics, and in particular the identification of speeding by numerous studies (Rescot et. al 2010, Debnath et. al 2014, Porter et. al 2008, Hendricks et. al 2001, Klauer et. al 2006, Bryden, 1998). The variability in driver speeds between distracted and non – distracted drivers was expected to show a difference for mean speeds of distracted drivers. However, this was not the obtained result as the case study data failed to reject the null hypothesis. After the initial comparison of descriptive statistics was completed, the pooled data for each of the case studies was statistically tested with the following hypothesis and significance level:

Null Hypothesis	Ho: μ (Non - Distracted) - μ (Distracted) = 0
Alternative Hypothesis	Ha: μ (Non - Distracted) - μ (Distracted) $\neq$ 0
α level:	0.05

TABLE 8: Case Study results

N. Tryon St. Charlotte NC	Case Study 1		Case Study 2		Case Study 3		Case Study 4	
	Non - Dist.	Dist.	Non - Dist.	Dist.	Non - Dist.	Dist.	Non - Dist.	Dist.
Mean	22.13	22.07	30.68	30.14	31.64	31.45	31.02	30.65
S.D	4.96	4.86	6.84	7.1	6.07	6.3	6.59	6.54
D.F	212		429		362		329	
Est. Difference	0.064		0.543		0.199		0.373	
95% CI for Difference	(-0.866, 0.995)		(-0.353, 1.440)		(-0.692,1.089)		(-0.495, 1.242)	
T - Value	0.14		1.19		0.44		0.85	
P - Value	0.892		0.234		0.661		0.398	

As provided in Table 8, the results of the two sample equivalence test, which tested speed versus distraction for both distracted and non – distracted drivers at each of the case study locations can be found. The result for each of the case studies are stated as, using the significance level of 0.05, it can be said that the null hypothesis was failed to be rejected, because there was not enough evidence to reject the hypothesis for any of the observed case study locations. Therefore, there is no significant difference in distracted or non – distracted driver speeds.

The sample of distracted and non - distracted drivers obtained from case study locations was also tested for variance of the sample. A two sample variance test of speed versus distracted, was completed using the following test hypothesis and significance level.

Null Hypothesis Ho: $\sigma\ (0)/\sigma\ (1) = 1$

Alternative Hypothesis Ha: $\sigma\ (0)/\sigma\ (1) \neq 1$

Significance Level $\alpha = 0.05$

The results of the Levene variance hypothesis testing as provided in Table 9 below, show that the case study data for each case study location fails to reject the null hypothesis, because there is not sufficient evidence to do so. Therefore, there is no significant variance in distracted and non – distracted driver speeds in the obtained case study data.

TABLE 9: Sample variance and confidence interval

95% Confidence Intervals				
Case Study	S.D Ratio	Variance Ratio	Test Statistic	P - Value
1	(0.895, 1.213)	(0.802, 1.472)	0.37	0.541
2	(0.842, 1.024)	(0.709, 1.048)	2.14	0.144
3	(0.889, 1.104)	(0.791, 1.219)	0.01	0.913
4	(0.915, 1.111)	(0.837, 1.235)	0.06	0.811

6.1: Survey Results

The case study observations from the "5 minute" observation site survey, include worker, motorist, and pedestrian safety hazard information, no environmental hazards were noted in any of the observation periods. The observed results from the "5 Minute survey" taken during the investigations include some of the following hazards:

- Construction vehicles and workers moving in and out of the work area into lanes of traffic.
- Workers using cell phones
- Heavy equipment operating within the site
- Pedestrians inside the work zone not using the provided temporary side walk
- High vehicle speeds of motorists within the work zone.
- High vehicle speeds of motorists while texting and talking on the phone within the work zone
- Observed distracted driving behavior from motorists

Construction workers were observed to leave the lane closure and cross active travel lanes during construction activities. This activity happens frequently during road construction; however it is a safety hazard to workers because it increases the chances of a construction worker being struck by a vehicle. Additionally, construction workers were observed to partake in using mobile devices, typically cell phones at a number of case study locations.

Pedestrians were observed to create safety hazards by entering the work zone or be within the work zone because of work zone characteristics, which included a temporary sidewalk. Work zones that provided a temporary sidewalk for pedestrians, did so to provide an egress that was safe for pedestrians to use. However, at numerous case study locations pedestrians were observed to not use the provided sidewalks or use pedestrian crossings at intersections. Pedestrians were observed to enter the work zone on multiple occasions, primarily crossing the work zone to get to a bus stop. This is a safety hazard because pedestrians are entering an active construction work space where heavy equipment was operating, and not wearing required PPE. Additionally, pedestrians were crossing lanes of traffic, increasing the chances for there to be a vehicle collision or being run over by operating heavy equipment.

Motorists were observed to be engaged in distracted driving behaviors at every case study location. (One motorist was even observed in Case Study 1 to have a collision with TTC devices). Other motorists were observed to drive with excessively high speeds close to the work zone, such as in Case Study 2, and 4. Additionally, motorists were observed to have many near miss accidents within stop and go traffic conditions within the work zone, this may be due to the high number of observed drivers who partake in using mobile devices, typically cell phones, and other distracted driving behaviors.

Table 10 summarizes the results of the gathered information from the brief worker surveys collected at the various case study locations. Unfortunately brief worker surveys were limited but the results are important to document because worker perceptions are valuable to work place safety. The primary challenge associated with the type of work regardless of worker job description, was related to traffic conditions. This came mainly from the heavy traffic volume in urban areas, driver behaviors with safety concerns of work zone set up, and driver reactions while performing work tasks. Workers primarily felt safe at work and felt protected by following rules and regulations. Additionally, workers relied on personal safety measures by keeping focused while in the work zone, and being vigilant for motorists entering the work zone. Safety concerns associated with work zone management came from a supervisory role, which included concerns with crew complacency and work zone design. All construction workers identified distracted driving behavior by motorists, some recalled accidents between vehicles and TTC, equipment, and construction workers.

TABLE 10: Brief worker survey results

Employee Position	**Challenges of Work**	**Challenges of Urban Environment**	**Safety Concerns**	**Observations of Distracted Motorists**
Flagger	Heavy Traffic	Traffic Volumes > Avg. Traffic Specific to Rush hour times (Lunch, Work Commutes)	**No Concerns** Follow safety rules Regulations Stay focused	**N/A**
Flagger	No	Heavy Traffic	Normally Safe	**(Yes)** High speeds Using cell phones & other Technology Eating Reading Observed near miss accidents
Driver	Driver Reactions	Heavy Traffic	**No Concerns**	**(Yes)** High speeds Using cell phones & other technology Eating Reading Disregard of work Zone signage Observed vehicular accidents with TTC
Grade Foreman	Advanced Warning Set up safety – not a large delineation of traffic	**Motorist Factors** Lower speeds Illegal U – turns Disobey Traffic lanes Many Stops and need for turns	**Concerns of Subordinate safety** Complacency of crew Work Zones with cones are not completely sufficient not completely sufficient (Creates Longitudinal Limitations)	**(Yes)** High speeds Using cell phones & other technology Eating Reading Disregard of work Zone signage Observed vehicular accidents with TTC Other: Applying make up

CHAPTER 7: NORTH CAROLINA WORK ZONE ACCIDENT COMPARISION

The North Carolina Department of Transportation (NCDOT) was requested to provide information on fatal and non – fatal accidents around work zones, to gather current statistics on accidents in urban and rural areas. Accidents were reported in sufficient detail and included a measure of incident severity. Accident severity information may provide insight into realistic accident counts, and the severity of accidents occurring in maintenance and construction zones. Accidents occurring in work zones may include non-motorists involvement, such as pedestrians or construction and maintenance workers. Accidents including non-motorists have the potential to result in a permanent disability or fatality, making accidents of this nature to have greater severity for non - motorists. In 2012, 4,743 pedestrians were killed in traffic related traffic crashes in the U.S. (NHTSA, 2014) and pedestrians are 1.5 times more likely than passenger vehicle occupants to be killed in a vehicle accident (Beck et al., 2007). The accuracy of the obtained data from NCDOT is dependent on the accident field report, filed with the NCDOT by the reporting highway patrol officers. This data is used to evaluate potential trends in accidents for short term construction and maintenance zones

7.1: Description of North Carolina Data

Accident data pertaining to North Carolina located in the FARS database (FARS 2014) is limited and insufficient when considering accidents that occurred in work zones. The data that can be accessed from the FARS database only includes accidents where a fatality occurred. Although fatal accidents are of interest to the study, the total amount of accidents occurring in work zones was hard to grasp, using only the FARS database. Therefore, accident data was requested from the North Carolina Department of Motor Vehicles (NCDMV 2013). The requested criteria of interest to the study included:

- Geographical location
- Location of the crash in regards to the work zone location
- Cause of the crash
- Severity of the accident
- Work zone activity or inactivity
- Motorist activity prior to the accident
- Non-motorist activity prior to the accident

The data was analyzed using Microsoft Excel, to sort and filter the provided accident reports. The obtained accident report data described geographical location by the percent developed, in the classifications of Rural (<30% Developed), Mixed (30% to 70% Developed), and Urban (>70% Developed). Primarily, the study is focused on urban environments; however mixed environments make up a large portion of urban environments being 30 to 70% developed, thus were included in the data analysis. Rural environments were included in the data analysis as a comparison to determine the percent of accidents occurring outside of urban areas.

