Safety Effects of Preventative Maintenance: Microsurfacing - A Case Study

by

Tara Christine Erwin

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

Various North American transportation agencies have implemented several preventative maintenance techniques to improve pavement performance and safety. The Region of York, located north east of Toronto, Ontario, has been resurfacing and remedying pavements with microsurfacing treatments to improve the pavement surface conditions. Often times these maintenance methods were selected because they seemed the most appropriate given a budget constraint however little was known if these treatments impacted road safety. The Region of York made their road and safety data accessible for the purpose of this research. Thus the focus of this thesis is to gain an understanding of how microsurfacing and resurfacing treatments impact road safety to help the Region of York and potentially other jurisdictions make more sound decisions when selecting pavement maintenance treatments.

Road related fatalities account for 90 percent of transportation related deaths in Canada despite safety measures such as stronger safety laws and public awareness campaigns. There is a need for engineers to think outside of the box and look at other ways to improve road safety. Given the high costs to society for crashes it only seems logical that safety should be a part of a preventative maintenance decision making process. A fair amount of research has been done on the influence of pavement friction on traffic safety; however no studies were uncovered that examined how microsurfacing (a treatment designed to improve the frictional properties of pavement) affected safety. This study accomplishes five research objectives based on the needs of the Region of York and past experience:

1. Establishes that there is a statistically significant relationship between microsurfacing treatments and safety for specific traffic conditions using a before-after analysis
2. Determines that there is a statistically significant relationship between resurfacing and safety under specific traffic conditions using a before-after analysis
3. Illustrates the need and value added if there is better cohesion between road data and safety data
4. Demonstrate that safety has a role to play in pavement management, especially regarding preventative maintenance strategies and offers guidance on how to approach the integration using York Region as a case study
5. Develops a concept decision making framework that demonstrates how safety data should be considered in pavement maintenance decision making at both the network level applying life cycle costs and project level using decision making flowcharts. These tools while specific to York Region can be adopted in jurisdictions with similar characteristics

The study concludes that microsurfacing and resurfacing safety effects are sensitive to the influence of treatment year data (which may be an anomaly period) and average annual daily traffic (AADT) per lane. The findings of this study have opened the door to additional research; integration of safety under the pavement umbrella seems logical and yet has barely been explored. Recommendations that have resulted from this work deal with data collected and how it is managed; analysis methodology and additional opportunities for further study; and finally how to optimize the application of the findings to best serve engineers that are involved in the maintenance decision making process. There is much potential for further research in the area of safety within a pavement management framework and the resultant studies will have a tremendous benefit to society.

ACKNOWLEDGEMENTS

First I would like to acknowledge the Region of York for making their data accessible to fulfill the objectives of this research. There are three York Region staff members in particular, Brian Harrison for suggesting this collaborative research opportunity and Calvin Mollett and Nick McNamee who assisted me with data requests and took the time to answer my questions. Without their partnership the valuable findings that were hiding in these data would not have come to the surface.

I would also like to expressively acknowledge Professor Tighe for inspiring me to pursue graduate studies. As my supervisor she was very accommodating to my special situation and provided unconditional support and encouragement throughout the entire writing process. It is because of her understanding that my thesis came to fruition.

DEDICATION

I would like to dedicate this work to my family who provided an unparallel support system: My husband who encouraged me every step of the way, my new baby son who supplied the motivation to get through the long days, and my parents who provided the safe haven to help me accomplish my goal. Your patience and unconditional love did not go unnoticed.

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1.0 INTRODUCTION

This chapter includes a brief background on preventative maintenance treatments that address skid resistance and provides the context of the research. Furthermore, the research scope and explicit objectives are laid out along with the organization of the thesis.

1.1 Background

Many transportation agencies have been working towards the development of preventative maintenance programs to ensure long-term pavement preservation. The purpose of such an initiative is to improve pavement quality and durability, extend the life cycle of pavement and promote more cost effective and efficient repair methods. In recent years, the Ministry of Transportation Ontario (MTO) has implemented preventative maintenance and holding strategies to optimize cost savings for repair operations to maintain pavement condition with the hope of replacing the previous “worst first” method of pavement repair [MTO 04].

The “worst first” method involves waiting until a pavement has succumbed to significant deterioration beyond its service life before attempting to repair the pavement surface. Evaluations have shown that waiting for this level of deterioration translates to major rehabilitation and reconstruction alternatives that come with a high price tag. In 2004 it was estimated that $1 invested early in a pavements life cycle can save in excess of $5 in the future.

In order to benefit from the potential savings, pavements require monitoring in order to implement a holding strategy. A holding strategy involves utilizing temporary repairs that can “hold” the pavement until funding for full rehabilitation of a roadway is acquired. This approach leads to a temporary yet effect repair while funding and asset planning efforts are diverted to other areas. Although an improvement over the “worst first” approach, it is still founded on an as needed basis.

Preventative maintenance is based on a regular road maintenance program that ensures the entire road network is an acceptable condition while minimizing costly rehabilitation work. To ensure longevity and durability of the pavement a number of methods are employed to extend the overall service life of the pavement while at the same time reducing future costs.

There are several treatments applied as part of a preventative maintenance program to combat deficient skid resistance and poor roughness of a flexible pavement surface. Slurry sealing, chip sealing, microsurfacing, and resurfacing are common treatments in North America for improving surface properties and sometimes the structural condition of the pavement.

Slurry Sealing

A slurry seal prevents moisture from entering into the pavement surface, while improving skid resistance properties [TAC 97]. An asphalt emulsion is mixed with fine aggregate and is thinly applied over the full width of the pavement. The application is typically less than 10 mm thick and is used more for low volume roads. The slurry sealing treatment typically extends the service life of the pavement by 3 to 5 years for a moderate cost.

Chip Sealing

Chip Sealing involves a spray application of bituminous binder followed by the distribution of aggregates that are later rolled into the binder [TAC 97]. These can be carried out as a single or double treatment. The aggregate itself can be a one size aggregate (or chip) or it can range to a fine aggregate. A graded aggregate is the most appropriate for surface treatments (Figure 1.1). The chip sealing treatment typically extends the service life of the pavement up to 5 to 7 years incurring a moderate cost.

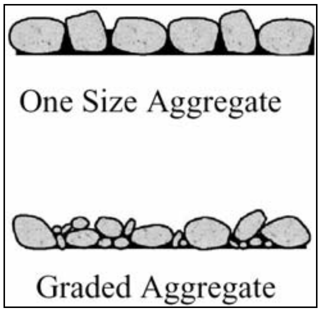


Figure 1.1: Illustration of one size versus graded aggregate

Microsurfacing

Microsurfacing is a mixture of a polymer modified asphalt emulsion, medium to fine graded high quality aggregate, filler, additives, and water [TAC 97]. It is placed using special equipment in layers ranging in thickness from 8 to 10 mm. Microsurfacing can extend service life of the pavement up to 7 to 9 years at a high cost. However despite the price tag, microsurfacing is viewed as a cost effective maintenance treatment as long as the pavement deterioration (roughness and surface distress) are well above minimum thresholds. An additional benefit is that it can help with other pavement surface issues such as rutting or other deficiencies in addition to providing a new riding surface and increased friction.

Resurfacing

Resurfacing is regarded more as a rehabilitation treatment as opposed to the previously discussed maintenance treatments. Overlaying or resurfacing with asphalt concrete restores the pavement back to an acceptable condition. The multi-stage process involves repair of specific distresses using sealing or patching techniques followed by the placement of the new surface. The thickness of the new surface is dependent on the existing condition of the pavement and the traffic loading it will be exposed to.

A thin overlay can extend the pavement surface life between 8 to 10 years at a low cost. Contrarily, a thick overlay can extend the pavement service life up to 12 to 15 years but at a relatively high cost. Resurfacing is not appropriate if the pavement is severely distorted or rutted [TAC 97].

1.2 Context of Research

Various North American transportation agencies have implemented several resurfacing techniques for improving pavement performance and safety. The Region of York (Figure 1.2), located north east of Toronto, Ontario, has been resurfacing and remedying pavements with microsurfacing treatments to improve the pavement surface conditions. Often times these maintenance treatments are selected following a visual field inspection by an experienced technician and the number of sites that receive treatment are constrained by budget instead of need. Prior to this study, little was known to what degree these maintenance treatments impacted road safety. The Region of York made their road and safety data accessible for the purpose of this research. Thus the focus of this thesis is to gain an understanding of how microsurfacing and resurfacing treatments impact road safety to help the Region of York and potentially other jurisdictions make more sound decisions when selecting pavement maintenance treatments.

York Region currently manages approximately 866 centreline kilometres of roads. In recent years the Region invested in a state-of-the-art pavement management system that assists with four main areas [Deighton 97]:

- determination of the existing condition of York's road network,
- determination of the amount of funding that is required to maintain the current level of condition,
- projection of the condition of the road network for specific budget scenarios, and
- preparation of a multiyear, optimized construction programme for York given specific budget constraints.

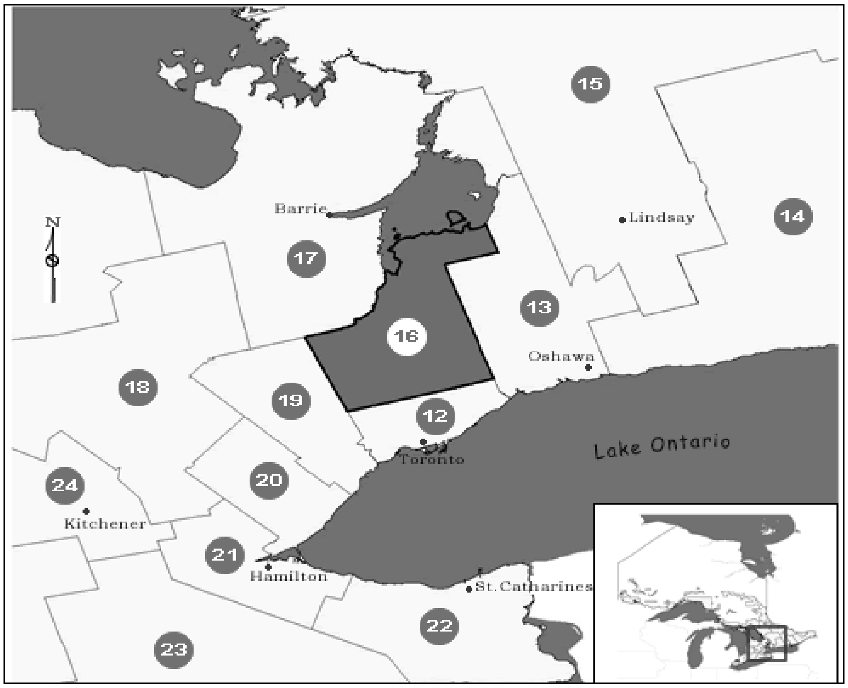


Figure 1.2: Location map that highlights the Region of York - No. 16

There is added value in using real data as opposed to simulated data, as it is able to account for true to life anomalies, such as driver behaviour, that may be experienced out in the field that simulation would not reproduce. This data although specific to the Region of York can be used as a good test case and the findings can be potentially applied to other jurisdictions with similar characteristics. These characteristics may include but are not limited to:

- Aggregate and aggregate source (similar quarry)
- Climate region
- Road geometric design guidelines, such as TAC Geometric Design Guide
- Pool of contractors to execute the construction or application of treatment
- Pool of engineering consultants that develop the design

1.3 Objectives and Scope of the Research

York Region is among industry leaders in Canada when it comes to pavement management and road safety given their extensive data management system and yet they, like many other engineering agencies, they have failed to recognize the potential benefits of integrating pavement management and safety management. The following research objectives are based on the needs of the Region of York and past experience:

1. establish if there is a statistically significant relationship between microsurfacing treatments and safety
2. determine if there is a statistically significant relationship between resurfacing and safety
3. illustrate the need and value added if there is better cohesion between road data and safety data
4. demonstrate that safety has a role to play in pavement management, especially regarding preventative maintenance strategies and offer guidance on how to approach the integration using York Region as a case study
5. develop a concept decision making framework that demonstrates how safety data should be considered in pavement maintenance decision making at both the network and project level in jurisdictions with similar characteristics

This will be accomplished by an in-depth analysis of skid resistance, friction, and roughness. Other factors associated with road safety, including driver behaviour or human factors, vehicle type, and vehicle safety performance are not covered in this thesis.

1.4 Organization of Thesis

Chapter One provides an overview of the research project. It provides a brief background on preventative maintenance strategies and explicitly outlines the scope and objectives of the research. Chapter Two is a literature review of road safety, pavement performance measures (including skid resistance and roughness), the relationship between friction and traffic safety, and microsurfacing.

Chapter Three reviews the data available and explains the methodology used in the research. Chapter Four presents the results of the analysis for microsurfacing and resurfacing, including a detailed sensitivity analysis. Chapter Five highlights applied results that translate into conceptual decision making tools that could be applied by road engineers. Chapter Six summarizes the final results and analysis of the data.

Chapter Seven proposes recommendations and emphasizes the potential for further development in the future. Chapter Eight includes a detailed list material referenced throughout the document. Appendices following Chapter Eight contain printouts of the raw data and analysis used in the development of this thesis.

2.0 LITERATURE REVIEW

There is a wealth of literature available on pavement surfaces and safety, but little information that link the two topics together. While both are important, the link between the two remains an area that needs further exploration. It is anticipated that a better knowledge of how each entity affects the other should help engineers to make cost effective decisions to preserve existing road infrastructure while improving road safety.

2.1 Road Safety

2.1.1 Role of the Engineer

Road safety measures can be designed to target either: the road-user, the vehicle, or the road system. Responsibility for road safety in Canada is a shared task in among the federal, provincial/territorial, and municipal levels of government. The governments embrace the role of regulating and directing activities aimed at the road-user and the vehicle, however often fall short on programs that deal with the road system due to the large impact they can have on their budgets. Hauer debunks two related myths in his paper "Two harmful myths and a thesis" [Hauer 97a], drawing heavily on work of the committee to review the safety of Highway 407 [PEO 97], and concludes that building safety into roads is an essential component of a balanced road safety policy that encompasses road users, vehicles, and the road system.

- Myth 1: Roads built to standards are safe
- Myth 2: Roads do not cause crashes, drivers do

Addressing Myth 1, Hauer explains that highway safety does not change abruptly when a dimension of the highway changes slightly. Many design standards are based on limit standards and just meeting a limit does not make a roadway the safest it can be. Likewise, many road features are not encompassed within design standards, for example, there are no standards to determine the number of interchanges on a freeway or the density of intersections on a highway. Design standards do not dictate what is safe and unsafe; they are a reflection of what a committee of professionals deems to be good overall practice.

In breaking down Myth 2, Hauer places responsibility on transportation engineers to ensure road safety is addressed in the management of our roadways for the benefit of the public. Society has been led to believe that since crashes are caused by drivers, the most suitable prevention actions are better training and education, more stringent licensing, tougher enforcement, higher fines, etc. However, history has shown that most crashes do not involve 'bad drivers' and it has not been proven that driver-oriented measures are the only or most effective remedy to avoid future crashes. Government crackdowns on 'bad drivers' are often an attempt to repair public relations.

Highlighting one of the objectives of this thesis, Hauer concludes by stating "If design-by-standards yields an unpremeditated level of safety on our roads, then the government and the engineering profession have a job to do."

2.1.2 The Current Situation

In Canada the number of drivers and vehicles on the road has steadily increased over the past 30 years, however traffic fatalities have declined (Figure 2.1). Traffic related deaths in 2003 were less than half of the deaths in 1975 and the lowest level since 1954 [TC 06].

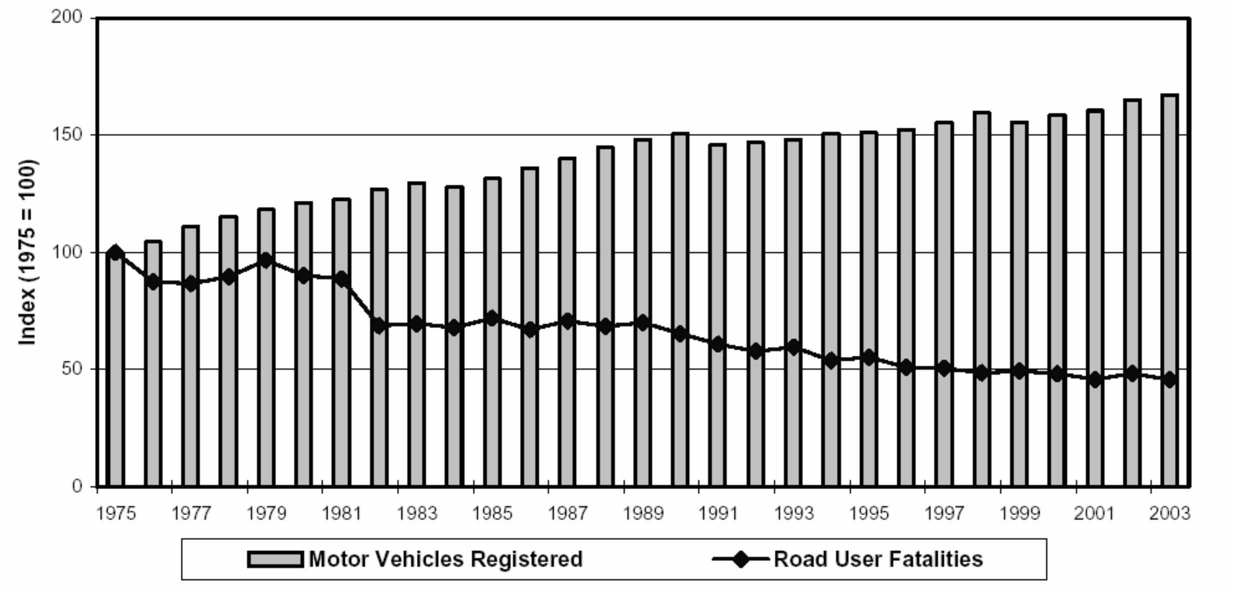


Figure 2.1: Registered Vehicles and Road User Fatalities 1975-2003 [TC 06]

Despite the huge improvements in road safety through the years, the fact can not be ignored that an average of 3,000 Canadians die on the roadway every year. Compared to other modes, road related fatalities account for 90 percent of transportation related deaths despite safety measures including stronger safety laws and public awareness campaigns (Figure 2.2).

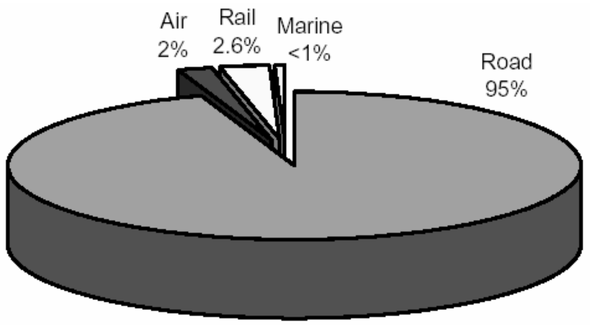


Figure 2.2: Comparison of Fatalities by Mode of Transportation [TC 06]

The Transport Canada report published that 7.6 people died on Canadian roads every day and 609 were injured. It is estimated that this cost society approximately $26 million in current dollars every day. Of the reported collisions, four out of five collisions occurred in clear weather.

Much of Canada's reduction in traffic fatalities and injuries can be attributed to 'Road Safety Vision 2001' and as a result the initiative has been extended and renamed 'Road Safety Vision 2010.' The big picture goal is to have the safest roads in the world; in 2001 Canada ranked fifth behind Great Britain, Sweden, the Netherlands, and Norway. To achieve this ambitious goal, the national target calls for a 30 percent decrease in the average number of road users killed or seriously injured during the 2008-2010 period compared to 1996-2001 average figures [TC 03]. To reach the national target annual fatalities must be cut by almost 900 and serious injuries need to be reduced by approximately 5,500. It should also be noted that while it is not always possible to eliminate crashes, reducing the severity of a crash is also an important goal [TC 03]. Historical trends demonstrate that this is achievable but it will require professionals to think outside of the box and look at additional ways to integrate safety into all aspects of transportation engineering.

Better management of data and incorporating multiple data sets is an option worth further exploration to attain the goal of 'Road Safety Vision 2010.' Since Canada has a very established infrastructure, there is an opportunity to integrate road safety improvement with pavement maintenance management. Although the literature review has revealed that very little has explicitly been done to incorporate safety into pavement management some studies have illustrated that that there is a definite relationship between road accident occurrence and pavement conditions.

2.1.3 Road Safety Factors Associated with Pavements

Analyses of traffic accidents are complex because there are so many potential contributing factors including geometric design, pavement related engineering, human factors, traffic operations, vehicle characteristics, etc. Traffic crashes can be considered as unique, random, multi-factor events, always proceeded by a situation in which one or more persons have failed to cope with their environments. Road crashes are rarely caused by a single factor. This makes it difficult for engineers and researchers to determine with certainty the impact of each factor on the safety of the roadway.

Eliminating driver error is considered and impossible task because of human related issues including fatigue, impairments due to intoxication, inexperience, and distraction. Thus it is the role of transportation professionals is to improve the roadway system in such a way that the consequences of driver error are minimized. There are many aspects of pavement engineering that influence road crashes including pavement roughness, skid resistance, surface condition, weather and environment conditions, and pavement colour and visibility [Li 98].

2.2 Pavement Performance Measures

Pavement performance was originally subjectively evaluated by visual inspection and an engineer's experience [TAC 97]. During the late 1950's, systems that could provide a more objective measurement were developed such as roughness meters, deflection, and skid test equipment. Friction and surface condition are the most common indicators of safety problems related to pavement. Skid resistance is one of the primary factors in evaluating pavement safety and the probability of wet weather crashes in particular. Other factors including roughness, surface condition, lane markings, and light reflectivity of pavement surfaces can also influence road safety [Li 98].

Through classification of the factors related to pavement safety the independent investigations into the cause of road accidents can be improved. Each factor has an associated safety indicator and has a varying impact on drivers (Table 2.1). A paper prepared by Li, Tighe and Haas claims there is a relationship between road accident occurrence rates and the pavement factors [Li 98].

Table 2.1: Classification of the Factors Associated with Pavement Safety [Li 98]

Type of Factor	Safety Element Measures or Indicator	Sensitivity to Drivers*
Surface Texture or Friction	Macrotexture and microtexture characters, such as International Friction Index (IFI) Skid resistance or skid number measures Vehicle tire type standards	Low
Pavement Roughness or Riding Quality	Riding comfort rating, International Roughness Index (IRI), Roughness and speed relationship	High
Pavement Surface Distress	Severity and extent of surface distresses such as ruts, faults, potholes, cracks, spalls, etc. Surface distress index	Medium
Pavement Geometric Design and Location	Widths of lanes and shoulders, median, and pedestrian paths Cross slopes of pavement surface	Medium
Visibility of Pavement Surface Features	Pavement surface colour and reflectivity Lane markings and signings Visibility at night and bad weather conditions	High
Paving Materials and Mix Design	Type of pavement Texture and colour of paving materials Mineralogy and anti-resistance properties	Low
Road Safety Measures	Safety warning signs Safety protection facilities	High
Environmental and Weather Conditions	Place and time of accident occurrence Roadside obstacles and safety facilities Overall conditions such as fog, rain, snow, and wind, etc.	High

*Sensitivity to drivers' safety attention is based on a large number of road accident statistics analyses and reviews of police accident reports and investigations

A high safety sensitivity indicator means that the drivers will pay much more attention to the safety elements and thus a reduction in road accidents can be expected. The authors support this with an example. In Canada more than 97 percent of the road accidents (fatal and injury) occurred on roads that were described as in “good” condition, indicating that drivers are more cautious when driving on pavements in “poor” condition [TC 95]. Another supporting argument is that speed is typically higher when driving on pavements in “good” condition resulting in lower skid resistance. Because surface texture or friction is something that cannot be visually observed by the driver due to the speed they are traveling, the study classifies it as having a low “sensitivity to drivers;” however, skid resistance provides the grip a tire needs to maintain vehicle control in the event a driver is visually distracted or needs to make a sudden stop.

The focus will be on skid resistance and roughness to fulfill the needs of this thesis, as they are most relevant to safety evaluations of microsurfacing, however it is understood that there may be situations where more than one of these factors pose a safety threat at a given site.

2.3 Skid Resistance

Skid resistance is an important pavement evaluation parameter and is especially relevant to the focus of this thesis. When a tire is prevented from rotating slides along the pavement surface, the resultant force is skid resistance. Skid resistance is a major factor in traffic safety because it is the force that provides the grip that a tire needs to maintain vehicle control and for stopping in emergency situations. Inadequate skid resistance will lead to higher incidences of skid related accidents. Many agencies have an obligation to provide users with a roadway that is “reasonably” safe.

There are two major components to skid resistance: adhesion and hysteresis [Cairney 07]. Adhesion results from the shearing of molecular bonds formed when the tire rubber is pressed into close contact with pavement surface particles (Figure 2.3). Hysteresis results from energy dissipation when the tire rubber is deformed when passing across a rough surface pavement. These two components of skid resistance are related to the two key properties of asphalt pavement surfaces, that is microtexture and macrotexture (Figure 2.4).

Microtexture refers to irregularities in the surfaces of the stone particles (fine-scale texture) that affect adhesion. These irregularities are what make the stone particles feel smooth or harsh to the touch. The magnitude of microtexture depends on initial roughness on the aggregate surface and the ability of the aggregate to retain this roughness against the polishing action of traffic [Jayawickrama 96]. Accordingly, microtexture is an aggregate-related property that can be controlled through the selection of aggregates with desirable polish-resistant characteristics. The evaluation of the aggregates with respect to their polishing behavior can be accomplished by using a laboratory test procedure that has been developed for this purpose [Noyce 05].

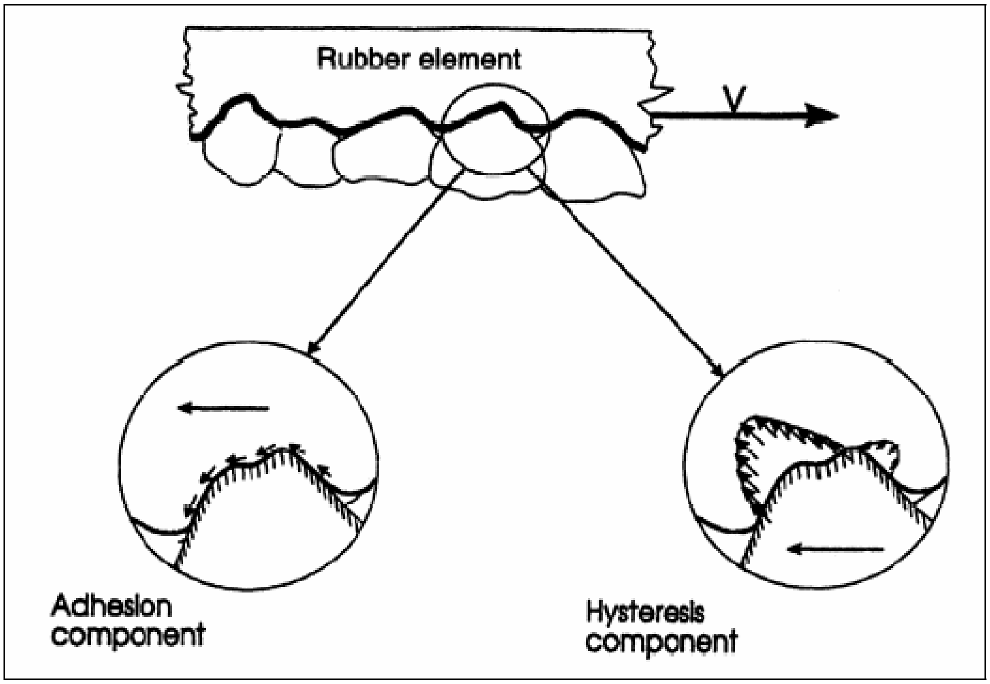


Figure 2.3: Schematic of the mechanisms of adhesion and hysteric components of friction [Henderson 06]

Macrotexture refers to the larger irregularities in the road surface (coarse-scale texture) that affects hysteresis. These larger irregularities are associated with voids between stone particles. The magnitude of this component will depend on several factors. The initial macrotexture on a pavement surface will be determined by the size, shape, and gradation of coarse aggregates used in pavement construction, as well as the particular construction techniques used in the placement of the pavement surface layer. Macrotexture is also essential in providing escape channels to water in the tire-surface interaction, thus reducing hydroplaning.

A study by Galambos et al. [Galambos 77] found that microtexture and adhesion contribute to skid resistance at all speeds and are the prevailing influence at speeds less than 50 km/h (30 mph). Conversely, macrotexture and hysteresis are less important at low speeds but a coarse macrotexture is very desirable for safe, wet-weather travel as the speed increases.

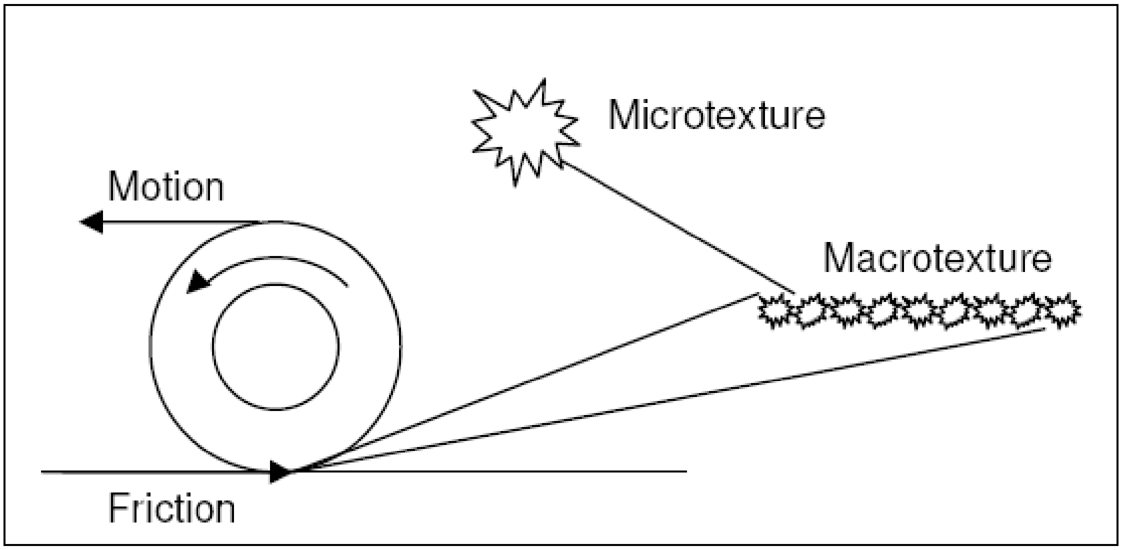


Figure 2.4: Friction Force and its Properties

Megatexture and roughness are two other road surface texture properties that are less significant than micro and macrotexture with respect to skid resistance, however play a role in the overall quality of the pavement surface (Figure 2.5). The term megatexture is used to describe irregularities that can result from rutting, potholes, patching, raveling, and major joints and cracks [McLean 98]. It influences noise levels and rolling resistance more than it influences skid resistance [Henry 00]. Roughness (also referred to as unevenness) refers to surface irregularities larger than megatexture that also influence ride quality and vehicle operating costs in addition to rolling resistance.

At the 18th World Road Congress, the Committee on Surface Characteristics of the World Road Association (PIARC) proposed the wavelength range for each on the texture categories to determine majority of the tire-road interactions [WRA 87] (Figure 2.6). These interactions include wet friction, noise, splash and spray, rolling resistance, and tire wear.

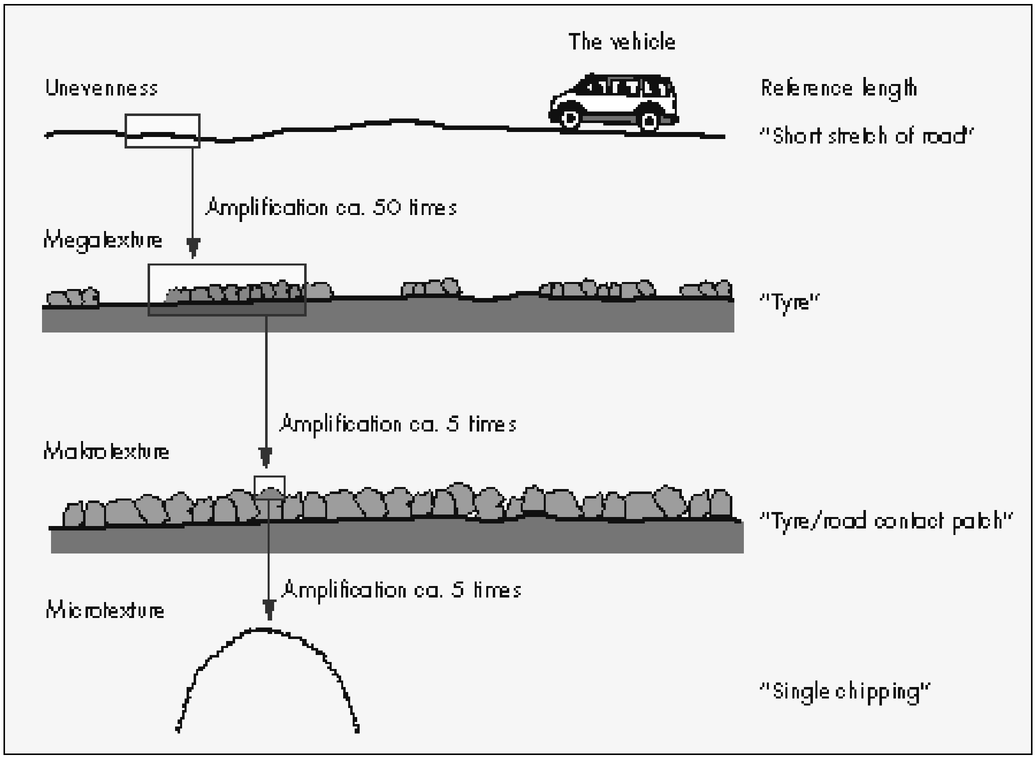


Figure 2.5: Simplified illustration of the various ranges of texture [Sandberg 97]

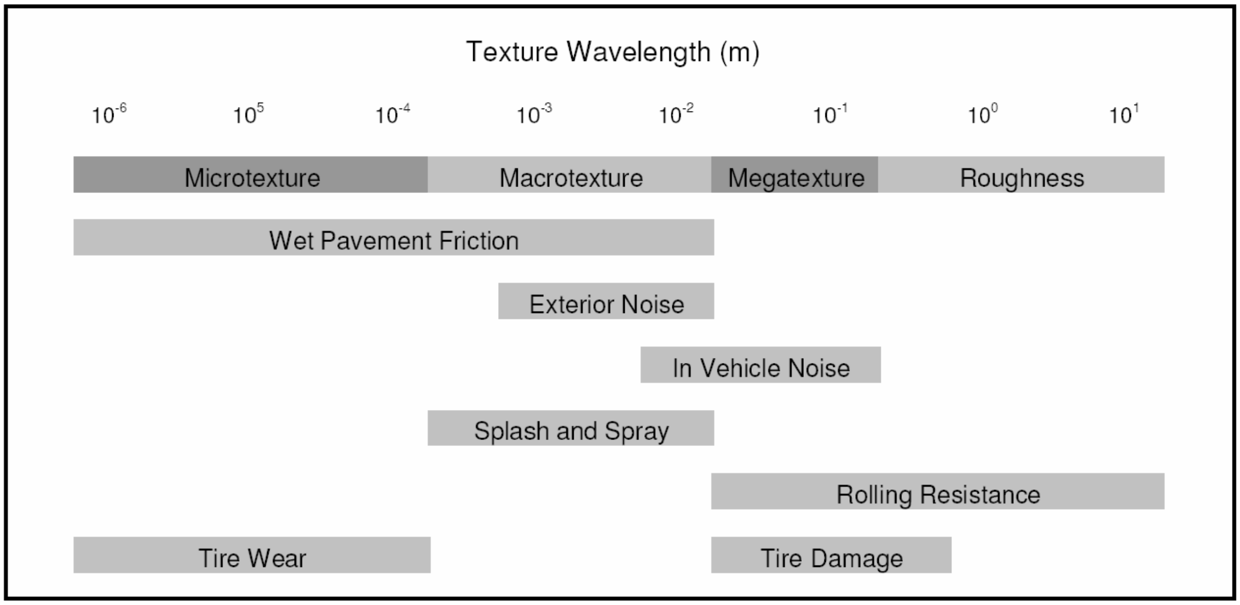


Figure 2.6: Texture Wavelength (m) Influence on Surface Characteristics [Henry 00]

Each category was expanded in more detail by Sandberg [Sanderg 97] to include the magnitude of the influence.

Table 2.2: Influence of Texture on Select Variables [Sanderg 97]

Effect on Vehicle, Driver, or Environment	Road Surface Characteristic of Importance	Magnitude of the Influence
Friction	Macrotexture Megatexture Microtexture	High Moderate Very High
Rolling Resistance/ Fuel Consumption/ Air Pollution	Macrotexture Megatexture Uneveness (Roughness)	High Very High High
Tire Wear	Macrotexture Microtexture	Moderate Very High
Exterior Noise	Macrotexture Megatexture	Very High Very High
Water Runoff	Macrotexture	High
Splash and Spray	Macrotexture	High
Light Reflection	Macrotexture Microtexture	High Little Known
Interior Noise	Macrotexture Megatexture Uneveness (Roughness)	High Very High High

2.3.1 Factors that Influence Skid Resistance

Skid resistance can be affected by several elements such as weather, poor drainage leading to increased water film thickness, condition of the vehicle tires, and characteristics of the pavement surface. Pavement surface in relation to skid resistance has already been discussed in detail in the previous section 2.3. Wallman and Astrom [Wallman 01] build upon this information and explain that skid resistance or friction measurements typically involve three bodies, the tire, the road surface and some type of contaminant or fluid that interacts with both the tire and the road surface. An example of a contaminant might be water (wet friction), dust or wear particles. The authors combine the works of Sandberg [Sandberg 97] and Kummer [Kummer 66] to develop a summary of the factors that influence road surface friction by category (Table 2.3).

Table 2.3: Factors influencing road surface friction [Wallman 01]

Road	Contaminant (fluid)	Tire
Macrotexture	Chemical structure	Tread pattern design
Microtexture	Viscosity	Rubber composition
Uneveness/Megatexture	Density	Inflation pressure
Chemistry of materials	Temperature	Rubber hardness
Temperature	Thermal conductivity	Load
Thermal conductivity	Specific heat	Sliding velocity
Specific heat	Film thickness	Temperature
		Thermal conductivity
		Specific heat

2.3.1.1 Weather

There are four main weather conditions to consider when discussing skid resistance: dry, wet, snow/slush, and ice. In dry conditions it is believe that there is enough skid resistance to avoid skidding problems and therefore the focus is on the later three conditions. Goodwin [Goodwin 02] analyzed both fatal and injury crashes on U.S. highways in wet, snowy, and icy road conditions between 1995 and 2001. The results overwhelming demonstrated that the number of severe wet weather crashes far exceeds the other two conditions as shown in Figure 2.7 and Figure 2.8.

The extreme variance between the conditions may be attributable to the fact that drivers are more cautious in the extreme weather conditions, but do not compensate sufficiently for wet weather conditions. The author offers the following explanation [Goodwin 02]. Vehicles operating at low speeds on wet pavements develop full hysteric friction force with the surface because the water in the surface is squeezed out from under the vehicle tire keeping in full contact with the surface. However, when vehicle speeds increase the skid resistance properties deteriorate as a result of a water film between the tire and the pavement surface which can result in hydroplaning.

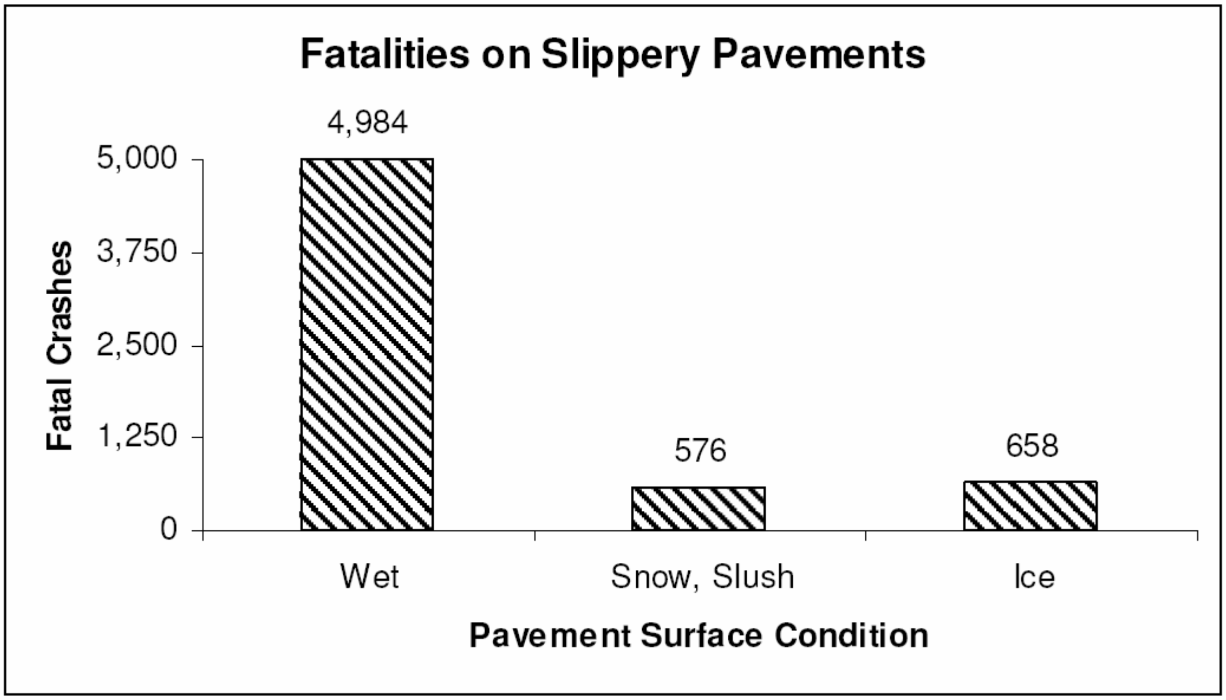


Figure 2.7: Average Fatal Crashes on US Highways on Slippery Pavements (1995-2001) [Goodwin 02]

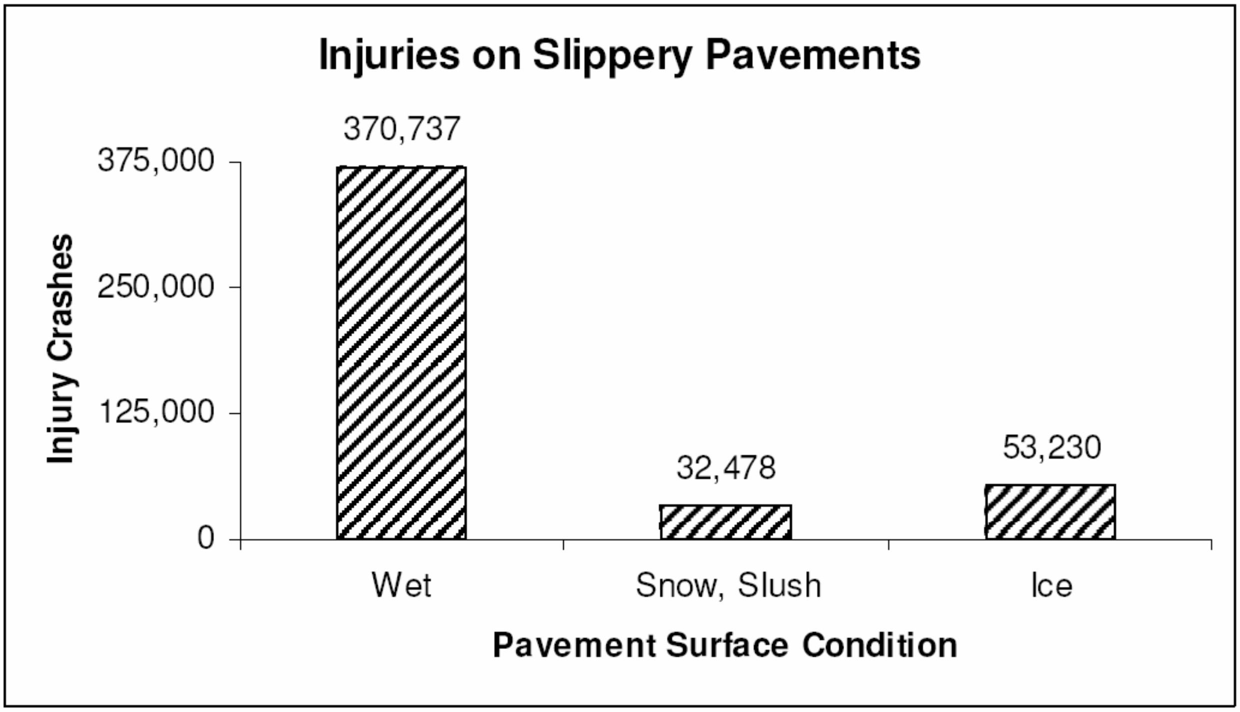


Figure 2.8: Average Injury Crashes on US Highways on Slippery Pavements (1995-2001) [Goodwin 02]

2.3.1.2 Drainage

If wet weather conditions are significant issue with respect to skid resistance than it is natural that drainage of rainwater from the pavement surface would play an important role. Proper drainage can mitigate hydroplaning and the development of water film thickness (WFT) on the pavement. Anderson [Anderson 98] explains that the water film that contributes to hydroplaning is the mean texture depth (MTD) plus the thickness of the water film above the tops of the surface (Figure 2.9).

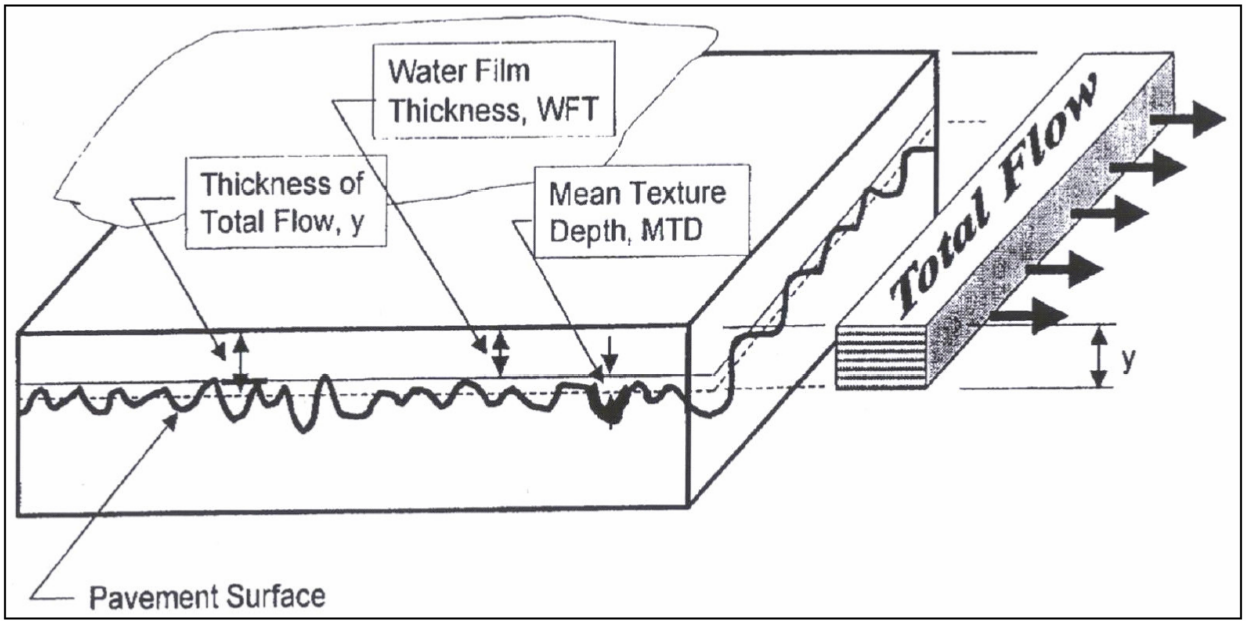
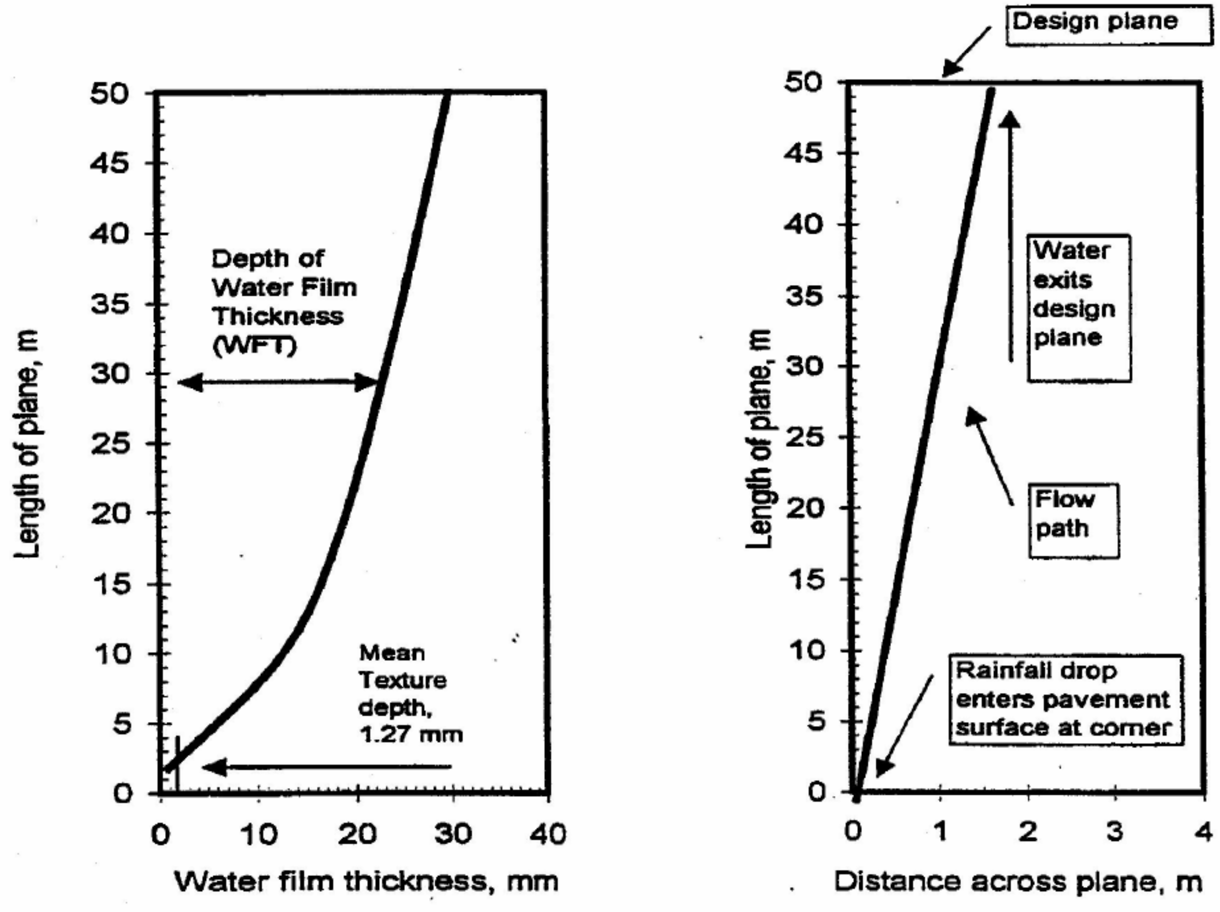


Figure 2.9: Definition of Water Film Thickness, Mean Texture Depth, and Total Flow [Anderson 98]

MTD is dependant on the macrotexture of the pavement surface and the water below the MTD is trapped in the surface and does not contribute to the drainage of the pavement. Required drainage is the total flow layer which is the WFT plus the MTD.

The flow path for a particle of water on pavement surface is defined as the line determined by the slope along the pavement surface. Thus, the maximum flow path for a pavement section is the longest flow path for the section (Figure 2.10 right). For a given quantity of rainfall per unit area of pavement, reducing the flow path will result in a more shallow depth of flow and a reduction in the tendency for hydroplaning (Figure 2.10 left).

One method of controlling WFT is to maximize the texture of the pavement surface. Since WFT is the total thickness of the film of water on the pavement minus the water trapped in the macrotexture of the pavement surface, WFT can be reduced in direct proportion to an increase in macrotexture. The importance of macrotexture is recognized in French practice where microsurfacing techniques are in common use and have replaced the use of porous asphalt where it did not meet performance standards and hydroplaning was an issue [Noyce 05].



Note: The figures above show a plan view of a design plane (right) and a profile of the water film thickness (WFT) as water flows along flow path (left). Water falling on the pavement first fills the macrotexture (lower left, here 1.27 mm deep) at which point it reaches tops of the asperities of the coarse aggregate particles. At this point, the depth of the water film increases (from zero) until the water exits either an edge of the pavement plane (case here) or a drainage appurtenance.

A plane is defined as a section of pavement that has the same geometric characteristics. In the drainage model used in this study, the drainage across the pavement is modeled by linking adjacent design planes.

Figure 2.10: Definition of Flow Path and Design Plane [Anderson 98]

2.3.1.3 Condition and Type of Tire

Friction is the result of interaction between the tire and the pavement interface, thus the condition of the tire including air pressure, temperature, composition, tread pattern and depth can all influence skid resistance. Friction values have proven to be very sensitive to the type of tire used, so much so that a standard tire from two different batches can produce different friction results [Wallman 01]. The difference might not be large but can be significant nevertheless. One explanation is the possibility of minor differences in the tire rubber composition or a minor variance in the tire geometry. When assessing friction values engineers should be aware of the tire tread to have a better understanding of the interaction between the tire and the road surface (Figure 2.11).

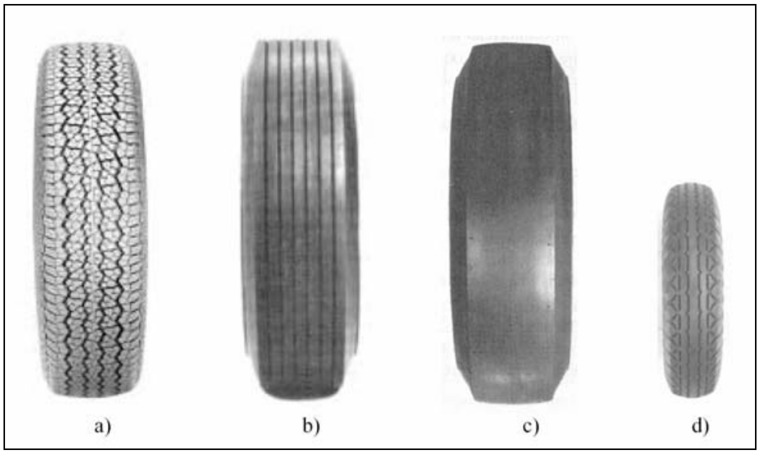


Figure 2.11: Four standard friction test tires. a) Patterned ASTM E1136 b) Ribbed ASTM E501 c) Smooth ASTM E524 d) Patterned T49 [Wallman 01]

A study involveing 82 passenger cars further illustrates the importance of the tire when evaluating road friction and demonstrates that individual cars can experience different friction levels despite constant pavement friction as evaluated using one standard tire [Wallman 01]. The best tire has an optimum wet friction coefficient of approximately 1.0, while the worst tire was approximately 0.7 (Figure 2.12). Another study by Nordstom and Gustavsson, as described in a literature review by Wallman and Astrom [Wallman 01], found a range for the optimum friction coefficient between 0.6 and 0.85 in a similar investigation using a large sample size of almost 250 different passenger cars. This type of information is important for engineers to consider when designing surfacing treatments to ensure they are designing to improve the worst optimal coefficient of friction.

Skid resistance changes over time: typically increasing in the first two years post construction and then decreasing over the remaining service life of the pavement. The road surface is worn away by traffic and the rough aggregate surfaces become exposed increasing skid resistance, but as the aggregates become more polished skid resistance decreases. Skid resistance is also impacted by season. Friction levels in the spring are expected to be higher than fall because of a depolishing effect in the surface caused by snow removal. In winter, friction tends to be higher than summer since the binder in the pavement mixture is “absorbed” causing more exposure of the aggregates [Wallman 01]. This effect does not hold true when ice or slush conditions are present. Optimum friction is the maximum static friction coefficient between the tire and the road to prevent slipping. If the wheel is locked and sliding, the force of sliding friction is determined by the coefficient of kinetic friction and is usually significantly less than optimum friction.

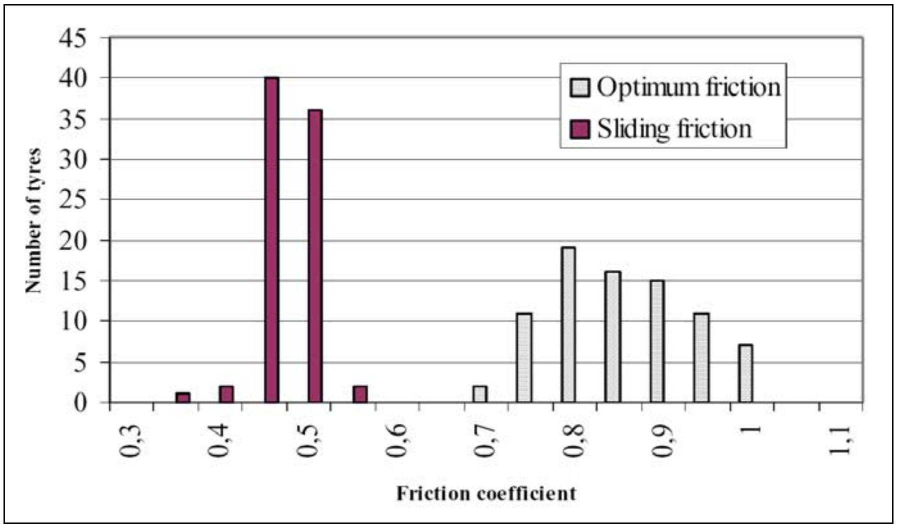


Figure 2.12: Optimum and sliding wet friction for 82 different passenger car tires measured on a normal road with asphalt concrete (extracted from Friction measurement methods and the correlation between road friction and traffic safety) [Wallman 01]

When a site has been treated to correct skid resistance problems or has revealed other potential road safety issues such as aging, bleeding, water accumulation, or surface contamination, it is in the best interest of agencies to measure and evaluate the surface skid resistance [Wallman 01].

2.3.1.4 Vehicle Speed

Speed is on of the most significant factors when traveling on wet pavements because the frictional demand increases with the square of the speed and the skid resistance at the tire-pavement point of contact decreases with increasing speed. McLean and Foley demonstrated that both macrotexture and microtexture have a significant impact on the level of friction at higher speeds as shown in Figure 2.13 and Figure 2.14.

This information and posted speed limits should play a role in the consideration of surface treatments and their composition to address insufficient skid resistance.

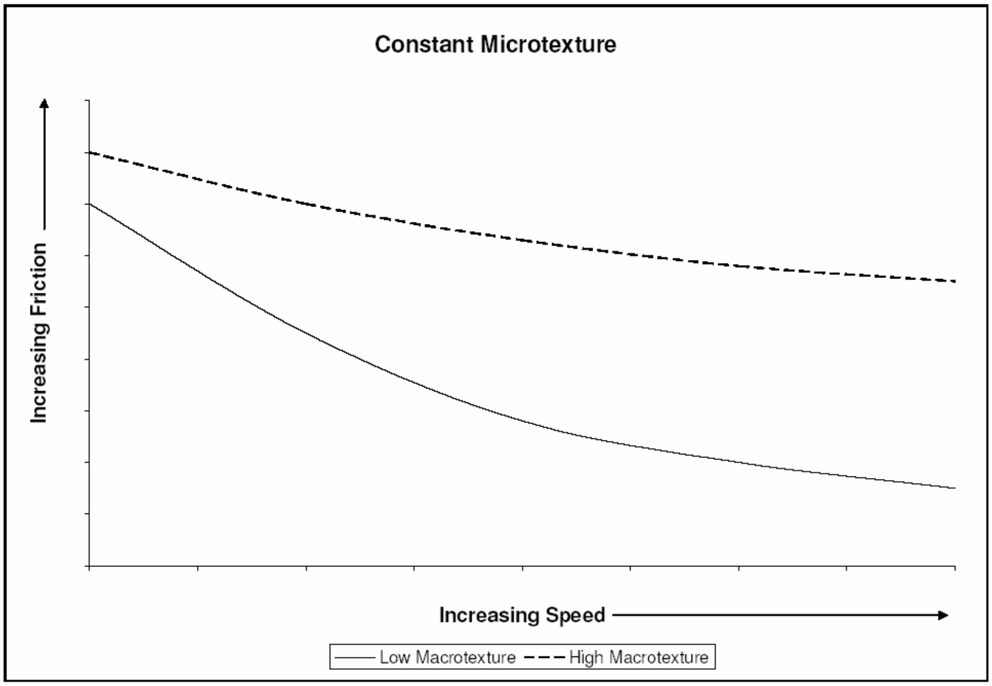


Figure 2.13: Effect of Macrotexture on Wet Pavement Skid Friction with a Constant Microtexture [McLean 98]

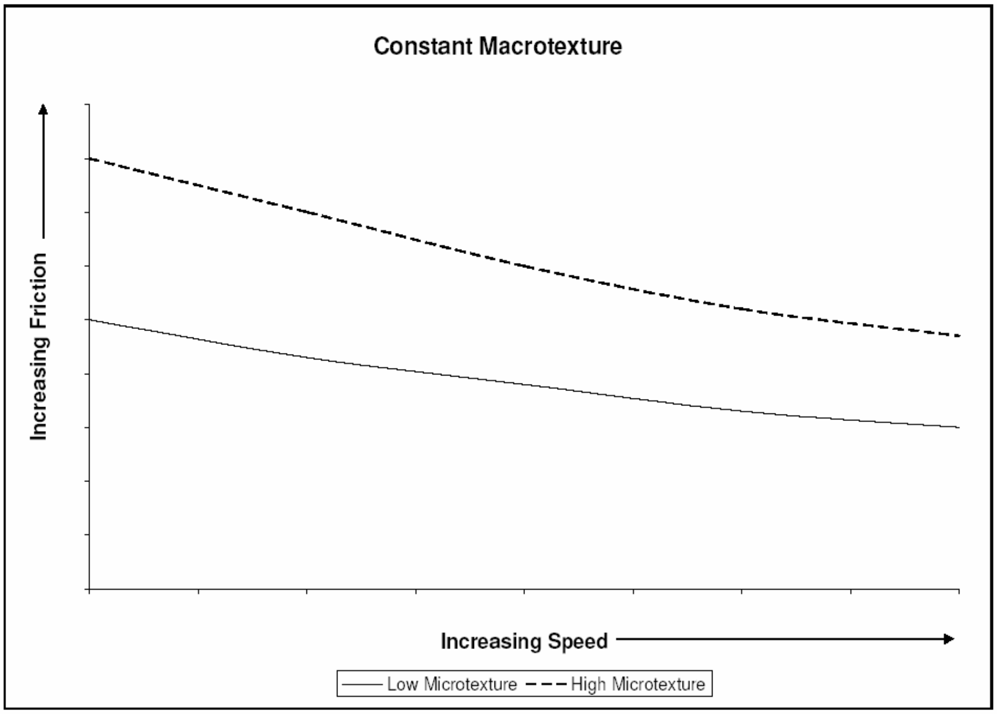


Figure 2.14: Effect of Microtexture on Wet Pavement Skid Friction with a Constant Macrotexture [McLean 98]

2.3.2 Quantifying Skid Resistance

There are various methods used throughout the industry to measure skid resistance and therefore direct comparisons of values between different testing organizations is not possible. The difference in friction using the same device could be in the range of five percent between two consecutive measurements of the same road surface; therefore results from two different devices are not equivalent nor are they directly comparable [Henry 00].

Skid resistance can be quantified by two means: friction factor or skid number. The coefficient of friction, f, is calculated by dividing the frictional resistance to motion in the plane of the interface, F, by the load acting perpendicular to the interface, L (Equation 2.1).

$$f = \frac{F}{L}$$ **(Equation 2.1)**

It is incorrect to state that a pavement has a particular friction factor because friction involves two components, the tires and the pavement. Standards have been developed compensate for this and require the specification of the tire, speed, temperature, water film thickness, and other conditions that influence may influence it. Most friction tests specify standard tires and environmental conditions to reduce variability. Skid numbers (SN) are a common measurement of skid resistance based on the locked wheel skid trailer standards and are calculated by multiplying the friction factor by 100 (Equation 2.2)

$$SN = 100f$$ **(Equation 2.2)**

2.3.2.1 Field Friction Measurement

NCHRP Synthesis 291 [Henry 00] sited 23 devices that are currently being used for field friction testing purposes. Each measurement device falls into one of four categories:

- Locked wheel testers
- Side force devices
- Fixed slip devices
- Variable slip devices

Locked Wheel Devices

The most common method for measuring pavement friction in the United States is the locked-wheel method [Henry 00]. The locked-wheel method is specified in ASTM E 274. This method is meant to test the frictional properties of the surface under emergency braking conditions for a vehicle without anti-lock brakes. The locked-wheel approach tests at a slip speed equal to the vehicle speed, this means that the wheel is locked and unable to rotate. The results of a locked-wheel test conducted under ASTM specifications are reported as a skid number (SN) or friction number (FN).

Locked-wheel friction testers usually operate at speeds between 65 and 100 km/h (40 and 60 mph). Once the target test speed has been attained, a film of water is sprayed onto the pavement 25 to 46 cm (10 to 18 inches) in front of the test tire. This water film has a nominal thickness of 0.5 mm. At this point, a vertical load of 1085 + 15 pounds is applied to the test wheel and the wheel is locked. The wheel is locked for a period of 1 second and the frictional force is measured and averaged over that period of time [ASTM 02a].

The locked-wheel trailer offers the advantage that the test variables are easy to understand and control (Figure 2.15). The primary disadvantage of this test method is that, unlike the side-force and fixed-slip methods, the friction measurement is not continuous over a test section [Henry 00]. In order to avoid undue wear on the test tire, the tire can only locked for one-second increments. This means that locations with low friction could be missed in the testing procedure.

Figure 2.15: Locked Wheel Skid Tester

Side Force Devices

The side-force method is used to measure the ability of vehicles to maintain control in curves [Henry 00]. This method involves maintaining a constant angle, the yaw angle, between the tire and the direction of motion. Water is applied to the pavement at a prescribed rate in front of the test wheel, a vertical load is applied to the test tire, and the force perpendicular to the plane of rotation (the side-force) is measured. The side-force coefficient (SFC) is calculated as:

$$SFC(V, \alpha) = (F_s/N)*100 = 100*f \quad \textbf{(Equation 2.3)}$$

where,

V = velocity of the test tire

α = yaw angle

N = normal force on the test tire

F_s = force perpendicular to plane of rotation

The slip speed, which is the relative velocity between the tire and the pavement surface, for these side-force devices can be estimated as Vsin(α) [Henry 00]. Since the yaw angle is typically small the slip speed is also quite low; this means that side-force testers are particularly sensitive to the pavement microtexture but are generally insensitive to changes in the pavement macrotexture.

The two most common side-force measuring devices are the Mu-Meter and the Side-Force Coefficient Road Inventory Machine (SCRIM) using yaw angles of 7.5 and 20 degrees, respectively. The Mu-Meter device was designed for measuring friction on airport runways while the SCRIM device was developed in Great Britain, specifically for highway measurement. A couple of the major advantages of the more sophisticated SCRIM are the continuous record of skid resistance and the high allowable operating speed (Figure 2.16 & Figure 2.17). A disadvantage is the high initial cost [Haas 94].

Figure 2.16: SCRIM Truck in New Zealand [Henderson 06]

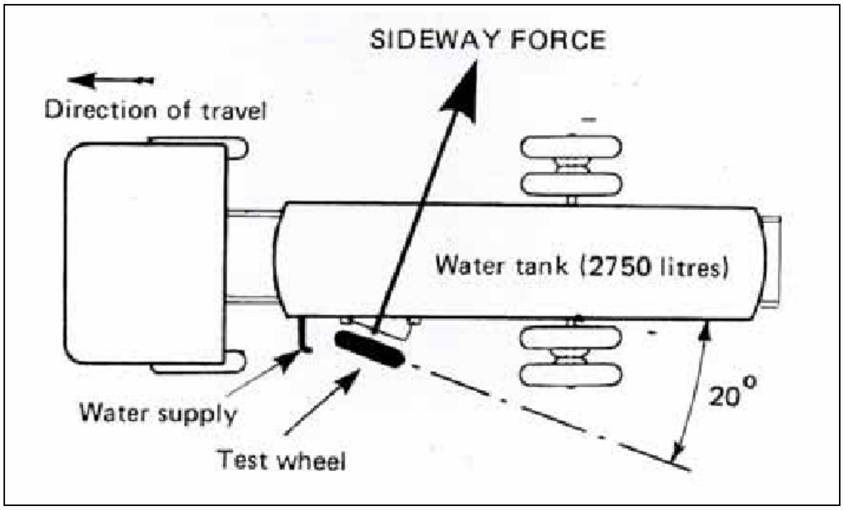


Figure 2.17: Diagram of a SCRIM resistance tester [Henderson 06]

Fixed Slip Devices

Fixed-slip devices are meant to measure the friction observed for vehicles with anti-lock brakes. Fixed-slip devices maintain a constant slip, typically between 10 and 20 percent, as a vertical load is applied to the test tire; the frictional force in the direction of motion between the tire and pavement is measured [Henry 00]. Percent slip is calculated as:

$$\text{Percent Slip} = [(V - r\omega)/V]*100 \qquad \textbf{(Equation 2.4)}$$

where:

Percent Slip = the ratio of slip speed to test speed (in percent)

V = test speed

r = effective tire rolling radius

ω = angular velocity of test tire

The measurements from fixed-slip devices are reported as brake slip numbers (BSN), which are calculated as:

$$\text{BSN}(V, \text{percent slip}) = (F/N)*100 \qquad \textbf{(Equation 2.5)}$$

where:

BSN (V, percent slip) = brake slip number for a given test speed and percent slip

F = measured friction force

N = vertical force on test tire

V = test speed

Fixed-slip devices share an advantage with the side-force measuring devices in that they can be operated continuously without producing undue wear on the test tire [Henry 00]. These devices are also more sensitive to microtexture as the slip speed is low.

Variable Slip Devices

Variable slip devices measure the frictional force as the tire is taken through a predetermined set of slip ratios [Henry 00]. ASTM Standard E 1859 outlines the full procedure for measuring pavement friction using a variable slip technique. The slip friction number (SFN) is a measurement of the longitudinal frictional force divided by the vertical force on the test tire [ASTM 02b]. The SFN is recorded over a range of slip speeds from zero up to the test speed and the results are presented in a graphical format.

2.3.2.2 Laboratory Friction Measurement

Two major devices are used for the measurement of pavement friction characteristics in the laboratory. These devices are the British Pendulum Tester (BPT) and the Dynamic Friction (DF) tester. Both these devices can also be used to measure frictional properties in the field. They both offer the advantage of being highly portable and easy to handle [Haas 94].

British Pendulum Tester

The procedure for measuring frictional properties using the BPT is specified in ASTM E 303. The BPT operates by releasing a pendulum from a fixed height above the pavement surface. The pendulum has a rubber slider attached to the end; as the slider moves across the pavement surface, the frictional force reduces the kinetic energy of the pendulum (Figure 2.18). The loss in kinetic energy and thus the magnitude of the frictional force in the pavement can be measured from the difference in the height of the pendulum before and after the slider crosses the pavement [Henry 00].

Figure 2.18: British Pendulum Tester (BPT) in use [Henderson 06]

The disadvantages of the BPT are that it only provides a measurement of the friction at very low speeds and that the BPN values do not correlate well with the frictional properties measured using other devices such as, the locked wheel trailer [Haas 94].

Dynamic Friction Tester

The DF tester was developed as an alternative to the BPT. The primary goal in its development was to produce a small-scale testing device which could measure the pavement friction and its speed dependency [Saito 96]. The DF tester is specified in ASTM E 1911.

The DF tester consists of a rotating disc with three attached rubber sliders. Water is applied to the pavement surface as the disc begins to rotate without contact between the sliders and the pavement surface. Once the target speed, typically 90 km/hr (55 mph), is reached, the water supply is stopped and the disc is lowered to the pavement surface and a vertical load is applied. As the disc rotates, a frictional force develops between the pads and pavement surface. The coefficient of friction is then computed based on the frictional force and the vertical load applied to the disc. The coefficient of friction is measured continuously as the speed of the disc's rotation decreases due to the application of the frictional force. This provides a profile of the speed dependency of the pavement friction [Saito 96].

2.3.3 International Friction Index (IFI)

The International Friction Index (IFI) was developed as a common reference scale for quantify pavement surface frictional properties. With measures of both macrotexture (mean profile depth, MPD) and friction (from any device), it is possible to estimate the IFI for a given pavement section. Guidelines for the implementation of IFI were developed as a result of the PIARC experiment to harmonize the different road friction devices. Today IFI is being adopted worldwide as the standard skid resistance measure.

The macrotexture measurement is necessary because the influence of slip speed on the friction value differs between different pavements, with different macrotextures. The friction index is calculated as [Wambold 95]:

$$FI = A + B*F*\exp[(S-60)/S_p] + C*Tx \qquad \textbf{(Equation 2.6)}$$

FI= friction index

$A, B,$ and C = device specific constants (for smooth tires $C = 0$)

F = measured friction value (with specific device)

S= slip speed in km/h

S_p = predicted so called golden value speed number = $a+b*Tx$

Tx = measure of the macrotexture (MPD in mm)

a and b = constant dependent on the macrotexture measurement device

Thus with one friction measurement at one slip speed and a measure of the surface texture, the friction at any slip speed can be estimated (Figure 2.19). In the PIARC experiment a slip speed of 60 km/h was used.

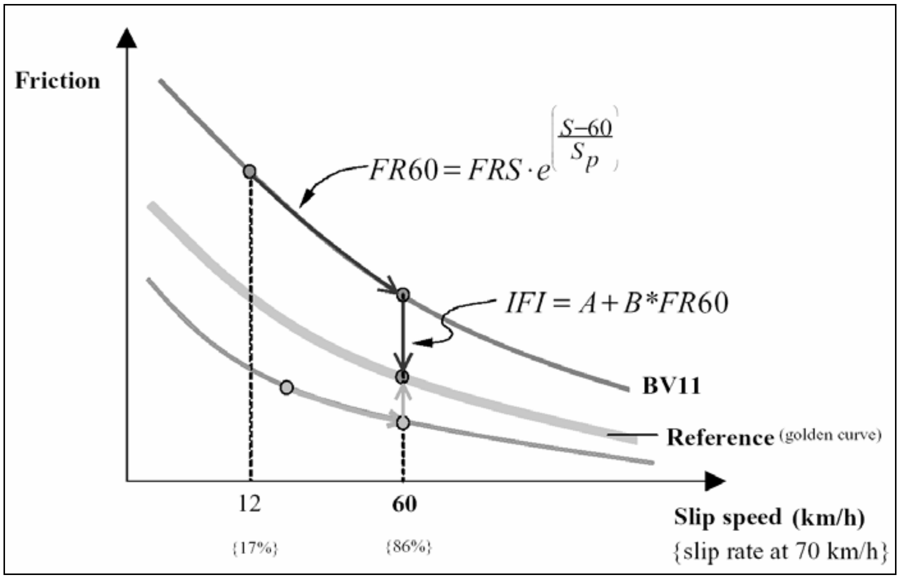


Figure 2.19: Demonstration of the calculation of the International Friction Index (IFI) [Wallman 01]

Wallmon and Astrom recommend that work continue to achieve optimal harmonization with respect to road friction measurement is engineers are to reach better specifications of acceptable road surface friction. This work would also facilitate the comparison of friction and accident rate data between different countries [Wallman 01].

2.3.4 Ranges of Skid Resistance Values

The friction resistance of most dry pavements is relatively high; wet pavements are more often the problem. In general, the number of accidents on wet pavements are twice as high as dry pavements, but other factors such as visibility are contributing factors in addition to skid resistance. The higher the skid number measurement, the better the skid resistance of the pavement (Table 2.4).

Table 2.4: Typical Skid Numbers [Jayawickrama 96]

Skid Number	Recommendations
< 30	Take measures to correct
≥ 30	Acceptable for low volume roads
31-34	Monitor pavement frequently
≥ 35	Acceptable for heavily traveled roads

In Canada the Transportation Association of Canada (TAC) Pavement Design and Management Guide has adopted criteria from Pennsylvania for identifying low friction pavement surfaces (Table 2.5). Minimum skid numbers are not commonly used in Canada and the United States because of the potential litigation implications [TAC 97].

Table 2.5: Criteria for identifying low friction pavement surfaces in Canada [TAC 97]

Category	Skid Number (SN_{40})	Accident Problem	Action by Engineering District
A	Less than 31	Yes	Improvements considered for programming on the Betterment or General Maintenance Programs in a prudent manner consistent with District priorities
B	31-34	Yes	Maintain surveillance and take corrective action as required
C	34 or less	No	Maintain surveillance and take corrective action as required
D	35-40	-	Maintain surveillance and take corrective action as required
E	Greater than 40		No further action required

To get an indication of the variance in numerical values for skid resistance, it is of interest to review European practices. Sweden measures road surface wet friction with fixed slip devices and a friction value of 0.5 is desirable at 100 km/h. Finland established acceptable friction levels as a function of speed (Table 2.6).

Table 2.6: Typical Skid Resistance Values in Finland [Noyce 05]

Speed (km/h)	Speed (mph)	Acceptable Friction
80	50	0.4
100	60	0.5
120	75	0.6

One of the leading countries regarding road friction monitoring is the United Kingdom. A policy has been established to govern acceptable friction levels for different road and traffic scenarios using a SCRIM device (Side force Coefficient Road Inventory Machine). It lists investigatory levels whereby a site requires an investigation or a surface treatment if the skid resistance value is at or below than the level listed (Table 2.7).

The Netherlands monitors the friction levels of the major road network taking measurements every other year, using 8 friction trailers. Sweden and Norway are leaders in winter road friction measurements. It is worth pointing out that all of the four countries that are ahead of Canada with respect to the worlds safest roads (Great Britain, Sweden, Netherlands, and Norway) are all actively collecting and analyzing friction measurements.

Some agencies in North America have monitoring programs to identify skid resistance problems related to frictional properties, however many do it on a reactionary basis to promote public safety. Friction test data has the potential to be used in a pavement management system to rank safety rehabilitation treatments eliminated the need for reactionary maintenance and rehabilitation.

Table 2.7: U.K.'s Investigative Skid Resistance Values [Noyce 05]

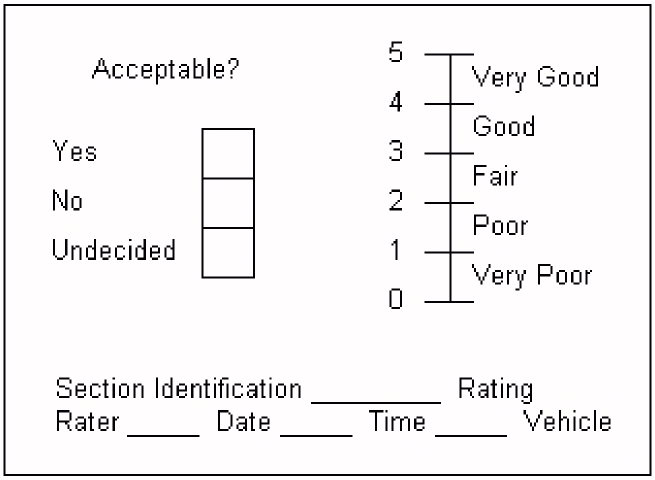
Skid Resistance Measure	Site Category	Skid Resistance Value
SCRIM at 50 km/h	A-Motorway (mainline)	0.35
	B-All-purpose dual carriageway – non-event sections	0.35
	C-Single carriageway – non-event sections	0.40
	D-All-purpose dual carriageway – minor junctions	0.40
	E-Single carriageway – minor junctions	0.45
	F-Approaches to and across major junctions	0.45
	G1-Grade 5 to 10%, longer than 50m	0.45
	G2-Grade > 10%, longer than 50 m	0.50
	H1-Curve with radius < 250 m bit subject to 65 km/h speed limit or lower	0.45
	J-Approach to roundabout	0.55
	K-Approach to traffic signals, pedestrian crossings, railway level crossings or similar	0.55
SCRIM at 20 km/h	H2-Curve with radius < 100 m not subject to 65 km/h speed limit or lower	0.60
	L-Roundabout	0.55

2.4 Roughness

Pavement roughness can be defined as a distortion of the pavement surface that contributes to an undesirable or uncomfortable ride [Haas 94]. Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption, maintenance costs, and safety.

2.4.1 Quantifying Roughness

Roughness is often quantified using either the present serviceability rating (PSR), riding comfort index (RCI), or international roughness index (IRI), with the latter being the most prevalent. The American Association of State Highway Officials (AASHO) Road Test developed a definition of pavement serviceability: “the judgment of an observer as to the current ability of a pavement to serve the traffic as it is meant to serve.” To establish the original AASHO Road Test PSR score, observers rode around the test tracks and rated their ride using a quantitative scale. The subjective ratings range from 5 (for excellent) to 0 (for impassable) (Figure 2.20). Although subjective, PSR generally provides insight into road roughness because it represents a passenger’s interpretation of ride quality. In Ontario the Pavement Condition Index (PCI) is used. This index combines both distresses and roughness.



Acceptable?

Yes ☐
No ☐
Undecided ☐

5
Very Good
4
Good
3
Fair
2
Poor
1
Very Poor
0

Section Identification _________ Rating
Rater _____ Date _____ Time _____ Vehicle

Figure 2.20: AASHTO Road Test Individual Present Serviceability Rating Form

The equivalent to the PSR in Canadian studies is the riding comfort index (RCI) developed by the Canadian Good Roads Association. Originally called the Present Performance Rating, the names was changed in 1968 to more accurately reflect the evaluation of pavement riding quality only [Haas 94]. They are similar as they both have 5 descriptive cues (very-good, good, fair, poor, and very-poor), the difference is that RCI has ten numerical categories (1 through 10), whereas the PSR scale only has five (1 through 5) (Table 2.8).

Table 2.8: Riding Comfort Index

RCI Value	Description
0-2	Very Poor
2-4	Poor
4-6	Fair
6-8	Good
8-10	Very Good

The International Roughness Index (IRI) was developed by the World Bank in 1980's to reduce the subjective nature of the roughness measurement and have continuity between agencies, provinces, states, and countries. IRI is a roughness statistic that is valid for all road surface types and all levels of roughness. The IRI is based on the average rectified slope (ARS), which is a filtered ratio of a standard vehicle's accumulated suspension motion (in mm or inches) divided by the distance traveled by the vehicle during the measurement (in km or miles). The final IRI is the ARS value multiplied by 1000. An IRI value of 0 mm/m indicates absolute smoothness at the opposite end of the scale, an IRI value of 10 mm/m represents a rough unpaved roadway (Figure 2.21).

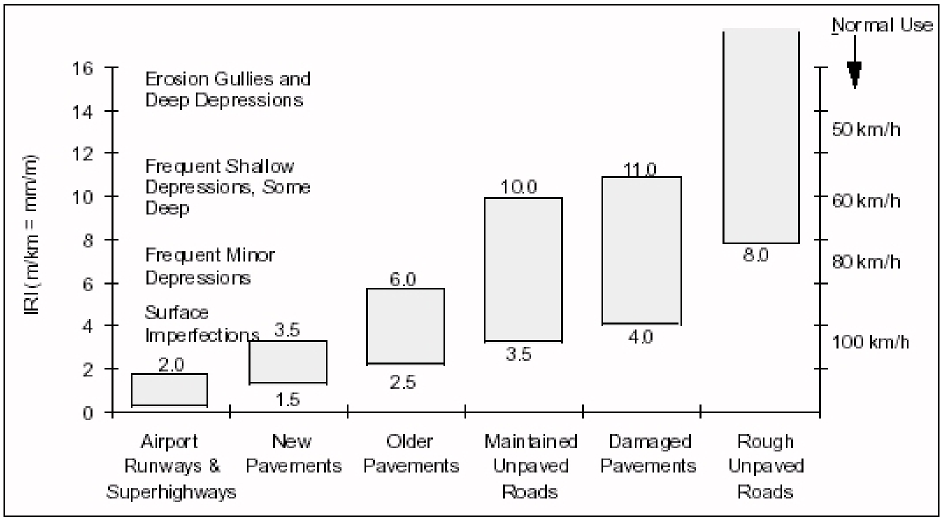


Figure 2.21: IRI Roughness Scale (replotted from Sayers et al., 1986) [TAC 97]

Roughness measurements from different devices and analysis techniques have been correlated with each other to achieve calibration or estimate another roughness statistic value. While these correlations can be very useful, they are highly dependent on the data being used and thus should applied only where the circumstances would make reasonable sense.