In North Carolina a total of 16,925 accidents occurred between 2009 and 2013 within, and in the proximity of work zones. Table 11 below, compares the location of the accident to the activity of the work zone. The number of accidents for the years of 2009 to 2011 was approximately 2.3 times less compared to the number of accidents in 2012 during which 5,897 accidents were recorded, totaling 34.84% of all accidents for the time period. Accidents were found to occur 61.46% of the time when there was apparent ongoing work, compared to work zones with no apparent work at 38.54%. Accidents occurred most regularly in urban, followed by rural, and mixed locations; totaling 47.50% of all accidents which occurred in work zones. Rural locations recorded 36.50%, and mixed locations recorded 16.00% of the total accidents.

TABLE 11: Area location vs. work zone activity

Year	Location	Accidents	Activity			
			Yes	No	% Yes	% No
2009	Rural	913	496	417	23.54%	19.79%
	Mixed	348	195	151	9.25%	7.17%
	Urban	846	485	361	23.02%	17.13%
	Sub Total	**2107**	**1176**	**929**	**55.81%**	**44.09%**
2010	Rural	1119	707	412	25.94%	15.12%
	Mixed	454	279	173	10.24%	6.35%
	Urban	1152	711	441	26.09%	16.18%
	Sub Total	**2725**	**1697**	**1026**	**62.28%**	**37.65%**
2011	Rural	988	626	362	22.69%	13.12%
	Mixed	486	278	206	10.08%	7.47%
	Urban	1285	749	536	27.15%	19.43%
	Sub Total	**2759**	**1653**	**1104**	**59.91%**	**40.01%**
2012	Rural	2123	1357	766	23.01%	12.99%
	Mixed	664	380	282	6.44%	4.78%
	Urban	3110	1986	1124	33.68%	19.06%
	Sub Total	**5897**	**3723**	**2172**	**63.13%**	**36.83%**
2013	Rural	1036	659	377	19.17%	10.97%
	Mixed	755	473	280	13.76%	8.15%
	Urban	1646	1020	625	29.68%	18.18%
	Sub Total	**3437**	**2152**	**1282**	**62.61%**	**37.30%**
Total		**16925**	**10401**	**6513**	**61.45%**	**38.48%**

Table 12 below, compares the activity of urban area work zones, to the location of the accident in relation to the work zone. A total of 8,039 accidents, approximately 47.50% of all accidents occurred within, and in proximity to work zones in urban areas; with 44.05% occurring adjacent to the work area, 34.13% in the work area approach taper, and 21.82% before the work area.

TABLE 12: Urban activity vs. accident location

Urban		Location			Location %			Total	
Year	Activity	Adjacent	In Taper	Before	Adjacent	In Taper	Before		
2009	On Going	206	167	112	24.35%	19.74%	13.24%	57.33%	485
	Not	204	110	47	24.11%	13.00%	5.56%	42.67%	361
	Sub Total	**410**	**277**	**159**	**48.46%**	**32.74%**	**18.79%**	**100.00%**	**846**
2010	On Going	248	265	198	21.53%	23.00%	17.19%	61.72%	711
	Not	208	149	84	18.06%	12.93%	7.29%	38.28%	441
	Sub Total	**456**	**414**	**282**	**39.58%**	**35.94%**	**24.48%**	**100.00%**	**1152**
2011	On Going	278	279	192	21.63%	21.71%	14.94%	58.29%	749
	Not	268	170	98	20.86%	13.23%	7.63%	41.71%	536
	Sub Total	**546**	**449**	**290**	**42.49%**	**34.94%**	**22.57%**	**100.00%**	**1285**
2012	On Going	811	700	475	26.08%	22.51%	15.27%	63.86%	1986
	Not	562	363	199	18.07%	11.67%	6.40%	36.14%	1124
	Sub Total	**1373**	**1063**	**674**	**44.15%**	**34.18%**	**21.67%**	**100.00%**	**3110**
2013	On Going	438	345	238	5.45%	4.29%	2.96%	12.70%	1021
	Not	318	196	111	3.96%	2.44%	1.38%	7.77%	625
	Sub Total	**756**	**541**	**349**	**9.40%**	**6.73%**	**4.34%**	**20.48%**	**1646**
Total		**3541**	**2744**	**1754**	**44.05%**	**34.13%**	**21.82%**	**100.00%**	**8039**

TABLE 13: Urban area totals

Urban	Adjacent	In Taper	Before	Adjacent	In Taper	Before	Total	
On Going	1981	1756	1215	24.64%	21.84%	15.11%	**4952**	29.26%
Not	1560	988	539	19.41%	12.29%	6.70%	**3087**	18.24%
Total	**3541**	**2744**	**1754**	**20.92%**	**16.21%**	**10.36%**	**8039**	47.50%

Table 13 shows the majority of accidents occurred in on-going work zones, 29.26% of accidents occurred within, and in proximity to work zones in urban areas. Urban area accidents within work zones, occurred 24.64% of the time adjacent to the work space, and 21.84% in the work area approach taper for work zones with ongoing activities. Accidents occurring adjacent to the work zone are often collisions with construction vehicles, equipment, workers, and pedestrians within the work zone (Bryden et al. 1998). Urban area accidents which were located within work zones, adjacent to the work space resulted in 20.93% of the recorded accidents from 2009 to 2013.

TABLE 14: Rural activity vs. accident location

Rural		Location			Location %			Total	
Year	Activity	Adjacent	In Taper	Before	Adjacent	In Taper	Before		
2009	On Going	166	194	136	18.18%	21.25%	14.90%	54.33%	496
	Not	197	152	68	21.58%	16.65%	7.45%	45.67%	417
	Sub Total	**363**	**346**	**204**	**39.76%**	**37.90%**	**22.34%**	**100.00%**	**913**
2010	On Going	218	280	209	19.48%	25.02%	18.68%	63.18%	707
	Not	173	150	89	15.46%	13.40%	7.95%	36.82%	412
	Sub Total	**391**	**430**	**298**	**34.94%**	**38.43%**	**26.63%**	**100.00%**	**1119**
2011	On Going	231	230	165	23.38%	23.28%	16.70%	63.36%	626
	Not	170	139	53	17.21%	14.07%	5.36%	36.64%	362
	Sub Total	**401**	**369**	**218**	**40.59%**	**37.35%**	**22.06%**	**100.00%**	**988**
2012	On Going	546	532	279	25.72%	25.06%	13.14%	63.92%	1357
	Not	396	260	110	18.65%	12.25%	5.18%	36.08%	766
	Sub Total	**942**	**792**	**389**	**44.37%**	**37.31%**	**18.32%**	**100.00%**	**2123**
2013	On Going	256	277	126	24.71%	26.74%	12.16%	63.61%	659
	Not	199	120	58	19.21%	11.58%	5.60%	36.39%	377
	Sub Total	**455**	**397**	**184**	**43.92%**	**38.32%**	**17.76%**	**100.00%**	**1036**
Total		**2552**	**2334**	**1293**	**41.30%**	**37.77%**	**20.93%**	**100.00%**	**6179**

In rural area locations a total of 6,179 accidents, approximately 36.51% of all accidents within, and in proximity to work zones occurred. Table 14 above, compares the activity of rural area work zones, to the location of the accident in relation to the work zone. A total of 41.30% of rural accidents occurred adjacent to the work area, 37.77% in the work area approach taper, and 20.93% before the work area. In 2009, 2011, 2012, and 2013 the majority of all rural accidents occurred adjacent to the work zone, while in 2010 the majority of accidents occurred in the work zone taper.

TABLE 15: Rural area totals

Rural	Adjacent	In Taper	Before	Adjacent	In Taper	Before	Total	
On Going	1417	1513	915	22.93%	24.49%	14.81%	3845	22.72%
Not	1135	821	378	18.37%	13.29%	6.12%	2334	13.79%
Total	**2552**	**2334**	**1293**	**15.08%**	**13.79%**	**7.64%**	**6179**	**36.51%**

Table 15 shows the majority of rural area accidents occurred in on going work zones, approximately 22.72%, of accidents occurred within, and in proximity to work zones. Rural area accidents within work zones, occurred most frequently 24.64% of the time adjacent to the work space, and 21.84% of the time in the work area approach taper for work zones with ongoing activities, between 2009 and 2013.

TABLE 16: Mixed activity vs. accident location

Mixed		Location			Location %			Total	
Year	Activity	Adjacent	In Taper	Before	Adjacent	In Taper	Before		
2009	On Going	81	76	39	23.28%	21.84%	11.21%	56.32%	196
	Not	75	49	28	21.55%	14.08%	8.05%	43.68%	152
	Sub Total	**156**	**125**	**67**	**44.83%**	**35.92%**	**19.25%**	**100.00%**	**348**
2010	On Going	103	115	62	22.69%	25.33%	13.66%	61.67%	280
	Not	85	67	22	18.72%	14.76%	4.85%	38.33%	174
	Sub Total	**188**	**182**	**84**	**41.41%**	**40.09%**	**18.50%**	**100.00%**	**454**
2011	On Going	120	103	56	24.69%	21.19%	11.52%	57.41%	279
	Not	110	59	38	22.63%	12.14%	7.82%	42.59%	207
	Sub Total	**230**	**162**	**94**	**47.33%**	**33.33%**	**19.34%**	**100.00%**	**486**
2012	On Going	173	142	66	26.05%	21.39%	9.94%	57.38%	381
	Not	153	90	40	23.04%	13.55%	6.02%	42.62%	283
	Sub Total	**326**	**232**	**106**	**49.10%**	**34.94%**	**15.96%**	**100.00%**	**664**
2013	On Going	218	182	75	28.87%	24.11%	9.93%	62.91%	475
	Not	149	98	33	19.74%	12.98%	4.37%	37.09%	280
	Sub Total	**367**	**280**	**108**	**48.61%**	**37.09%**	**14.30%**	**100.00%**	**755**
Total		**1267**	**981**	**459**	**46.80%**	**36.24%**	**16.96%**	**100.00%**	**2707**

Above in Table 16, compares the activity of mixed area work zones, to the location of the accident in relation to the work zone. Mixed area work zones recorded 2,356 accidents, approximately 16.00% of all accidents within, and in proximity to work zones. The majority of accidents occurred within work zones, adjacent to the work area between 2009 and 2013. Table 17 shows the majority of accidents occurred in on going work zones, approximately 9.52%, when compared to the total number of accidents from 2009 to 2013. Mixed accidents, occurred most regularly adjacent to the work zone and totaled 25.93%, for work zones with ongoing work. However, mixed environments did not contribute as much to the total number of accidents, when compared to urban or rural environments and made up a small percentage.