The characterization of pavement roughness has been a challenge due to the differences in the dynamic response of each vehicle travelling over the pavement. Many methods and devices have been developed to assist in achieving a quantifiable measure of pavement roughness. There are 3 basic categories [TAC 97]:

- Profile measuring devices – used to directly obtain pavement profile data
- Response measuring devices – which measure vehicle response from the movement over a pavement surface
- Subjective ratings – where test subjects are asked to evaluate the quality of their ride over a test course

The World Bank Report 46 places roughness measurement methods into one of four classifications ranging from Class 1 which are the most accurate to Class 4 considered to be the least accurate (Table 2.9). Class 1 has negligible measurement error with an accuracy of plus or minus two percent for a 320 m long section. Class 2 devices employ non-biased profilometric methods and Class 3 incorporates response type devices that can be correlated to IRI. Lastly, Class 4 includes subjective ratings and uncalibrated measures.

Table 2.9: Common roughness measurement methods [TAC 97]

Class 1 – Precision Profiles	Digital Incremental Profiler (Dipstick)
	Rod and Level
	Transport Research Laboratory (TRL) Profilometer
Class 2 – Other Profilometric Methods	Automatic Road Analyzer (ARAN)
	California Profilograph
	Dynatest Model 5051 RSP Laser Test System
	K.J. Law Inertial Profilometer
	Longitudinal Profile Analyzer (France)
	Road Surface Tester (Laser RST) – Sweden
	Road Tester 3000
	South Dakota Road Profiler
Class 3 – Response Type Devices	K.J Law Model 8300 Roughness Surveyor
	Mays Ride Meter (also a trailer version)
	Portable Universal Roughness Device (PURD)
	Walker Roughness Device
Class 4 – Subjective Ratings	Riding Comfort Index (from panel ratings)
	Present Serviceability Rating or Index (from panel ratings)

Some commonly used methods and devices for measuring roughness include Digital Incremental Profiler (Dipstick), California Prolifograph, and South Dakota Road Profiler, to name a few. When selecting a method it is important to consider the required speed for data collection, accuracy, and size of the sample. Correlation procedures allow many of these methods to be compared to the common standard, IRI [TAC 97].

2.5 Friction and Traffic Safety

Throughout the literature it is repeated that friction between the vehicle tires and the pavement surface is one of the main factors influencing traffic safety. Drivers are required to adapt their behaviour to changing friction conditions by modifying their travel speed. However studies have concluded that friction conditions have little influence on a driver’s speed.

A study by the Finnish National Road Administration [Noyce 05] evaluated the extent to which drivers account for pavement slipperiness. The test group drivers were asked to evaluate the road slipperiness on a scale measured and divided into four categories of friction coefficients:

- Good grip (f > 0.45)
- Fairly good grip (0.35 < f < 0.45)
- Fairly slippery (0.25 < f < 0.35)
- Slippery (f < 0.25)

The results showed that less than 30 percent of the evaluations coincided with the measured values and more than 27 percent differed by two to three categories listed above. The study concluded that drivers were poor at assessing the actual road conditions and that as friction values decreased the accuracy of the drivers' estimate of friction increased.

A study conducted by Wallman [Noyce 05] was conducted using a driver simulator. Drivers were requested to drive in both summer and winter conditions. The subjects first drove under summer conditions with a coefficient of friction set at 0.8. Next subject drove the same road under winter condition with coefficients of friction set to 0.8, 0.4, and 0.25. Two test designs were developed, with different friction distributions along the road in winter scenario.

The mean speed difference between the summer and winter scenarios were 11-12 km/h and 16-17 km/h for the first and second test design, respectively. Conversely the mean speed difference between each winter scenario was only 1 km/h independent of the surface friction. Confirming the belief that visual information had more relevance on the driver's choice speed than friction values.

Another study by Oberg [Wallman 01] illustrated how stopping distance is influence by the coefficient of friction. Plotting mean stopping distance calculated from measured speeds against actual median friction coefficients on five rural road suggest that required stopping distance increases exponentially at friction coefficient values less than 0.3 (Figure 2.22).

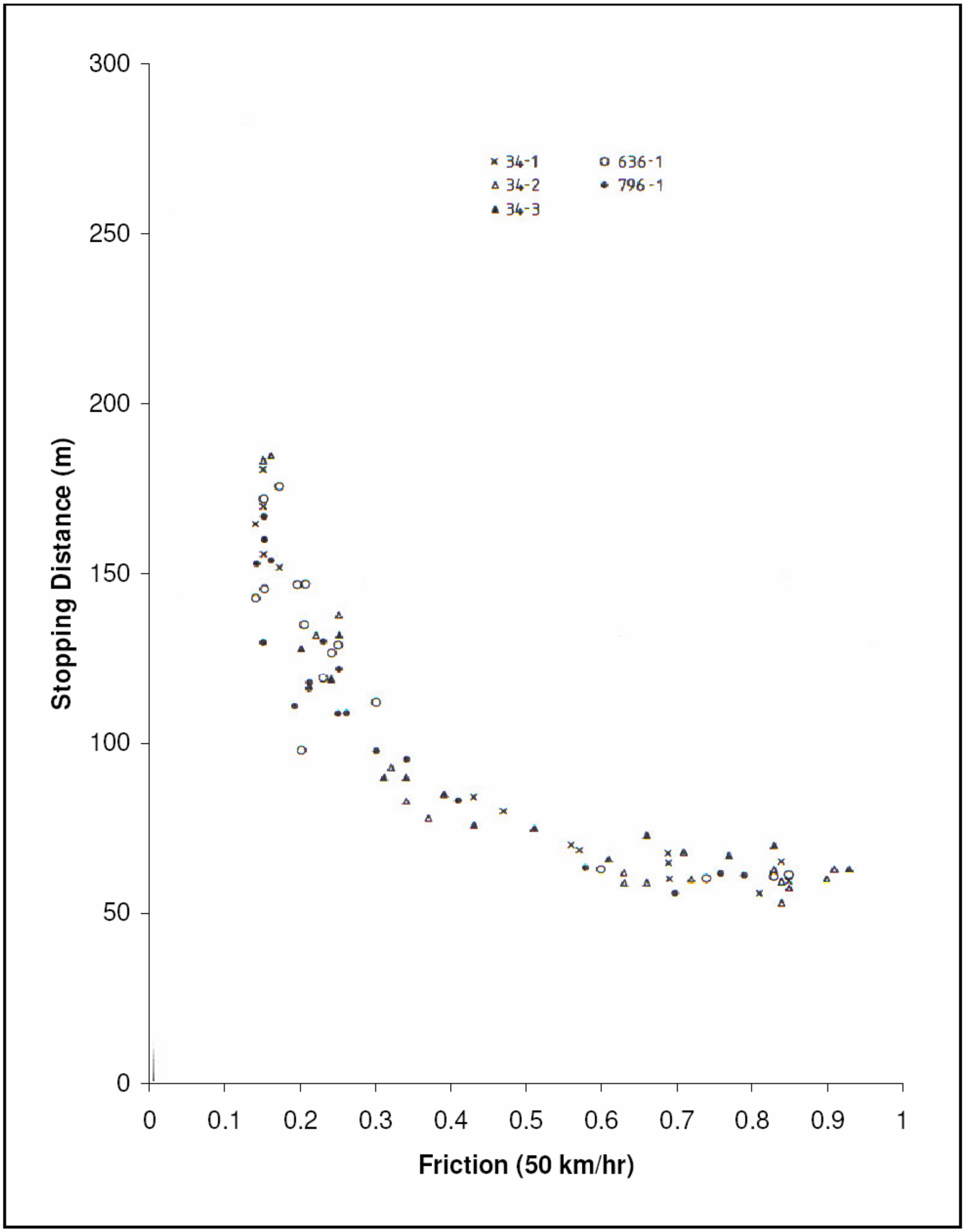


Figure 2.22: Actual stopping distance in m at different friction coefficients [Wallman 01]

A study done in the early 1960's still holds relative information. Giles et al. investigated the correlation between skid numbers and skidding accidents [Giles 64]. Skid resistance was measured at sites where frequent skidding accidents had been reported in wet weather and compared to measurements taken at randomly chosen sites. For accident sites the mean skid-resistance was 45 compared to 60 for the random sample (Figure 2.23). The shifted distribution illustrates that skid related accidents are more likely to occur on pavements with a lower skid resistance.

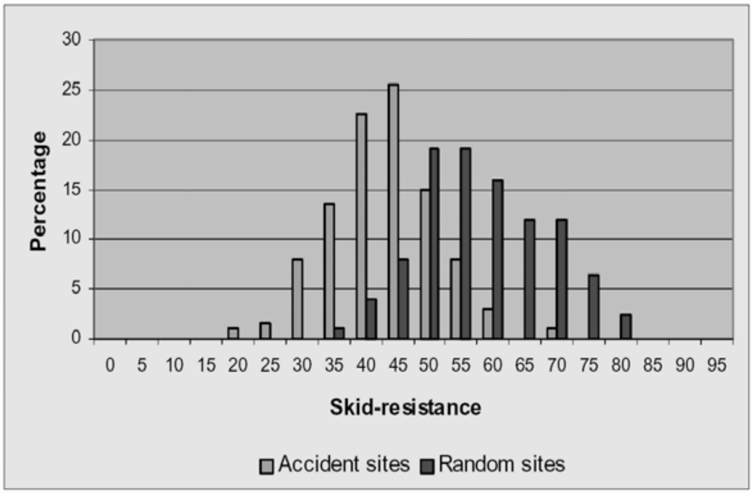


Figure 2.23: Distributions of skid-resistance measured at skidding-accident sites and randomly chosen sites [Giles 64]

Conversely, another attempt to correlate wet pavement safety and skid number was unsuccessful [Henry 00]. Based on skid numbers taken with a ribbed tire from site in Kentucky, the ratios of wet-to-dry crashes were plotted (Figure 2.24). Despite these results, many professionals are of the opinion that if the pavement surface is wet, than the risk of surface friction related crashes are increased.

Regression analysis conducted in Germany by Schulze [Schulze 76]] gives insight into the general trend of the increasing percentage of wet weather crashes with a decreasing friction level. The regression between friction numbers and crashes was not directly based on the frequency of crashes; instead it was based on the proportion of crashes that occurred in wet weather pavement conditions. In general, on most of the road sections the proportion of accidents occurring in wet weather conditions fell within the range of zero to approximately 50 percent (Figure 2.25). If on any particular section of road the proportion of wet weather crashes significantly exceeds this range of percentages, it can be taken as an indication of reduced traffic safety under wet conditions.

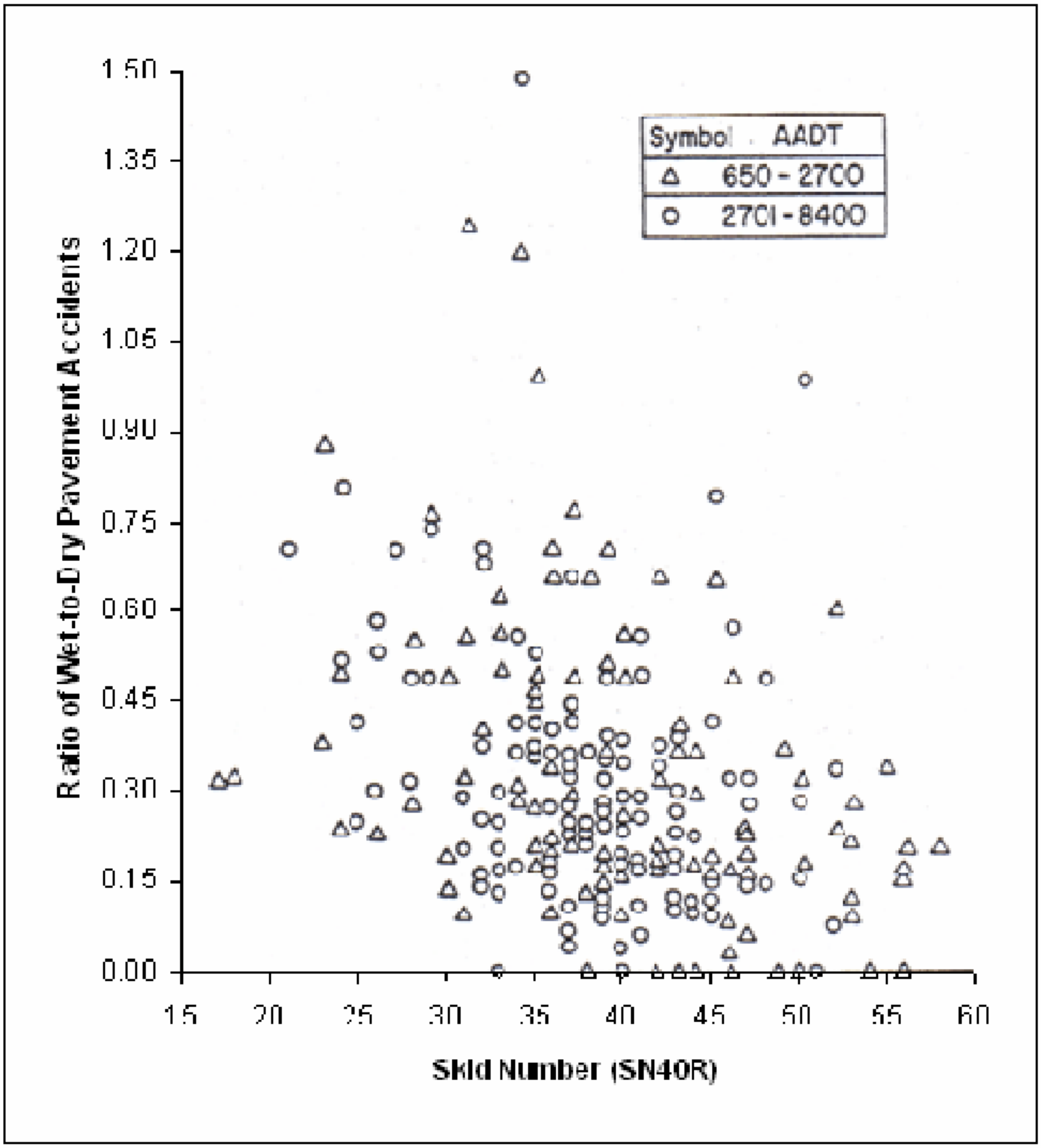


Figure 2.24: Ratio of wet-to-dry pavement accidents versus skid number [Henry 00]

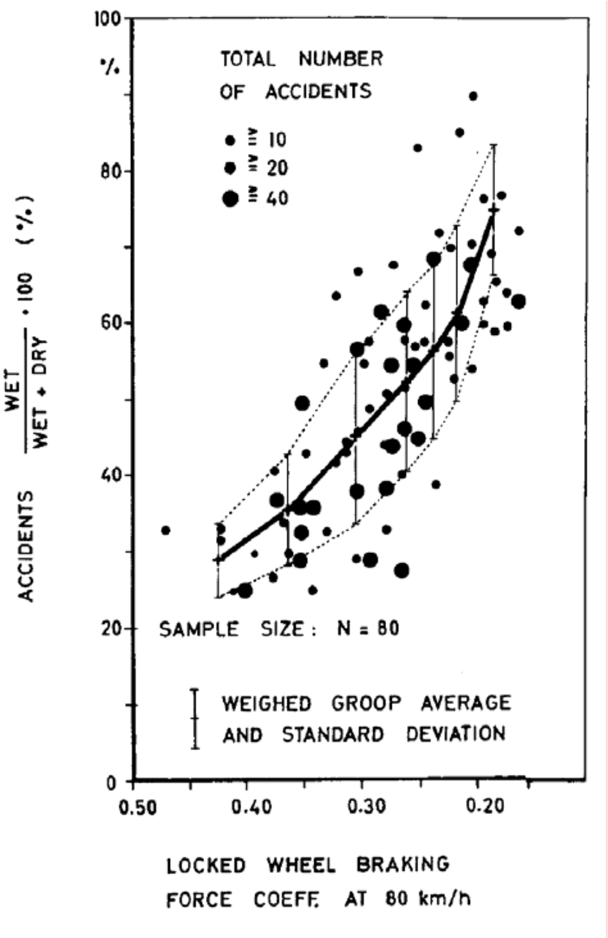


Figure 2.25: Percentage of Wet Pavement Accidents against Friction Number [Schulze 76]

Despite this trend it is essential to remember that many other factors contribute to crashes including pavement conditions, speed, and traffic conditions and therefore one should not expect to be able to predict crash frequency from skid resistance data alone [Henry 00, Noyce 05].

Griffin [Griffin 84] developed a multiple linear regression model for wet weather accidents. Several variables were used as surrogates for vehicle demand for friction:

ADT: average daily traffic
ACC: access (a standardized subjective scale of roadway congestion)
SN: skid number at 65 km/h (40 mph)
TW: proportion of time wet
VM: mean traffic speed
V: standard deviation of the speed distribution
LN: number of traffic lanes

Approximately 58 percent of the variance in wet accident rate (WAR-wet pavement accidents per mile per year) on high speed roads (55 mph) could be accounted for by the following equation:

$$WAR = -21.7+0.0009*ADT+2.35-ACC-0.40*SN+286*TW+1.32*LN \qquad \textbf{(Equation 2.7)}$$

Approximately 46 percent of the variance in WAR on low speed roads could be accounted for by the following equation:

$$WAR = -0.75+0.0001*ADT-0.053*VM+0.54*V+0.69*ACC-0.025*SN \qquad \textbf{(Equation 2.8)}$$

Unfortunately, no more relevant information about the equations was provided in the reference.

The relationship between friction and accident rate is no easy problem to explain. Wallman and Astrom attempt to relate friction intervals to an accident rate based on a Norwegian study (Table 2.10) [Wallman 01]. There is not enough information given to validate these findings and the original publication was not available in English.

Table 2.10: Accident rates (personal injuries per million vehicle kilometres) at different friction intervals [Wallman 01]

Friction Interval	Accident Rate
< 0.15	0.80
0.15 – 0.24	0.55
0.25 – 0.34	0.25
0.35 – 0.44	0.20

2.5.1 Current Practices and Case Studies

In 1980, the Skid Accident Reduction Program was developed in the United States to minimize wet weather skidding accidents through the identification and correction of roadway sections with high or potentially high skid accident history. The program also addresses new construction projects to ensure they have adequate surface friction properties. However this presents a new problem, determining a friction threshold value that can define the breakpoint in crash frequencies. Several transportation agencies have developed road friction threshold values that give the lowest acceptable road friction condition after which surface restoration or maintenance becomes mandatory.

Examination of the state experience provides insight into the possibility of a friction threshold. When a friction level is at or below the threshold it is assumed that the crash risk is increased and therefore action must be taken by the responsible agency to improve the friction level. Maine, Washington and Wisconsin use 35, 30, and 38, respectively at their threshold value as published in NCHRP Synthesis 291 [Henry

00]. Minnesota uses 45 as their friction threshold, illustrating the extent of the variance between states within the same country. Having a higher friction threshold could have a big impact on the maintenance budget and create greater opportunities for liability. This may explain why more states opt for a lower threshold. It would be interesting to compare maintenance costs before and after the implementation of the friction threshold.

In Missouri it took a fatal car crash to change their practices. The court ruled that it is the responsibility of the state DOT to improve skid resistance and/or warn motorists when the highway is slippery to prevent future accidents where two vehicles collide as a result of poor skid reistance [Noyce 05]. FHWA has resisted specifying a minimum friction level and defends that each state is best qualified to determine the appropriate regulations for their specific conditions. The governing body in Australia stated that no straightforward method exists for defining a skid resistance value at which a site automatically transforms from being “safe” to “hazardous [Austroads 05].”

Giles, Sabey and Cardew, as reviewed by Noyce et al.[Noyce 05] found that the risk of a skid related crash increased significantly for skid resistance values below 50 and but was minimal for friction values above 60 (Figure 2.26). The comparison study analyzed 120 sites where a skid related crash had occurred and 100 randomly chosen comparison sites on roadways of similar functional class and traffic volume. The resulting relative risk was calculated by dividing the proportion of skid related crash sites by the proportion of control sites for different skid resistance categories. The plotted results show that there is no additional benefit when skid resistance was above 60; also, the significant increase in relative risk when skid resistance is below 50 is questionable because of the severe extrapolation.

A large study conducted in Texas by McCullough and Hankins, as reviewed by Cairney [Cairney 97] examined 571 sites and recommended a minimum desirable friction coefficient of 0.4 at 50 km/h. Similar to other studies and beliefs, the results showed that a large proportion of crashes occurred in the presence of low skid resistance and very few occurred in the presence of high skid resistance. The friction coefficient of 0.4 was selected as it was close to the point where the slope of the resultant curves decreased and was thought to be a convenient rounded value.

A before-after study conducted by Miller and Johnson in England and reported by Cairney [Cairney 97] looked at the effect that resurfacing to improve friction had on the number of crashes. The findings reported claimed that resurfacing increased the average friction from 0.4 to 0.55 at 80km/h (50 mph). The study period was two years before and two years after resurfacing occurred. In the end over 500 incidents were analyzed and concluded that pavement resurfacing led to a 63 percent reduction in wet weather crashes and a 28 percent reduction in dry weather crashes.

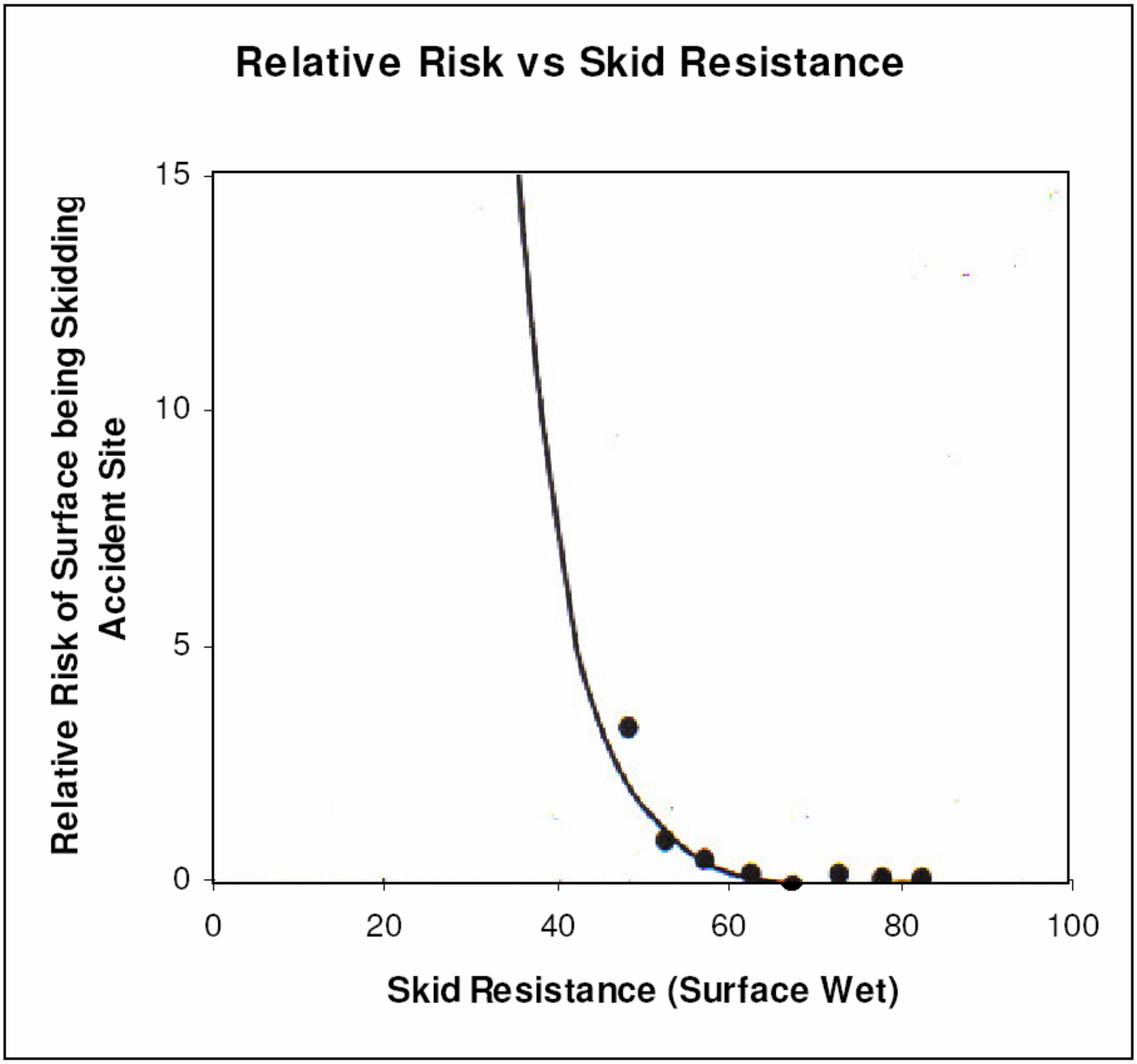


Figure 2.26: Relative Risk of a Crash as a Function of Friction [Noyce 05]

In Ontario, Kamel and Gartshore experienced similar results [Kamel 82]. Resurfacing treatments at hazardous intersections with low friction levels saw a 71 percent reduction in wet pavement crashes and a 21 percent reduction in dry pavement crashes. Rehabilitation at 8 problematic freeway sites resulted in a 54 percent crash reduction in wet conditions and a 16 crash reduction in dry conditions. The findings were attributed to the improved mix design that resulted in better surface textures and longer lasting skid resistance characteristics.

New York State Department of Transportation's (NYSDOT's) Skid Accident Reduction Program (SKARP) [Bray 03] identifies sections of pavement experiencing unusually high proportions of wet road crashes, friction tests them, and treats those sections which are experiencing both high wet road crashes and low friction numbers. The treatment generally involves a 1 and 1/2" resurfacing, or a 1/2" microsurfacing and costs roughly $20,000 (US dollars) per lane mile. "Before and After" accident analyses have shown that each year more than 740 annually recurring accidents are being reduced as a consequence of treatments undertaken at 40 sites between 1995 and 1997 on Long Island alone. Five hundred and forty (540) of those crashes were wet road crashes. The study yielded the following crash modification factors for the SKARP program: total crashes (T) should be expected to decline by 20%, wet road crashes (WRC) should be expected to decline by 60%, and severe (fatal and injury-F/I) wet road crashes should be expected to decline by 70% (Table 2.11).

Table 2.11: SKARP Crash Reduction Summary

Study Period (months)	Number of Sites	WRC Before		WRC After		WRC Reduced		WRC % Reduction	
		T	F/I	T	F/I	T	F/I	T	F/I
7	5	22	15	4	2	18	13	82	84
19	13	346	224	91	40	255	184	74	82
31	6	72	56	28	14	44	42	61	75
36	16	348	280	124	76	224	204	64	73

In total, 40 locations were treated and evaluated under the Program. All but one of the 40 sites treated in this study involve intersections. Improving pavement friction at intersections experiencing high wet road crashes and low friction numbers, presents a relatively low cost improvement which should be expected to produce large crash reductions especially when dealing with severe crashes.

Based on the size and consistency of the differences in crash experience and friction numbers during each year before and following resurfacing at identified high wet road crash sites, Bray concludes that the Program selection and treatment strategies are appropriate and effective. Percentages of wet road crashes (compared with total crashes) remained consistently high during years before treatment, and consistently low following treatment. Particularly noteworthy, is that the percentages remained high during the before period even during years when the identified high wet road crash sites did not appear on the annual high wet road crash listing (suggesting a minimal effect of regression to the mean at identified high crash sites experiencing low friction numbers).

Work performed in the U.K. by McLean reported by Noyce et al.[Noyce 05] produced different findings. Crash rates on rural asphalt roadways were found to increase following resurfacing projects, indicating that surface treatments alone do not necessarily improve safety. The results showed that while wet pavement crashes were reduced, the increase in dry pavement crashes resulted in an overall increase in total crashes (Table 2.12).

Table 2.12: Effects on Crash Rates on Rural Asphalt Roadway Following Resurfacing [Noyce 05]

Type of Crash	Percentage of Change in Crash Rate		
	First Year after Resurfacing	Final Year of Project	Average Over Project Life
Wet Road	-15	0	-7
Dry Road	+10	0	+6
Total	+5	0	+3

Earlier literature has stated that directly following a treatment drivers have been known to increase speeds and reduce attention to the road as a result of the improved ride quality. This can lead to one of two trains of thought: certain time frame following the treatment could be excluded from the study or perhaps a maximum friction threshold is also required to avoid this scenario.

The United Kingdom recently published a document that served as a revision to their Skid Resistance Policy [Viner 04]. The revised document is based on 15 years of experience and establishes desirable, investigatory, and minimum friction levels for paved highway surfaces. The updated policy requires annual SCRIM and macrotexture surveys be carried out on the entire U.K. road network. It is considered a Best Practice to annually review sites with higher than average accident rates to determine if low friction and/or texture values are a contributing factor to the number of crashes. The report also notes that there can be a large number of reasons for higher than average accident rates outside of poor fiction/texture.

The results of the modeling work done in the U.K. found that increasing the texture depth from 0.3 mm to 1.5 mm reduces the accident rate by about 50 percent. Increasing the skid resistance for 0.35 to 0.6 reduces the accident rate approximately 65 percent [Viner 04] (Figure 2.27).

Texas DOT recently started using annual macrotexture surveys and periodic locked wheel skid trailer tests with a blank tire (non-standard rubber) at 80 km/h (50 mph) to make the highways safer. The mean profile depth (MPD), pavement type, and aggregate type are used to estimate friction every 80 feet within +/- 6 friction numbers. The data are further summarized to obtain the average, maximum, minimum, and standard deviation of the estimated friction every 0.1 miles to evaluate variability. Texas takes macrotexture measurements on all of their roads and tests friction on 25 percent of all roads annually, except the interstate system where testing occurs every other year.

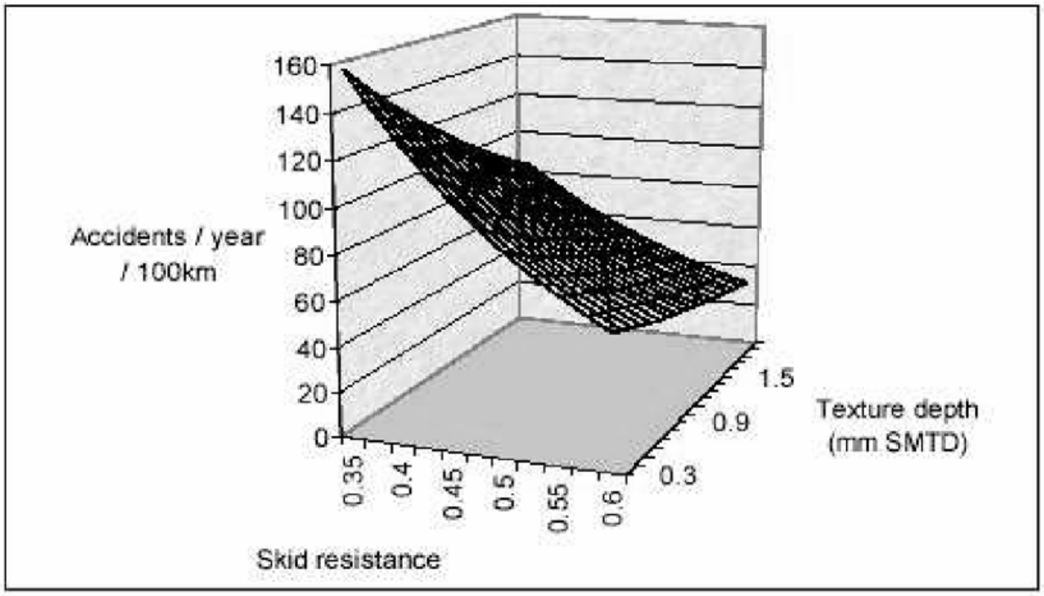


Figure 2.27: 3-D accident model for skid resistance and texture depth on single carriageways [Viner 04]

Their latest report listed the following benefits that could be anticipated in a 10 year period [Larson NDA]:

- Pavement Surface Texture measurement System: 12 lives saved, 1,100 accidents prevented, and $5,922,000 saved.
- Micro-Deval Aggregate Test: $1,495,000 saved.
- Alternate Polish Value and Soundness Specification Requirements (New Wet Weather Accident Reduction Program): 60 lives saved and 8060 accidents prevented.

While these estimates appear to potentially be over inflated, the evidence still suggests that significant benefits can be expected from employing new technology and recognizing the relationship between surface friction and crashes.

2.6 Microsurfacing

The Region of York's primary concern is with understanding the safety effects if any of microsurfacing. For this reason the topic of microsurfacing is revisited in much greater detail in the following section.

2.6.1.1 History of Microsurfacing

Microsurfacing has been used in Germany, Spain, and France since 1976 and was introduced to the United States in 1980 [Pederson 88]. It came to Canada in the early 1990's to restore pavement surface characteristics and to preserve the life of a pavement [Miller 06]. This tough, durable, thin cold overlay material can be used to restore existing pavements that are still structurally sound to their original properties. Microsurfacing has been used around the world to correct pavement irregularities and as a preventative maintenance treatment.

Since its debut, microsurfacing has been used in a variety of applications including:

- Major highways to restore the surface
- PCC pavements and bridge decks to provide frictional properties
- City streets and boulevards
- Traffic delineation
- To fill ruts in asphalt pavements
- Providing surface and scratch courses
- Correction of friction problems

Microsurfacing consists of polymer modified emulsion, high quality aggregate, mineral filler, additives, and water. A description of these five components and their role in microsurfacing are discussed individually in more detail in accordance with the International Slurry Surfacing Association (ISSA) “Recommended Performance Guidelines for Microsurfacing” [ISSA 05].

Polymer Modified Emulsion

In general, microsurfacing suppliers supply the emulsion to the contractor along with a mix design. Typically the polymer is co-milled with the asphalt cement and emulsifier; this is called a CSS-1H emulsion. Different polymers, or a combination of polymers can be added to the emulsion and these tend to be proprietary. Each polymer has its own unique properties that will enhance the performance characteristics of the emulsion. These performance characteristics could be stiffness of the emulsion at high temperatures, resistance to flushing, and elasticity of the emulsion at low temperatures. The amount and type of the emulsifier will affect the setting characteristics and compatibility of the emulsion.

Aggregate

The aggregate’s key physical characteristics for suitable incorporation into a microsurfacing mix can be defined by geology, shape, texture, age and reactivity, cleanliness and soundness, and abrasion resistance [Caltrans 03].

Geology determines the aggregate’s compatibility with the emulsion in addition to its adhesive and cohesive properties.

- Shape: the aggregate should have fractured faces in order to form the required interlocking strength as opposed to rounded aggregate that results in poor mix strength.
- Texture is important because rough surfaces form bonds more easily with emulsions.
- Age and Reactivity work together because freshly crushed aggregates have a higher surface charge than aged (weathered) aggregates. Surface charge plays a primary role in reaction rates.

- Cleanliness is very important because deleterious materials such as clay, dust, or silt can cause poor cohesion and adversely affect reaction rates.
- Soundness and Abrasion Resistance features are especially important in areas that experience freeze-thaw cycles or are very wet.

The quality of the aggregate is critical since aggregate is approximately 94% of the finished microsurfacing treatment by weight. The aggregate should be a manufactured crushed stone such as granite, slag, limestone, chat, or another high-quality aggregate, or combination thereof. The aggregate must be 100% crushed and be densely graded to meet the requirements of one of the two gradations described in Table 11 (based on the International Slurry Surfacing Association (ISSA)).

Table 2.13: Suggested Aggregate Gradations (ISSA A-143) [ISSA 05]

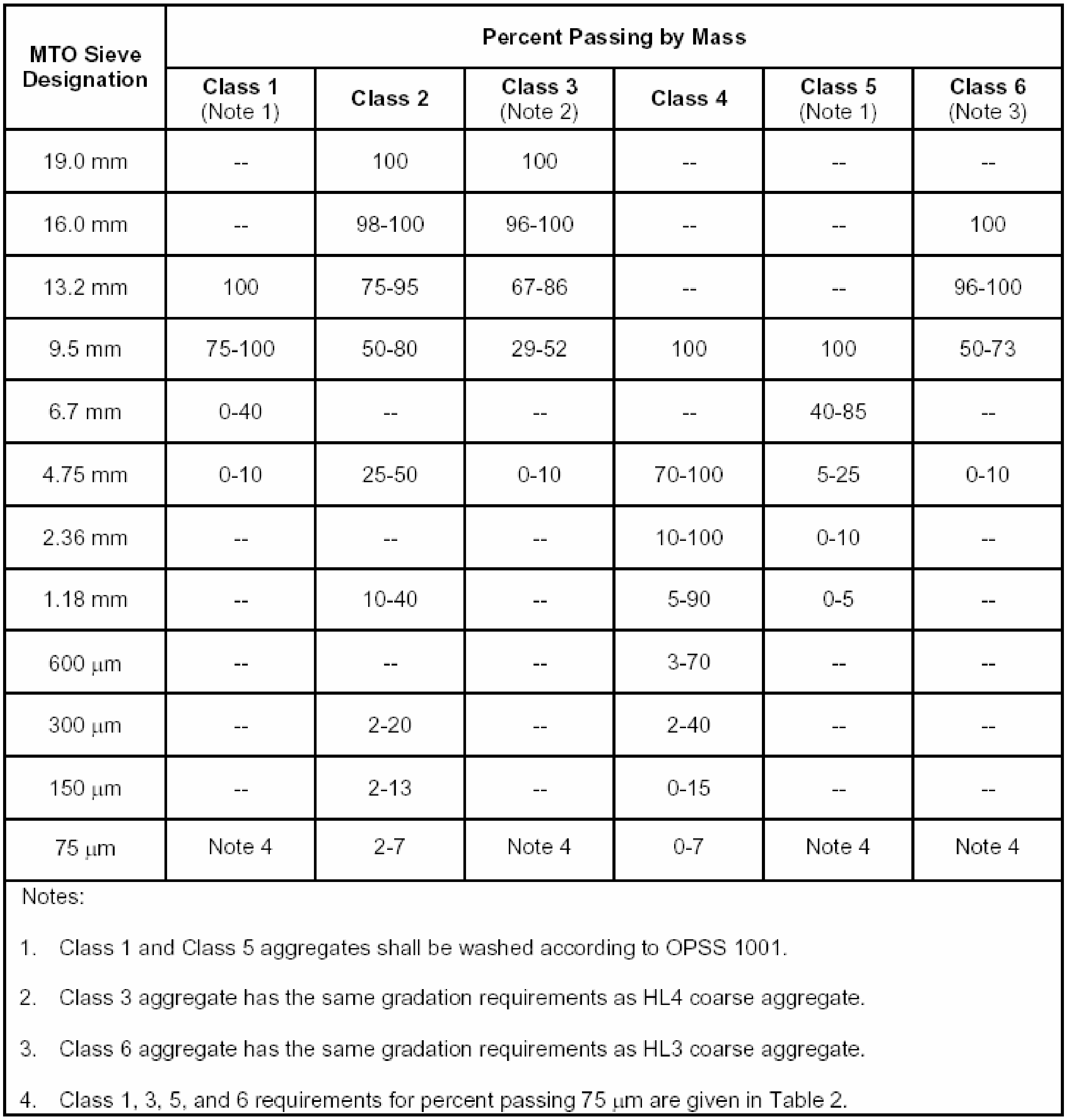
Sieve Size	Type II Percent Passing	Type III Percent Passing	Stockpile Tolerance
9.5 mm	100	100	
4.75 mm	90-100	70-90	± 5%
2.36 mm	65-90	45-70	± 5%
1.18 mm	45-70	28-50	± 5%
600 μm	30-50	19-34	± 5%
330 μm	18-30	12-25	± 4%
150 μm	10-21	7-18	± 3%
75 μm	5-15	5-15	± 2%

In Ontario, the requirements for aggregates used in surface treatments must comply with Ontario Provincial Standard Specification (OPSS) as described in Table 2.14.

As well as grading tests, several tests in accordance with the American Association of State Highway Transportation Officials (AASHTO) to ensure the quality of the aggregate are required: AASHTO T-176, AASHTO T-104, and AASHTO T-96. It is recommended that the aggregate meet the corresponding minimum requirements outlined in Table 2.15.

Individual agencies may have other requirements, i.e., insoluble residue or polish value for friction resistance. The abrasion test is to be run on the aggregate and this aggregate should meet the approved polishing values of the local agency.

Table 2.14: OPSS Gradation Requirements [OPSS 06]



MTO Sieve Designation	Percent Passing by Mass					
	Class 1 (Note 1)	Class 2	Class 3 (Note 2)	Class 4	Class 5 (Note 1)	Class 6 (Note 3)
19.0 mm	--	100	100	--	--	--
16.0 mm	--	98-100	96-100	--	--	100
13.2 mm	100	75-95	67-86	--	--	96-100
9.5 mm	75-100	50-80	29-52	100	100	50-73
6.7 mm	0-40	--	--	--	40-85	--
4.75 mm	0-10	25-50	0-10	70-100	5-25	0-10
2.36 mm	--	--	--	10-100	0-10	--
1.18 mm	--	10-40	--	5-90	0-5	--
600 μm	--	--	--	3-70	--	--
300 μm	--	2-20	--	2-40	--	--
150 μm	--	2-13	--	0-15	--	--
75 μm	Note 4	2-7	Note 4	0-7	Note 4	Note 4

Notes:

1. Class 1 and Class 5 aggregates shall be washed according to OPSS 1001.
2. Class 3 aggregate has the same gradation requirements as HL4 coarse aggregate.
3. Class 6 aggregate has the same gradation requirements as HL3 coarse aggregate.
4. Class 1, 3, 5, and 6 requirements for percent passing 75 μm are given in Table 2.

Table 2.15: Aggregate Quality Test Specifications (ISSA A-143) [ISSA 05]

Quality	AASHTO Test No.	ASTM Test No.	Specification
Sand Equivalent	AASHTO T-176	ASTM D-2419	65 minimum
Soundness	AASHTO T-104	ASTM C-88	15% maximum using Na_2SO_4 or 25% maximum using $MgSO_4$
Abrasion Resistance	AASHTO T-96	ASTM C-131	30% maximum

Mineral Filler

Mineral filler is used in microsurfacing to trigger the chemical reaction between the emulsion and the aggregate. According to the ISSA Guidelines, if mineral filler is required it should be non-air entrained Portland cement or hydrated lime that is free from lumps. Type I Portland cement is more commonly used, however; hydrated lime is used where the aggregate is very reactive with the emulsion, in which case the lime will retard the reaction time. Another advantage of the mineral filler is that it adds consistency to the mix and prevents segregation.