TABLE 17: Rural area totals

Mixed	Adjacent	In Taper	Before	Adjacent	In Taper	Before	Total	
On Going	695	618	298	25.67%	22.83%	11.01%	1611	9.52%
Not	572	363	161	21.13%	13.41%	5.95%	1096	6.48%
Total	**1267**	**981**	**459**	**7.49%**	**5.80%**	**2.71%**	**2707**	**16.00%**

Tables 12 through 17 suggest that work zone accidents occur more frequently in active work zones, where ongoing construction activities are present compared to those that have no apparent activity, and the majority of these accidents occur adjacent to, or in the taper with respect to the work zone.

7.2: North Carolina Accident Severity Analysis

The data provided by the NCDOT (NCDMV 2013), was further analyzed to determine if work zone activity had a significant correlation to accident severity for urban and rural locations. The severity scale for accidents provided by the NCDMV can be described by the following accident severity scale, listed in descending order of severity:

- K – Fatality, Most severe accident classification
- A – Disabling Injury, Serious accident for those involved
- B – Imminent Injury, Less severe but considerably damaging to those involved
- C – Possible Injury, Less severe and results in minor injuries
- PDO – Property Damage Only, Less severe costly damage to property/equipment
- UNK – Unknown, least severe, accident circumstances are unknown.

TABLE 18: Urban activity vs. severity

Urban		Severity %						Total	
Year	Activity	K	A	B	C	PDO	UNK		
2009	On Going	0.00%	0.36%	2.14%	15.78%	38.55%	0.36%	57.18%	482
	Not	0.24%	0.24%	3.68%	12.10%	26.22%	0.36%	42.82%	361
	Total	**0.24%**	**0.59%**	**5.81%**	**27.88%**	**64.77%**	**0.71%**	**100.00%**	**846**
2010	On Going	0.37%	0.27%	3.39%	10.71%	43.96%	0.92%	59.62%	651
	Not	0.27%	0.18%	3.21%	9.71%	26.56%	0.46%	40.38%	441
	Total	**0.64%**	**0.46%**	**6.59%**	**20.42%**	**70.51%**	**1.37%**	**100.00%**	**1152**
2011	On Going	0.08%	0.31%	3.35%	15.33%	38.52%	0.70%	58.29%	749
	Not	0.08%	0.16%	2.49%	9.26%	29.26%	0.47%	41.71%	536
	Total	**0.16%**	**0.47%**	**5.84%**	**24.59%**	**67.78%**	**1.17%**	**100.00%**	**1285**
2012	On Going	0.03%	0.19%	3.50%	16.40%	43.18%	0.55%	63.86%	1986
	Not	0.13%	0.10%	2.64%	8.23%	24.41%	0.64%	36.14%	1124
	Total	**0.16%**	**0.29%**	**6.14%**	**24.63%**	**67.59%**	**1.19%**	**100.00%**	**3110**
2013	On Going	0.00%	0.24%	3.22%	15.19%	42.65%	0.73%	62.03%	1021
	Not	0.12%	0.12%	2.19%	9.17%	25.76%	0.61%	37.97%	625
	Total	**0.12%**	**0.36%**	**5.41%**	**24.36%**	**68.41%**	**1.34%**	**100.00%**	**1646**

Tables 18 through 20, show that North Carolina accidents around work zones have fluctuations in the distribution of accident severity between ongoing and no apparent work for work zones between 2009 and 2013. This made it challenging to determine a trend, if any to be established. As a result, no trend was established from looking at the distribution of accident percentages based on the descriptive information of North Carolina work zones accidents alone. Primarily, the most frequent accident type is PDO, 65.49% of accidents resulted in damage to the vehicle only, followed by 24.87% of C type accidents which are minor injury related accidents. Regardless of work zone activity, fatalities (K), and accidents of greater severity such as A and B type accidents do occur.

TABLE 19: Rural activity vs. severity

Rural		Severity %						Total	
Year	Activity	K	A	B	C	PDO	UNK		
2009	On Going	0.55%	0.44%	5.26%	13.36%	34.39%	0.33%	54.33%	496
	Not	0.33%	0.66%	6.02%	11.72%	26.40%	0.55%	45.67%	417
	Total	**0.88%**	**1.10%**	**11.28%**	**25.08%**	**60.79%**	**0.88%**	**100.00%**	**913**
2010	On Going	0.36%	0.36%	4.56%	16.62%	40.93%	0.36%	63.18%	707
	Not	0.54%	0.45%	3.13%	9.03%	23.24%	0.45%	36.82%	412
	Total	**0.89%**	**0.80%**	**7.69%**	**25.65%**	**64.16%**	**0.80%**	**100.00%**	**1119**
2011	On Going	0.40%	0.51%	6.58%	17.81%	37.65%	0.40%	63.36%	626
	Not	0.10%	0.30%	4.05%	7.39%	24.49%	0.30%	36.64%	362
	Total	**0.51%**	**0.81%**	**10.63%**	**25.20%**	**62.15%**	**0.71%**	**100.00%**	**988**
2012	On Going	0.42%	0.71%	4.95%	15.69%	41.64%	0.52%	63.92%	1357
	Not	0.42%	0.47%	4.66%	7.77%	22.04%	0.71%	36.08%	766
	Total	**0.85%**	**1.18%**	**9.61%**	**23.46%**	**63.68%**	**1.22%**	**100.00%**	**2123**
2013	On Going	0.29%	0.48%	4.44%	15.93%	41.99%	0.48%	63.61%	659
	Not	0.39%	0.39%	3.76%	7.05%	24.03%	0.77%	36.39%	377
	Total	**0.68%**	**0.87%**	**8.20%**	**22.97%**	**66.02%**	**1.25%**	**100.00%**	**1036**

TABLE 20: Mixed activity vs. severity

Mixed		Severity %						Total	
Year	Activity	K	A	B	C	PDO	UNK		
2009	On Going	0.00%	0.57%	2.87%	16.67%	35.06%	1.15%	56.32%	196
	Not	0.29%	0.57%	2.59%	9.48%	30.17%	0.57%	43.68%	152
	Total	**0.29%**	**1.15%**	**5.46%**	**26.15%**	**65.23%**	**1.72%**	**100.00%**	**348**
2010	On Going	0.00%	0.66%	4.19%	17.62%	38.55%	0.66%	61.67%	280
	Not	0.44%	0.00%	1.98%	10.35%	25.33%	0.22%	38.33%	174
	Total	**0.44%**	**0.66%**	**6.17%**	**27.97%**	**63.88%**	**0.88%**	**100.00%**	**454**
2011	On Going	0.62%	0.00%	3.29%	14.40%	38.68%	0.41%	57.41%	279
	Not	0.21%	0.00%	4.94%	11.93%	24.49%	1.03%	42.59%	207
	Total	**0.82%**	**0.00%**	**8.23%**	**26.34%**	**63.17%**	**1.44%**	**100.00%**	**486**
2012	On Going	0.15%	0.45%	4.67%	14.16%	37.50%	0.45%	57.38%	381
	Not	0.45%	0.45%	2.56%	10.54%	27.86%	0.75%	42.62%	283
	Total	**0.60%**	**0.90%**	**7.23%**	**24.70%**	**65.36%**	**1.20%**	**100.00%**	**664**
2013	On Going	0.66%	0.13%	4.37%	15.63%	41.85%	0.26%	62.91%	475
	Not	0.00%	0.13%	2.65%	10.46%	22.91%	0.93%	37.09%	280
	Total	**0.66%**	**0.26%**	**7.02%**	**26.09%**	**64.77%**	**1.19%**	**100.00%**	**755**

To determine if accidents which occur in North Carolina work zones have the potential to be more severe, such as K, A, or B, an Ordered 2 x K Contingency analysis was completed. The 2 x K contingency test produces a z – test statistic that will be compared to an alpha (α) of 0.05 for a confidence level of 95% as described by (Le

1998). This test method is suitable for performing an analysis of categorical data, which applies to annual traffic accident reports. Typically, a chi – squared test can be used in this application, however a chi – squared calculation takes no account for the extent of the injury, as it has a natural ordering progression of severity (PDO < C < B < A < K). Therefore, the 2 x K test method was specially developed to detect a trend such as in injury severity (Le 1998).

The 2 x K contingency test method developed by Le (1998) uses the following procedure to detect a natural ordering trend such as in accident severity.

	Column Level				
Row	1	2	…	*k*	Total
1	a_1	a_2	…	a_k	A
2	b_1	b_2	…	b_k	B
Total	n_1	n_2	…	n_k	N

The number of "concordances" is calculated by

$$C = a_1(b_2 + \cdots + b_K) + a_2(b_3 + \cdots + b_k) + \cdots + a_{k-1}b_k.$$

The number of "discordances" is

$$D = b_1(a_2 + \cdots + a_K) + b_2(a_3 + \cdots + a_k) + \cdots + b_{k-1}a_k.$$

The calculation of the statistic is

$$S = C - D$$

Standardize the statistic to obtain

$$z = \frac{S - \mu_s}{\sigma_D}$$

Where $\mu_s = 0$ and the mean of S under the null hypothesis and

$$\sigma_s = \{\frac{AB}{3N(N-1)}[N^3 - n_1^3 - n_2^3 - \cdots - n_k^3]\}^{1/2}$$

The standardized z - score is distributed as standard normal if the null hypothesis is true.

The NCDOT accident data (NCDMV 2013), was again filtered using Microsoft Excel from the original accident reports to useable tables, such as Table 21. This table shows the number of accidents for North Carolina urban environments, which are greater than 70% developed, the activity of the work zone at the time of the accident, and the severity of the accident as reported by the reporting police officer.

TABLE 21: Severity analysis (Urban)

Urban		Severity					
Year	**Activity**	**K**	**A**	**B**	**C**	**PDO**	**UNK**
2009	On Going	0	3	18	133	325	6
	Not	2	2	31	102	221	3
	Total	**2**	**5**	**49**	**235**	**546**	**9**
2010	On Going	4	3	37	177	480	10
	Not	3	2	35	106	290	5
	Total	**7**	**5**	**72**	**283**	**770**	**15**
2011	On Going	1	4	43	197	495	9
	Not	1	2	32	119	376	6
	Total	**2**	**6**	**75**	**316**	**871**	**15**
2012	On Going	1	6	109	510	1343	17
	Not	4	3	82	256	759	20
	Total	**5**	**9**	**191**	**766**	**2102**	**37**
2013	On Going	0	4	53	250	702	12
	Not	2	2	36	151	424	10
	Total	**2**	**6**	**89**	**401**	**1126**	**22**

The 2 x K test was performed using the data as shown in Table 21, and rural accidents (not shown) located in Appendix C for accidents with the severity of K, A, B, and C; unknown accidents were disregarded in the analysis, because of unknown severity of the accident. Urban and rural locations were first tested separately in the following two tests:

- Urban work zone accidents versus work zone activity

- Rural work zone accidents versus work zone activity

Next, an analysis (Table 22) of the severity for accidents located in rural and urban locations around work zones was completed, before the 2 x K contingency test method was applied to establish a trend in accident severity for urban versus rural locations.

TABLE 22: Inputs for Urban vs. Rural accident severity analysis

Urban & Rural		Severity				
Year	**Activity**	**K**	**A**	**B**	**C**	**PDO**
2009	Urban	2	5	49	235	546
	Rural	8	10	103	229	555
	Total	**10**	**15**	**152**	**464**	**1101**
2010	Urban	4	3	37	177	480
	Rural	10	9	86	287	718
	Total	**14**	**12**	**123**	**464**	**1198**
2011	Urban	2	6	75	316	871
	Rural	5	8	105	249	614
	Total	**7**	**14**	**180**	**565**	**1485**
2012	Urban	5	9	191	766	2102
	Rural	18	25	204	498	1352
	Total	**23**	**34**	**395**	**1264**	**3454**
2013	Urban	2	6	89	401	1126
	Rural	7	9	85	238	684
	Total	**9**	**15**	**174**	**639**	**1810**

Using the above inputs from Table 22 and the 2 x K contingency analysis procedure, an example of urban accident severity versus rural accident severity for 2009 is shown in Figure 29. The result of the example shows a significant trend that rural accidents within, and in proximity to work zones result in more severe accidents than in urban locations respectably.

Looking at 2009 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	546	555	1101
C	235	229	464
B	49	103	152
A	5	10	15
K	2	8	10
Total	837	905	1742

Concordances	C=	220457		
Discordances	D=	175070		
Statistic	S= C - D=	45387		
Z statistic	A=	837	sigmaS=	17899.04
	B=	905		
	N=	1742	z=	2.535723
	n1=	1101		
	n2=	464	P value=	0.005611
	n3=	152		
	n4=	15		
	n5=	10		

FIGURE 29: Urban accident severity vs. rural accident Severity

7.3: North Carolina Accident Analysis Results

An analysis of accident severity around North Carolina work zones was needed to validate the study. Ha et. al (1995) concluded that work zone crashes are slightly less severe than crashes that occurred in non-work zones. However, Kopelias (2007) had contradictory conclusions, which stated that the amount and severity of accidents increased as speed limits decreased, proposing that accidents that occur in work zones at lower speed limits have the potential to be more severe than accidents with higher speed limits outside of work zones. Additionally, Reiprich et al. (2010) found that accidents occurred as a result of the work zone and would not have occurred otherwise. The role of distraction in North Carolina accidents around work zones is unknown, however the severity of categorical accidents between urban and rural environments, and work zone activity was determined using an Ordered Two x K Contingency analysis described by Le (1998).

The first analysis completed by the 2 x K test method was work zone activity versus accident severity; both urban and rural environments were tested separately to establish a trend between 2009 and 2013. The results, located in Appendix C for this analysis did not provide conclusive evidence that there was a trend in severity, between accident area and work zone activity, for the accidents located in either rural or urban locations. The only significant finding for rural environments was for 2009, with a P-value of 0.036. Accidents which occurred in 2009 were more severe in work zones with no apparent activity, compared to accidents in work zones with ongoing activity respectively.

The investigation of urban environments, which tested the accident severity of ongoing activity vs. no apparent activity for work zone accidents found two significant findings. In 2012, accidents which occurred in ongoing work zones were found to be significant with a P-value of 0.012, therefore accidents which occurred were more severe than accidents which occurred in work zones with no activity. The second significant finding was in 2009 with a P-value of 0.036. Accidents which occurred in 2009 were of less significance than in 2012, but suggest that accidents in work zones with no apparent activity to be of greater severity than work zones with ongoing activity respectively.

The results provided as Table 23, of the analysis for Urban Severity vs. Rural Severity established a significant trend occurring annually between 2009 and 2013. The trend fluctuated in significance from 2009 until it peaked in 2012, before slightly decreasing in 2013.The trend is significantly supported at the significance level of 0.05, and suggests that a motorist is more likely to be involved in an accident with greater severity within, and in proximity to work zones in rural areas compared to accidents which occur in urban areas.

TABLE 23: 2 x K results urban vs. rural severity

2xK Contingency Test		
Urban Severity vs. Rural Severity		
Year	Z Score	P Value
2009	2.5357	0.0056
2010	18052	0.0245
2011	3.5826	0.0002
2012	3.9582	3.80E-05
2013	1.8965	0.0289

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1: Conclusions

The investigation of the case studies did not prove the hypothesis of the study, distracted drivers speeds did not significantly vary from the speeds of non – distracted drivers. It was observed that in all of the case studies, distracted drivers and non – distracted drivers both had similar speed averages and standard deviations. This finding was not what the researchers initially suspected, in fact based on literature of accidents and distracted driving, it was believed the opposite to be true. However, this finding is of great concern, because it suggests that distracted drivers behave similarly to non – distracted drivers; but when considering literature of distracted driver response times, chances of accident involvement, and accidents specific to the urban environment by distracted drivers, the behavior of distracted drivers is very different.

These findings raise a concern based on the case study observations, many drivers participated in distracted driving behavior, without considering a safe following distance, especially in traffic conditions that were congested or behind buses, and construction vehicles. This increases the potential for accidents or near miss accidents to occur within work zones, because distracted drivers break harder (Bellinger, et. al 2009, Hancock, et. al 2003) and may in turn cause accidents to occur as a consequence.

Additional findings of the study found that in North Carolina, accidents occurred more frequently in urban areas, and in work zones with apparent ongoing activities.

However, despite recording a greater number of accidents within, and in proximity to work zones, urban areas do not record accidents with greater significant severity compared to work zones located in rural environments. This is supported when considering in 2013, 54% of fatalities occurred in rural areas, and 46% occurred in urban areas (NHTSA 2015).

In conclusion distracted driving is a great concern for work zone users, at any given time approximately 20% of motorists were found to be distracted while driving through a work zone. Primarily, this came from drivers participating in distracted driver behavior such as talking on cell phones, and texting and driving. This is a major concern for the construction industry, because it is likely that on a daily basis the number of distracted drivers is greater; which has the potential for accidents and near miss accidents to occur in work zones as a result of distraction. The likelihood that the true number of distracted drivers on average is greater than 20% is likely when considering both distraction from cell phone use, and distraction from secondary tasks (Klauer, et al. 2006) not associated with cell phone use. Construction workers are exposed to work related hazards as well as external factors, such as motorists behaviors and intrusion accidents into TTC, construction vehicles, and equipment (Bryden et al. 1998). It is apparent that there is a need for increased safety in short term work zones, as performing a lane closure is a hazardous activity of any road construction project (Ibarguen 2009), and construction workers are reliant on work zone design. However distracted driving has no engineering solution (Debnath et al. 2015) as errant motorist speed, intentionally disobeying work zone signage, and display aggression towards construction workers. In the United States, phone use is permitted; only 14 states and Washington D.C. banned hand held phone use when driving completely, while 38 states and D.C. have laws that limit phone use by young drivers. Almost all states except Arizona, Missouri, Montana, and Texas, have a ban on texting and driving (GHSA 2015). Therefore stricter enforcement of distracted driving laws and regulations may need to be implemented to deter motorists from driving distracted, and in doing so will improve the safety of construction workers within work zones.