Additives

Additives may be required to speed up or slow down the setting time based on environmental or traffic conditions. Essentially the additive retards the setting properties of the mixture, in order to allow the placement of the material over a wide range of temperatures. A liquid additive is carried on the paving unit and may be added to the emulsion mix or any of the component materials. The additive is often the same emulsifier that is used to manufacture the emulsion and must be included as part of the mix design and be compatible with the other components of the mix. Alternatively other additives may be used to alter the production rate.

Water

Water is primarily used to help the mixture to flow into the paving box and ensure that the mix is spread evenly. Only water that is potable and free of harmful soluble salts, reactive chemicals, or any other contaminants is permitted according to the ISSA Guidelines.

2.6.1.2 Mix Design

The mix design is prepared for the paving contractor by the emulsion supplier or by an independent laboratory that has experience designing microsurfacing mixtures. The design specifies the proper proportion of polymer modified emulsion, high quality aggregate, mineral filler, additives, and water. The achievement of a suitable mix design is empirical in nature. A trial and error process that runs multiple combinations is used to optimize the ultimate mix design while still adhering to the testing requirements recommended by ISSA-143 (Table 2.16).

The mixing time test method involves a matrix of mix recipes that are put together. The manual mixing time is recorded for each mixture. At this stage, events such as foaming and coating are assessed visually. The mixing time must be at least 120 seconds at 25°C. To simulate anticipated field conditions, the test can be repeated at elevated or reduced temperatures. The best mix is then selected based on a good mixture consistency (Figure 2.28).

Table 2.16: Microsurfacing Mix Design Tests (ISSA A-143) [ISSA 05]

Test Name	ISSA Test No.	Description	Specification
Traffic Time (Wet Cohesion Test)	TB-139	Wet cohesion @ 30 minutes minimum (set) @ 60 minutes minimum (traffic)	12 kg-cm minimum 20 kg-cm minimum or near spin
Excess Binder	TB-109	Excess asphalt by Loaded Wheel Tester sand adhesion	538 g/m^2 maximum
Adhesion (Wet Strip)	TB-114	Wet stripping	Pass (90% minimum)
Wear Loss	TB-100	Wet-track abrasion loss One-hour soak Six-day soak	 538 g/m^2 maximum 807 g/m^2 maximum
Deformation (Upper Binder Limit)	TB-147	Lateral displacement Specific gravity after 1000 cycles of 56.71 kg	5% maximum 2.10 maximum
Integrity Test	TB-144	Classification compatibility	11 grade points minimum (AAA, BAA)
Mixing Time Test	TB-113	Mix time @ 25°C	Controllable to 120 seconds minimum

The traffic time test determines the cohesion build-up in the slurry mix. It is best performed at the anticipated field temperatures to better estimate the properties of the microsurfacing treatment at the project site.

Figure 2.28: Photograph illustrating good mixture consistency [Caltrans 03]

The purpose of the wet track abrasion test is to determine the minimum asphalt content of the slurry system; it is performed in the laboratory. The mix is soaked for 1-hour and 6-day testing periods. Following the soaking period, a standard rubber hose is orbitally ground over the surface of the sample (while still submerged) for a set period of time (Figure 2.29). The wear loss can then be calculated. It is not recommended as a field quality control test. The mixing test is more for the benefit of the contractor as it provides an indication of operational performance. In short, this test predicts how long a material can be mixed in the machines before it begins to break or set. At this point the product must be placed because if it breaks in production it will not set on the road.

Figure 2.29: Orbital grinding of sample using rubber hose attachment [Caltrans 03]

The upper binder limit is established using a Loaded Wheel Tester (LWT) to get deformation measurement (Figure 2.30). A loaded wheel is place on a cured strip of the microsurfacing mixture and the surface is tested and measured. Next hot sand is poured over the surface and the sample is retested. The amount of retained sand is measured, which in turn gives a measure of the free asphalt on the sample's surface, also known as the excess binder.

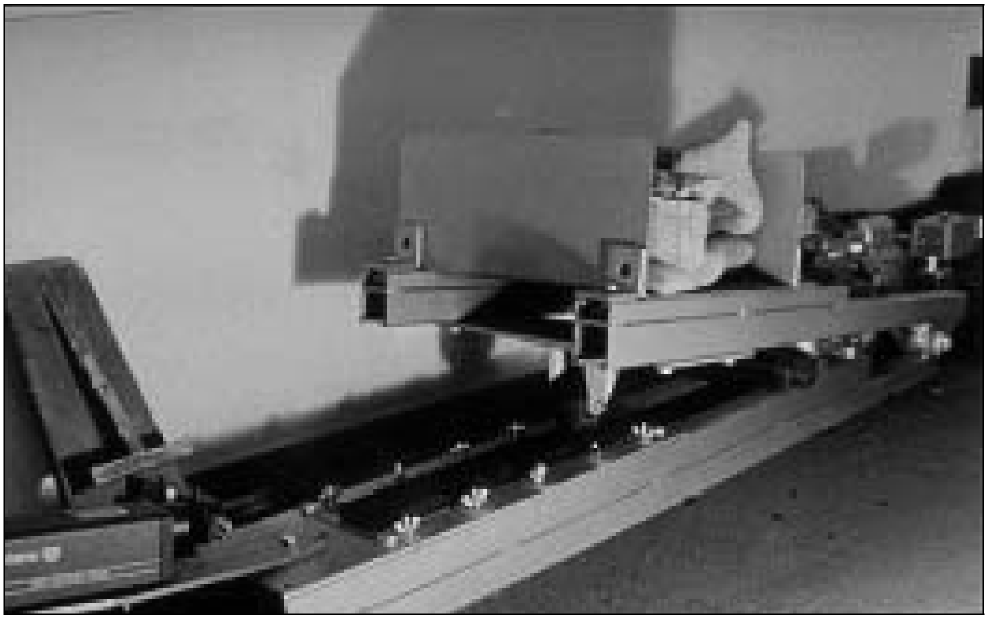


Figure 2.30: Loaded Wheel Tester (LWT) apparatus [Caltrans 03]

The optimum percentage of emulsion or binder content is determined by plotting the results from the Wet Track Abrasion Test and the Deformation Test. A sample of typical plot of test results is illustrated in Figure 2.31. The optimum emulsion content is where the two plotted lines intersect. Since the laboratory testing does not account for all field conditions, a rule of thumb is to select the highest emulsion content that passes both tests for low traffic conditions and the lowest binder content for heavy traffic conditions. This step requires a well seasoned engineer or designer with practical knowledge.

A laboratory report details the percentages of each individual material required for the mixture. Due to variable field conditions, it is acceptable to make some adjustments during construction. However, the mix design must still adhere to the limits set by ISSA (Table 2.17).

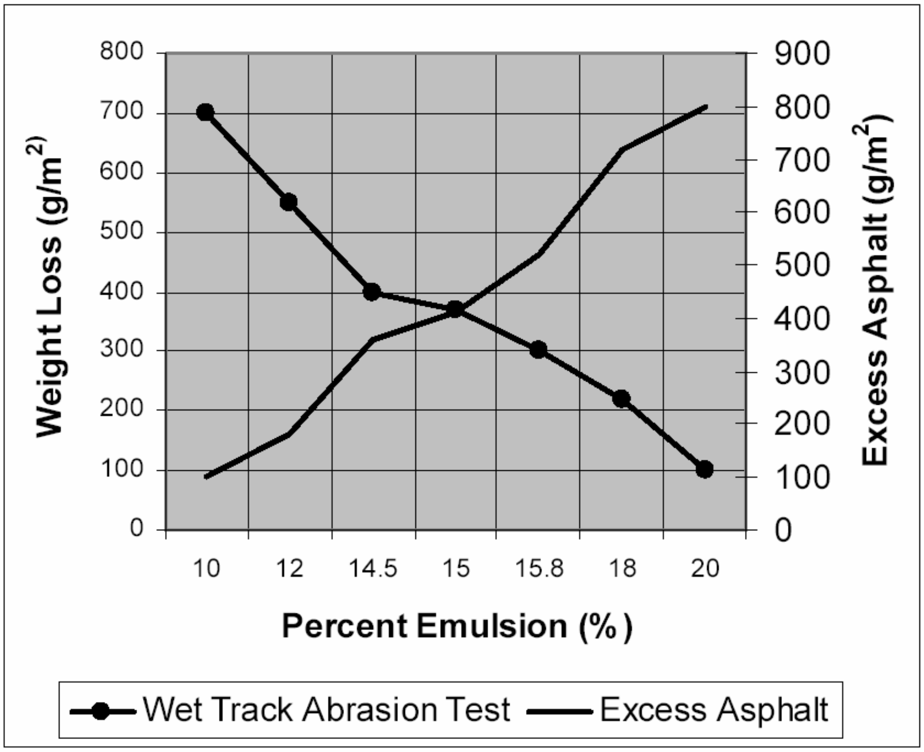


Figure 2.31: Typical plot to determine optimum emulsion or binder content [Caltrans 03]

Table 2.17: Component Material Limitations (ISSA A-143) [ISSA 05]

Component Materials	Limits
Residual Asphalt	5.5 to 10.5% by dry weight of aggregate
Polymer Modified Emulsion	Minimum of 3% solids based on bitumen weight content
Mineral Filler	0.0 to 3% by dry weight of aggregate
Additives	As needed
Water	As required to produce proper mix consistency

Suggested application rates of the microsurfacing mixture vary by aggregate type and the location of the treatment (Table 2.18). The suggested application rates are based upon the weight of the dry aggregate in the mixture because application rate is affected by the unit weight of the aggregate.

Table 2.18: Suggested Application Rates (ISSA A-143) [ISSA 05]

Aggregate Type	Location	Suggested Application Rate
Type II (< 5 mm)	Urban and Residential Streets	5.4-10.8 kg/m^2
	Airport Runways	
Type III (< 9.5 mm)	Primary and Interstate Routes	8.1-16.3 kg/m^2
	Wheel Ruts	Varies based on rut depth

Microsurfacing is typically laid down in two full-width passes in place of rut-filling when the rutting or deformation is not severe. The first pass is a scratch course and is made by using a metal or stiff rubber strike-off and applying only what the surface demands for leveling, and then the second course follows. Multiple course applications are required if any of the following conditions are present: surface irregularities, rutting, polished aggregate. Sometimes a single course application may be sufficient if its purpose is to retard oxidation or improve friction.

2.6.1.3 Equipment

The equipment used to place microsurfacing has improved over recent years to enhance and maximize the contractor's productivity. The equipment can be divided into two categories: mixing equipment and placement equipment.

Mixing Equipment

All of the ingredients are stored on a self-propelled chassis that contains a double shafted pugmill that can efficiently mix the ingredients that have been proportioned into the mixer [Moulthrop 96]. The feeding mechanisms for all of the components are interlocked so that interruptions in the delivery of any ingredient will cause the device to automatically shut down (Figure 2.32).

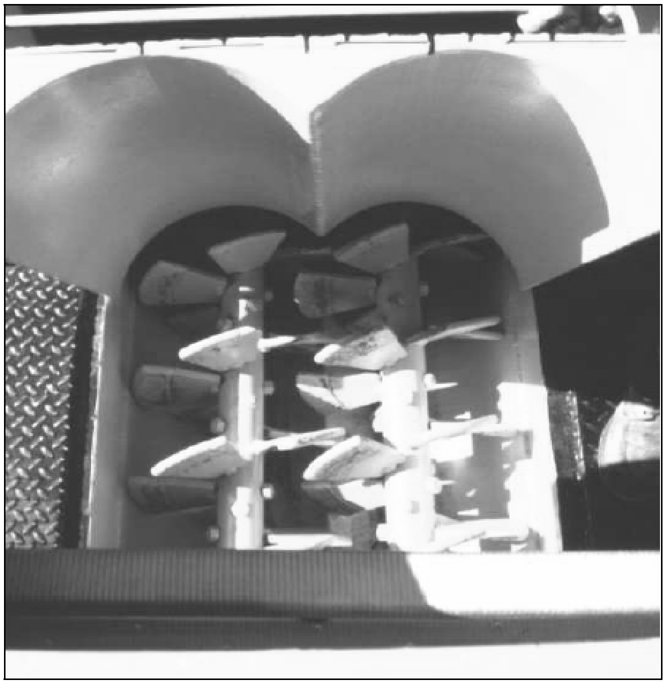


Figure 2.32: Microsurfacing Machine Pugmill [Galehouse NDA]

There are two types of chassis available: self contained (machine mount) and self loading (continuous). The self contained machine works in a batch-to-batch mode, where enough material is stored on the machine to place approximately seven cubic metres of mix and then the machine returns to a nearby stockpile to reload. Alternatively, the self loading machine works continuously and is configured with some storage as well but is capable of being reloaded continuously from "nurse" units (Figure 2.33). The advantage is that the nurse units return to the stockpile to reload and the machine continues to place the microsurfacing mix.

Figure 2.33: Continuous application microsurfacing placement machine [Galehouse NDA]

Placement Equipment

Once the mixture exits the pugmill, it is directed by a chute into a paving box where it is evenly spread across the width of the pavement by augers or paddles. Adjustments for pavement width and application rate are easy as the paving box is hydraulically operated. Rubber seals at the front and rear of the paving box ensure a uniform texture and appearance. The front seal ensures no loss of the mixture at the road contact point and the rear seal acts a final strike-off.

In the event a "scratch" course is required, the contractor replaces the rear rubber seal with a steel plate and places the paving box directly on top of the pavement (Figure 2.34). This allows the placement of a thin 5.5 to 8 kg/m^2 leveling course that fills any depressions in the existing pavement prior to the placement of the final surface. Once a scratch or rut fill is placed traffic is usually introduced for at least twelve hours before the final surface is placed.

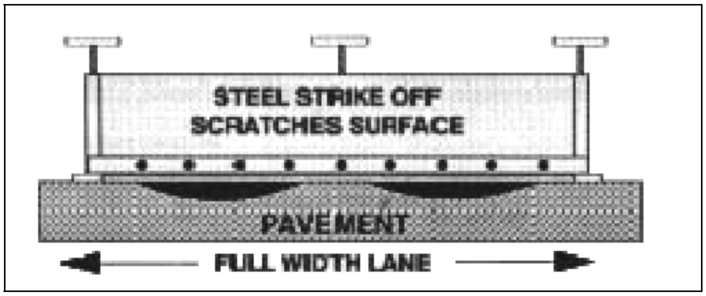


Figure 2.34: Illustration of steel strike-off scratching the surface [Caltrans 03]

Figure 2.35 illustrates the process of microsurfacing in a schematic. The graphic shows the typical mixing order of aggregate, followed by cement, water, the additive and lastly the emulsion.

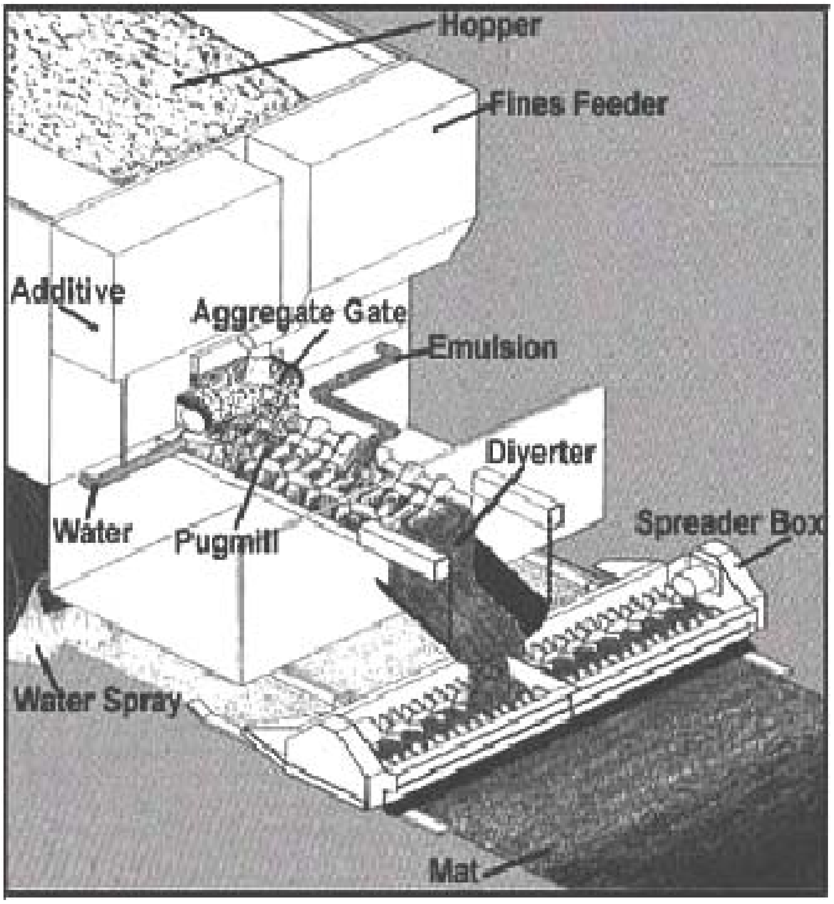


Figure 2.35: Schematic of Microsurfacing Mixing Machine

2.6.1.4 Preparation, Placement, and Restrictions

Prior to the placement of microsurfacing there are specified surface preparations that have to be carried out and the placement must not violate any of the outlined restrictions. The surface of the existing pavement should be cleaned and free of any debris. Tight cracks should be cleaned and sealed, wide cracks should be filled, and the pavement surface should be broomed and cleaned [Moulthrop 96]. Utility inlets should be covered with heavy paper or roofing felt adhered to the surface of the inlet which is removed once the treatment has cured (Figure 2.36).

Figure 2.36: Photographs illustrating covering utilities with paper and removal after curing [Caltrans 03]

A tack coat is not typically required for flexible pavements, but may be necessary if the surface is extremely dry and raveled or is another material such as concrete or brick. If it is deemed that a tack coat is required. It must be noted in the project plan and allowed to cure sufficiently before applying the microsurfacing. Failure to take the proper surface preparation steps can result in delamination as a result of poor adhesion (Figure 2.37).

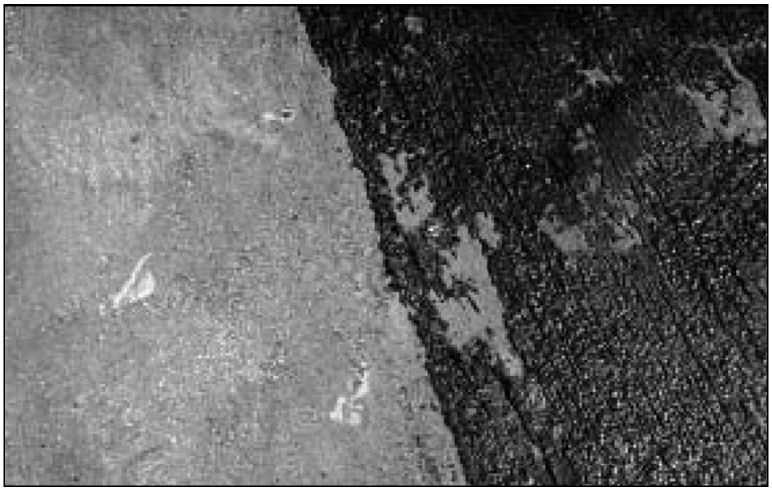


Figure 2.37: Example of delamination as a result of poor surface preparation [Caltrans 03]

When placing microsurfacing, the surface may be pre-wetted by fogging ahead of the paving box if required by local conditions. Proportioning devices are used in material calibration and can assist in determining the material output at any time. The provision of individual volume or weight control for proportioning materials for the mix is mandatory and they should be clearly marked.

Once a proper mixture is achieved it needs to be agitated and spread uniformly. This result is achieved by means of a surfacing box which uses either twin-shafted paddles or spiral augers in the spreader box (Figure 2.38). A Hydraulic Spreader Box is designed specifically for microsurfacing and quick set slurry seal mixes. The widths are hydraulically adjusted from 2.4 to 4.3 m in 15 cm increments and the primary and secondary strikeoff heights are adjustable. The spreader box has to move the stiff mixture quickly and spread it before the emulsion breaks, ensuring no loss of the mixture and a uniform consistency. The spreader box squeegee must be able to compensate for variations in the pavement geometry (Figure 2.39).

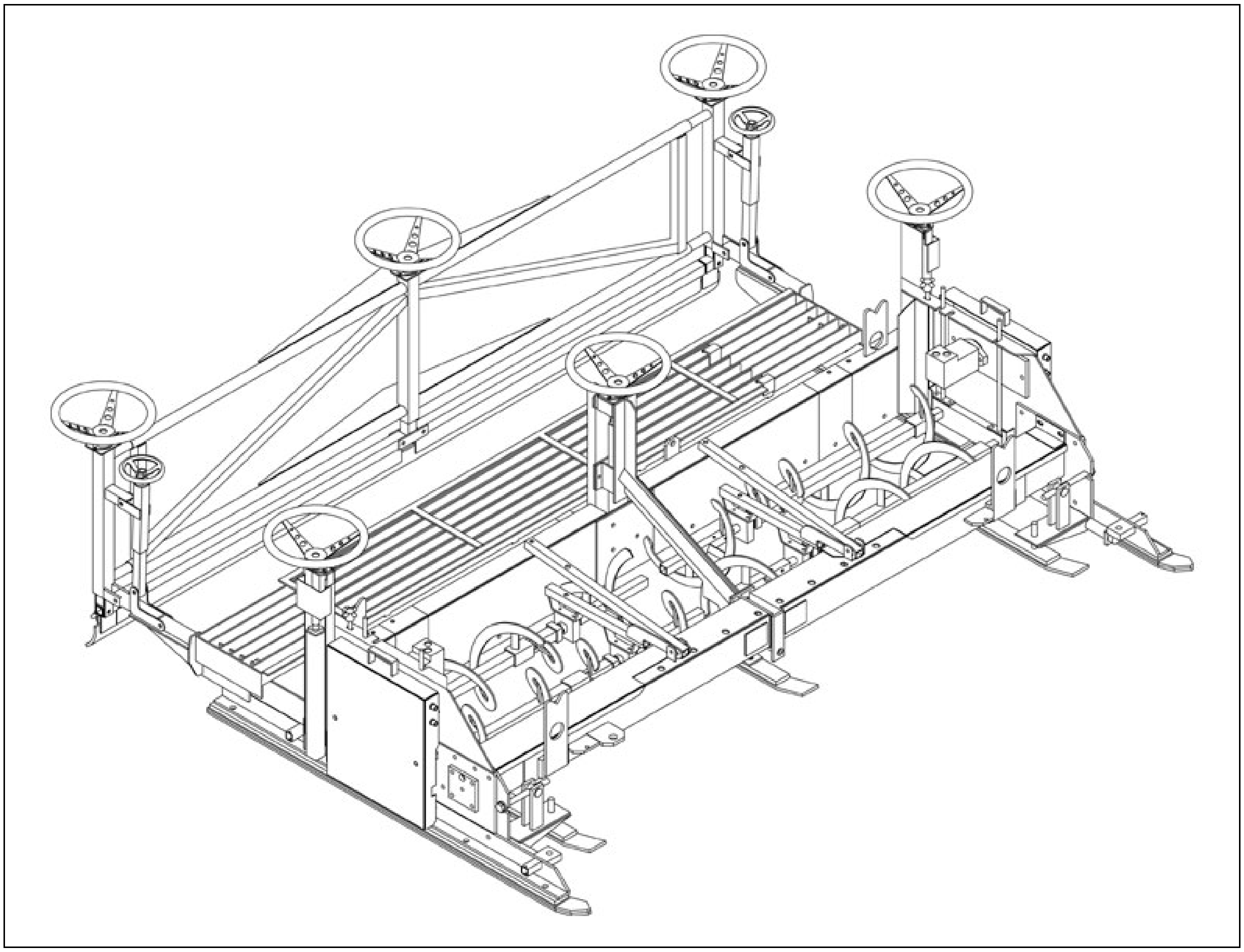


Figure 2.38: Diagram of a hydraulic spreader box [Bergkamp 07]

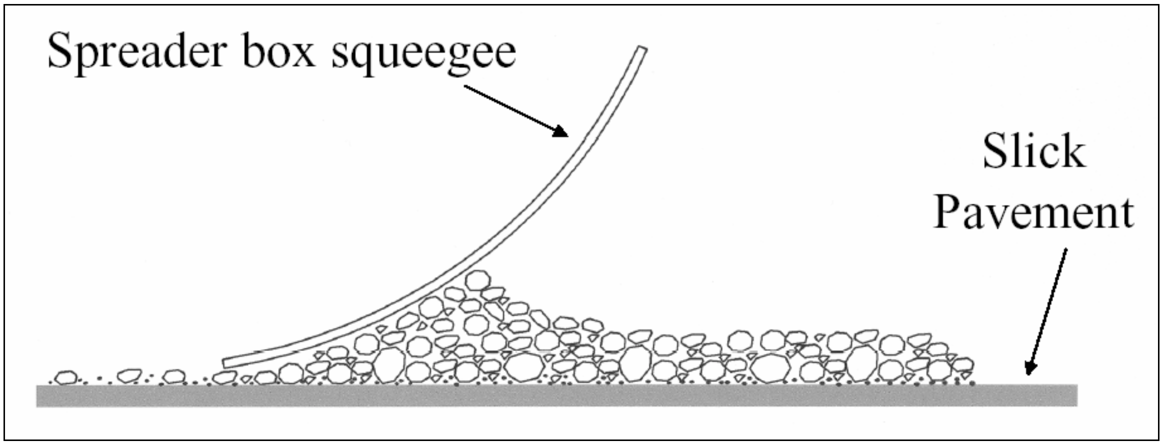


Figure 2.39: Illustration of a microsurfacing application [Jahren NDA]

Special boxes are used to where rut filling is required for ruts greater than 12 mm deep. The rut box design allows wheel path ruts to fill to a desired level with wasting any of the microsurfacing mixture and leaves a crowned finish to compensate for post compaction due to trafficking (Figure 2.40). The v-shaped design helps channel the larger size aggregate in the mix to the deeper parts of the rut (Figure 2.41).

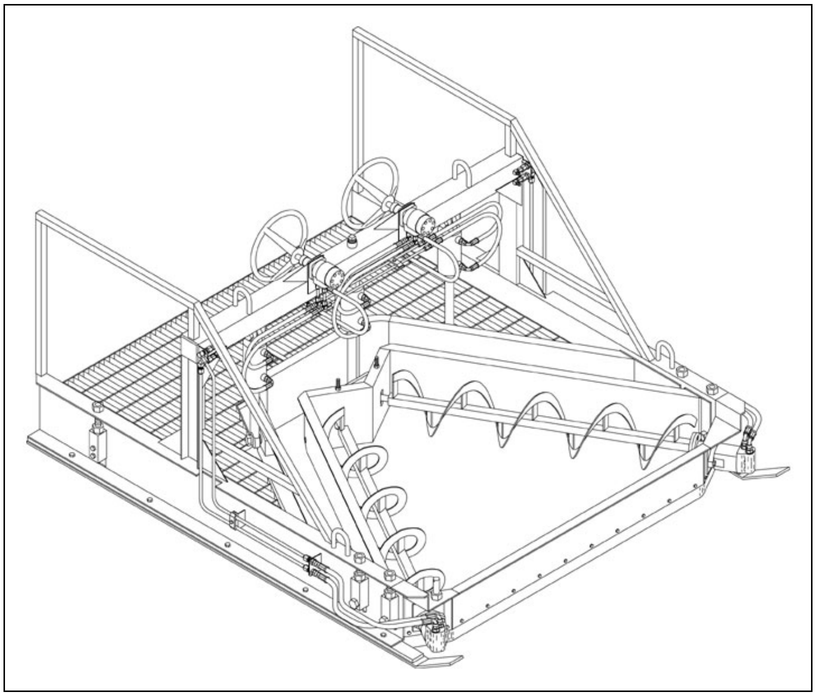


Figure 2.40: Drawing of a rut box [Bergkamp 07]

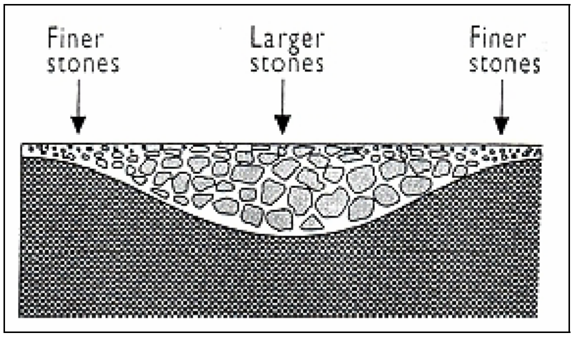


Figure 2.41: Cross section of a filled rut illustrating aggregate distribution [Caltrans 03]

One of the application conditions for microsurfacing is that the emulsion must be able to break and form continuous films because this is how the slurry mixture becomes cohesive. As a result, consideration must be give to humidity, wind, and temperature. Microsufacing should not be applied if the pavement or air temperature is below 10°C (50°F) and continuing to fall, however it may be applied when both the pavement and air temperatures are above 7°C (45°F) and continuing to rise. Figure 2.42 illustrates the impact of temperature on the breaking rate of emulsion. Humidity should be 60% or less and a light breeze is beneficial. If rain or freezing temperatures are anticipated within 24 hours microsurfacing should not be applied.

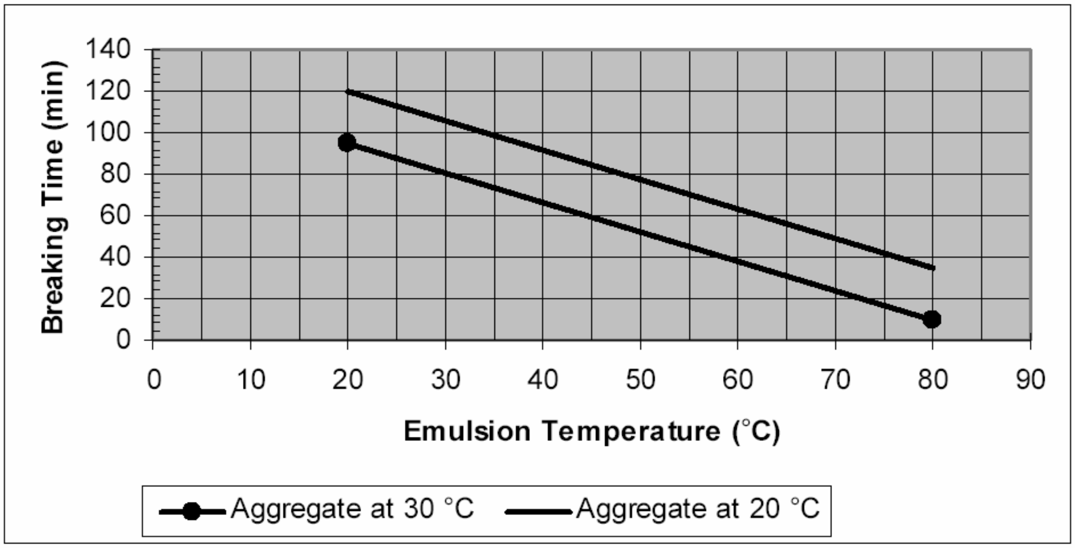


Figure 2.42: Influence of temperature on break rate of emulsion [Caltrans 03]

Traffic is permitted on the finished pavement after the emulsion has broken and set, which is typically within one hour following the microsurfacing placement. Deviations to this rule occur if the mixture sets slower or weather conditions dictate otherwise.

Figure 2.43 illustrates a road in Michigan receiving a microsurfacing treatment.

Figure 2.43: Example of microsurfacing placement [Galehouse NDA]

2.6.1.5 Potential Microsurfacing Defects and Their Causes

Uneven mixes can lead to segregation. Mix designs with low cement content or with a water content that is too high can cause the mix to separate once movement in the box has stopped. The result of segregation is a black and flushed looking surface that has poor texture (Figure 2.44). Separated mixes can cause the emulsion to break into fine material called "false slurry" that results in delamination of the surface (Figure 2.45).

Figure 2.44: Example of segregation [Caltrans 03]

Figure 2.45: Example of delamination resulting from a False Slurry [Caltrans 03]

If the treated site it opened prematurely to traffic, this can result in surface damage. The microsurfacing treatment must be able to resist abrasion due to traffic and therefore must build up sufficient cohesion. If a mixture is reopened too early it will ravel off quickly (Figure 2.46). A general rule to avoid premature raveling is to wait to open the road to traffic until the microsurfacing treatment is expelling clear water.

Figure 2.46: Raveling damage caused by premature exposure to traffic [Caltrans 03]

The process of emulsion systems loosing their water can take up to several weeks. For this reason microsurfacing treatments should not be placed if freeing weather is anticipated in the near future. During the period of water loss, the surface is water resistant, but if the water freezes it can cause rupture of the binder film and result in raveling.

Light rain following a surface treatment is within acceptable limits, a heavy rainfall combined with heavy traffic can result in a damaged surface (Figure 2.47). This is because asphalt emulsion based systems cannot re-emulsify, and if not cured fully they are sensitive enough to re-disperse under heavy rain and traffic conditions. Broken aggregate or asphalt particles that have not fully coalesced into films are dispersed in the water causing the emulsion to disintegrate.

Figure 2.47: Damage resulting after heavy rain in a high traffic location [Caltrans 03]

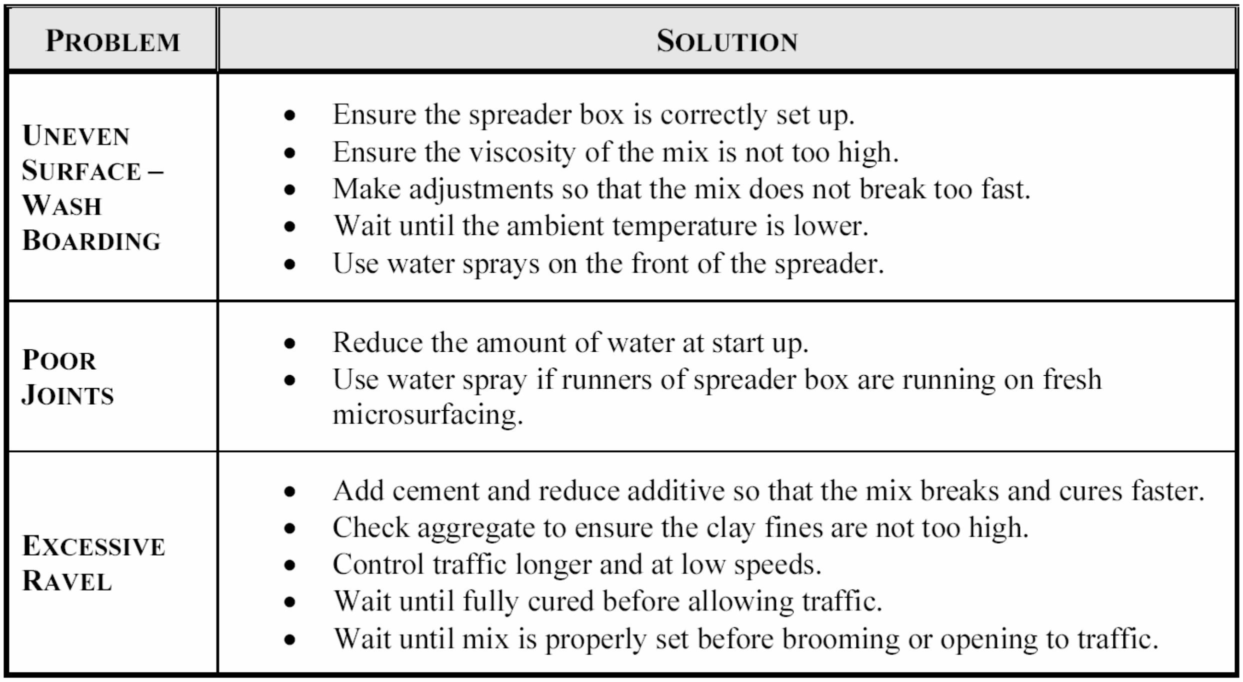
Caltrans has developed troubleshooting guidance to assist maintenance personnel address common problems that may occur on a microsurfacing project. Table 2.19 associates common problems to potential causes that may require further exploration. These causes could be related to the emulsion, mix design, environmental or surface conditions.

A secondary table lists the 3 most common problems encountered with microsurfacing treatments (uneven surface, poor joints, excessive raveling) and provides a bulleted list of possible solutions (Table 2.20).

Table 2.19: Caltrans guidance for trouble shooting microsurfacing job problems [Caltrans 03]

Cause	Problem									
	Brown	Whitish	Won't Set	Poor Coating	Delayed Opening to Traffic	Breaks in Box	Ravels	Flushes	Delamination	Segregation
Emulsion										
Emulsion Unstable				•		•			•	
Emulsion too Stable	•		•		•		•			
Emulsion too hot						•				
Too Little Emulsion	•			•			•			
Too Much Emulsion								•		
Mix										
Too many fines				•		•	•			
Too much cement		•				•				
Too little cement			•		•		•			•
Too little additive				•		•	•			
Too much additive		•	•		•		•			
Too much water	•		•		•		•	•		•
Too little water		•		•		•	•		•	
Aggregate/emulsion			•	•	•		•		•	•
Conditions										
Too hot	•			•		•	•	•		
Too cold			•		•		•		•	
Rain	•		•	•	•		•	•	•	
High humidity		•	•							
Surface										
Fatty			•					•		

Table 2.20: Caltrans list of common problems and related solutions [Caltrans 03]



PROBLEM	SOLUTION
UNEVEN SURFACE – WASH BOARDING	• Ensure the spreader box is correctly set up. • Ensure the viscosity of the mix is not too high. • Make adjustments so that the mix does not break too fast. • Wait until the ambient temperature is lower. • Use water sprays on the front of the spreader.
POOR JOINTS	• Reduce the amount of water at start up. • Use water spray if runners of spreader box are running on fresh microsurfacing.
EXCESSIVE RAVEL	• Add cement and reduce additive so that the mix breaks and cures faster. • Check aggregate to ensure the clay fines are not too high. • Control traffic longer and at low speeds. • Wait until fully cured before allowing traffic. • Wait until mix is properly set before brooming or opening to traffic.

2.6.1.6 Warranty Clauses

To give more protection to agencies using microsurfacing in Canada and the United States, warranty specifications have been trialled. With these specifications, the contractor designs the mix, completes the work, with little or no direction from the agency, and provides the owner with a warranty that essentially guarantees the performance of the microsurfacing treatment for a given period of time. A typical period is two years. If there are any defects that occur during the warranty period the contractor is responsible for repairing them.

Typically the performance of a microsurfacing treatment can be evaluated in terms of one or more of the following items related to road engineering:

- Additional frictional properties provided to the existing surface
- Surface profile correction
- Pavement flushing correction
- Protection of the existing pavement from the adverse effects of oxidization

Uniformity of the surface texture and noise level are additional performance criteria to be considered.

2.6.2 Research on Available Treatments

Iowa State University compared chip seal, slurry seal, microsurfacing, cape seal, and thin lift overlay treatments on four sets of test sections between the years 1997 to 1999. Each test section was subdivided and each subdivision received a different treatment application (Figure 2.48). The subdivided test sections were evaluated by comparing the pavement condition index (PCI), individual distresses, and friction level.

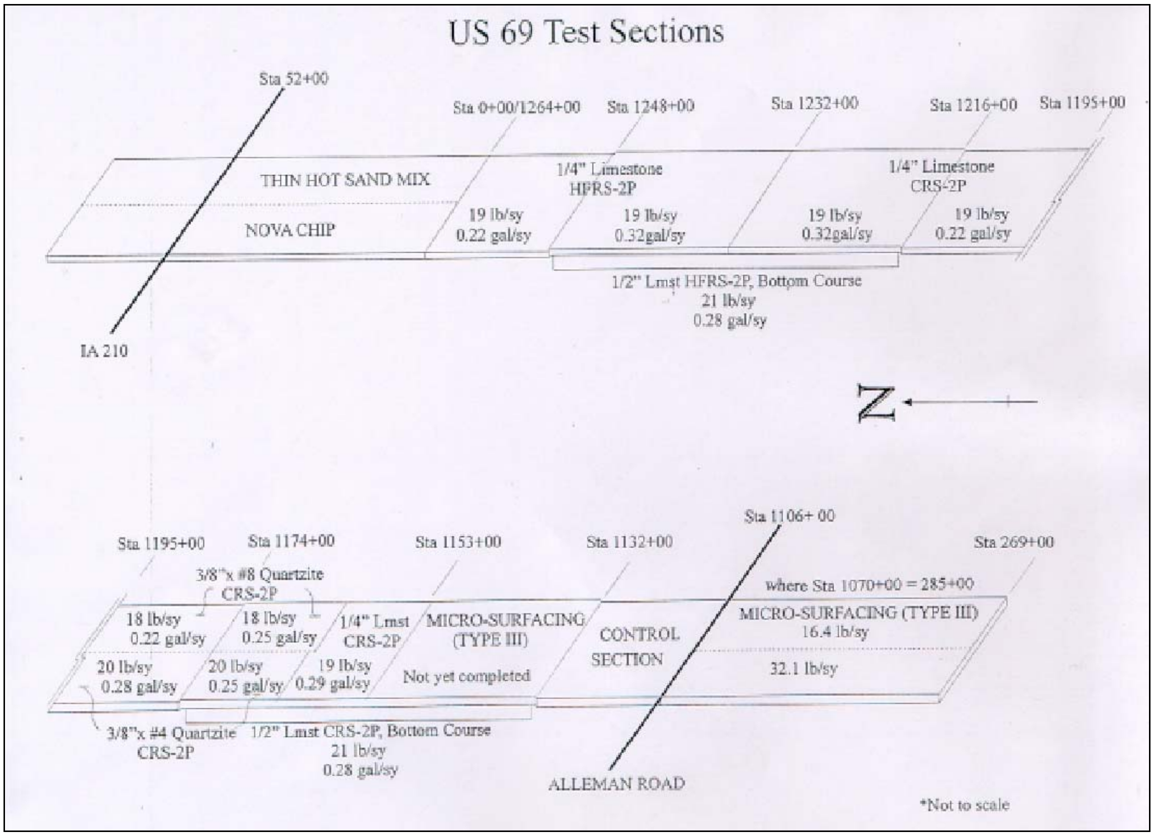


Figure 2.48: Example of how the test sections were subdivided and treated [Jahren NDA]

The results from one of the test sections shows a significant increase in PCI following most of the treatments and then the PCI remains fairly constant for the next two years (Figure 2.49). For the same test section it can be observed that the microsurfacing increases the friction value following treatment and continued to increase friction almost one year after treatment (Figure 2.50).