8.2: Recommendations

This study may not have been successful in proving that the speeds of distracted drivers are significantly different from non – distracted drivers, however distracted driving is a danger to all road users. The following are some recommendations drawn from the study to reduce distracted driving, and increase construction worker safety:

- Enforce regulations on mobile devices while driving

The U.S. has regulations in place varying by state, age, license type, and device use, however stricter enforcement of the in place regulations to discourage motorists is needed to reduce the number of distracted drivers.

- Place regulations on hand held use of cell phones

Only 14 states and D.C. have regulations that ban hand held phone use while driving (GHSA 2015). States such as North Carolina allow hand held use, but prohibit texting and driving. Many motorists were engaged in either texting or talking on cell phones while driving. Therefore, the enforceability of these laws and adoption of new laws needs to be recommended to improve safety for all users of the roadway including construction workers.

- Have law enforcement present in work zones

On average approximately 20% of motorist were distracted from Case Study observations. Additionally, motorist's behavior showed instances of speeding, and aggressive driving, as well as complete disregard for the work zone and signage. Studies such as Debnath, Blackman et al (2015) and Levine and Kabat (1984) showed that law enforcement presence improved driver performance, reduced speeding, and aggressive driving instances. An observation from Case study 4 showed that less motorists were observed to be distracted because the video camera was more visible to drivers, suggesting that as the level of supervision increases, drivers are less likely to participate in distracted driving behavior.

8.3: Future Research

This study provided valuable insight into distracted driving, and work zone accidents in North Carolina, however improvements to the study for future research are needed to improve upon the result. Improvements for future research include:

- Exploring options to hide the video camera in a construction cone or barricade.

This would improve the quality of the collected data as motorists would not see the video camera and change their behaviors, theoretically increasing the number of observed distracted drivers at case study locations.

- Improve video and video editing software.

This again would improve the quality of the collected data, as the researchers would not be standing blatantly next to the video camera, and improve the quality of the video data. The improved video quality resulting from improved editing software would allow for a greater video analysis of driver behaviors within work zones.

- Explore improvements to the methodologies and analysis

The current research study was limited to analyzing only one traffic analyzer, by pairing speed and video data. If the methodologies could be altered to include an analysis between two or more traffic analyzers, motorists could be observed more effectively in a case study observation. This would allow for a comparison between the number of distracted drivers as they progressed through the lane closure between work zone locations of before and adjacent.

- Perform case studies at locations on different roadway segments and in work zones with no long term construction.

The current research study was limited to observing work zones located on one construction project. Although the observed lane closures were temporary, construction activities are more consistent with long term construction. A research study focused on utility and maintenance type work zones with truly short durations would be ideal in determining driver interpretation of the work zones.

- Improve upon the brief survey method

The current research study was limited in the number of construction worker surveys; a more adequate measure for obtaining the “sample of convenience” from the brief worker surveys is needed to improve upon the result. Construction worker perceptions are important to improving construction worker safety and should be further studied in the future.

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APPENDIX A: 5 MINUTE SITE SURVEY

Date: ___________________________ Location: _____________________________________

Size of Crew: _____________________ Type of Work: _______________________________

Equipment Used: ____

No.	Time Start	Time end	Hazard?		Hazard type (from list)	Notes
			Yes	No		
1.						
2.						

Hazard type:

Worker Safety Hazard	Motorist Safety Hazard
W1. Worker moving out of work zone and into lanes with traffic W2. Required Flagger not in place W3. Workers not wearing PPE W4. Objects from traffic lanes “fly” into work zone W5. Workers distracted with cell phones and other Devices W6. Heavy equipment operating w/in the site W7. Observed Worker/Equipment accidents	M1. Vehicle moving into work zone M2. Vehicle speeds high close to work zone M3.Vehicle traffic bottlenecks close to work zone M4. Vehicle traffic bottlenecks beyond warning signs M5. Objects from work zone “fly” into traffic lanes M6. Observed distracted drives/Accidents M7. Construction work occurs above travel lanes.
Pedestrian Safety Hazard P1. Pedestrian moving into work zone P2. Sidewalk within work zone P3. No alternative pedestrian access provided	**Environment Safety Hazard** E1. Decreased visibility (fog) E2. Inclement weather E3. Signs and barriers not in place E4. Obstruction of SSD Buildings, corners, medians E5. Work zone restrictive for work type

APPENDIX B: BRIEF WORKER SURVEY

Date: _______________________________ Location of work: _________________________

Crew: _______________________________ Name: _________________________
(optional)

Q1. Employee Position	Q2. What is your average shift time in hours?

Q3. List specific challenges of work zone set up and demobilization
Q4. What would be the biggest challenge of urban work zone construction?
Ex. Tight working quarters, small lane widths, limited ROW, high traffic volume
Q5. What are your own areas of personal safety during work?

Q6. Have you notice/observed distracted drivers traveling adjacent to the work zone? (**Check all that apply)**		
☐ High rate of speed ☐ using their cell phone or other technology	☐ Eating ☐ Reading ☐ Disregard of posted speeds and signage	☐ Vehicular Accidents with equipment, barricade, or workers
☐ Other	*Please explain if Other	

Q7. What additional safety measures would make you feel safer?
Q8. What project site features are unique to urban work zone construction? (Road conditions, etc.)
Q9. Please enter any comments that you might have about Urban Construction and Recommendations to remedy unsafe situations.

APPENDIX C: RAW CALCULATIONS

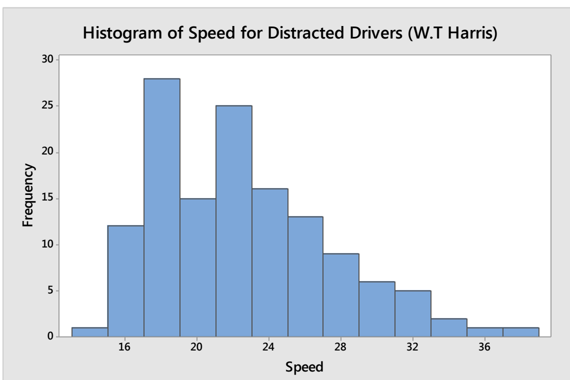
C1: Case Study Analysis

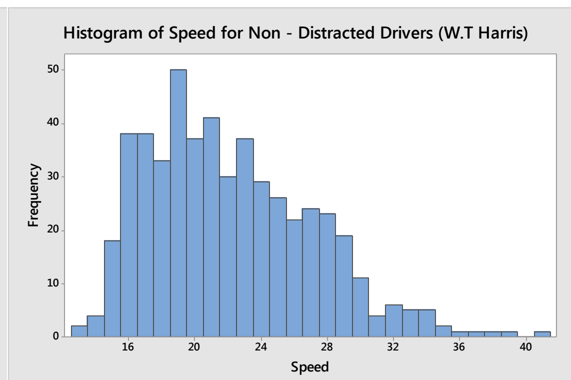
C1.1.1: Case Study 1 – North Tryon St. and W.T. Harris Intersection

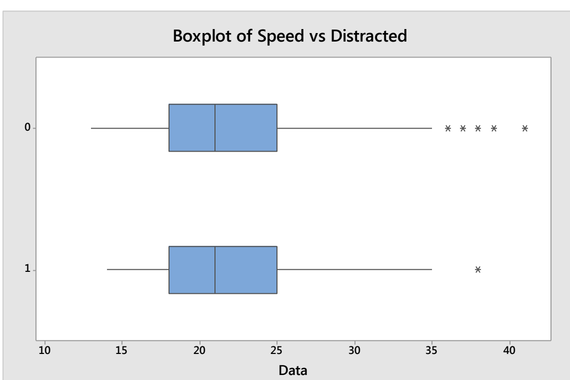
Results for: Case1.1.1
Descriptive Statistics: Speed

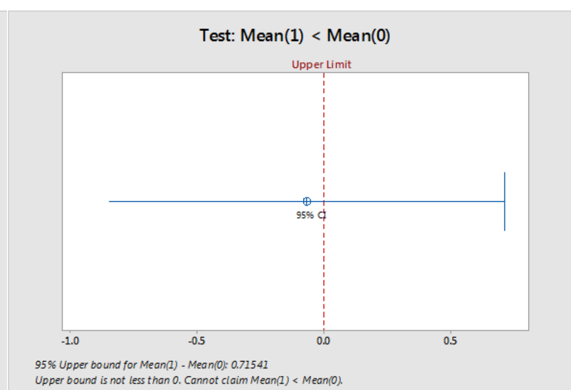
Variable	Distracted	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Speed	0	509	0	22.132	0.220	4.959	13.00	18.00	21.00	25.00
	1	134	0	22.067	0.418	4.836	14.00	18.00	21.00	25.00

Variable	Distracted	Maximum
Speed	0	41.000
	1	38.000









Results for: Case1.1.1
Two-Sample T-Test and CI: Speed, Distracted

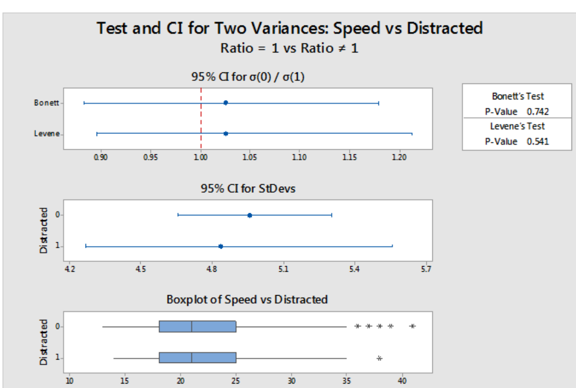
Two-sample T for Speed

Distracted	N	Mean	StDev	SE Mean
0	509	22.13	4.96	0.22
1	134	22.07	4.84	0.42

```
Difference = μ (0) - μ (1)
Estimate for difference:  0.064
95% CI for difference:  (-0.866, 0.995)
T-Test of difference = 0 (vs ≠): T-Value = 0.14  P-Value = 0.892  DF = 212
```