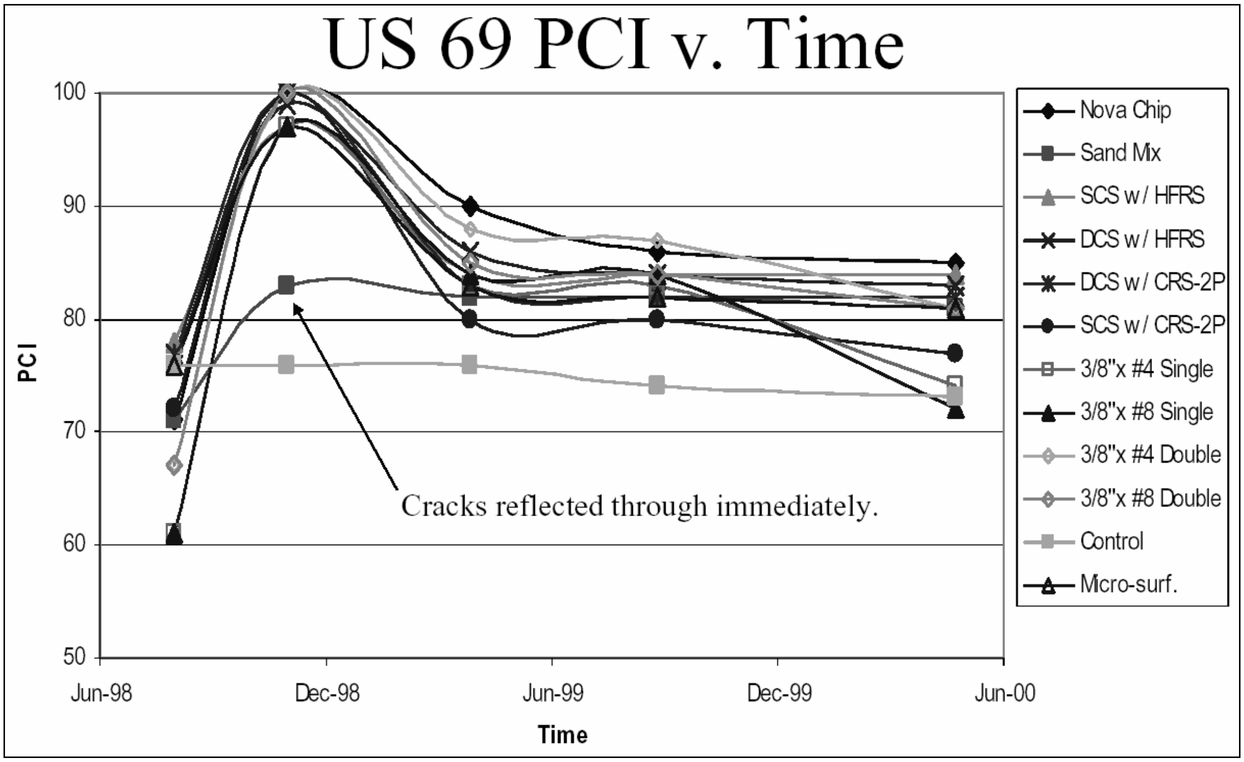


Figure 2.49: Changes in PCI over time for each treatment at one test section [Jahren NDA]

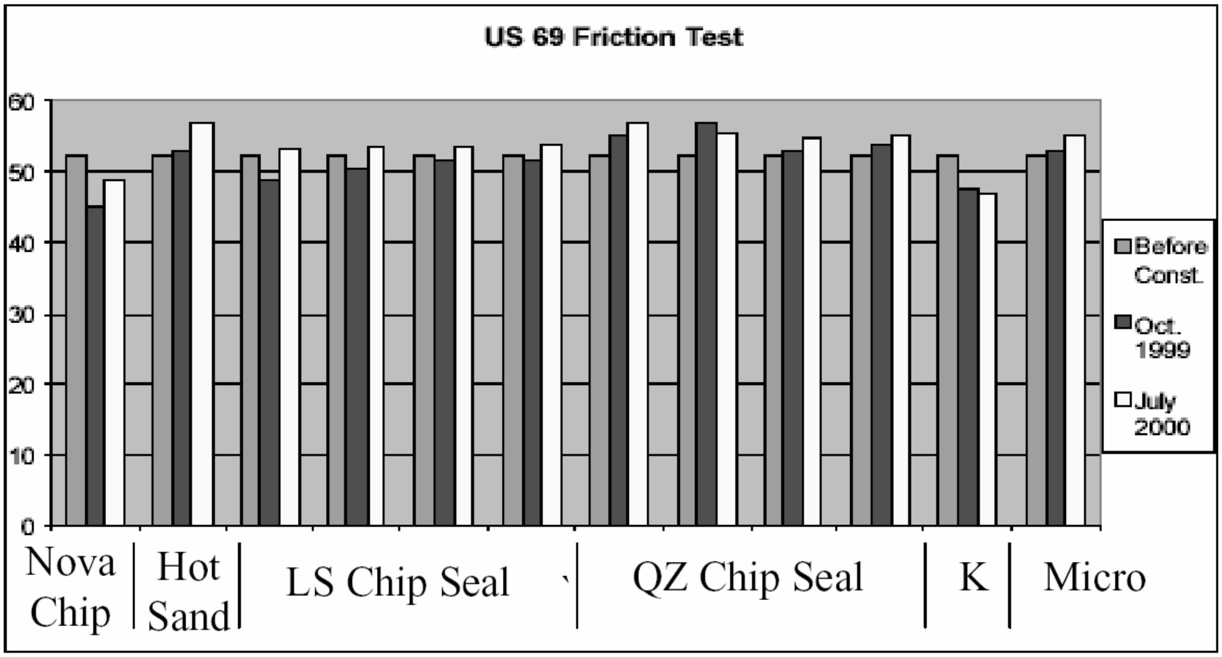
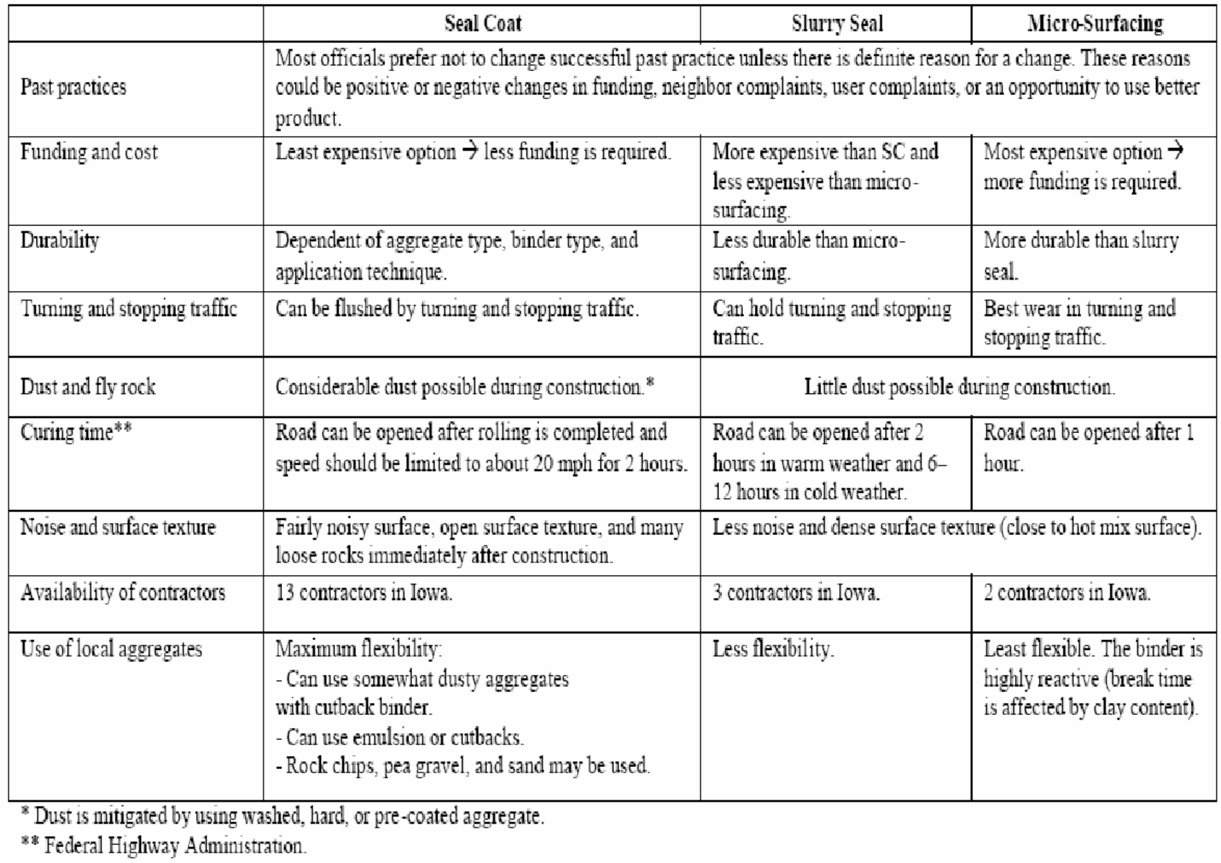


Figure 2.50: Results of the Friction Test by treatment type for one test section [Jahren NDA]

The authors concluded that most agencies prefer not to change their maintenance practices if they have been effective and that change in treatment is usually the result of an increase or decrease in funding, neighbour complaints, user complaints, or an opportunity to try a better product. Microsurfacing was the most expensive option; however it was found to be the most durable option and demonstrated the best wear in turning and stopping traffic (Table 2.21).

Table 2.21: Additional factors impacting think maintenance surface decisions [Jahren NDA]



	Seal Coat	Slurry Seal	Micro-Surfacing
Past practices	Most officials prefer not to change successful past practice unless there is definite reason for a change. These reasons could be positive or negative changes in funding, neighbor complaints, user complaints, or an opportunity to use better product.		
Funding and cost	Least expensive option → less funding is required.	More expensive than SC and less expensive than micro-surfacing.	Most expensive option → more funding is required.
Durability	Dependent of aggregate type, binder type, and application technique.	Less durable than micro-surfacing.	More durable than slurry seal.
Turning and stopping traffic	Can be flushed by turning and stopping traffic.	Can hold turning and stopping traffic.	Best wear in turning and stopping traffic.
Dust and fly rock	Considerable dust possible during construction.*	Little dust possible during construction.	
Curing time**	Road can be opened after rolling is completed and speed should be limited to about 20 mph for 2 hours.	Road can be opened after 2 hours in warm weather and 6–12 hours in cold weather.	Road can be opened after 1 hour.
Noise and surface texture	Fairly noisy surface, open surface texture, and many loose rocks immediately after construction.	Less noise and dense surface texture (close to hot mix surface).	
Availability of contractors	13 contractors in Iowa.	3 contractors in Iowa.	2 contractors in Iowa.
Use of local aggregates	Maximum flexibility: - Can use somewhat dusty aggregates with cutback binder. - Can use emulsion or cutbacks. - Rock chips, pea gravel, and sand may be used.	Less flexibility.	Least flexible. The binder is highly reactive (break time is affected by clay content).

* Dust is mitigated by using washed, hard, or pre-coated aggregate.
** Federal Highway Administration.

A study conducted in Minnesota looked at the impact of microsurfacing on friction numbers among other things [Wood 01]. The findings showed a significant increase in friction numbers at the sites that had been treated with microsurfacing when compared to the control section. An acceptable friction number in Minnesota is 35 and most of the sites that were treated with microsurfacing yielded friction numbers in the low to mid 60's (Figure 2.51). One of the explanations of the high friction numbers is the Class A aggregate that is 100 percent crushed and angular in nature, thus providing superior friction characteristics, used in the microsurfacing mix. Other conclusions noted were that microsurfacing helps to re-establish cross-sections, fill in rutting (rutting must be permanent and non-progressive), improve ride qualities, and provide a good background for pavement markings. Microsurfacing does not seal reflective cracks and increases noise created by traffic.

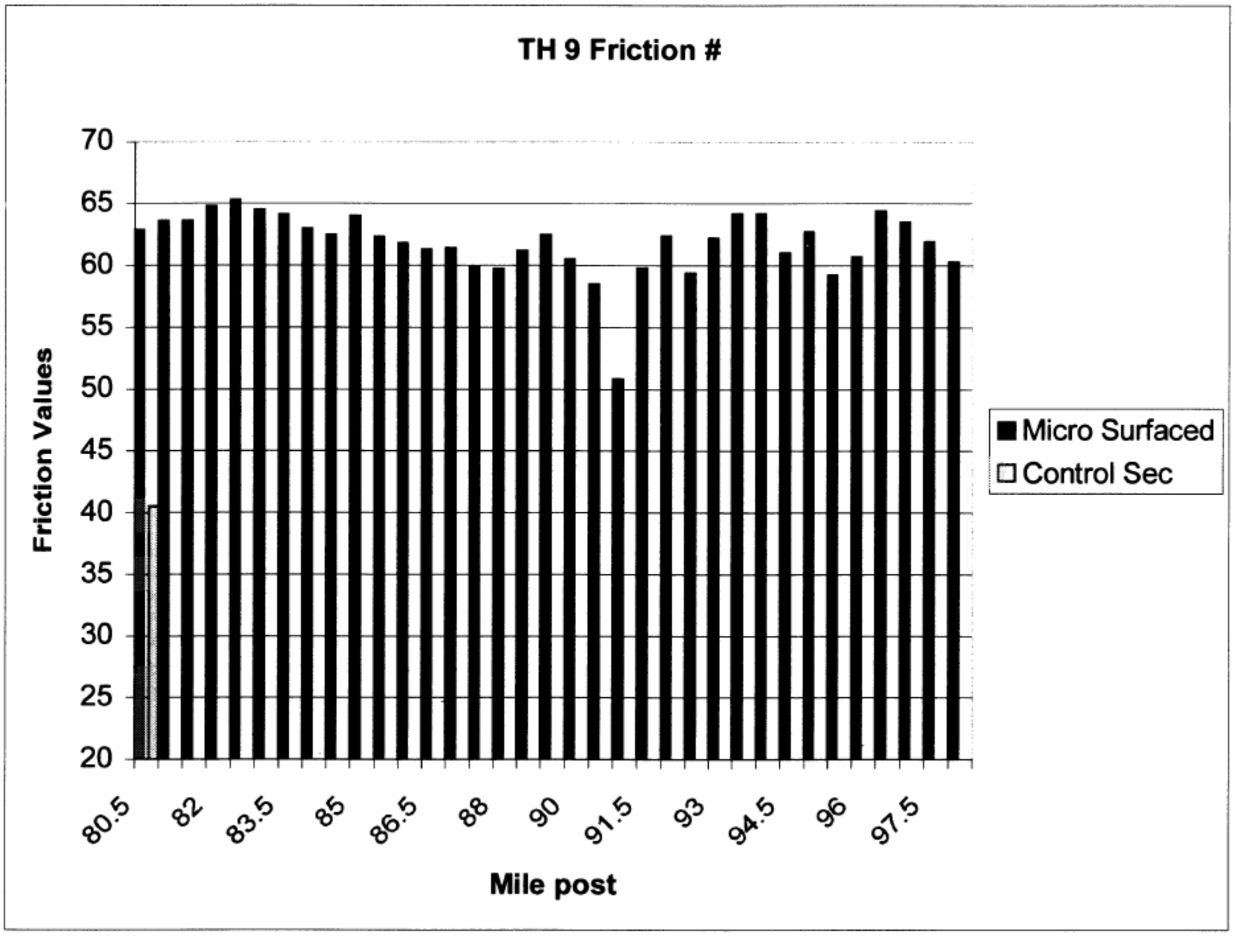


Figure 2.51: Friction numbers at different mile posts after microsurfacing compared against the control section [Wood 01]

Takamura et al. demonstrated microsurfacing treatments to be both cost effective and environmentally friendly when compared to thin hot-mix overlay treatments [Takamura 02]. An eco-efficiency analysis was used as a decision making tool to determine the best treatment alternatives with the least environmental impact at the best cost. The base study assumed a 7 year life for a microsurfacing treatment, a 10 year life for a thin hot-mix asphalt overlay, and a 13 year life for a polymer modified hot-mix overlay (Figure 2.52).

The environmental impacts studied were classified into five parameters: raw materials consumption, energy consumption, emissions, potential health effects, and risk of accident and misuse. In a profile plot when compared to hot-mix asphalt and modified hot-mix asphalt, cold-mix microsurfacing has the lowest environmental "footprint" (Figure 2.53).

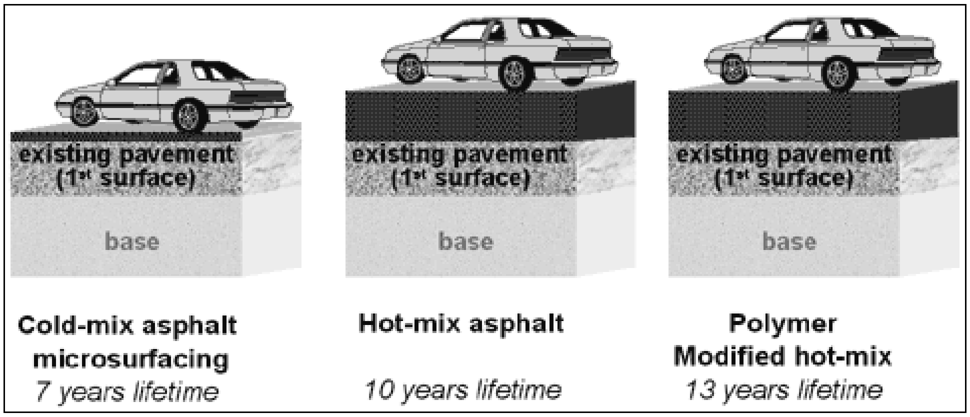


Figure 2.52: Service life assumptions for the eco-efficiency analysis [Takamura 02]

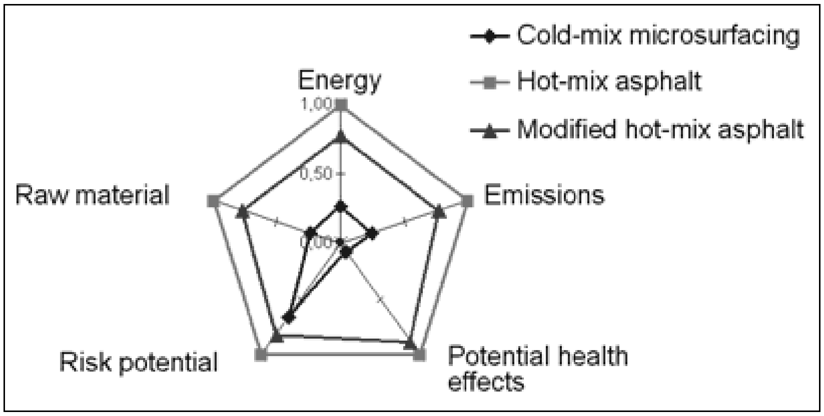
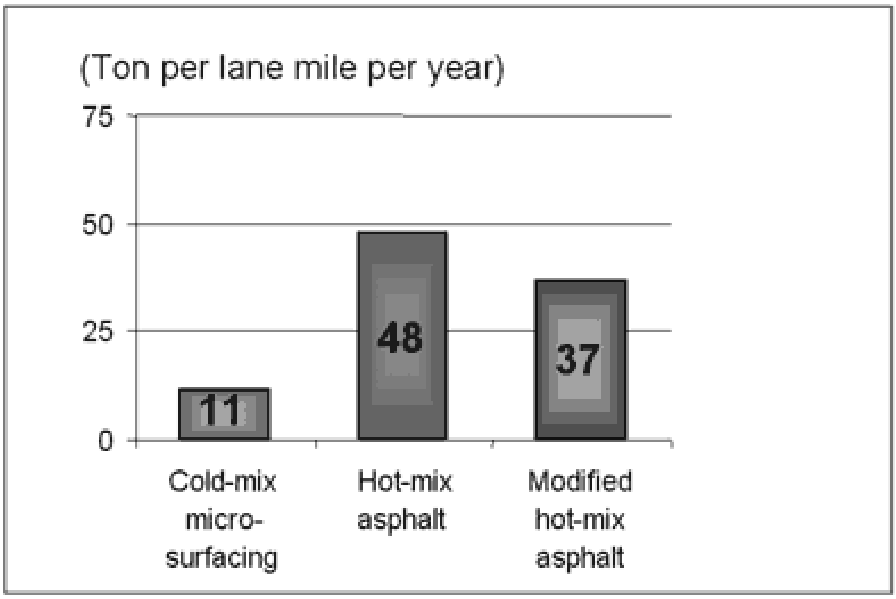


Figure 2.53: Environmental Profile Plot of the five parameters considered [Takamura 02]

In a time when non renewable resources and global warming are frequently mentioned in the news Takamura et al. concludes that microsurfacing is a favourable option because it requires the least amount of raw material and is the smallest contributor to atmospheric emissions that contribute to global warming, acid rain, and ozone depletion when compared to the other two treatments.

When the environmental results are combined with the annual relative costs for treatment, the conclusion is that microsurfacing provides a better balance between cost-effectiveness and environmental impact when compared to other hot-mix asphalt overlays (Figure 2.56). In summary, microsurfacing is the preferred treatment option because less material is required, less transportation of materials, and lower overall emissions during the life of the treatment.



Note: This is a summation of all process steps.
Energy carriers used to provide electricity and process heat are included.

Figure 2.54: Estimated raw materials used averaged over the expected life of the treatment [Takamura 02]

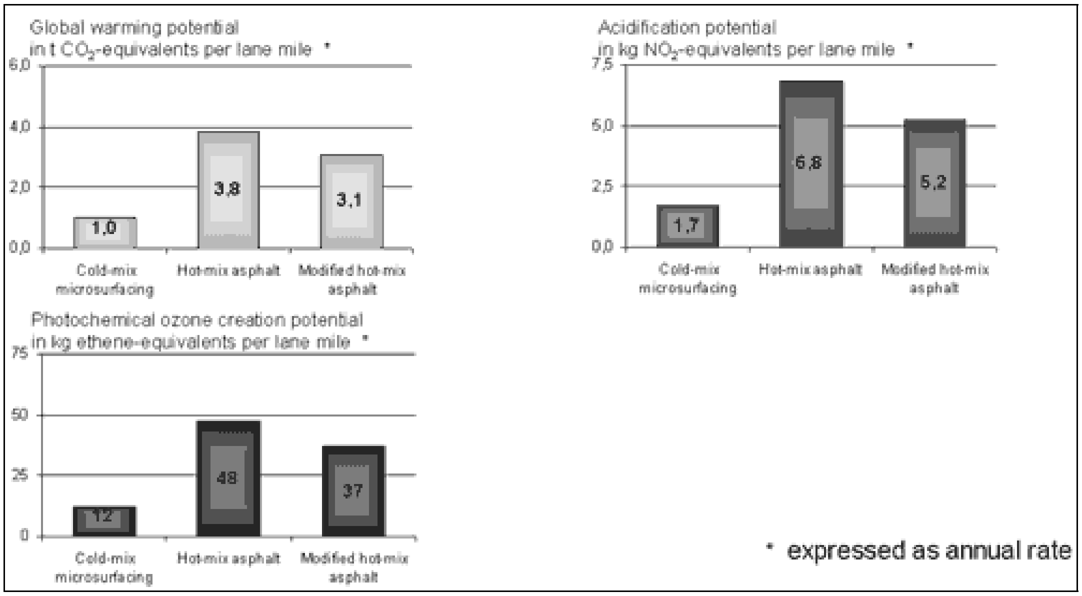


Figure 2.55: Estimated emissions contributing to global warming, acid rain, and ozone depletion [Takamura 02]

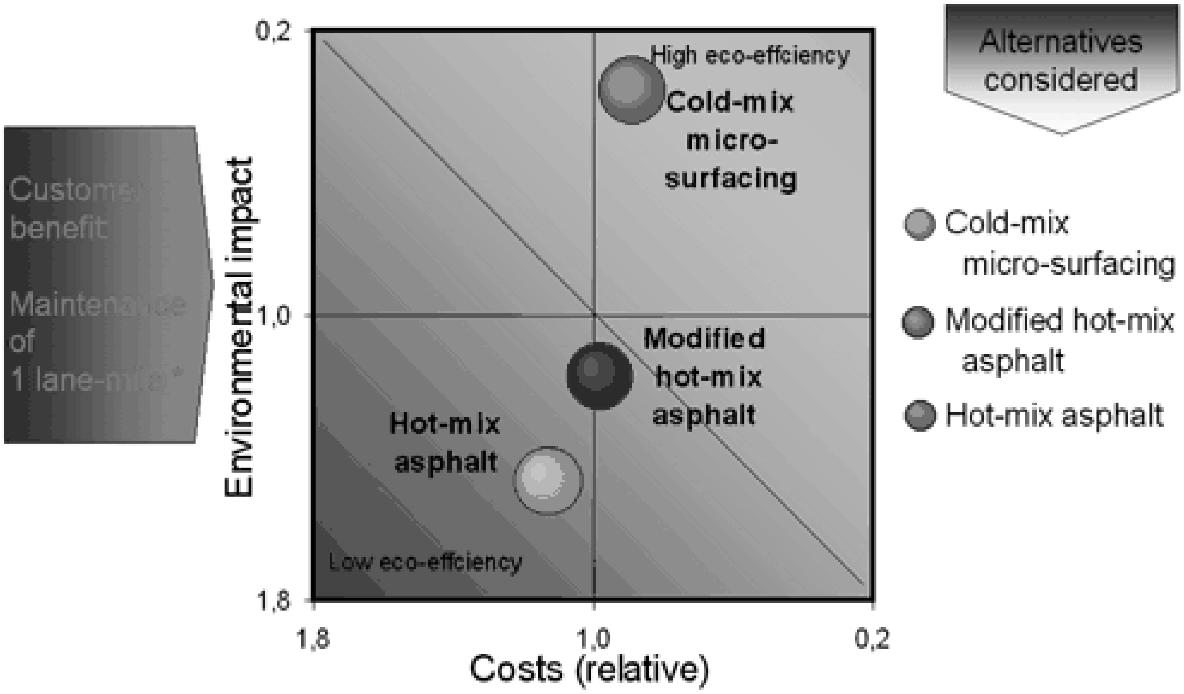


Figure 2.56: Environmental impact versus relative costs for treatments studied [Takamura 02]

3.0 METHODOLOGY

The study design is based on a naïve before-after analysis that can assist in the derivation of knowledge on the consequences of a decision or treatment that may impact safety. The concept of the before-after study is very straightforward. It is based on the assumption that if nothing else changed, the crash experience before the improvement is a good estimate of what would have happened during the post improvement period without the improvement. It is important to note that although these data are specific to the Region of York, they represent a tremendous resource for many cities and municipalities that operate under similar conditions and constraints.

3.1 Data

Data were obtained from the Region of York in two separate files. First was a file that listed the surface treatment projects, namely microsurfacing, by number, year, location, and type of treatment that was applied (Table 3.1). There are three contractors in the area that can apply microsurfacing but the Region of York generally uses one for all of their projects as they are the most localized. York Region always uses Type 3 microsurfacing with consistent aggregate and emulsion according to specification that has not changed during the study period.

Table 3.1: Project list provided by the Region of York

Project	Year	Road	From	To	Treatment	Type
1	2000	Old Homestead Rd.(Y.R.79)	Woodbine	Warden	Resurfacing	Pulverize + Foamed + 50HL4
3	2000	Davis Dr.(Y.R.31)	Hwy. 48	Y.D. Line	Resurfacing	Pulverize + Foamed + 50HL4
4	2000	9th Line(Y.R.69)	Millard	Bloomington	Resurfacing	Pulverize + Foamed + 50HL4
5	2000	Bloomington Rd.(Y.R.40)	Hwy. 48	10th Line	Resurfacing	Plane 50, 50DFC
6	2000	King Rd.(Y.R.11)	Keele	Jane	Resurfacing	Plane 80, 40HDBC + 40DFC
7	2000	Major Mack. Dr. East(Y.R.25)	Hwy.48	9th Line	Resurfacing	Pulverize, 50HL4
9	2001	Mulock Dr.	College Manor Dr.	Bayview Ave.	Microsurfacing	3
10	2001	Leslie St.	St.Johns Sdrd.	Mulock Dr.	Microsurfacing	3
11	2001	Woodbine Ave.	St. Johns Sdrd.	Aurora Rd.	Microsurfacing	3
12	2001	Wellington St.	Yonge St.	Bathurst St.	Microsurfacing	3
13	2001	Leslie St.	Mulock Dr	Davis Dr.	Microsurfacing	3
14	2001	Keele St./17 SR	200m South of intersection	200m North of intersection	Microsurfacing	3
16	2001	Prospect St.	Pearson Street	Queen Street	Microsurfacing	3

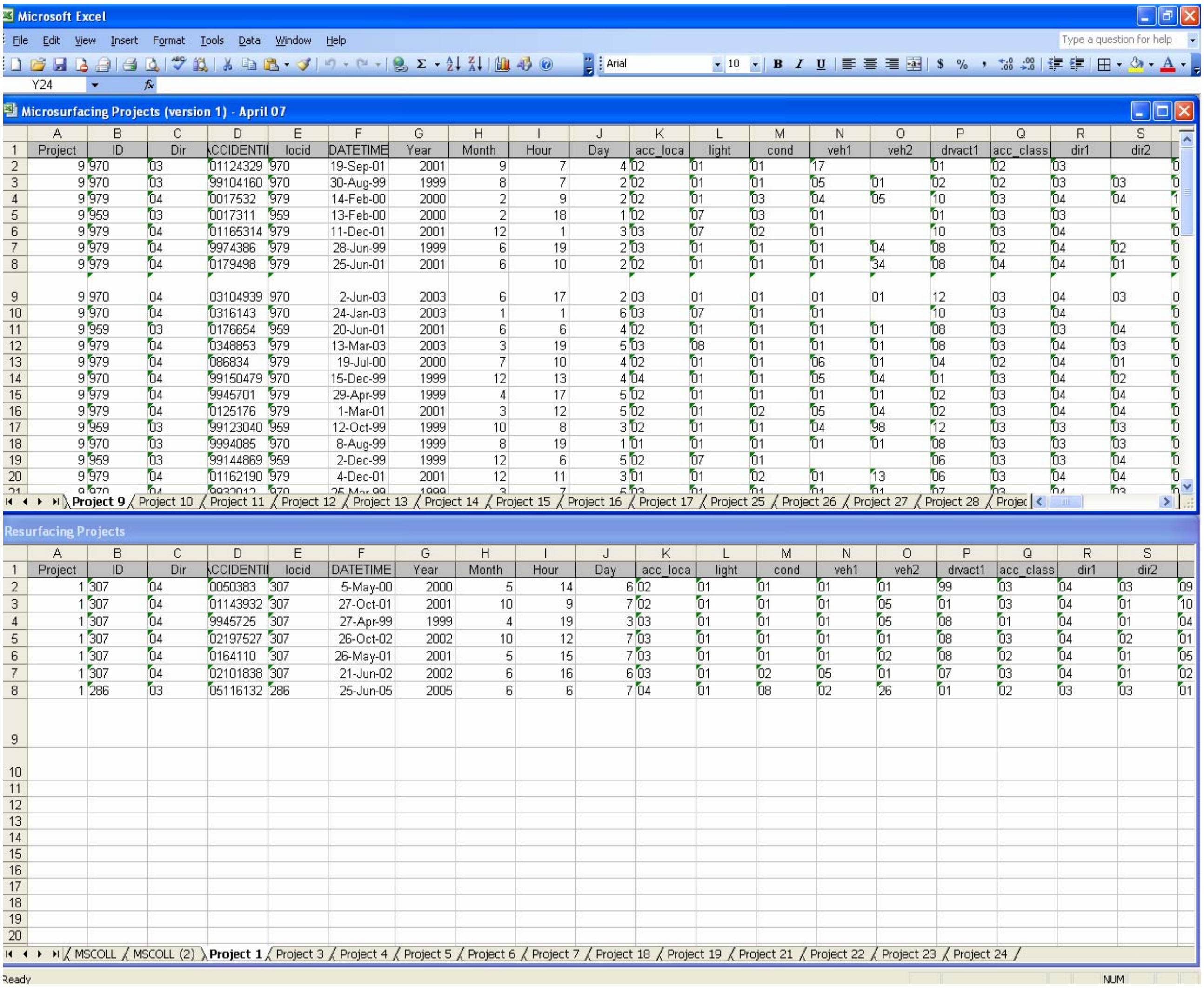
Project	Year	Road	From	To	Treatment	Type
17	2001	Hwy. 7	Keele St.	Credistone Rd.	Microsurfacing	3
18	2001	Hwy. 7	Weston Rd.	Pine Valley Dr.	Resurfacing	
19	2001	Keele St.,	Hwy.407	Langstaff Rd.	Resurfacing	
22	2001	Warden Ave.	Boag Rd.	Ravenshoe Rd.	Resurfacing	
23	2001	St.Johns S/R	Bayview Ave.	Leslie St.	Resurfacing	
24	2001	Pine Valley Dr.	Rutherford Rd.	Major Mac. Dr.	Resurfacing	
25	2002	Davis Dr.(Y.R.31)	Ashton/Carlson Road	Leslie Street	Microsurfacing	3
26	2002	Keele St	Steeles Avenue	300m North	Microsurfacing	3
27	2002	Stouffville Road	Yonge Street	Hwy 404	Microsurfacing	3
28	2002	Hwy 7	Hwy 427	Hwy 27	Microsurfacing	3
29	2002	Yonge Street	Major Mackenzie Drive	50m North	Microsurfacing	3
30	2002	Bathurst Street	Steeles Avenue	Centre Street	Microsurfacing	3
41	2003	Vivian Road	West of Warden Avenue	East of McCowan Road	Microsurfacing	
42	2003	Major Mackenzie Drive	West limit of Hwy. 404	2000 m West	Microsurfacing	
46	2003	16th Avenue	175m East of Village Parkway	175m West of Village Parkway	Microsurfacing	
48	2003	Bathurst Street	Bloomington Road	900m North	Microsurfacing	
31	2004	Leslie St.	at Davis Intersection		Microsurfacing	3
32	2004	Bathurst Street	at Bloomington Intersection		Microsurfacing	3
33	2004	Highway 7	at Warden		Microsurfacing	3
34	2004	16th Avenue	at Leslie Street		Microsurfacing	3
35	2004	Highway 7	Warden	RW X-ing	Microsurfacing	3
36	2004	Weston	407	Highway 7	Microsurfacing	3
37	2004	Old Yonge	at Mt Albert		Microsurfacing	3
38	2004	Mt Albert Road	at 2nd Conc		Microsurfacing	3
40	2004	Woodbine/Baseline Curve			Microsurfacing	3

A second, much larger file, provided crash data between 1999 and 2005 for all of the applicable treatment sites (Table 3.2). Appendix A provides a sample of the accident report template that deciphers the numerical coding.

Table 3.2 : Sample of Raw Crash Data provided by the Region of York

Project	ID	Dir	ACCIDENTID	locid	DATETIME	Year	Month	Hour	Day	acc_loca	light	cond	veh1	veh2	drvact1	acc_class	dir1	dir2	man1	man2	itype	eve1
30	2972	01	0180614	2972	27-Jun-01	2001	6	8	4	02	01	01	04	05	08	03	01	01	01	10	03	01
17	2969	04	9975061	2969	30-Jun-99	1999	6	6	4	02	01	01	01	01	07	02	04	03	01	04	05	01
42	2017	04	9973257	2017	26-Jun-99	1999	6	12	7	02	01	01	01	01	12	03	04	04	01	01	03	01
36	3050	01	9971298	3050	22-Jun-99	1999	6	17	3	01	01	01	04	01	12	03	01	01	07	01	04	01
46	2062	03	0188108	2062	10-Jul-01	2001	7	20	3	02	05	02	01	01	01	03	03	03	02	02	03	01
32	1509	01	0184800	1509	4-Jul-01	2001	7	18	4	02	01	02	01	01	10	03	01	01	01	01	03	01
35	2255	04	0184340	2255	3-Jul-01	2001	7	20	3	02	06	01	32	01	01	04	04	04	01	02	03	01
16	911	01	99105857	911	2-Sep-99	1999	9	20	5	02	07	01	01	05	99	03	01	01	01	10	03	01
18	3027	03	0181365	3027	28-Jun-01	2001	6	14	5	02	01	01	04	01	10	03	03	03	01	01	03	01
19	2882	02	9977567	2882	5-Jul-99	1999	7	8	2	01	01	01	01	13	12	03	02	02	07	01	04	01
30	2917	01	0180244	2917	26-Jun-01	2001	6	16	3	01	01	01	01	04	02	03	01	01	02	02	03	01
11	1102	02	0179994	1102	26-Jun-01	2001	6	7	3	04	01	01	01	01	02	02	02	02	01	10	03	01
18	3038	04	01121641	3038	14-Sep-01	2001	9	8	6	02	01	01	01	01	02	02	04	04	01	02	03	01
17	2945	03	01121394	2945	13-Sep-01	2001	9	15	5	02	01	01	09	09	01	03	03	03	01	03	02	01
18	3063	04	01120939	3063	12-Sep-01	2001	9	17	4	01	01	01	01	01	02	03	04	04	01	10	03	01
30	2889	02	01120210	2889	11-Sep-01	2001	9	8	3	02	01	01	01	04	06	02	02	02	04	01	05	01
36	3027	01	01119482	3027	9-Sep-01	2001	9	16	1	02	01	01	01	01	02	03	01	01	02	02	03	01
19	2945	01	0184122	2945	3-Jul-01	2001	7	14	3	02	01	01	01	01	01	03	01	01	01	10	01	01
9	970	03	01124329	970	19-Sep-01	2001	9	7	4	02	01	01	17		01	02	03		01		07	03
31	820	02	0179425	820	25-Jun-01	2001	6	7	2	01	01	01	01	01	06	05	02	01	04	01	05	01
9	970	03	99104160	970	30-Aug-99	1999	8	7	2	02	01	01	05	01	02	02	03	03	02	10	03	01
17	2969	04	99103076	2969	27-Aug-99	1999	8	0	6	01	07	01	05	01	99	03	04	03	09	10	04	01
19	2777	02	99102930	2777	27-Aug-99	1999	8	19	6	01	01	01	01	01	12	03	02	02	07	01	04	01
30	2946	02	01127254	2946	24-Sep-01	2001	9	21	2	02	07	02	01	01	02	03	02	02	02	02	01	01
19	2882	01	01126927	2882	24-Sep-01	2001	9	9	2	01	01	02	01	01	12	03	01	01	07	01	04	01

In order to analyze the data it had to be organized into a more user friendly format. First the crash data was separated into two separate files, microsurfacing project sites and resurfacing project types. Next all of the crashes associated with a particular project site were organized on a separate worksheet within the same excel work book (Figure 3.1).



Microsurfacing Projects (version 1) - April 07

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
1	Project	ID	Dir	ACCIDENTI	locid	DATETIME	Year	Month	Hour	Day	acc_loca	light	cond	veh1	veh2	drvact1	acc_class	dir1	dir2	
2	9	970	03	01124329	970	19-Sep-01	2001	9	7	4	02	01	01	17		01	02	03		0
3	9	970	03	99104160	970	30-Aug-99	1999	8	7	2	02	01	01	05	01	02	02	03	03	0
4	9	979	04	0017532	979	14-Feb-00	2000	2	9	2	02	01	03	04	05	10	03	04	04	1
5	9	959	03	0017311	959	13-Feb-00	2000	2	18	1	02	07	03	01		01	03	03		0
6	9	979	04	01165314	979	11-Dec-01	2001	12	1	3	03	07	02	01		10	03	04		0
7	9	979	04	9974386	979	28-Jun-99	1999	6	19	2	03	01	01	01	04	08	02	04	02	0
8	9	979	04	0179498	979	25-Jun-01	2001	6	10	2	02	01	01	01	34	08	04	04	01	0
9	9	970	04	03104939	970	2-Jun-03	2003	6	17	2	03	01	01	01	01	12	03	04	03	0
10	9	970	04	0316143	970	24-Jan-03	2003	1	1	6	03	07	01	01		10	03	04		0
11	9	959	03	0176654	959	20-Jun-01	2001	6	6	4	02	01	01	01	01	08	03	03	04	0
12	9	979	04	0348853	979	13-Mar-03	2003	3	19	5	03	08	01	01	01	08	03	04	03	0
13	9	979	04	086834	979	19-Jul-00	2000	7	10	4	02	01	01	06	01	04	02	04	01	0
14	9	970	04	99150479	970	15-Dec-99	1999	12	13	4	04	01	01	05	04	01	03	04	02	0
15	9	979	04	9945701	979	29-Apr-99	1999	4	17	5	02	01	01	01	01	02	03	04	04	0
16	9	979	04	0125176	979	1-Mar-01	2001	3	12	5	02	01	02	05	04	02	03	04	04	0
17	9	959	03	99123040	959	12-Oct-99	1999	10	8	3	02	01	01	04	98	12	03	03	03	0
18	9	970	03	9994085	970	8-Aug-99	1999	8	19	1	01	01	01	01	01	08	03	03	03	0
19	9	959	03	99144869	959	2-Dec-99	1999	12	6	5	02	07	01			06	03	03	04	0
20	9	979	04	01162190	979	4-Dec-01	2001	12	11	3	01	01	02	01	13	06	03	04	04	0

Resurfacing Projects

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
1	Project	ID	Dir	ACCIDENTI	locid	DATETIME	Year	Month	Hour	Day	acc_loca	light	cond	veh1	veh2	drvact1	acc_class	dir1	dir2	
2	1	307	04	0050383	307	5-May-00	2000	5	14	6	02	01	01	01	01	99	03	04	03	09
3	1	307	04	01143932	307	27-Oct-01	2001	10	9	7	02	01	01	01	05	01	03	04	01	10
4	1	307	04	9945725	307	27-Apr-99	1999	4	19	3	03	01	01	01	05	08	01	04	01	04
5	1	307	04	02197527	307	26-Oct-02	2002	10	12	7	03	01	01	01	01	08	03	04	02	01
6	1	307	04	0164110	307	26-May-01	2001	5	15	7	03	01	01	01	02	08	02	04	01	05
7	1	307	04	02101838	307	21-Jun-02	2002	6	16	6	03	01	02	05	01	07	03	04	01	02
8	1	286	03	05116132	286	25-Jun-05	2005	6	6	7	04	01	08	02	26	01	02	03	03	01
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				

Figure 3.1 : Screenshot of the crash data files sorted by treatment and project number

In total there were 28 sites with 1560 reported crashes that received a microsurfacing treatment and 12 sites with 840 reported crashes that received a resurfacing treatment between 2001 and 2004 (Figure 3.2 and Figure 3.3).