Test and CI for Two Variances: Speed vs Distracted

```
Method

Null hypothesis         σ(0) / σ(1) = 1
Alternative hypothesis  σ(0) / σ(1) ≠ 1
Significance level      α = 0.05

Statistics

                                           95% CI for
Distracted    N  StDev  Variance        StDevs
0           509  4.959    24.591  (4.654, 5.304)
1           134  4.836    23.386  (4.267, 5.562)

Ratio of standard deviations = 1.025
Ratio of variances = 1.052


95% Confidence Intervals

                                   CI for
         CI for StDev            Variance
Method      Ratio                  Ratio
Bonett  (0.882, 1.180)  (0.778, 1.393)
Levene  (0.895, 1.213)  (0.802, 1.472)

Tests
                          Test
Method  DF1  DF2  Statistic  P-Value
Bonett    —    —          —    0.742
Levene    1  641       0.37    0.541
```

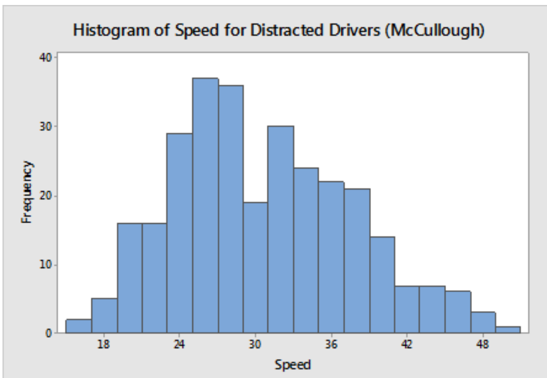


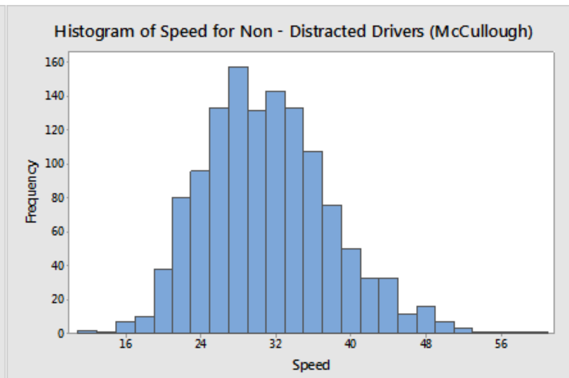
C1.1.2: Case Study 2 – North Tryon St. North of McCullough Dr.

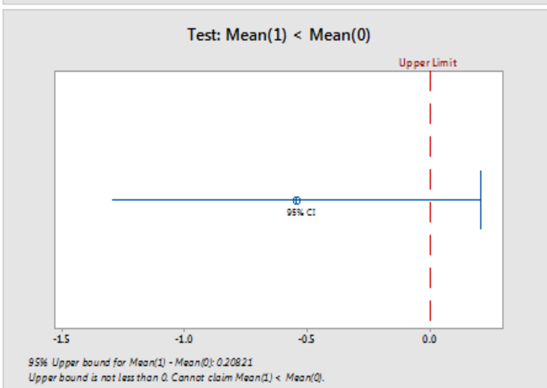
Results for: Case1.1.2
Descriptive Statistics: Speed

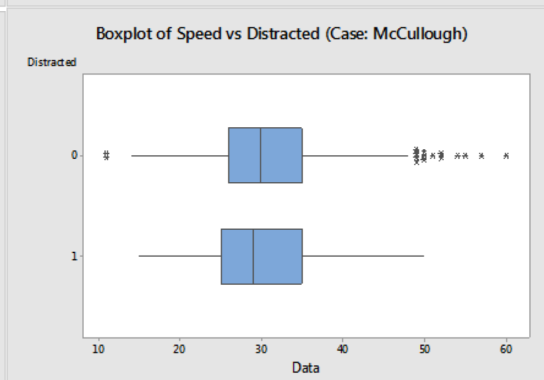
Variable	Distracted	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Speed	0	1272	0	30.682	0.192	6.842	11.00	26.00	30.00	35.000
	1	295	0	30.139	0.414	7.104	15.00	25.00	29.00	35.000

Variable	Distracted	Maximum
Speed	0	60.000
	1	50.000









Results for: Case1.1.2

Two-Sample T-Test and CI: Speed, Distracted

Two-sample T for Speed

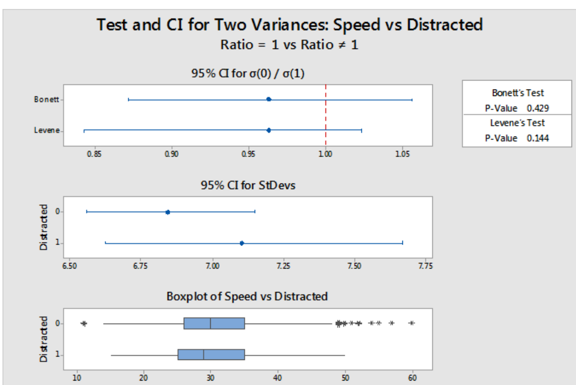
Distracted	N	Mean	StDev	SE Mean
0	1272	30.68	6.84	0.19
1	295	30.14	7.10	0.41

Difference = μ (0) - μ (1)
Estimate for difference: 0.543
95% CI for difference: (-0.353, 1.440)

```
T-Test of difference = 0 (vs ≠): T-Value = 1.19  P-Value = 0.234  DF = 429
```

Test and CI for Two Variances: Speed vs Distracted

```
Method

Null hypothesis          σ(0) / σ(1) = 1
Alternative hypothesis   σ(0) / σ(1) ≠ 1
Significance level       α = 0.05

Statistics
                                             95% CI for
Distracted      N  StDev  Variance         StDevs
0            1272  6.842    46.820  (6.559, 7.149)
1             295  7.104    50.474  (6.625, 7.670)

Ratio of standard deviations = 0.963
Ratio of variances = 0.928

95% Confidence Intervals

                                    CI for
         CI for StDev          Variance
Method       Ratio              Ratio
Bonett  (0.872, 1.057)  (0.760, 1.117)
Levene  (0.842, 1.024)  (0.709, 1.048)

Tests

                            Test
Method  DF1   DF2  Statistic  P-Value
Bonett    —     —          —    0.429
Levene    1  1565       2.14    0.144
```



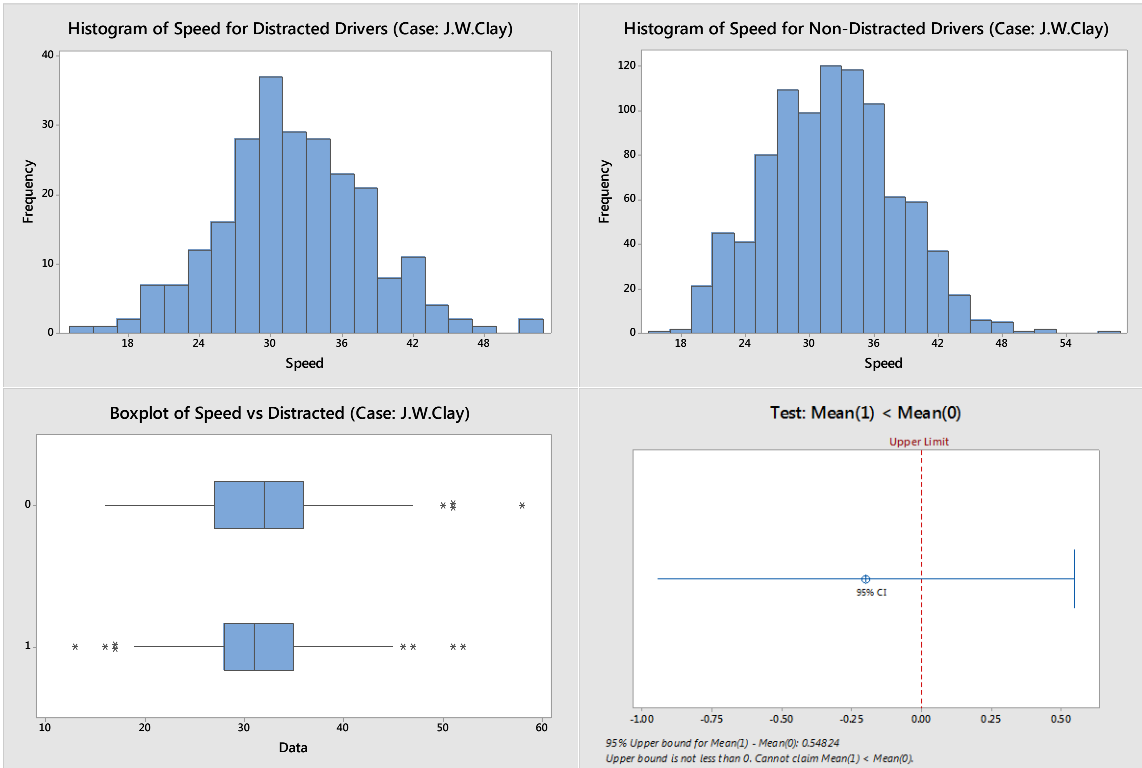
C1.1.3: Case Study 3 – North Tryon St. and J.W. Clay Intersection

Results for: Case1.1.3

Descriptive Statistics: Speed

```
Variable Distracted    N  N*  Mean  SE Mean  StDev  Minimum    Q1  Median    Q3
Speed     0          928  0  31.644   0.199  6.071    16.00  27.00  32.00  36.00
```

```
          1           240  0  31.446  0.407  6.300   13.00  28.00  31.00  35.00

Variable  Distracted  Maximum
Speed     0            58.000
          1            52.000
```



Results for: Case1.1.3

Two-Sample T-Test and CI: Speed, Distracted

```
Two-sample T for Speed

Distracted    N   Mean  StDev  SE Mean
0           928  31.64   6.07     0.20
1           240  31.45   6.30     0.41

Difference = μ (0) - μ (1)
Estimate for difference:  0.199
95% CI for difference:  (-0.692, 1.089)
T-Test of difference = 0 (vs ≠): T-Value = 0.44  P-Value = 0.661  DF = 362
```

Test and CI for Two Variances: Speed vs Distracted

```
Method

Null hypothesis         σ(0) / σ(1) = 1
Alternative hypothesis  σ(0) / σ(1) ≠ 1
Significance level      α = 0.05
```

Statistics

Distracted	N	StDev	Variance	95% CI for StDevs
0	928	6.071	36.859	(5.805, 6.363)
1	240	6.300	39.687	(5.724, 6.991)

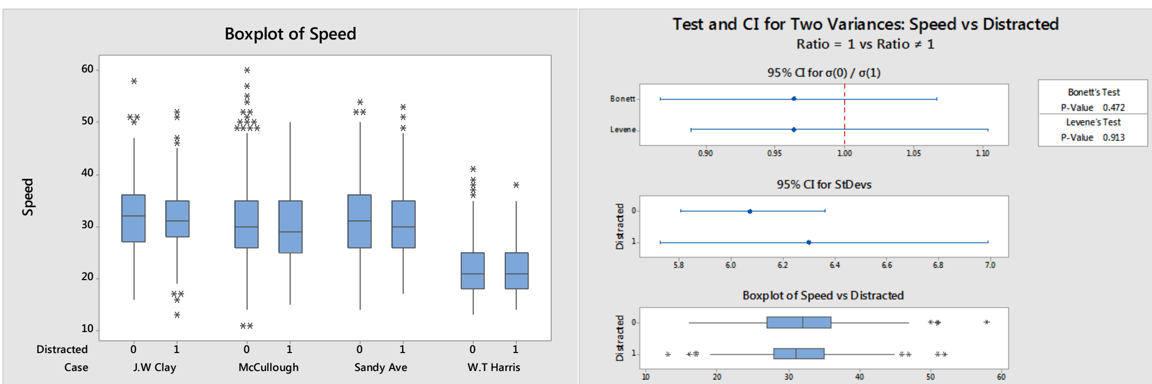
Ratio of standard deviations = 0.964
Ratio of variances = 0.929

95% Confidence Intervals

Method	CI for StDev Ratio	CI for Variance Ratio
Bonett	(0.866, 1.067)	(0.751, 1.138)
Levene	(0.889, 1.104)	(0.791, 1.219)

Tests

Method	DF1	DF2	Test Statistic	P-Value
Bonett	–	–	–	0.472
Levene	1	1166	0.01	0.913



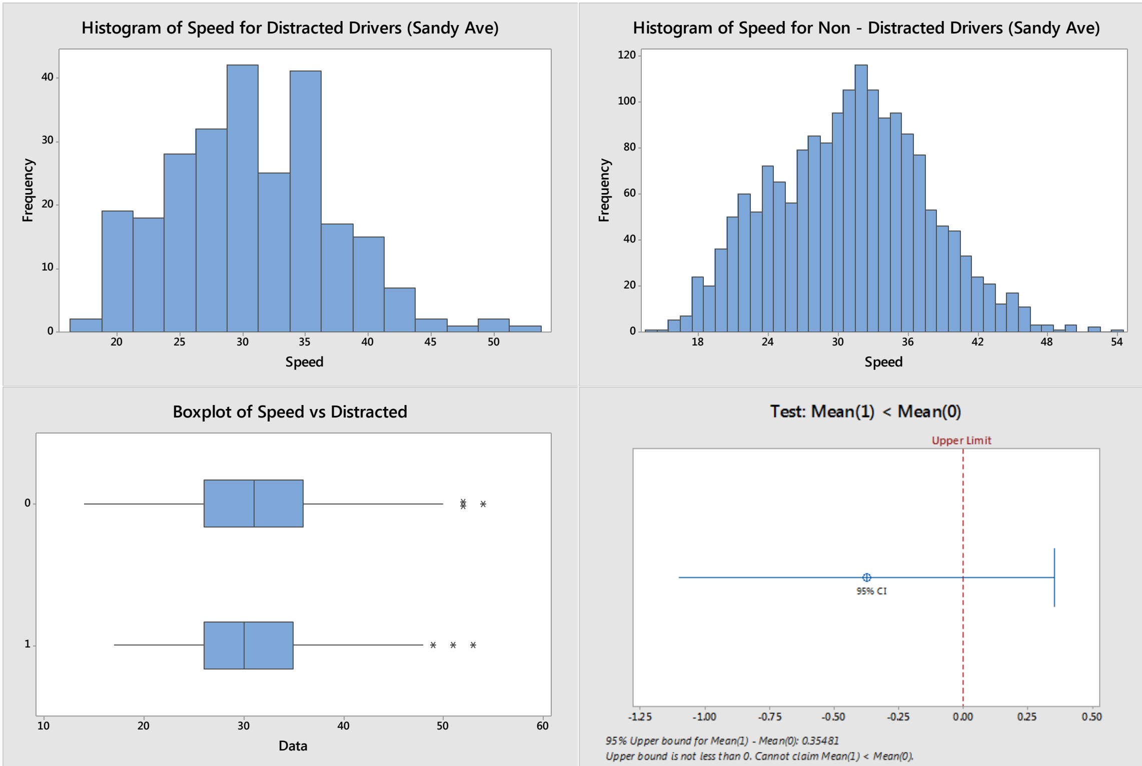
C1.1.4: Case Study 4 – North Tryon St. after Sandy Ave.

Results for: Case1.1.4

Descriptive Statistics: Speed

Variable	Distracted	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Speed	0	1741	0	31.024	0.158	6.595	14.00	26.00	31.00	36.00
	1	252	0	30.651	0.412	6.543	17.00	26.00	30.00	35.00

Variable	Distracted	Maximum
Speed	0	54.000
	1	53.000



Results for: Case1.1.4

Test and CI for Two Variances: Speed vs Distracted

Method

Null hypothesis	σ(0) / σ(1) = 1
Alternative hypothesis	σ(0) / σ(1) ≠ 1
Significance level	α = 0.05

Statistics

Distracted	N	StDev	Variance	95% CI for StDevs
0	1741	6.595	43.493	(6.401, 6.803)
1	252	6.543	42.810	(5.994, 7.198)

Ratio of standard deviations = 1.008
Ratio of variances = 1.016

95% Confidence Intervals

Method	CI for StDev Ratio	CI for Variance Ratio
Bonett	(0.921, 1.097)	(0.848, 1.204)
Levene	(0.915, 1.111)	(0.837, 1.235)

Tests

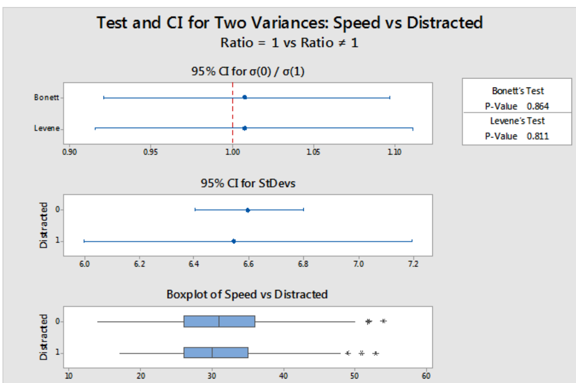
Method	DF1	DF2	Test Statistic	P-Value
Bonett	—	—	—	0.864
Levene	1	1991	0.06	0.811

Two-Sample T-Test and CI: Speed, Distracted

Two-sample T for Speed

Distracted	N	Mean	StDev	SE Mean
0	1741	31.02	6.59	0.16
1	252	30.65	6.54	0.41

Difference = μ (0) - μ (1)
Estimate for difference: 0.373
95% CI for difference: (-0.495, 1.242)
T-Test of difference = 0 (vs ≠): T-Value = 0.85 P-Value = 0.398 DF = 329



C2: 2xK Contingency Analysis

C2.1: Urban vs. Severity Analysis

Urban		Severity					
Year	Activity	K	A	B	C	PDO	UNK
2013	On Going	0	4	53	250	702	12
	Not	2	2	36	151	424	10
	Total	2	6	89	401	1126	22
2012	On Going	1	6	109	510	1343	17
	Not	4	3	82	256	759	20
	Total	5	9	191	766	2102	37
2011	On Going	1	4	43	197	495	9
	Not	1	2	32	119	376	6
	Total	2	6	75	316	871	15
2010	On Going	4	3	37	177	480	10
	Not	3	2	35	106	290	5
	Total	7	5	72	283	770	15
2009	On Going	0	3	18	133	325	6
	Not	2	2	31	102	221	3
	Total	2	5	49	235	546	9

Looking at 2013 (On going and not on going in urban areas)

Severity	On Going	Not	Total
PDO	702	424	1126
C	250	151	401
B	53	36	89
A	4	2	6
K	0	2	2
Total	**1009**	**615**	**1624**