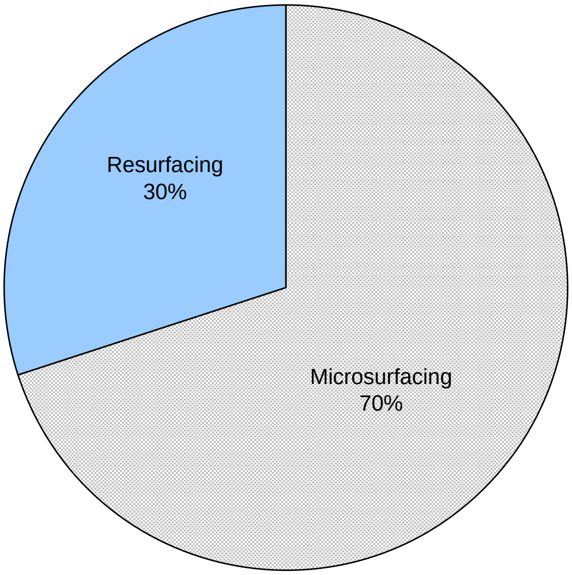


Figure 3.2: Number of Projects by Treatment Type

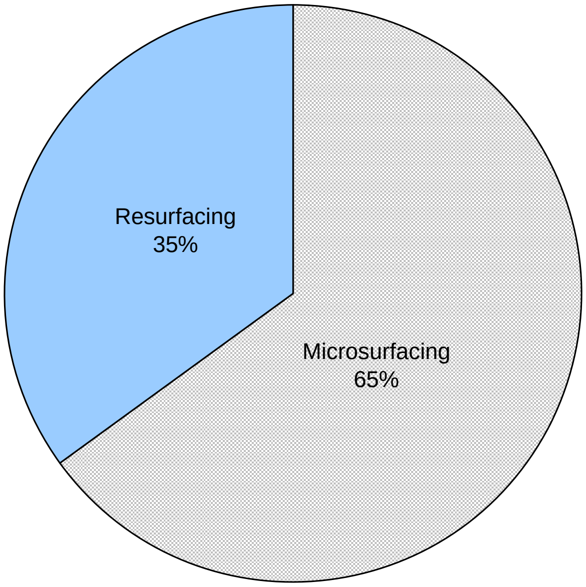


Figure 3.3: Number of Crashes by Treatment Type

For sites treated with microsurfacing the distribution of crashes by year was fairly constant, with the most occurring in 2001 and the least occurring in 2005. The distribution of crashes by year was more even for the sites that received resurfacing (Figure 3.4).

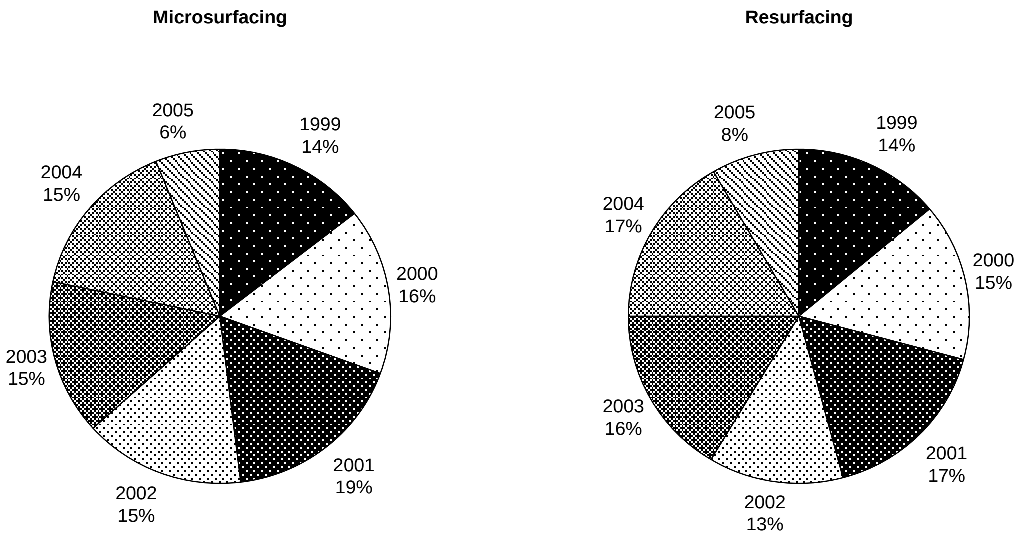


Figure 3.4 : Distribution of Crashes by Year and Treatment Type

All of the crashes were organized by year and by project so that before and after periods could be established. Within the seven year study period there were 1560 crashes that occurred at the microsurfacing treatment sites (Table 3.3).

Table 3.3: Number of sites by year that received microsurfacing treatment

Year of Treatment	No. of Sites	Before Period (years)	After Period (years)
2001	10	2	5
2002	5	3	4
2003	4	4	3
2004	9	5	2

Five of the microsurfacing project sites analyzed had no crashes in both the before and after period.

Within the seven year study period there were 840 crashes that occurred at the resurfaced treatment sites (Table 4.1). All of the project sites experienced at least two or more crashes during the study period.

Table 3.4: Number of sites by year that received a resurfacing treatment

Year of Treatment	No. of Sites	Before Period (years)	After Period (years)
2001	9	1	6
2002	3	2	5

The crash data file provided detailed crash information as entered from police reports. Some of the relevant data fields include:

- Year of accident
- Accident location
- Road surface condition
- Classification of accident (fatal, injury, property damage only, etc)
- Initial impact type (rear end, angle, sideswipe, etc.)
- Lighting condition

The location of the crash is important. Often crashes related to skidding occur at intersections, or other locations that require the driver to brake suddenly. Most of the crashes in the database occur at intersections or were intersection related (Figure 3.5).

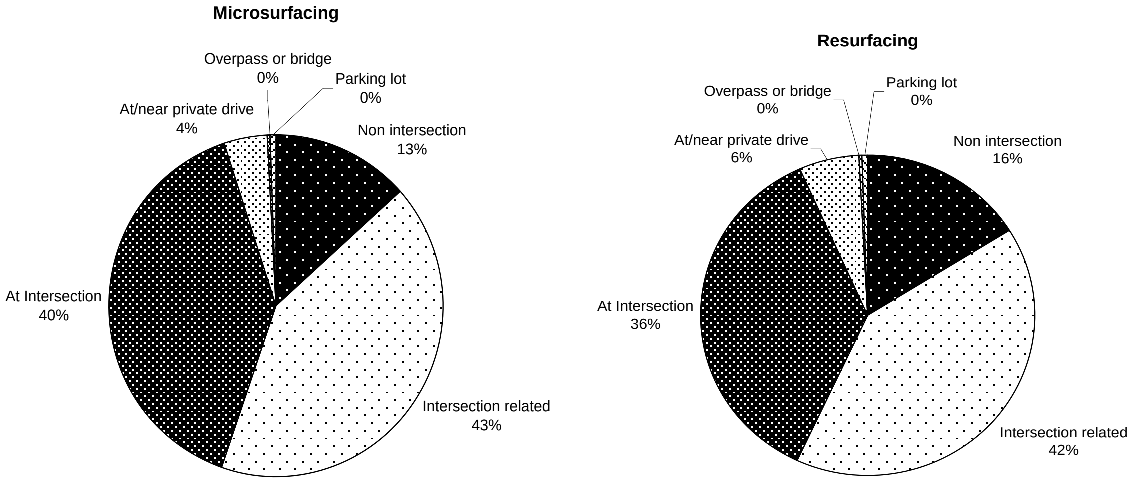


Figure 3.5 : Distribution of Crashes by Location and Treatment Type

Based on the literature review, road surface condition is another major factor that has been studied in association with skidding. It is understood that many crashes occur on dry road surfaces. However, those related to skidding and loss of friction often have wet or slick road surfaces (Figure 3.6).

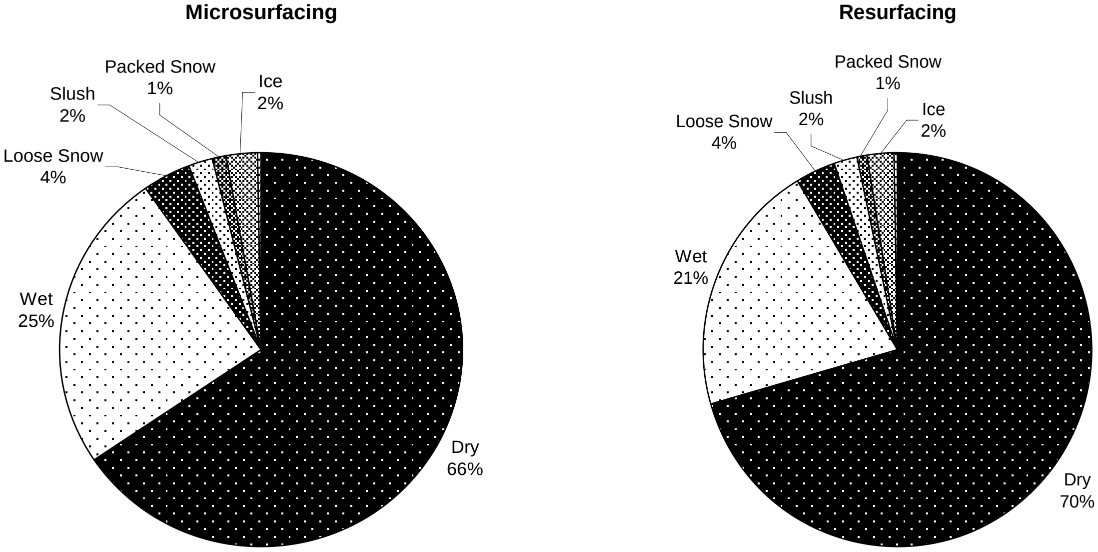


Figure 3.6 : Distribution of Crashes by Road Surface Condition and Treatment Type

Engineers and Politicians are always interested in the severity of crashes as it is their goal to protect the public. On this basis, it can be argued that the reduction of fatal and injury collisions is more important than property damage only (PDO) (Figure 3.7).

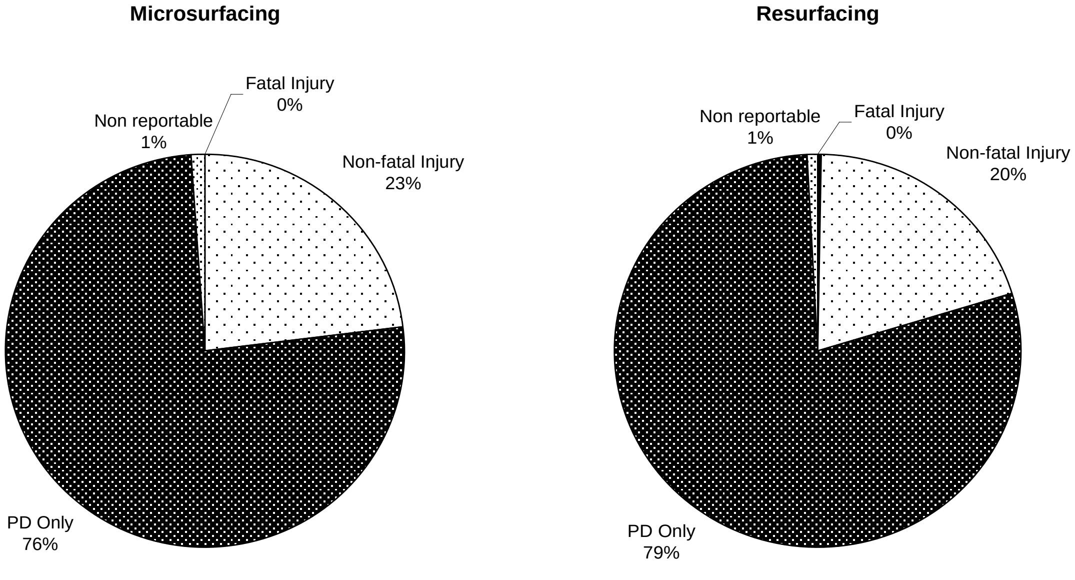


Figure 3.7 : Distribution of Crashes by Severity and Treatment Type

Lastly, impact type is important when reviewing crash data. Rear end crashes are commonly associated with skidding as they result from not braking in time. The better the friction on the road surface the more efficient the braking and therefore essentially rear end crashes can be avoided. Rear end crashes are the most common amongst both the microsurfacing and resurfacing data sets (Figure 3.8).

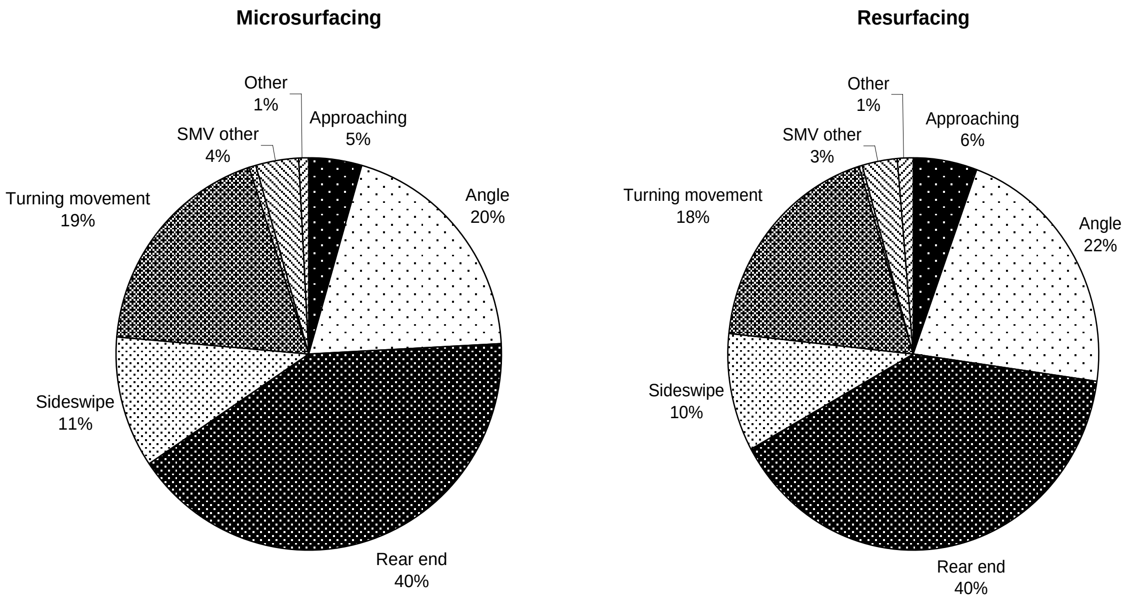


Figure 3.8 : Distribution of Crashes by Impact Type and Treatment Type

Lighting condition could be a factor in a crash if poor or obscure illumination prevents the driver from observing a physical object such as an animal, debris, signage, etc. It is interesting to note that most crashes occur during daylight and the same held true for both the microsurfacing and resurfacing data sets (Figure 3.9). However, since it is not likely that lighting has any direct influence on skidding, this data was not used to fulfill the purposes of this study.

The attribute data was tabulated for each project separately (Figure 3.10). It was not sufficient to just know the quantity of crashes by project and attribute, in order to assess safety effectiveness it was necessary to understand when, in terms of year, a specific crash occurred to carry out a before-after analysis. Microsoft Excel was used to further sort and sum the number of crashes by project and year (Figure 3.11).

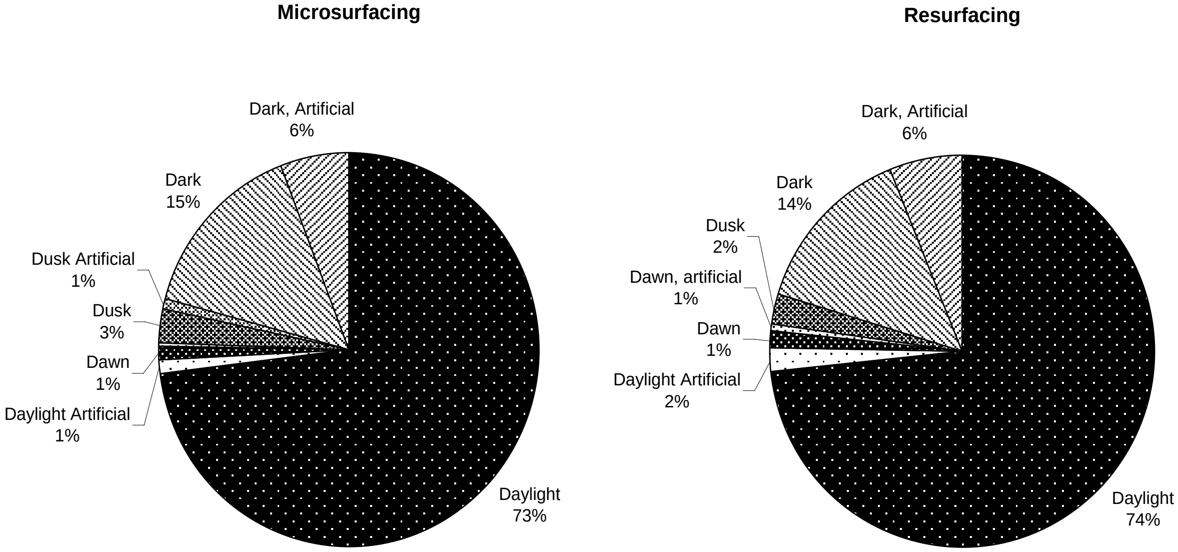
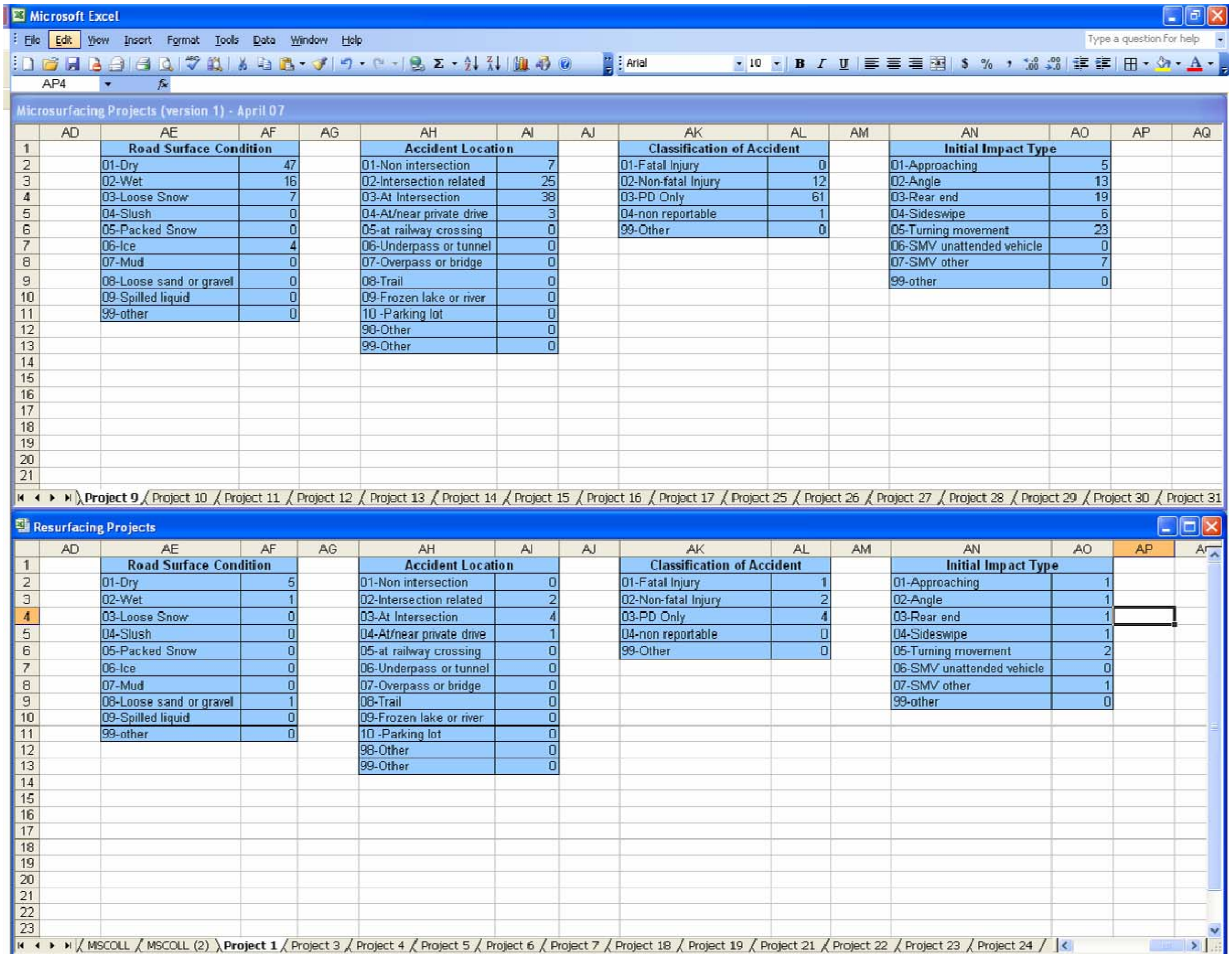


Figure 3.9 : Distribution of Crashes by Lighting Condition and Treatment Type

The summary worksheet in each file is linked to the separate project worksheets and the formulae can be altered to check different columns in each work sheet and count the crash occurrences if they meet a specific criterion embedded in the formula. This is how the before and after crash data was developed for each study condition.



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Road Surface Condition	
01-Dry	47
02-Wet	16
03-Loose Snow	7
04-Slush	0
05-Packed Snow	0
06-Ice	4
07-Mud	0
08-Loose sand or gravel	0
09-Spilled liquid	0
99-other	0

Accident Location	
01-Non intersection	7
02-Intersection related	25
03-At Intersection	38
04-At/near private drive	3
05-at railway crossing	0
06-Underpass or tunnel	0
07-Overpass or bridge	0
08-Trail	0
09-Frozen lake or river	0
10 -Parking lot	0
98-Other	0
99-Other	0

Classification of Accident	
01-Fatal Injury	0
02-Non-fatal Injury	12
03-PD Only	61
04-non reportable	1
99-Other	0

Initial Impact Type	
01-Approaching	5
02-Angle	13
03-Rear end	19
04-Sideswipe	6
05-Turning movement	23
06-SMV unattended vehicle	0
07-SMV other	7
99-other	0

Resurfacing Projects

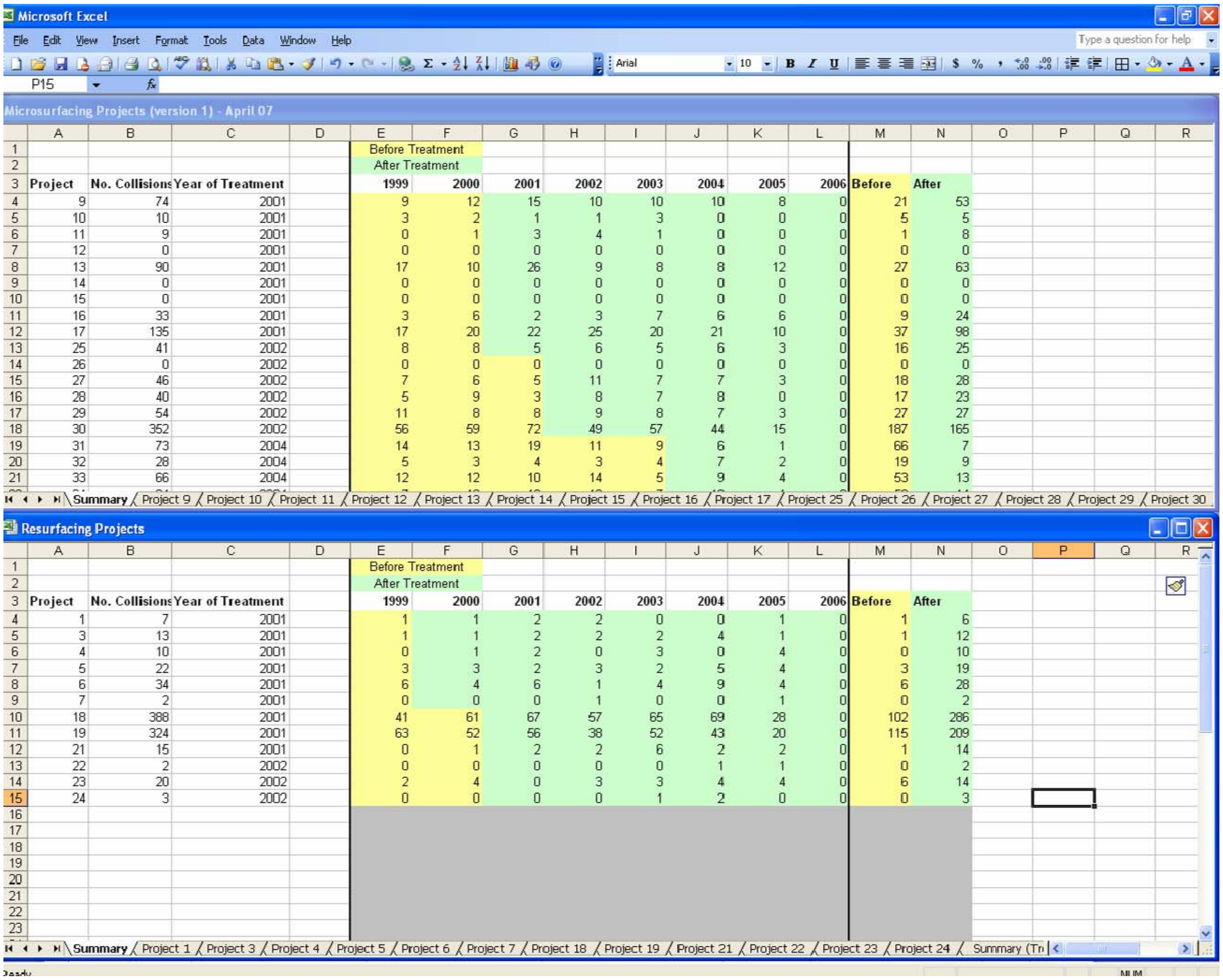
Road Surface Condition	
01-Dry	5
02-Wet	1
03-Loose Snow	0
04-Slush	0
05-Packed Snow	0
06-Ice	0
07-Mud	0
08-Loose sand or gravel	1
09-Spilled liquid	0
99-other	0

Accident Location	
01-Non intersection	0
02-Intersection related	2
03-At Intersection	4
04-At/near private drive	1
05-at railway crossing	0
06-Underpass or tunnel	0
07-Overpass or bridge	0
08-Trail	0
09-Frozen lake or river	0
10 -Parking lot	0
98-Other	0
99-Other	0

Classification of Accident	
01-Fatal Injury	1
02-Non-fatal Injury	2
03-PD Only	4
04-non reportable	0
99-Other	0

Initial Impact Type	
01-Approaching	1
02-Angle	1
03-Rear end	1
04-Sideswipe	1
05-Turning movement	2
06-SMV unattended vehicle	0
07-SMV other	1
99-other	0

Figure 3.10 : Screenshot illustrating individual project tabulations for different safety attributes



Microsurfacing Projects (version 1) - April 07

Before Treatment
After Treatment

Project	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	74	2001	9	12	15	10	10	10	8	0	21	53
10	10	2001	3	2	1	1	3	0	0	0	5	5
11	9	2001	0	1	3	4	1	0	0	0	1	8
12	0	2001	0	0	0	0	0	0	0	0	0	0
13	90	2001	17	10	26	9	8	8	12	0	27	63
14	0	2001	0	0	0	0	0	0	0	0	0	0
15	0	2001	0	0	0	0	0	0	0	0	0	0
16	33	2001	3	6	2	3	7	6	6	0	9	24
17	135	2001	17	20	22	25	20	21	10	0	37	98
25	41	2002	8	8	5	6	5	6	3	0	16	25
26	0	2002	0	0	0	0	0	0	0	0	0	0
27	46	2002	7	6	5	11	7	7	3	0	18	28
28	40	2002	5	9	3	8	7	8	0	0	17	23
29	54	2002	11	8	8	9	8	7	3	0	27	27
30	352	2002	56	59	72	49	57	44	15	0	187	165
31	73	2004	14	13	19	11	9	6	1	0	66	7
32	28	2004	5	3	4	3	4	7	2	0	19	9
33	66	2004	12	12	10	14	5	9	4	0	53	13

Resurfacing Projects

Before Treatment
After Treatment

Project	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	7	2001	1	1	2	2	0	0	1	0	1	6
3	13	2001	1	1	2	2	2	4	1	0	1	12
4	10	2001	0	1	2	0	3	0	4	0	0	10
5	22	2001	3	3	2	3	2	5	4	0	3	19
6	34	2001	6	4	6	1	4	9	4	0	6	28
7	2	2001	0	0	0	1	0	0	1	0	0	2
18	388	2001	41	61	67	57	65	69	28	0	102	286
19	324	2001	63	52	56	38	52	43	20	0	115	209
21	15	2001	0	1	2	2	6	2	2	0	1	14
22	2	2002	0	0	0	0	0	1	1	0	0	2
23	20	2002	2	4	0	3	3	4	4	0	6	14
24	3	2002	0	0	0	0	1	2	0	0	0	3

Figure 3.11 : Screenshot of summarized crash data by year and treatment type

3.2 Basic Building Blocks

Although simplistic compared to other analysis techniques, sometimes the naïve (also known as simple) before-after approach is the only option due to data restrictions. To develop a better understanding of how to carryout the before-after analysis it is helpful to review some of the basic concepts on which the methodology is based [Persaud 05, Hauer 97b].'

Unbiased estimates of the reduction in the number of crashes (δ) is:

$$\delta = \pi - \lambda \qquad \textbf{(Equation 3.1)}$$

For a single entity, let:

π = the estimated number of target crashes in the after period had the treatment not been applied.

λ = the expected number of target crashes in the after period after the treatment has been applied.

Thus π is the prediction and λ is the estimate. The safety effect of a strategy is determined by comparing π and λ as in Equation 4.1.

Its variance, VAR(δ), is given by:

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$ **(Equation 3.2)**

When dealing with numerous treatments sites a similar set of calculations are required to determine the safety effectiveness of a composite entity of ‘n’ treatment sites.

For j=1, 2, ….., n-1, n estimate $\lambda(j)$ and $\pi(j)$:

$\lambda = \Sigma\lambda(j)$ **(Equation 3.3)**

$\pi = \Sigma\pi(j)$ **(Equation 3.4)**

For j=1, 2, ….., n-1, n estimate VAR[$\lambda(j)$] and VAR[$\pi(j)$] (assuming that all of the $\lambda(j)$’s and $\pi(j)$’s are mutually independent) :

$VAR(\lambda) = \Sigma VAR[\lambda(j)]$ **(Equation 3.5)**

$VAR(\pi) = \Sigma VAR[\pi(j)]$ **(Equation 3.6)**

The index of effectiveness is also commonly referred to as the accident or crash modification factor. An unbiased estimate of the index of effectiveness (θ) is:

$\theta = (\lambda/\pi)[1+ \left[1+\frac{VAR(\pi)}{\pi^2}\right]^{-1}$ **(Equation 3.7)**

And its variance, VAR(θ), is given by:

$$\mathrm{VAR}(\theta) = \theta^2 \left[\frac{\frac{VAR(\lambda)}{\lambda^2} + \frac{VAR(\pi)}{\pi^2}}{1 + \frac{VAR(\pi)}{\pi^2}} \right]^2$$ **(Equation 3.8)**

For a treatment to be considered effective, $\delta > 0$ and $\theta < 1$. The resulting crash reduction factor is:

$$\mathrm{CRF} = 100(1-\theta)$$ **(Equation 3.9)**

The next step is to determine δ and θ, from earlier:

$$\delta = \pi - \lambda$$ **(Equation 3.1)**

$$\theta = (\lambda/\pi)[1+ \left[1 + \frac{VAR(\pi)}{\pi^2} \right]^{-1}$$ **(Equation 3.7)**

The last step is to calculate VAR(δ) and VAR(θ), from the single entity set of equations:

$$\mathrm{VAR}(\delta) = \mathrm{VAR}(\pi) + \mathrm{VAR}(\lambda)$$ **(Equation 3.2)**

$$\mathrm{VAR}(\theta) = \theta^2 \left[\frac{\frac{VAR(\lambda)}{\lambda^2} + \frac{VAR(\pi)}{\pi^2}}{1 + \frac{VAR(\pi)}{\pi^2}} \right]^2$$ **(Equation 3.8)**

The following section details the proper steps that should be carried out to achieve the most reliable outcome from a naïve before-after study. First assume that a strategy is applied to a number of treatment sites numbered 1, 2, 3,… j,….n. During the before period the crash counts are $K_b(1)$, $K_b(2)$, $K_b(3)$, …, $K_b(n)$ and during the after period the crash counts are $L_a(1)$, $L_a(2)$, $L_a(3)$, …, $L_a(n)$.

Since it is possible for the before and after periods to differ in length from treatment site to treatment site it is necessary to define the 'ratio-of-durations':

$r_d(j) = T_a(j)/ T_b(j)$ **(Equation 3.10)**

$T_a(j)$ = duration of the after period for treatment site j.
$T_b(j)$ = duration of the before period for treatment site j.
$r_d(j)$ = ratio-of-durations

Now in four steps the safety effectiveness of the treatment can be estimated.

Step 1: calculate λ and π.

$\lambda = \Sigma L_a(j)$ **(Equation 3.11)**
$\pi = \Sigma\, r_d(j)\, K_b(j)$ **(Equation 3.12)**

Step 2: calculate $VAR(\lambda)$ and $VAR(\pi)$.

$VAR(\lambda) = \Sigma L_a(j)$ **(Equation 3.13)**
$VAR(\pi) = \Sigma\, r_d(j)^2\, K_b(j)$ **(Equation 3.14)**

Step 3: calculate δ and θ.

$\delta = \pi - \lambda$ **(Equation 3.1)**

$\theta = (\lambda/\pi)[1+ \left[1+\frac{VAR(\pi)}{\pi^2}\right]^{-1}$ **(Equation 3.7)**

The crash reduction percentage (CR%) is:

$CR\% = 100(1- \theta)$ **(Equation 3.9)**

If the CR% is found to be negative than it would be expected that the treatment actually increases crashes as opposed to reducing them.

Step 4: calculate VAR(δ) and VAR(θ).

$$\mathrm{VAR}(\delta) = \mathrm{VAR}(\pi) + \mathrm{VAR}(\lambda) \qquad \textbf{(Equation 3.2)}$$

$$\mathrm{VAR}(\theta) = \theta^2 \left[\frac{\dfrac{VAR(\lambda)}{\lambda^2} + \dfrac{VAR(\pi)}{\pi^2}}{1 + \dfrac{VAR(\pi)}{\pi^2}} \right]^2 \qquad \textbf{(Equation 3.8)}$$

Calculating the standard deviation is necessary to establish if the results are statistically significant.

$$\mathrm{STDV} = 2^* \, [\mathrm{VAR}(\theta)]^{-0.5} \qquad \textbf{(Equation 3.15)}$$

If CR% +/- 100*STDV does not change sign from positive to negative or vise versa than the results are statistically significant.

To further comprehend the statistical analysis methodology, an applied example follows using to the sorted microsurfacing data. Once the formulas were developed in Excel, they were applied to the data for each project in the data set (Table 3.5).

Table 3.5 : Sample of Crash Data Analysis for Microsurfacing Data Set

			Years Before	Years After	Before (B)	After (A)			
Project	No. Collisions	Year of Treatment	$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
9	74	2001	2	5	21	53	2.5	52.5	131.25
10	10	2001	2	5	5	5	2.5	12.5	31.25
11	9	2001	2	5	1	8	2.5	2.5	6.25
12	0	2001	2	5	0	0	2.5	0	0
13	90	2001	2	5	27	63	2.5	67.5	168.75
14	0	2001	2	5	0	0	2.5	0	0
15	0	2001	2	5	0	0	2.5	0	0
16	33	2001	2	5	9	24	2.5	22.5	56.25
17	135	2001	2	5	37	98	2.5	92.5	231.25
25	41	2002	2	5	16	25	2.5	40	100
26	0	2002	3	4	0	0	1.33	0	0
27	46	2002	3	4	18	28	1.33	24	32
28	40	2002	3	4	17	23	1.33	22.67	30.22
29	54	2002	3	4	27	27	1.33	36	48

			Years Before	Years After	Before (B)	After (A)			
Project	No. Collisions	Year of Treatment	$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
30	352	2002	3	4	187	165	1.33	249.33	332.44
31	73	2004	5	2	66	7	0.4	26.4	10.56
32	28	2004	5	2	19	9	0.4	7.6	3.04
33	66	2004	5	2	53	13	0.4	21.2	8.48
34	64	2004	5	2	50	14	0.4	20	8
35	34	2004	5	2	19	15	0.4	7.6	3.04
36	125	2004	5	2	102	23	0.4	40.8	16.32
37	0	2004	5	2	0	0	0.4	0	0
38	4	2004	5	2	2	2	0.4	0.8	0.32
40	12	2004	5	2	3	9	0.4	1.2	0.48
41	5	2003	4	3	3	2	0.75	2.25	1.69
42	104	2003	4	3	67	37	0.75	50.25	37.69
46	48	2003	4	3	29	19	0.75	21.75	16.31
48	26	2003	4	3	14	12	0.75	10.5	7.88
					$\Sigma L_{a(j)}=$	681	$\Sigma r_{d(j)}K_{b(j)}=$	832.35	1281.47

With the data in Table the Steps one through four can be completed.

Step 1: calculate λ and π.

$\lambda = \Sigma L_a(j) = 681$ **(Equation 3.11)**

$\pi = \Sigma\, r_d(j)\, K_b(j) = 832.35$ **(Equation 3.12)**

Step 2: calculate VAR(λ) and VAR(π).

$VAR(\lambda) = \Sigma L_a(j) = 681$ **(Equation 3.13)**

$VAR(\pi) = \Sigma\, r_d(j)^2\, K_b(j) = 1281.47$ **(Equation 3.14)**

Step 3: calculate δ and θ.

$\delta = \pi - \lambda = 832.35 - 681 = 151.35$ **(Equation 3.1)**

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1} = (681/832.35)[1+(1281.47/832.35\char`^2)]^{-1} = 0.82$ **(Equation 3.7)**

The crash reduction percentage (CR%) is:

$$CR\% = 100(1- \theta) = 100\ (1-0.82) = 18.3\ \% \qquad \textbf{(Equation 3.9)}$$

The potential crash reduction percentage is 18.3 percent, but the statistical significance needs to be verified.

Step 4: calculate VAR(δ) and VAR(θ).

$$VAR(\delta) = VAR(\pi) + VAR(\lambda) = 1281.47 + 681 = 1962.47 \qquad \textbf{(Equation 3.2)}$$

$$VAR(\theta) = \theta^2 \left[\frac{\dfrac{VAR(\lambda)}{\lambda^2} + \dfrac{VAR(\pi)}{\pi^2}}{1 + \dfrac{VAR(\pi)}{\pi^2}} \right]^2 \qquad \textbf{(Equation 3.8)}$$

$$= (0.82)^2[681/681^2 + 1281.47/832.35^2]/[1+1281.47/832.35^2]^2 = 0.002205$$

Calculating the standard deviation is necessary to establish if the results are statistically significant.

$$STDV = 2^* [VAR(\theta)]^{-0.5} = 2^* [0.002205]^{-0.5} = 0.09391 \qquad \textbf{(Equation 3.15)}$$

Since 18.3 % +/- 9.4% produces a potential crash reduction range of 8.9% to 27.7% that does not cross over zero, the result is statistically significant.

3.3 Potential Data Issues and Preferred Analysis Methods

Good quality data is difficult to obtain, and perfect data in road safety does not exist. The Region of York has a solid data collection program and is considered to be advanced in comparison to other local agencies; however, their data are not without limitations. For example the crash data is supplied from police reports and cannot capture property damage only (PDO) crashes that are not reported or crashes that settle outside of insurance. In addition the self reporting collision centre is reliant on driver honesty and their interpretation of the possible options to describe the collision. Each driver involved in a crash fills out a separate form and often drivers from the same incident have very different crash reports. Crash reports cannot report driver errors or distractions that may have contributed to the crash. Due to this potential variability it is imperative that data managers maintain the quality of the facets of data over which they can control.

One method of accounting for some of the potential data issues is to use comparison sites that did not receive treatment as a baseline on which to compare the results. Using a comparison group can improve prediction by accounting for factors that are not recognized as affecting safety, that are recognized but not measures, or whose influence on safety is not understood. The selection of the treatment group, in this study and what is often the case, is assigned in a non-random manner, based on poor safety records or a particular treatment. Due to this fact it is not likely that the expected number of crashes in the treatment group will change in the same manner as in the comparison group.

The before-after study with comparison group method is based on two fundamental assumptions [Hauer 97b]:

1. The factors that affected safety have changed in the same way from the before period to after the improvement on both treatment and comparison groups, and
2. The changes in the various factors influence the safety of treatment and comparison groups in the same manner.

Under these assumptions, it can be assumed that the change in the number of crashes before and after the implementation of countermeasures in the treated sites, if the treatment has not been improved, would have been in the same proportion as that for the comparison group.

Ideally the study would employ the Empirical Bayes (EB) methodology and develop a safety performance function for microsurfacing but the data that would be required to complete the study were not available at the time of the study from the Region of York. The EB method adjusts for the regression-to-the mean bias, and is based on three assumptions [Hauer et al. 01]:

1. The number of crashes at any site follows a Poisson distribution
2. The means for a population of systems can be approximated by a Gamma distribution
3. Changes from year to year from different factors are similar for all reference sites

The idea behind the EB method is that it predicts the number of crashes that would have been expected to have occurred during the after period had the treatment not been implemented.

Several studies have compared the performances of the three different before-after methods. The findings revealed that the simple or naïve before-after method generally overestimates the safety benefits and the EB method provides results that are generally comparable to those obtained from the before-after with comparison group method.

4.0 RESULTS

Applying the methodology from Section 3.0 to the formatted data produced the results that follow.

4.1 Microsurfacing Results

It was found that an eighteen percent reduction in crashes could be anticipated following the microsurfacing treatment. The standard deviation gave a range of nine percent indicating that the result is statistically significant (Table 4.1). Appendix B provides more detail on the microsurfacing analysis.

Based on the literature and the attention given to wet weather crashes and skid resistance the data was further broken down by road surface condition to see how it might impact the safety effectiveness of microsurfacing. Three conditions were studied: dry, wet, and not dry. The 'not dry' condition refers to all crashes experienced with road surface conditions that were either wet, icy, snowy, etc. The results were in line with the majority of the literature and statistically significant. The effectiveness of microsurfacing was higher for roads with wet pavement conditions- a 32 percent reduction in crashes. The safety effectiveness was reduced when 'not dry' conditions were analyzed (26 percent) and even further reduced for the dry condition (fourteen percent).

Table 4.1: Summary of results for various study conditions on sites treated with a microsurfacing application

Study Condition	CR%	STDV	CR% +/- STDV		Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.18	0.09	0.09	0.27	Yes	820	740	1560
Dry	0.14	0.12	0.02	0.26	Yes	523	496	1019
Wet	0.32	0.15	0.17	0.47	Yes	220	166	386
Not Dry	0.26	0.14	0.12	0.40	Yes	297	244	541
Severe	0.18	0.19	0.00	0.37	No	186	172	358
Intersection	0.24	0.09	0.15	0.33	Yes	686	583	1269
Rear End	0.29	0.12	0.17	0.41	Yes	358	274	632

Since most skidding accidents involve braking and occur at intersections, the data were reanalyzed using intersection locations only. Intersection locations included those described as 'intersection related' or 'at intersection' according to the police reports. The results showed that microsurfacing could reduce intersection crashes by 24 percent. Furthermore, the most common intersection related crash involves rear end impact. The analysis suggests that microsurfacing treatment can reduce rear end collisions by 29 percent.

The total scenario and the intersection scenario yielded the smallest standard deviation while the severity scenario had the largest standard deviation (Figure 4.1).

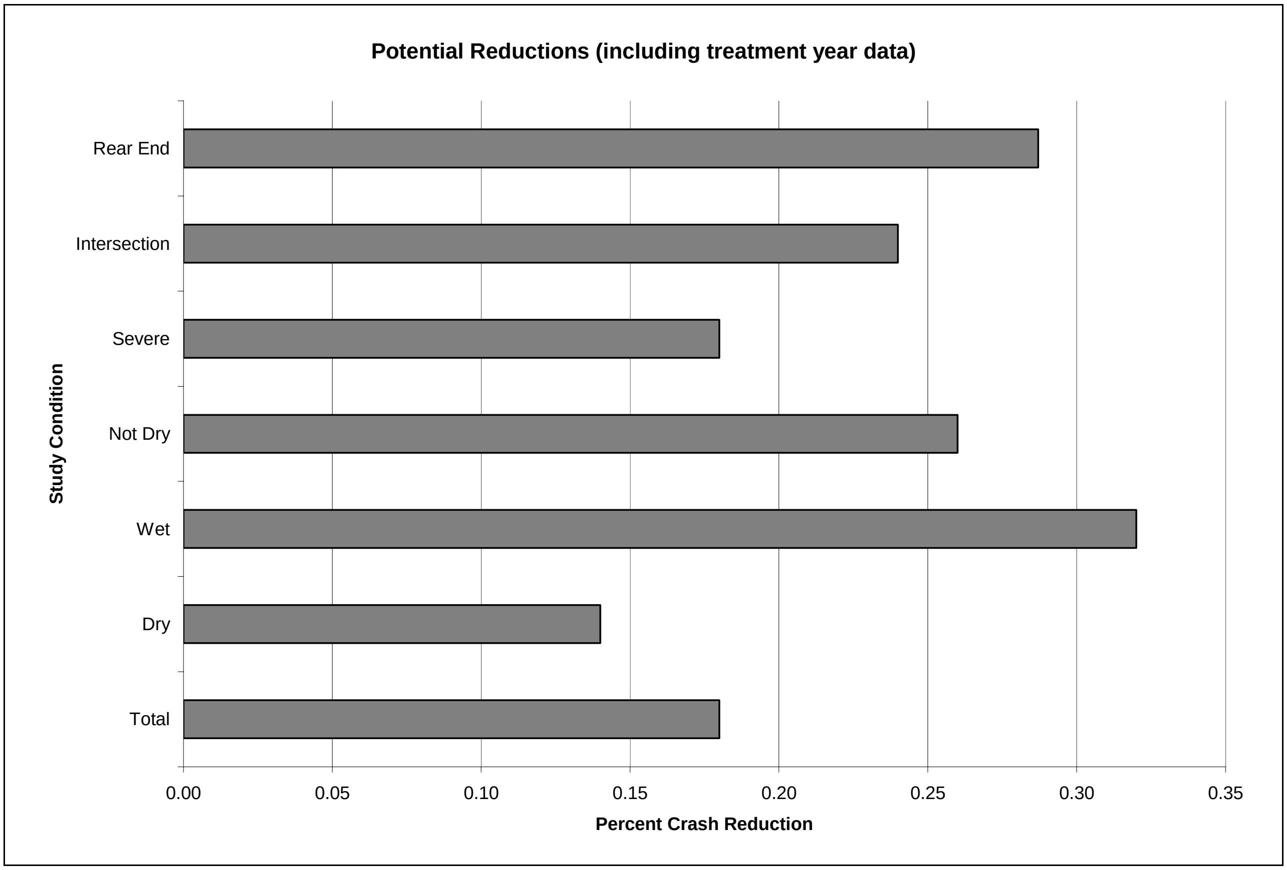


Figure 4.1: Range of potential crash reduction by study condition for microsurfacing

What is often most important in safety studies is the severity of crashes. If the severity of a crash can be reduced from a fatal to an injury or PDO it is regarded as a positive effect as lives are saved and the costs to society are lessened. For this reason the impact of microsurfacing on severe crashes was analyzed. Severe crashes are classified as fatal or injury. The effectiveness calculated was the same as the total analysis, a potential crash reduction of eighteen percent as shown in Figure 4.1. However, the standard deviation was +/- nineteen percent and the result was not deemed statistically significant as the range crosses over zero. As this is a very important issue further sensitivity analysis was carried out in Section 4.3.

4.2 Resurfacing Results

It was found that a four percent reduction in crashes may be anticipated following the pavement resurfacing. The standard deviation gave a range of fifteen percent indicating that the result is not statistically significant (Table 4.2). In fact majority of the results from the resurfacing analysis were not statistically significant. Appendix C provides more detail on the resurfacing analysis.

The resurfacing data were analyzed using the same methodology that was applied to the microsurfacing data in an attempt to establish the safety effectiveness for comparison purposes. Three weather related conditions were studied: dry, wet, and not dry. None of the results were statistically significant with high standard deviations. The effectiveness of resurfacing was higher; a 22 percent reduction in crashes for roads with wet pavement conditions. The safety effectiveness was reduced when dry conditions were analyzed (six percent) and even further reduced for the ‘not dry’ condition (one percent).

Table 4.2: Summary of results for various study conditions on sites treated with a resurfacing treatment

Study Condition	CR%	STDV	CR% +/- STDV		Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.04	0.15	0.00	0.19	No	235	605	840
Dry	0.06	0.17	0.00	0.23	No	169	421	590
Wet	0.22	0.26	0.00	0.48	No	53	120	173
Not Dry	0.01	0.29	0.00	0.30	No	66	184	250
Severe	-0.06	0.38	-0.44	0.00	No	43	128	171
Intersection	0.15	0.15	0.00	0.30	Yes	199	447	646
Rear End	-0.01	0.26	-0.27	0.00	No	87	245	332

The severity and rear end analysis, although not statistically significant, produce results that indicate resurfacing could actually cause a six percent increase in severe crashes and a one percent increase in rear end crashes.

The data were reanalyzed using intersection locations only. Intersection locations included those described as ‘intersection related’ or ‘at intersection’ according to the police reports. The results showed that resurfacing could reduce intersection crashes by fifteen percent (Figure 4.2). This result was statistically significant by a very narrow margin prior to rounding the results. The large standard deviation is still not favourable and further studies are recommended before accepting the potential fifteen percent for intersection related crashes.

Similarly to the microsurfacing analysis, the total scenario and the intersection scenario yielded the smallest standard deviations in comparison to the other scenarios, while the severity study condition had the largest standard deviation.

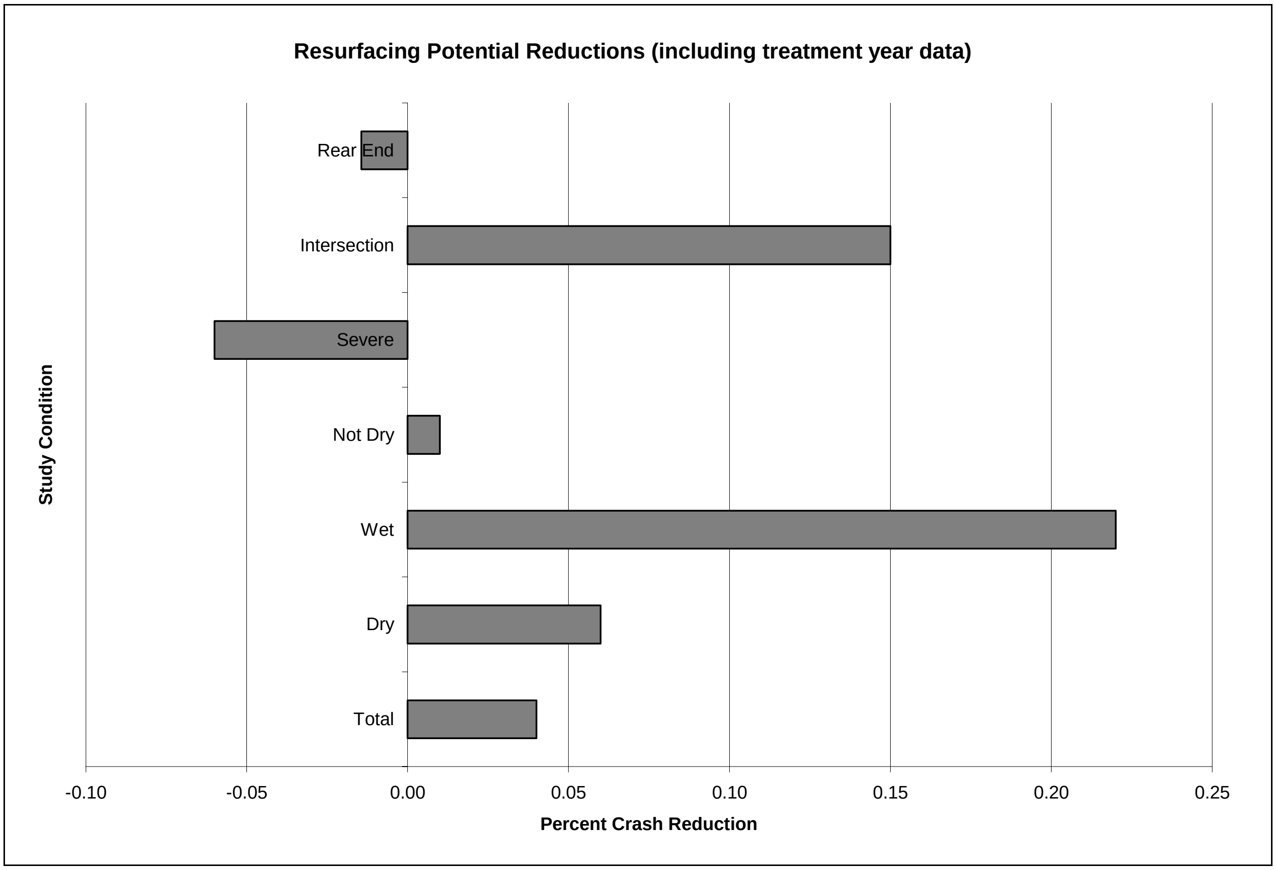


Figure 4.2: Range of potential crash reduction by study condition for resurfacing

The standard deviations cross over zero for all of the scenarios except intersection related crashes that touches the zero at its lowest range. An explanation for the inconsistency in the resurfacing results is that HL4 is not expected to perform as well in skid resistance as a dense friction course (DFC). As opposed to the microsurfacing projects that all used Type 3. Table 3.1 lists which projects used HL4 and which used a DFC.

4.3 Sensitivity Analysis

As a result of the high level of uncertainty associated with the original findings, an alternative approach was used to see how sensitive the results were to changes within the data.

4.3.1 Treatment Year

In the literature review, it was seen several times that crash rates may actually rise following a surface treatment. This, combined with the fact that the data provided from York Region does not pinpoint exactly the point in time within the year that the treatment was applied, provided the impetus for a change in the research approach. The data scenarios were reanalyzed omitting the data from the year of treatment. For example, if the microsurfacing treatment was applied in 2002, all crashes that occurred at the project site during the year 2002 were omitted and the after period was reduced by one year. Appendix D and E provide more detail on the microsurfacing and resurfacing analysis with treatment year omitted, respectively.

With the treatment year omitted the crash reduction percentage increased for all scenarios, most of the standard deviations remained the same, and each scenario was found to be statistically significant (Table 4.3). Analyzing severe crashes under these conditions saw a ten percent increase in crash reduction potential.

Table 4.3: Summary of results for various study conditions on site treated with a microsurfacing application excluding treatment year data

Study Condition	CR%	STDV	CR% +/- STDV		Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.27	0.09	0.18	0.37	Yes	820	478	1298
Dry	0.23	0.12	0.11	0.36	Yes	523	320	843
Wet	0.41	0.15	0.26	0.56	Yes	220	104	324
Not Dry	0.34	0.14	0.20	0.48	Yes	297	158	455
Severe	0.28	0.19	0.09	0.47	Yes	186	110	296
Intersection	0.33	0.09	0.24	0.43	Yes	686	371	1057
Rear End	0.40	0.12	0.27	0.52	Yes	358	168	526

The wet study condition still yielded the highest level of safety effectiveness with a 41 percent potential crash reduction followed by rear end impact collisions with a 40 percent reduction. All of the scenarios yielded positive ranges of effectiveness with none of the study conditions crossing zero (Figure 4.3).

To see if there was a similar relationship between treatment year and crashes, a similar sensitivity analysis was carried out with the resurfacing data. The data scenarios were reanalyzed omitting the data from the year of treatment. As previously explained, if the resurfacing treatment was applied in 2002, all crashes that occurred at the project site during the year 2002 were omitted and the after period was reduced by one year.

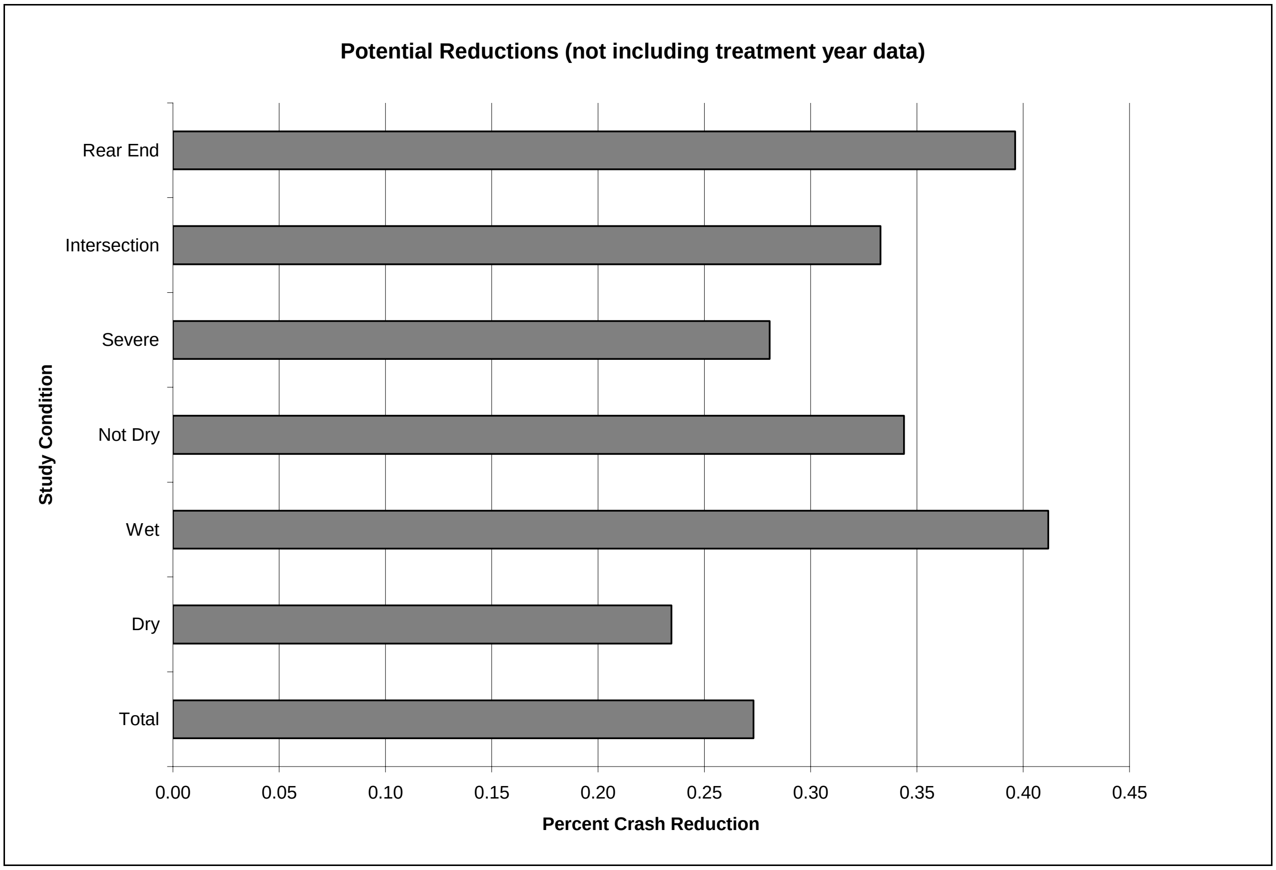


Figure 4.3: Range of potential crash reduction by study condition for microsurfacing excluding treatment year data

In a similar pattern, with the treatment year omitted, the crash reduction percentage increased for all study conditions and half of the standard deviations remained the same, but it was not enough of an improvement to make the results statistically significant (Table 4.4). Only the finding for intersection related crashes was statistically significant with a potential nineteen percent reduction in crashes following a resurfacing treatment.

Table 4.4: Summary of results for various study conditions on site treated with a resurfacing treatment excluding treatment year data

Study Condition	CR%	STDV	CR% +/- STDV		Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.07	0.15	0.00	0.22	No	235	470	705
Dry	0.10	0.17	0.00	0.27	No	169	323	492
Wet	0.25	0.27	0.00	0.52	No	53	93	146
Not Dry	0.02	0.30	0.00	0.32	No	66	147	213
Severe	0.02	0.37	0.00	0.39	No	43	96	139
Intersection	0.19	0.15	0.04	0.34	Yes	199	342	541
Rear End	0.05	0.26	0.00	0.31	No	87	185	272

The wet study condition still yielded the highest level of safety effectiveness with a 25 percent potential crash reduction, but the result was not statistically significant (Figure 4.4). All of the scenarios illustrated ranges of effectiveness that crossed over zero with the exception of intersection related crashes that maintain a positive range of effectives between four and 34 percent.

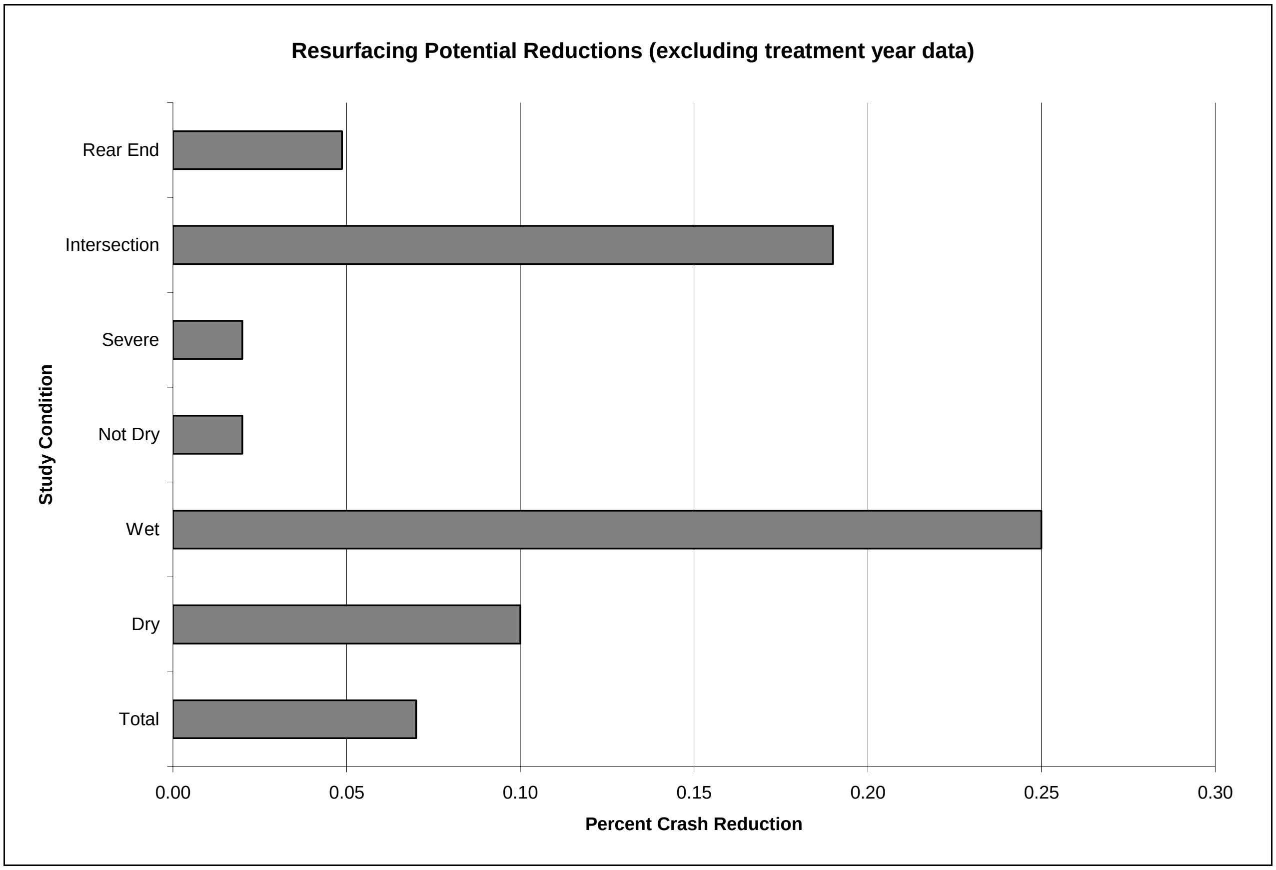


Figure 4.4: Range of potential crash reduction by study condition for resurfacing excluding treatment year data

4.3.2 Increasing the Sample Size

With encouraging results from the microsurfacing analysis and inconclusive results from the resurfacing analysis the question arises as to how the results would change if the two data sets were analyzed together; essentially obtaining results for surface treatments with a larger sample size. The data were analyzed using all crashes to make up the total study condition as well as using all crashes with the treatment year omitted. The findings were found to be statistically significant with a standard deviation of 0.08 (Table 4.5). The potential crash reduction was twelve percent for the total combined study condition and increased to eighteen percent for the total combined with treatment year data excluded condition. Appendix F provides more detail on the microsurfacing and resurfacing combined analysis.

Table 4.5: Summary of results for the total study condition for sites treated with either a resurfacing or microsurfacing treatment

Study Condition	Potential Reduction	STDV	CR% +/- STDV		Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	12%	0.08	0.04	0.20	Yes	1027	1286	2313
Total (TYE)*	18%	0.08	0.10	0.26	Yes	1027	902	1929

*TYE-treatment year excluded

In comparing all of the total scenario conditions graphically it is evident that the standard deviation range for both of the total resurfacing scenarios are much greater than the total combined and the total microsurfacing scenarios. Comparing the microsurfacing and resurfacing results with the combined results indicates that microsurfacing with treatment year excluded produces the greatest potential crash reduction factor (Figure 4.5).

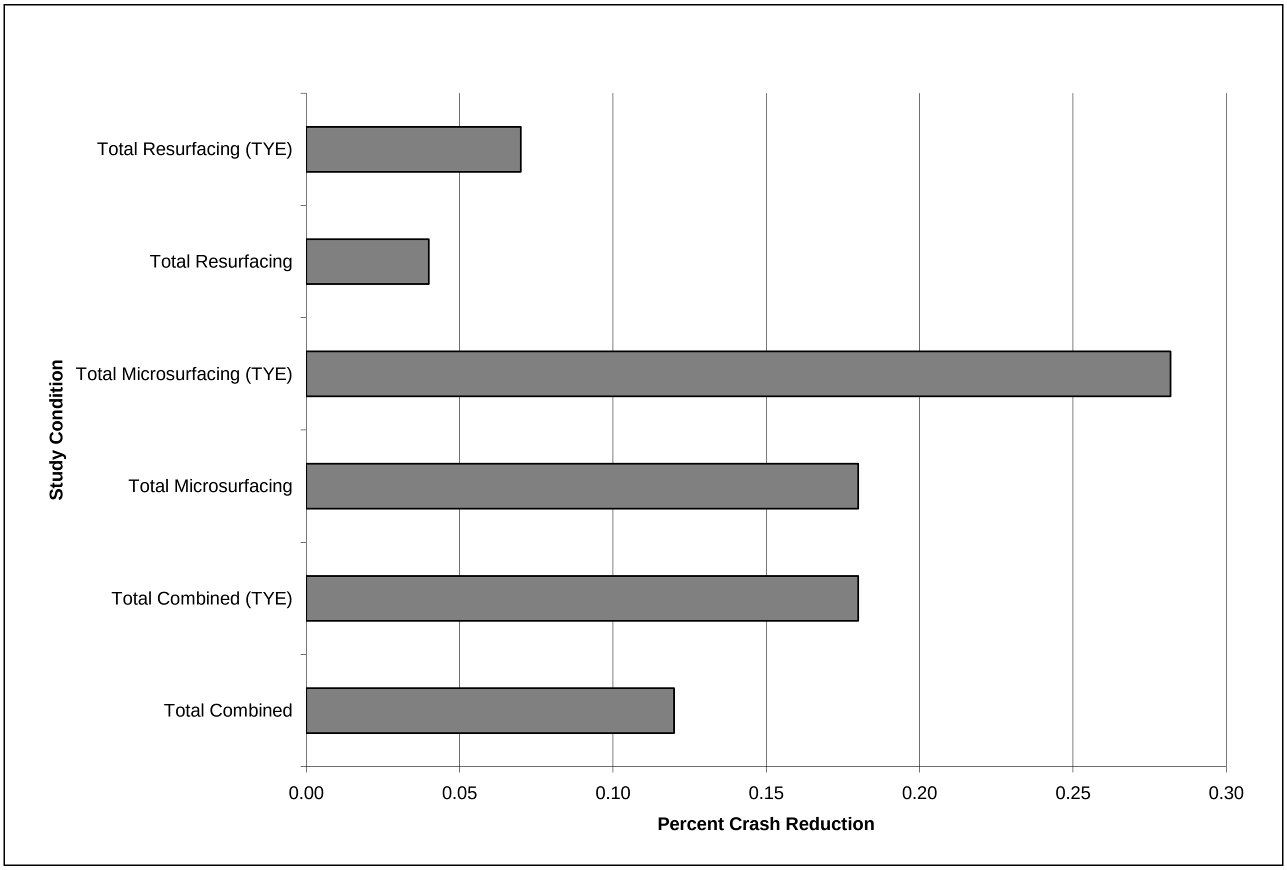


Figure 4.5: Range of potential crash reduction for all total scenario conditions

4.3.3 Normalizing the Data

The potential for crashes at a particular location increases with traffic volume as a result of increased exposure. To compensate for this fact, the data were normalized using Average Annual Daily Traffic (AADT) per lane. The AADT values were averaged over the study period for each project location and divided by the number of lanes to get the AADT per lane. Next, each project was assigned one of three categories based on the AADT per lane value. Table 4.6 contains the Category classification.

Table 4.6: Category Classification based on AADT per Lane

	AADT per lane Range
Category 1	0-2999
Category 2	3000-6999
Category 3	7000+

The data were separated by type of treatment and category number. Figure 4.6 provides an illustrative understanding of how the data were spread out. Despite having a reasonable number of project locations (more than five) for both microsurfacing and resurfacing treatments, category 1 held a very small sample size of crashes for both treatments. Conversely, category 3 for resurfacing held a significant number of crashes considering there was only a single project treatment site.

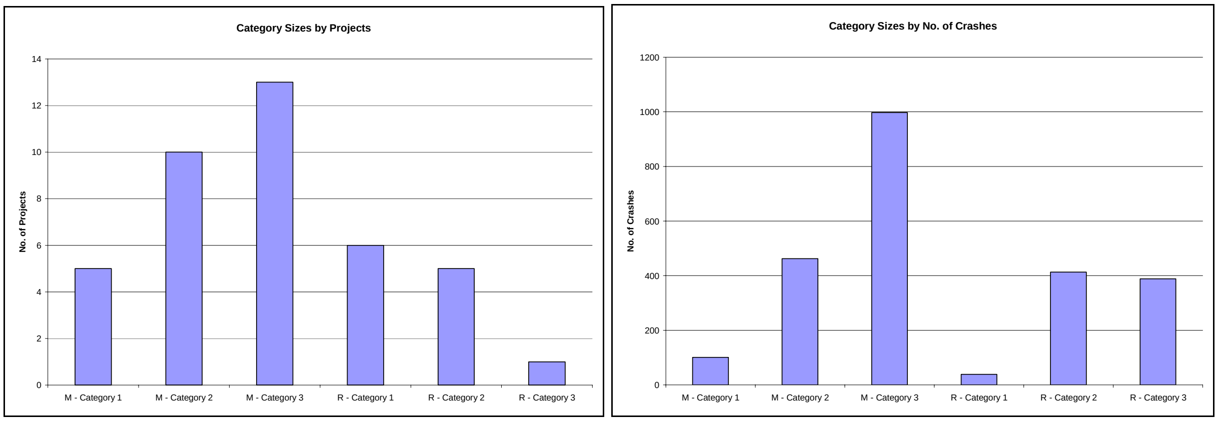


Figure 4.6: Distribution of data for Microsurfacing (M) and Resurfacing (R) Treatments by Number of Projects and Number of Collisions

All of the data were reanalyzed for total, dry, wet, not dry, severe, intersection, and rear end study conditions both with and omitting the treatment year data since it had previously demonstrated to have a significant impact on the reduction factors.

The results from the microsurfacing analysis were as follows.

For the total study condition, the percent crash reduction improved for both category 2 and category 3 with potential reductions as great as 37 and 26 percent, respectively with the treatment year omitted (Table 4.7 and Table 4.8). Appendix G and H provides more detail on the normalized microsurfacing analysis with and without treatment year, respectively.

Table 4.7: Total Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.18	0.09	Yes	820	740	1560
Total Category 1	0.11	0.38	No	32	69	101
Total Category 2	0.20	0.17	Yes	267	195	462
Total Category 3	0.19	0.11	Yes	521	476	997

Table 4.8: Total Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.27	0.09	Yes	820	478	1298
Total Category 1	0.14	0.38	No	32	53	85
Total Category 2	0.37	0.17	Yes	267	108	375
Total Category 3	0.26	0.11	Yes	521	317	838

However, for category 1 with AADT per lane less than 3000 the results were not statistically significant for either scenario and the analysis indicated that it was the least influenced group as a result of a microsurfacing treatment (Figure 4.7).

Regarding road surface conditions, only category 2 with AADT per lane between 3000 and 6999 and category 3 with AADT per lane greater than or equal to 7000 for the wet study condition and category 3 with AADT per lane greater then or equal to 7000 for the not dry study condition produced statistically significant findings when the treatment year data was included. All of which produced potential crash reductions of 34 percent or more (Table 4.9, Table 4.10, and Table 4.11).

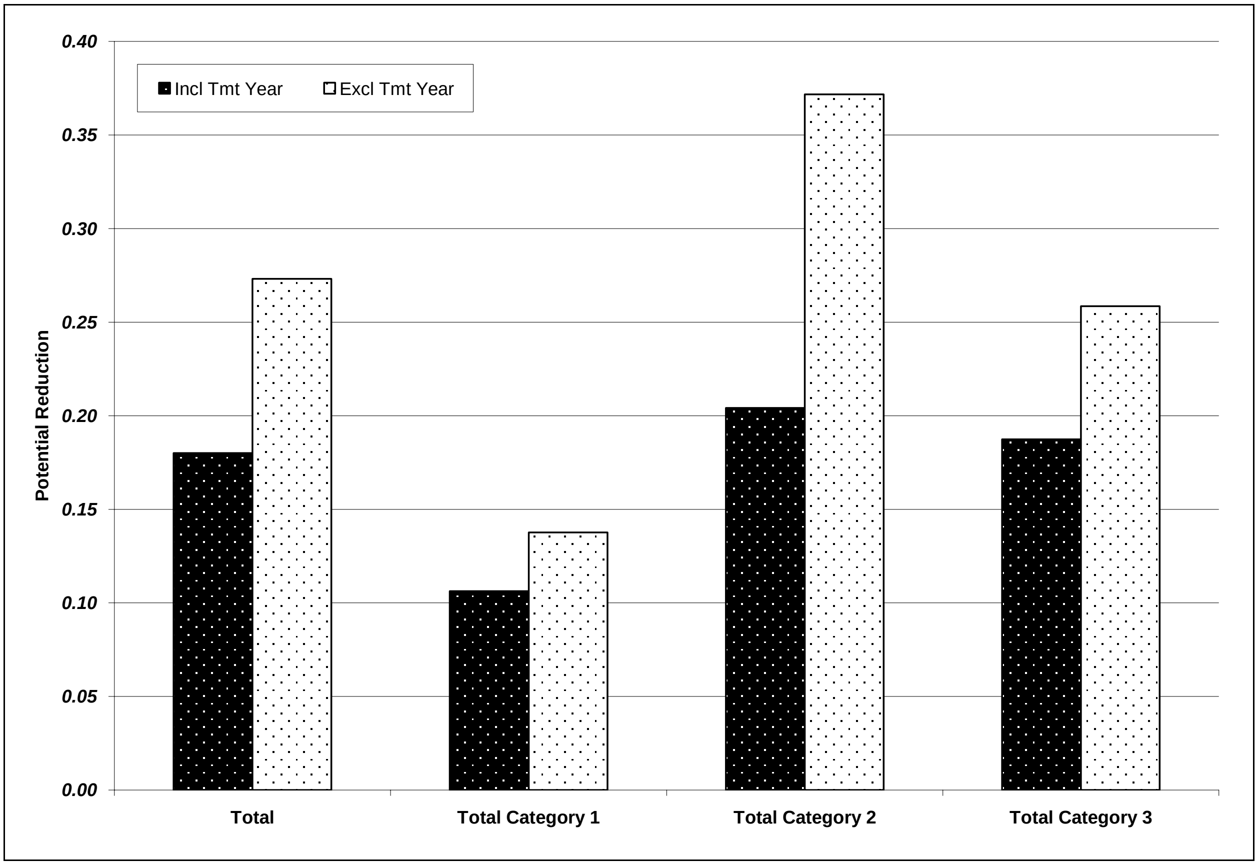


Figure 4.7: Total Condition for Microsurfacing plotted for each data set

Table 4.9: Dry Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Dry	0.18	0.09	Yes	820	740	1560
Dry Category 1	0.25	0.38	No	21	41	62
Dry Category 2	0.20	0.22	No	177	128	305
Dry Category 3	0.09	0.15	No	323	329	652

Table 4.10: Wet Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Wet	0.14	0.12	Yes	523	496	1019
Wet Category 1	-0.53	1.26	No	5	23	28
Wet Category 2	0.36	0.28	Yes	66	43	109
Wet Category 3	0.39	0.16	Yes	149	100	249

Table 4.11: Not Dry Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Not Dry	0.32	0.15	Yes	220	166	386
Not Dry Category 1	-0.29	0.90	No	9	30	39
Not Dry Category 2	0.24	0.28	No	90	67	157
Not Dry Category 3	0.34	0.15	Yes	198	147	345

None of the results were statistically significant for the dry study condition and the category 1 with AADT per lane less than 3000 results for the wet and not dry condition indicated that microsurfacing may actually increase the number of crashes (Figure 4.8).

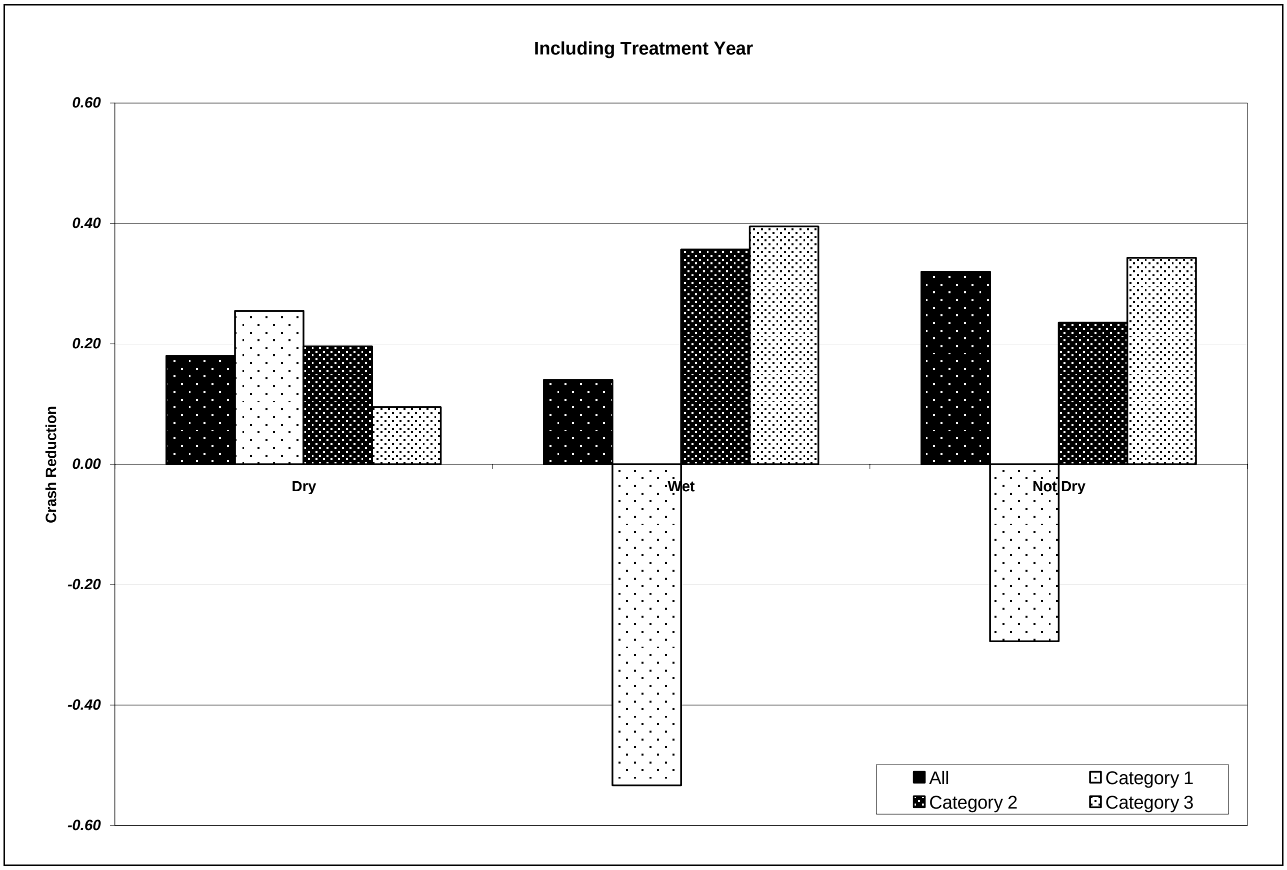


Figure 4.8: Potential Crash Reduction for Microsurfacing under different Surface Conditions Including Treatment Year Data

Running the analysis again with the treatment year omitted produces more promising results. All of the findings were statistically significant except for category 1 with AADT per lane less than 3000 for both wet and not dry conditions which illustrated the potential to increase the number of crashes as a result of a microsurfacing treatment (Table 4.12, Table 4.13, and Table 4.14).

Table 4.12: Dry Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Dry	0.23	0.12	Yes	523	320	843
Dry Category 1	0.36	0.35	Yes	23	29	52
Dry Category 2	0.38	0.21	Yes	177	69	246
Dry Category 3	0.16	0.16	Yes	323	222	545

Table 4.13: Wet Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Wet	0.41	0.15	Yes	220	104	324
Wet Category 1	-0.42	1.20	No	5	17	22
Wet Category 2	0.54	0.25	Yes	66	55	88
Wet Category 3	0.46	0.17	Yes	149	65	214

Table 4.14: Not Dry Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Not Dry	0.34	0.14	Yes	297	158	455
Not Dry Category 1	-0.30	0.93	No	9	24	33
Not Dry Category 2	0.37	0.27	Yes	90	39	129
Not Dry Category 3	0.42	0.15	Yes	198	95	293

The greatest potential crash reduction was 54 percent for the wet surface condition with Category 2 data with AADT per lane between 3000 and 6999. High crash reduction factors were also identified for Category 3 data with AADT per lane greater than or equal to 7000 under both wet and not dry surface conditions (Figure 4.9).