Concordances	C=	144302		
Discordances	D=	138919		
Statistic	S=C-D=	5383		
Z statistic	A=	1009	sigmaS=	14797.71
	B=	615		
	N=	1624	z=	0.363773
	n1=	1126		
	n2=	401	P value=	0.358014
	n3=	89		
	n4=	6		
	n5=	2		

Looking at 2012 (On going and not on going in urban areas)

Severity	On Going	Not	Total
PDO	1343	759	2102
C	510	256	766
B	109	82	191
A	6	3	9
K	1	4	5
Total	**1969**	**1104**	**3073**

Concordances	C=	509512		
Discordances	D=	505407		
Statistic	S=C-D=	4105		
Z statistic	A=	1969	sigmaS=	38464.23
	B=	1104		
	N=	3073	z=	0.106723
	n1=	2102		
	n2=	766	P value=	0.457505
	n3=	191		
	n4=	9		
	n5=	5		

Looking at 2011 (On going and not on going in urban areas)

Severity	On Going	Not	Total
PDO	495	376	871
C	197	119	316
B	43	32	75
A	4	2	6
K	1	1	2
Total	**740**	**530**	**1270**

Concordances	C=	83258		
Discordances	D=	97994		
Statistic	S=C-D=	-14736		
Z statistic	A=	740	sigmaS=	10486.51
	B=	530		
	N=	1270	z=	-1.40523
	n1=	871		
	n2=	316	P value=	0.920024
	n3=	75		
	n4=	6		
	n5=	2		

Looking at 2010 (On going and not on going in urban areas)

Severity	On Going	Not	Total
PDO	480	290	770
C	177	106	283
B	37	35	72
A	3	2	5
K	4	3	7
Total	**701**	**436**	**1137**

Concordances	C=	77354		
Discordances	D=	69007		
Statistic	S=C-D=	8347		
Z statistic	A=	701	sigmaS=	8838.062
	B=	436		
	N=	1137	z=	0.944438
	n1=	770		
	n2=	283	P value=	0.172473
	n3=	72		
	n4=	5		
	n5=	7		

Looking at 2009 (On going and not on going in urban areas)

Severity	On Going	Not	Total
PDO	325	221	546
C	133	102	235
B	18	31	49
A	3	2	5
K	0	2	2
Total	**479**	**358**	**837**

Concordances	C=	49258		
Discordances	D=	36269		
Statistic	S=C-D=	12989		
Z statistic	A=	479	sigmaS=	5790.876
	B=	358		
	N=	837	z=	2.243011
	n1=	546		
	n2=	235	P value=	0.012448
	n3=	49		
	n4=	5		
	n5=	2		

C2.2: Rural vs. Severity Analysis

Rural		Severity					
Year	Activity	K	A	B	C	PDO	UNK
2013	On Going	3	5	46	165	435	5
	Not	4	4	39	73	249	8
	Total	7	9	85	238	684	13
2012	On Going	9	15	105	333	884	11
	Not	9	10	99	165	468	15
	Total	18	25	204	498	1352	26
2011	On Going	4	5	65	176	372	4
	Not	1	3	40	73	242	3
	Total	5	8	105	249	614	7
2010	On Going	4	4	51	186	458	4
	Not	6	5	35	101	260	5
	Total	10	9	86	287	718	9
2009	On Going	5	4	48	122	314	3
	Not	3	6	55	107	241	5
	Total	8	10	103	229	555	8

Looking at 2013 (On going and not on going in Rural areas)

Severity	On Going	Not	Total
PDO	435	249	684
C	165	73	238
B	46	39	85
A	5	4	9
K	3	4	7
Total	654	369	1023

Concordances	C=	60343		
Discordances	D=	58797		
Statistic	S=C-D=	1546		
Z statistic	A=	654	sigmaS=	7527.684
	B=	369		
	N=	1023	z=	0.205375
	n1=	684		
	n2=	238	P value=	0.418639
	n3=	85		
	n4=	9		
	n5=	7		

Looking at 2012 (On going and not on going in Rural areas)

Severity	On Going	Not	Total
PDO	884	468	1352
C	333	165	498
B	105	99	204
A	15	10	25
K	9	9	18
Total	1346	751	2097

Concordances	C=	291596		
Discordances	D=	239967		
Statistic	S=C-D=	51629		
Z statistic	A=	1346	sigmaS=	22524.29
	B=	751		
	N=	2097	z=	2.292147
	n1=	1352		
	n2=	498	P value=	0.010949
	n3=	204		
	n4=	25		
	n5=	18		

Looking at 2011 (On going and not on going in Rural areas)

Severity	On Going	Not	Total
PDO	372	242	614
C	176	73	249
B	65	40	105
A	5	3	8
K	4	1	5
Total	**622**	**359**	**981**

Concordances	C=	51533		
Discordances	D=	66274		
Statistic	S=C-D=	-14741		
Z statistic	A=	622	sigmaS=	7340.745
	B=	359		
	N=	981	z=	-2.00811
	n1=	614		
	n2=	249	P value=	0.977684
	n3=	105		
	n4=	8		
	n5=	5		

Looking at 2010 (On going and not on going in Rural areas)

Severity	On Going	Not	Total
PDO	458	260	718
C	186	101	287
B	51	35	86
A	4	5	9
K	4	6	10
Total	**703**	**407**	**1110**

Concordances	C=	76467		
Discordances	D=	69959		
Statistic	S=C-D=	6508		
Z statistic	A=	703	sigmaS=	8683.396
	B=	407		
	N=	1110	z=	0.749476
	n1=	718		
	n2=	287	P value=	0.226785
	n3=	86		
	n4=	9		
	n5=	10		

Looking at 2009 (On going and not on going in Rural areas)

Severity	On Going	Not	Total
PDO	314	241	555
C	122	107	229
B	48	55	103
A	4	6	10
K	5	3	8
Total	**493**	**412**	**905**

Concordances	C=	61946		
Discordances	D=	49763		
Statistic	S=C-D=	12183		
Z statistic	A=	493	sigmaS=	6790.365
	B=	412		
	N=	905	z=	1.79416
	n1=	555		
	n2=	229	P value=	0.036394
	n3=	103		
	n4=	10		
	n5=	8		

C3.3: Urban and Rural vs. Severity

Rural		Severity				
Year	**Activity**	**K**	**A**	**B**	**C**	**PDO**
2009	Urban	2	5	49	235	546
	Rural	8	10	103	229	555
	Total	**10**	**15**	**152**	**464**	**1101**
2010	Urban	4	3	37	177	480
	Rural	10	9	86	287	718
	Total	**14**	**12**	**123**	**464**	**1198**
2011	Urban	2	6	75	316	871
	Rural	5	8	105	249	614
	Total	**7**	**14**	**180**	**565**	**1485**
2012	Urban	5	9	191	766	2102
	Rural	18	25	204	498	1352
	Total	**23**	**34**	**395**	**1264**	**3454**
2013	Urban	2	6	89	401	1126
	Rural	7	9	85	238	684
	Total	**9**	**15**	**174**	**639**	**1810**

Looking at 2013 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	1126	684	1810
C	401	238	639
B	89	85	174
A	6	9	15
K	2	7	9
Total	**1624**	**1023**	**2647**

Concordances	C=	423681		
Discordances	D=	364416		
Statistic	S=C-D=	59265		
Z statistic	A=	1624	sigmaS=	31249.4
	B=	1023		
	N=	2647	z=	1.896516
	n1=	1810		
	n2=	639	P value=	0.028946
	n3=	174		
	n4=	15		
	n5=	9		

Looking at 2012 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	2102	1352	3454
C	766	498	1264
B	191	204	395
A	9	25	34
K	5	18	23
Total	**3073**	**2097**	**5170**

Concordances	C=	1763567		
Discordances	D=	1417863		
Statistic	S=C-D=	345704		
Z statistic	A=	3073	sigmaS=	87338.53
	B=	2097		
	N=	5170	z=	3.958207
	n1=	3454		
	n2=	1264	P value=	3.78E-05
	n3=	395		
	n4=	34		
	n5=	23		

Looking at 2011 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	871	614	1485
C	316	249	565
B	75	105	180
A	6	8	14
K	2	5	7
Total	**1270**	**981**	**2251**

Concordances	C=	357950		
Discordances	D=	266509		
Statistic	S=C-D=	91441		
Z statistic	A=	1270	sigmaS=	25523.48
	B=	981		
	N=	2251	z=	3.582622
	n1=	1485		
	n2=	565	P value=	0.00017
	n3=	180		
	n4=	14		
	n5=	7		

Looking at 2010 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	480	718	1198
C	177	287	464
B	37	86	123
A	3	9	12
K	4	10	14
Total	701	1110	1811

Concordances	C=	207478		
Discordances	D=	171944		
Statistic	S=C-D=	35534		
Z statistic	A=	701	sigmaS=	18052.09
	B=	1110		
	N=	1811	z=	1.968414
	n1=	1198		
	n2=	464	P value=	0.02451
	n3=	123		
	n4=	12		
	n5=	14		

Looking at 2009 (Urban and Rural areas and severity)

Severity	Urban	Rural	Total
PDO	546	555	1101
C	235	229	464
B	49	103	152
A	5	10	15
K	2	8	10
Total	**837**	**905**	**1742**

Concordances	C=	220457		
Discordances	D=	175070		
Statistic	S= C - D=	45387		
Z statistic	A=	837	sigmaS=	17899.04
	B=	905		
	N=	1742	z=	2.535723
	n1=	1101		
	n2=	464	P value=	0.005611
	n3=	152		
	n4=	15		
	n5=	10		