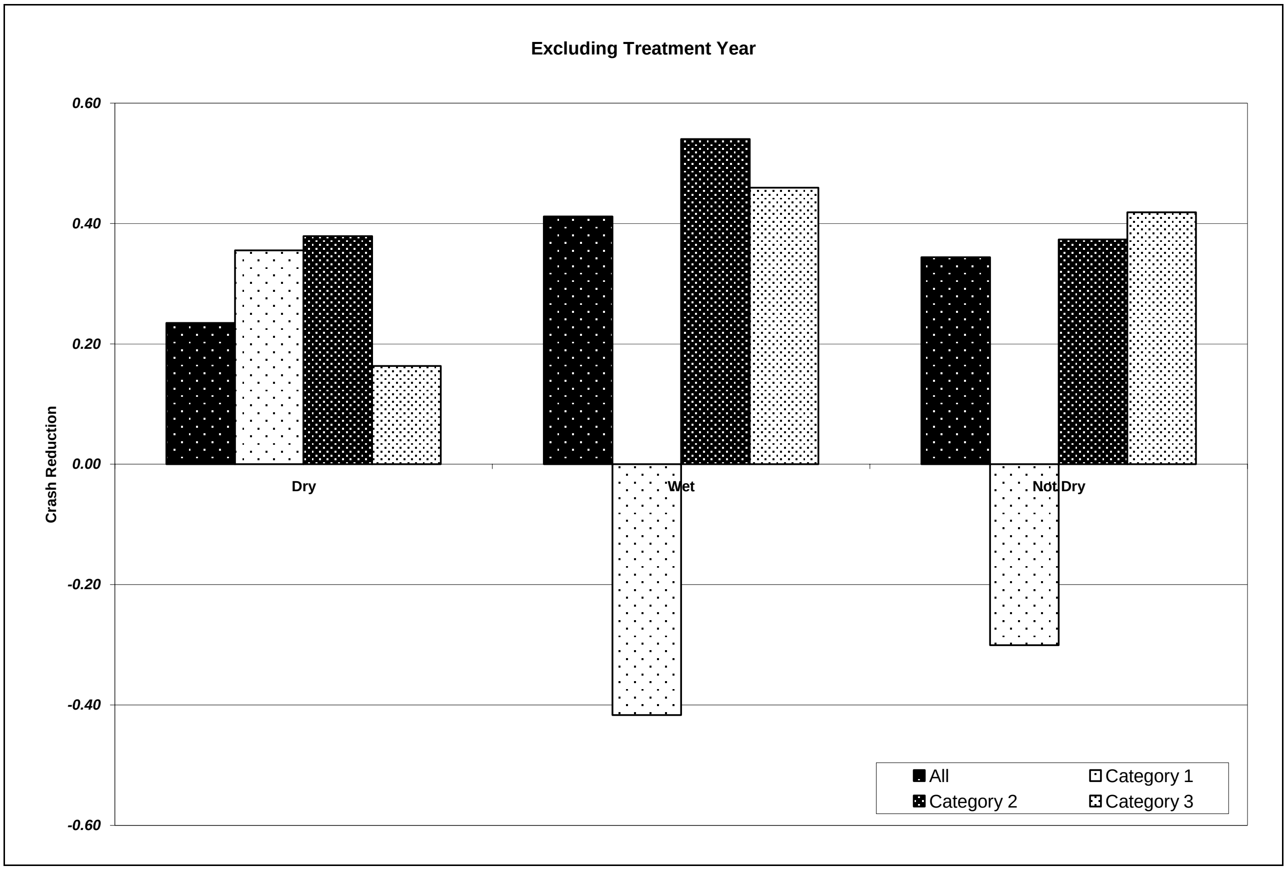


Figure 4.9: Potential Crash Reduction for Microsurfacing under different Surface Conditions Excluding Treatment Year Data

Previous analysis found that the percent reduction for severe crashes was not statistically significant unless the treatment year data was omitted. However, category 2 with AADT per lane between 3000 and 6999 produced a statistically significant result with treatment year data included. Category 2 with AADT per lane between 3000 and 6999 and category 3 with AADT per lane greater than or equal to 7000 also produced a statistically significant result with treatment year data excluded (Table 4.15 and Table 4.16).

Table 4.15: Severe Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Severe	0.26	0.14	Yes	297	244	541
Severe Category 1	0.14	0.63	No	9	20	29
Severe Category 2	0.32	0.31	Yes	62	42	104
Severe Category 3	0.14	0.24	No	115	110	225

Table 4.16: Severe Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Severe	0.28	0.19	Yes	186	110	296
Severe Category 1	0.13	0.66	No	9	16	25
Severe Category 2	0.43	0.30	Yes	62	25	87
Severe Category 3	0.26	0.24	Yes	115	69	184

The severe study condition analysis demonstrated that microsurfacing was the most effective for category 2 with AADT per lane between 3000 and 6999 at reducing fatal or injury crashes with a reduction of 32 percent and 43 percent both with and without treatment year data, respectively (Figure 4.10).

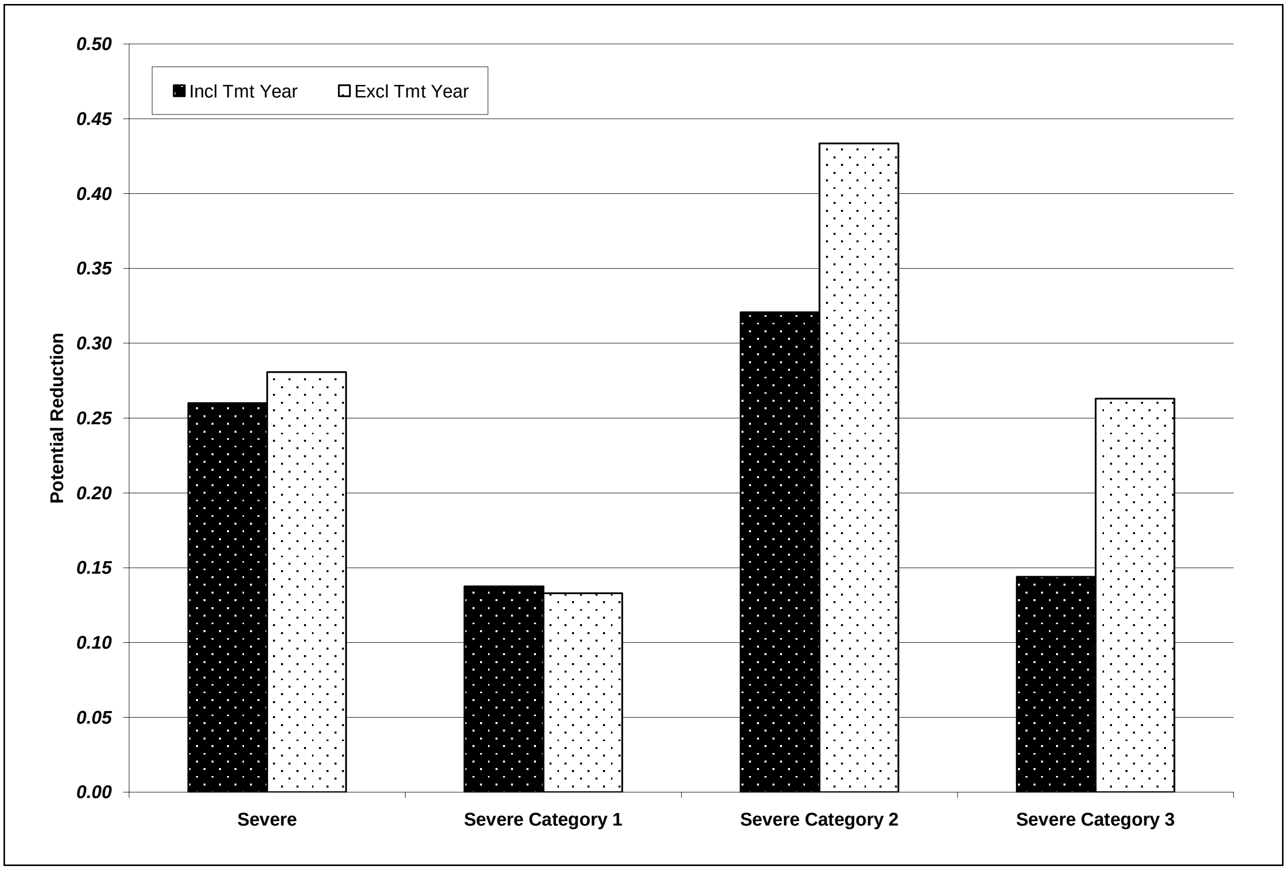


Figure 4.10 : Severe Study Condition for Microsurfacing plotted for each data set

The analysis of intersection related crashes provided statistically significant results for all data sets except category 1 with AADT per lane less than 3000, which had the lowest number of total crashes (Table 4.17 and Table 4.18).

Table 4.17: Intersection Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Intersection	0.18	0.19	No	186	172	358
Intersection Category 1	0.22	0.36	No	28	54	82
Intersection Category 2	0.25	0.18	Yes	228	162	390
Intersection Category 3	0.24	0.11	Yes	430	367	797

Table 4.18: Intersection Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Intersection	0.33	0.09	Yes	686	371	1057
Intersection Category 1	0.29	0.34	No	28	39	67
Intersection Category 2	0.38	0.18	Yes	228	94	322
Intersection Category 3	0.33	0.12	Yes	430	238	668

Data in category 2 with AADT per lane between 3000 and 6999 and category 3 with AADT per lane greater than or equal to 7000 produced high reduction factors of 38 and 33 percent, respectively, with treatment year data omitted (Figure 4.11). Despite not being statistically significant, the category 1 with AADT per lane less than 3000 analysis suggests that microsurfacing could potentially reduce intersection crashes.

Lastly, the analysis for rear end impact crashes followed a similar trend to that observed intersection related crashes. With respect to statistical significance all of the results were statistically significant for all data sets except category 1 with AADT per lane less than 3000 (Table 4.19 and Table 4.20). The similarity is logical because most rear end crashes are intersection related.

Category 2 with AADT per lane between 3000 and 6999 and category 3 with AADT per lane greater than or equal to 7000 produced very high crash reduction factors when analyzed for rear end crashes, as high as 50 percent for category 2 with treatment year omitted (Figure 4.12). Data in category 1 with AADT per lane less than 3000 did not yield statistically significant results but once again it is suggested that microsurfacing could increase the number of crashes where AADT per lane is less than 3000 veh/lane.

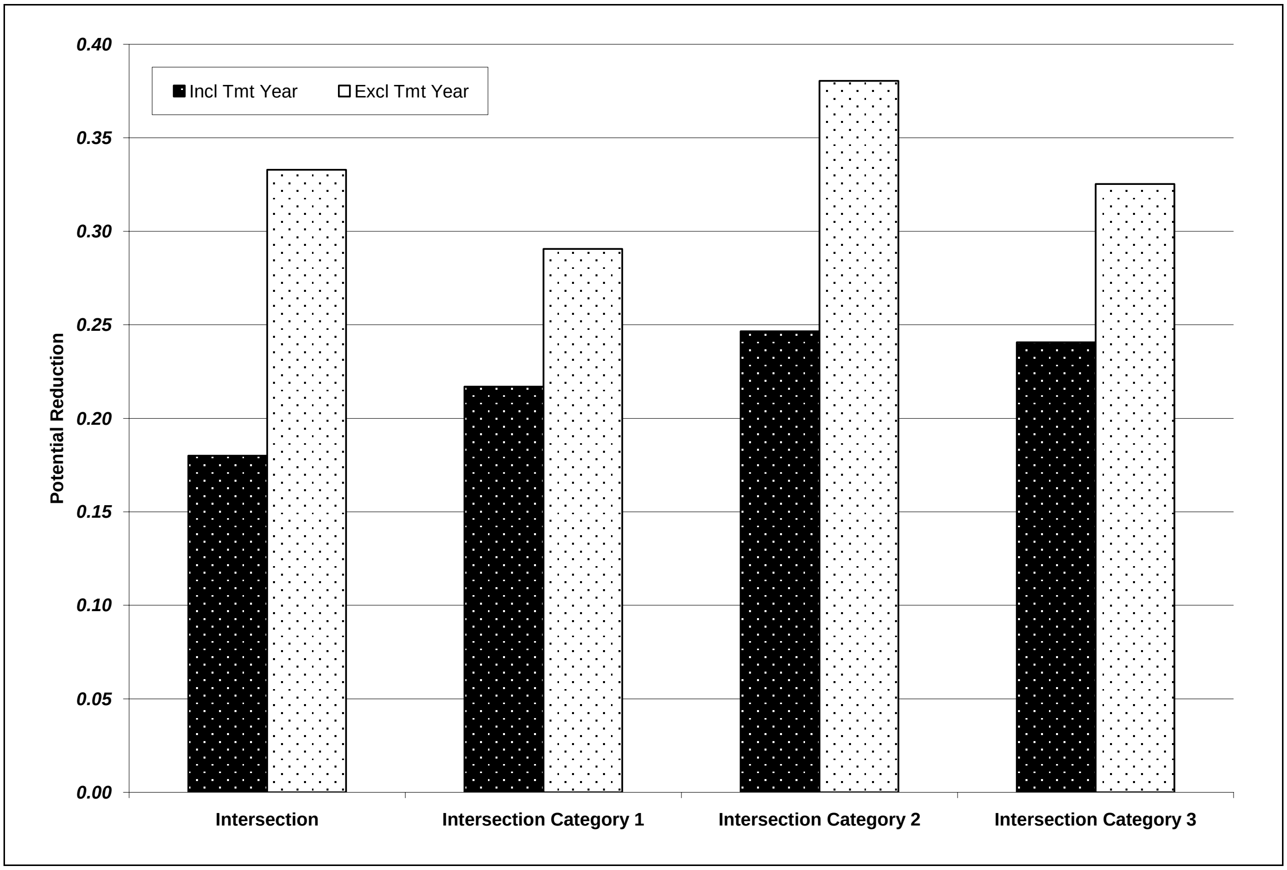


Figure 4.11 : Intersection Study Condition for Microsurfacing plotted for each data set

Table 4.19: Rear End Study Condition for Microsurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Rear End	0.29	0.12	Yes	358	274	632
Rear End Category 1	-0.53	1.26	No	5	23	28
Rear End Category 2	0.35	0.23	Yes	104	63	167
Rear End Category 3	0.32	0.14	Yes	249	188	437

Table 4.20: Rear End Study Condition for Microsurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Rear End	0.40	0.12	Yes	358	168	526
Rear End Category 1	-0.33	1.14	No	5	16	21
Rear End Category 2	0.50	0.22	Yes	104	34	138
Rear End Category 3	0.41	0.14	Yes	249	118	367

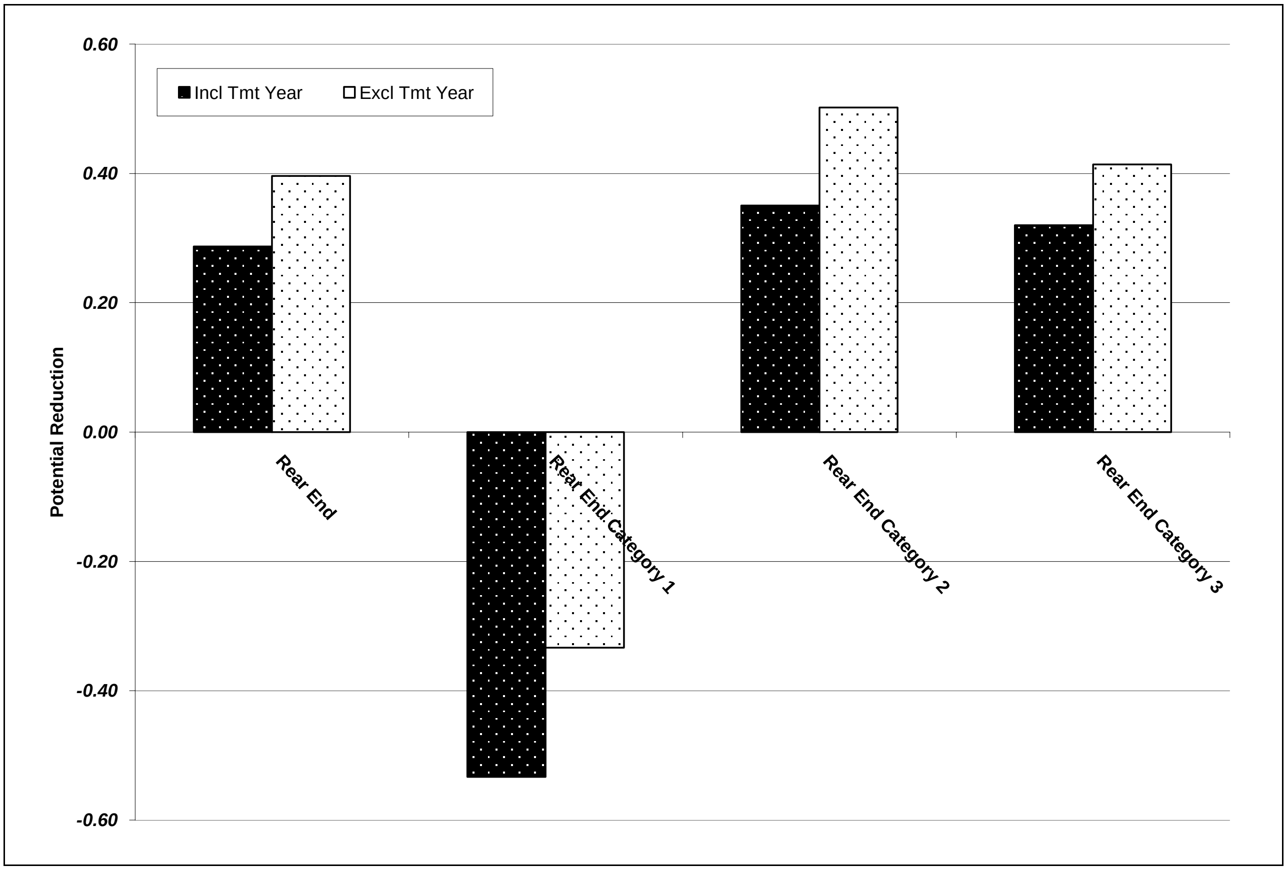


Figure 4.12 : Rear End Study for Microsurfacing Condition plotted for each data set

The findings from the resurfacing analysis were of particular interest due to the poor results reported previously. A summary of the safety effect of resurfacing in accordance to the category number classification follows. Appendix I and J provides more detail on the normalized resurfacing analysis with and without treatment year, respectively.

For the total study condition a statistically significant percent crash reduction due to resurfacing improved only for category 2 with AADT per lane between 3000 and 6999 for a potential reduction of 23 and 26 percent with and without the treatment year data, respectively (Table 4.21 and Table 4.22).

Table 4.21: Total Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.04	0.15	No	235	605	840
Total Category 1	-1.75	2.71	No	2	37	39
Total Category 2	0.23	0.17	Yes	131	282	413

Total Category 3	-0.11	0.25	No	102	286	388

Table 4.22: Total Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Total	0.07	0.15	No	235	470	705
Total Category 1	0.14	0.17	No	2	33	35
Total Category 2	0.26	0.17	Yes	131	218	349
Total Category 3	-0.06	0.25	No	102	219	321

Results for category 1 with AADT per lane less than 3000 and category 3 with AADT per lane greater than or equal to 7000 were not statistically significant for either scenario and the analysis indicated that for both the high and low end of the traffic volume categories there was potential for an increase in crashes after resurfacing (Figure 4.13).

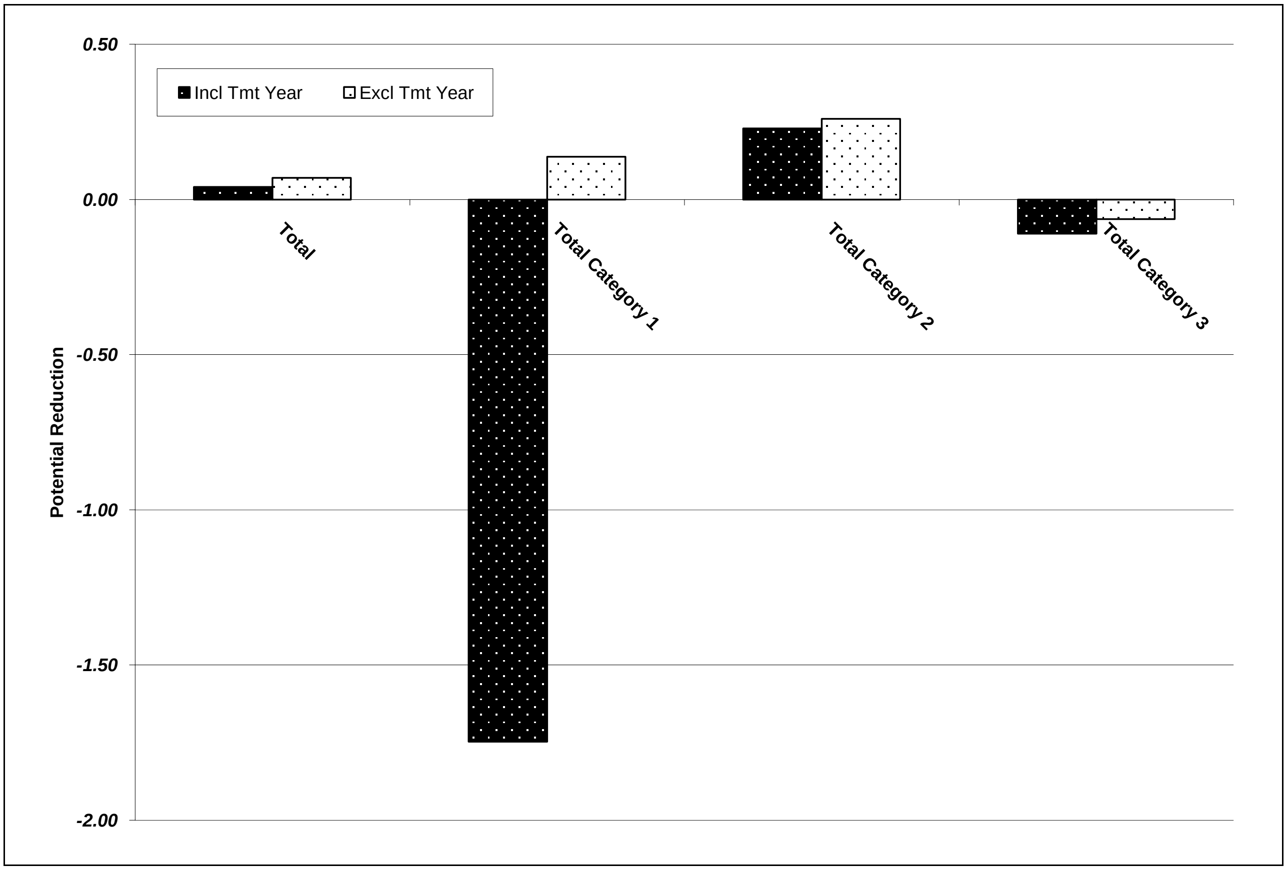


Figure 4.13: Total Condition for Resurfacing plotted for each data set

Regarding road surface conditions, only category 2 with AADT per lane between 3000 and 6999 for the wet study condition and the not dry condition produced statistically significant findings when the treatment year data was included for resurfacing. The potential crash reductions were high- 46 and 29 percent for wet and not dry, respectively (Table 4.23, Table 4.24, and Table 4.25). Due to the fact that there were no crashes in the before period for the category 1 with AADT per lane less than 3000 wet condition, a potential crash reduction factor could not be calculated as it is not mathematically possible to divide by zero.

Table 4.23: Dry Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Dry	0.06	0.17	No	169	421	590
Dry Category 1	-0.92	1.96	No	1	23	24
Dry Category 2	0.20	0.22	No	82	180	262
Dry Category 3	0.00	0.25	No	86	218	304

Table 4.24: Wet Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Wet	0.04	0.15	No	235	605	840
Wet Category 1	-	-	-	0	9	9
Wet Category 2	0.46	0.22	Yes	41	67	108
Wet Category 3	-0.35	0.81	No	12	44	56

Table 4.25: Not Dry Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Not Dry	0.06	0.17	No	169	421	590
Not Dry Category 1	-1.80	2.90	No	1	14	15
Not Dry Category 2	0.29	0.25	Yes	49	102	151
Not Dry Category 3	-0.60	0.84	No	16	68	84

Results for category 1 with AADT per lane less than 3000 and category 3 with AADT greater than or equal to 7000 were not statistically significant and produced crashed reduction values ranging from zero to -1.8 percent with large standard deviations when the treatment year data was included in the analysis (Figure 4.14).

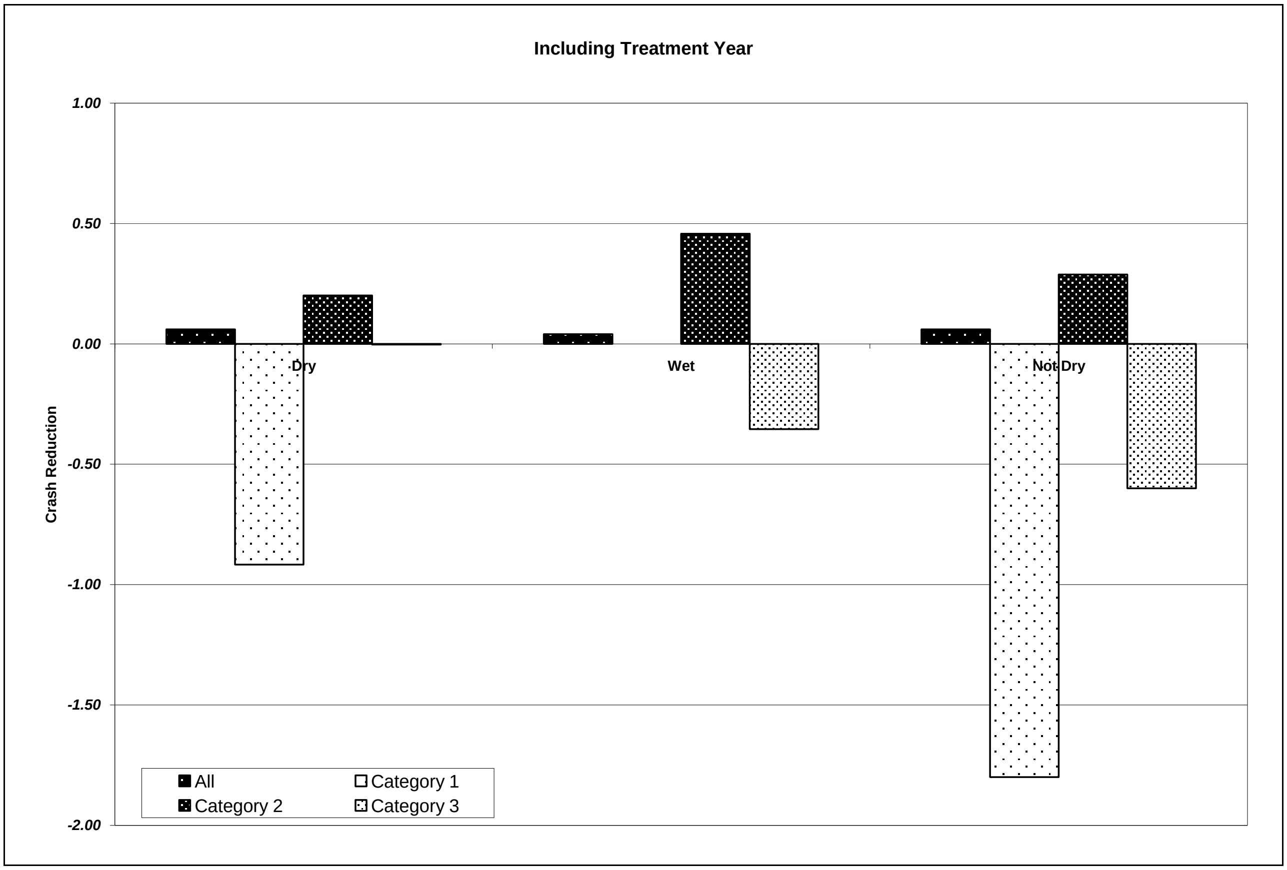


Figure 4.14: Potential Crash Reduction for Resurfacing under different Surface Conditions Including Treatment Year Data

Running the analysis again with the treatment year omitted produces similar results. As before, only the results for category 2 with AADT per lane between 3000 and 6999 for wet and not dry study conditions were statistically significant and it was not possible to get a reduction value for category 2 for the wet condition because there were no crashes in the before period (Table 4.26, Table 4.27, and Table 4.28).

Table 4.26: Dry Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Dry	0.10	0.17	No	169	323	492
Dry Category 1	-1.00	2.05	No	1	20	21
Dry Category 2	0.22	0.22	No	82	142	224
Dry Category 3	0.07	0.24	No	86	161	247

Table 4.27: Wet Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Wet	0.25	0.27	No	53	93	146
Wet Category 1	-	-	-	0	8	8
Wet Category 2	0.51	0.21	Yes	41	49	90
Wet Category 3	-0.38	0.85	No	12	36	48

Table 4.28: Not Dry Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Not Dry	0.07	0.15	No	235	470	705
Not Dry Category 1	-2.25	3.37	No	1	13	14
Not Dry Category 2	0.34	0.25	Yes	49	76	125
Not Dry Category 3	-0.71	0.91	No	16	58	74

The greatest potential crash reduction was 51 percent for the wet surface condition for category 2 with AADT per lane between 3000 and 6999. Although not statistically significant the high negative crash reduction factors for category 1 with AADT per lane less than 3000 graphically overshadow the positive category 2 results (Figure 4.15).

No statistically significant results were produced for any data set for the severe study condition analysis with and without the treatment year data. (Table 4.29 and Table 4.30).

Severity analysis did not produce conclusive results and when plotted does not illustrate any data trends (Figure 4.16). A small sample size (87 crashes or less) in each Category may be a contributing factor to the lack of statistically significant results.

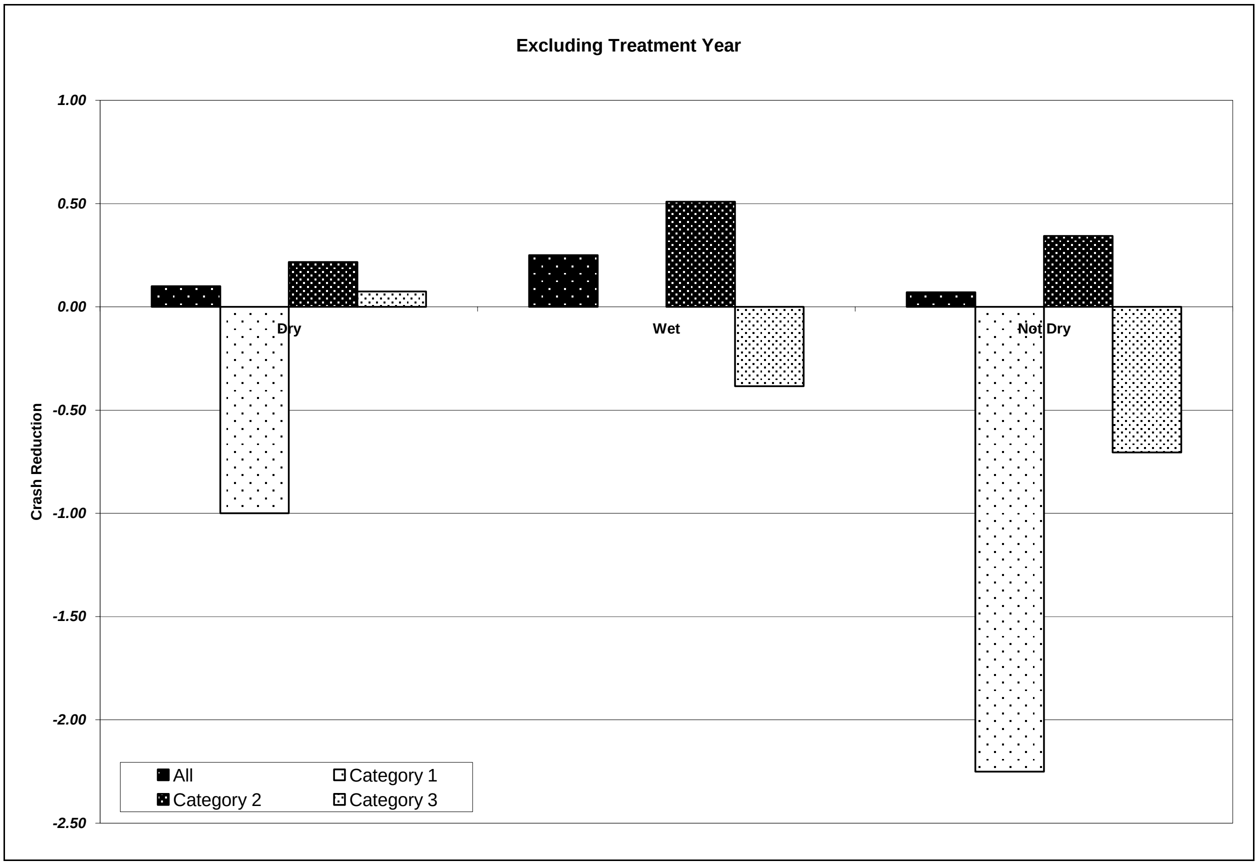


Figure 4.15: Potential Crash Reduction for Resurfacing under different Surface Conditions Excluding Treatment Year Data

Table 4.29: Severe Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Severe	0.22	0.26	No	53	120	173
Severe Category 1	-0.08	1.12	No	1	13	14
Severe Category 2	0.06	0.51	No	18	52	70
Severe Category 3	-0.01	0.46	No	24	63	87

Table 4.30: Severe Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Severe	0.10	0.17	No	169	323	492
Severe Category 1	-0.10	1.15	No	1	11	12
Severe Category 2	0.15	0.48	No	18	38	56
Severe Category 3	0.06	0.45	No	24	47	71

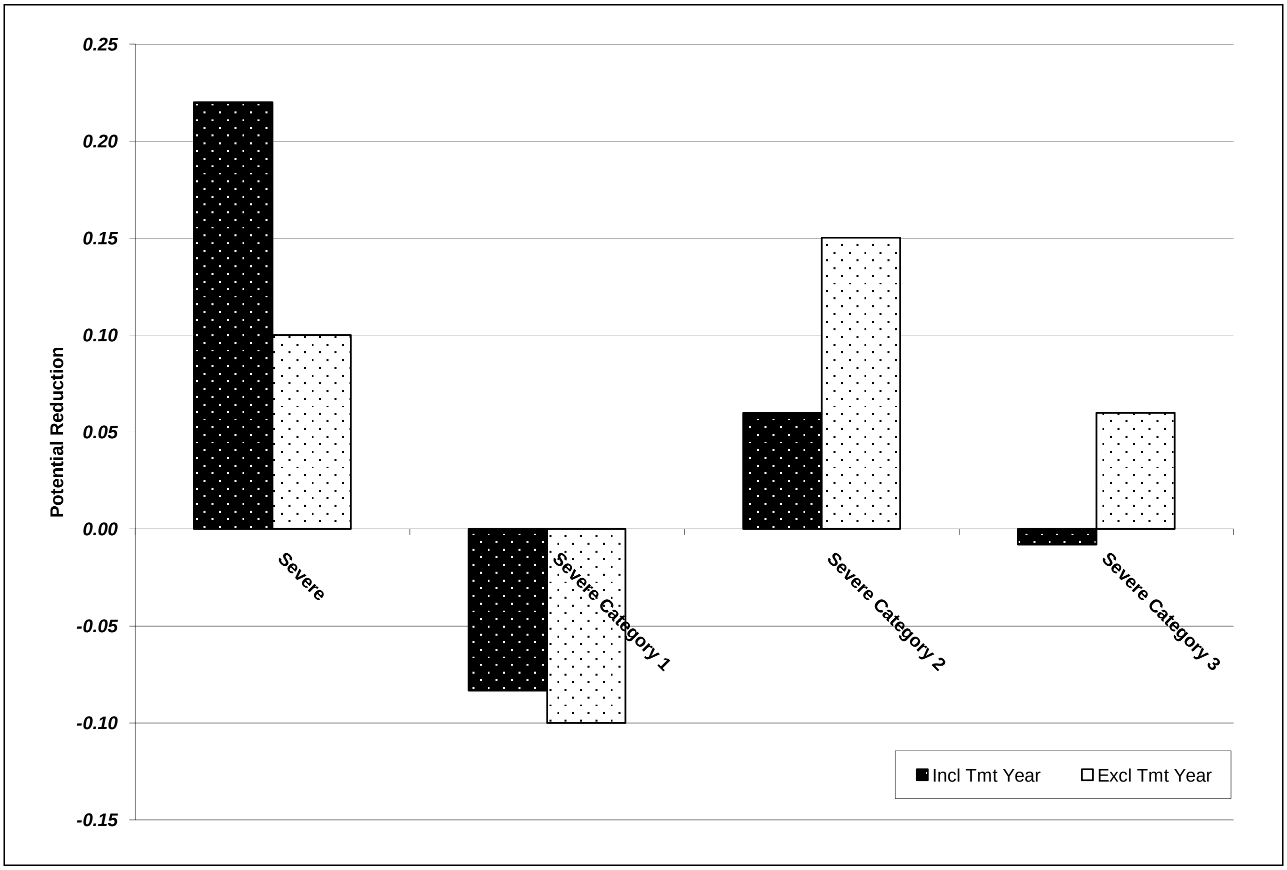


Figure 4.16 : Severe Study Condition for Resurfacing plotted for each data set

The analysis of intersection related crashes at resurfaced sites only provided statistically significant results for the category 2 with AADT per lane between 3000 and 6999 data set both with and without the treatment year data (Table 4.31 and Table 4.32).

Table 4.31: Intersection Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Intersection	0.01	0.29	No	66	184	250
Intersection Category 1	-0.86	1.85	No	2	25	27
Intersection Category 2	0.31	0.17	Yes	110	206	316
Intersection Category 3	0.02	0.25	No	87	216	303

Table 4.32: Intersection Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Intersection	0.25	0.27	No	53	93	146
Intersection Category 1	-0.97	1.98	No	2	22	24
Intersection Category 2	0.36	0.16	Yes	110	155	265
Intersection Category 3	0.06	0.25	No	87	165	252

The data in category 2 with AADT per lane between 3000 and 6999 produced high reduction factors of 31 and 36 percent both with and without treatment year data, respectively (Figure 4.17). Despite not being statistically significant, the Category 1 with AADT per lane less than 3000 analysis suggests that resurfacing could potentially increase intersection crashes at locations with low AADT's.

Lastly the analysis for rear end impact crashes followed a similar trend with intersection related crashes with respect to statistical significance; only Category 2 with AADT per lane between 3000 and 6999 produced results that were statistically significant (Table 4.33 and Table 4.34). The similarity is again logical because most rear end crashes are intersection related. Once again, due to the fact that there were no crashes in the before period for Category 1 with AADT per lane less than 3000 a potential crash reduction factor could not be calculated.

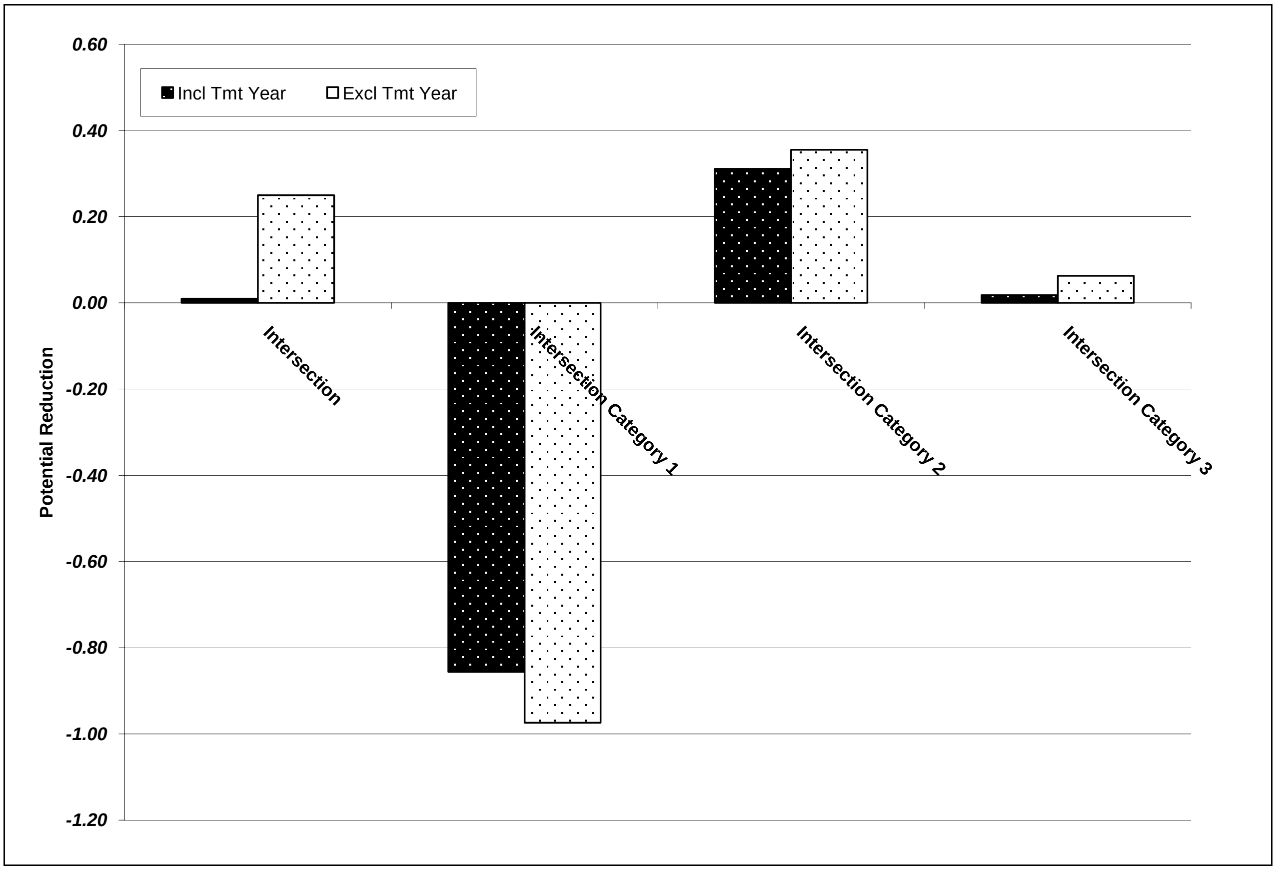


Figure 4.17 : Intersection Study Condition for Resurfacing plotted for each data set

Table 4.33: Rear End Study Condition for Resurfacing with Treatment Year Data Included

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Rear End	-0.01	0.26	No	87	245	332
Rear End Category 1	-	-	-	0	9	9
Rear End Category 2	0.27	0.26	Yes	49	107	156
Rear End Category 3	-0.32	0.48	No	38	129	167

Table 4.34: Rear End Study Condition for Resurfacing with Treatment Year Data Excluded

Study Condition	CR%	STDV	Statistically Significant	Crashes Before	Crashes After	Crashes Total
Rear End	-0.05	0.26	No	87	185	272
Rear End Category 1	-	-	-	0	7	7
Rear End Category 2	0.33	0.25	Yes	49	79	128
Rear End Category 3	-0.27	0.48	No	38	129	167

Category 3 with AADT per lane greater than or equal to 7000 produced negative crash reduction factors when analyzed for rear end crashes although the findings are not statistically significant (Figure 4.18). One explanation for the lack of statistical significance for the category 3 analysis is that despite reasonable sample sizes, all of the crashes occurred at a single location. If the resurfacing was poorly done, or there were other issues associated with the site, this could have heavy influence on the results.

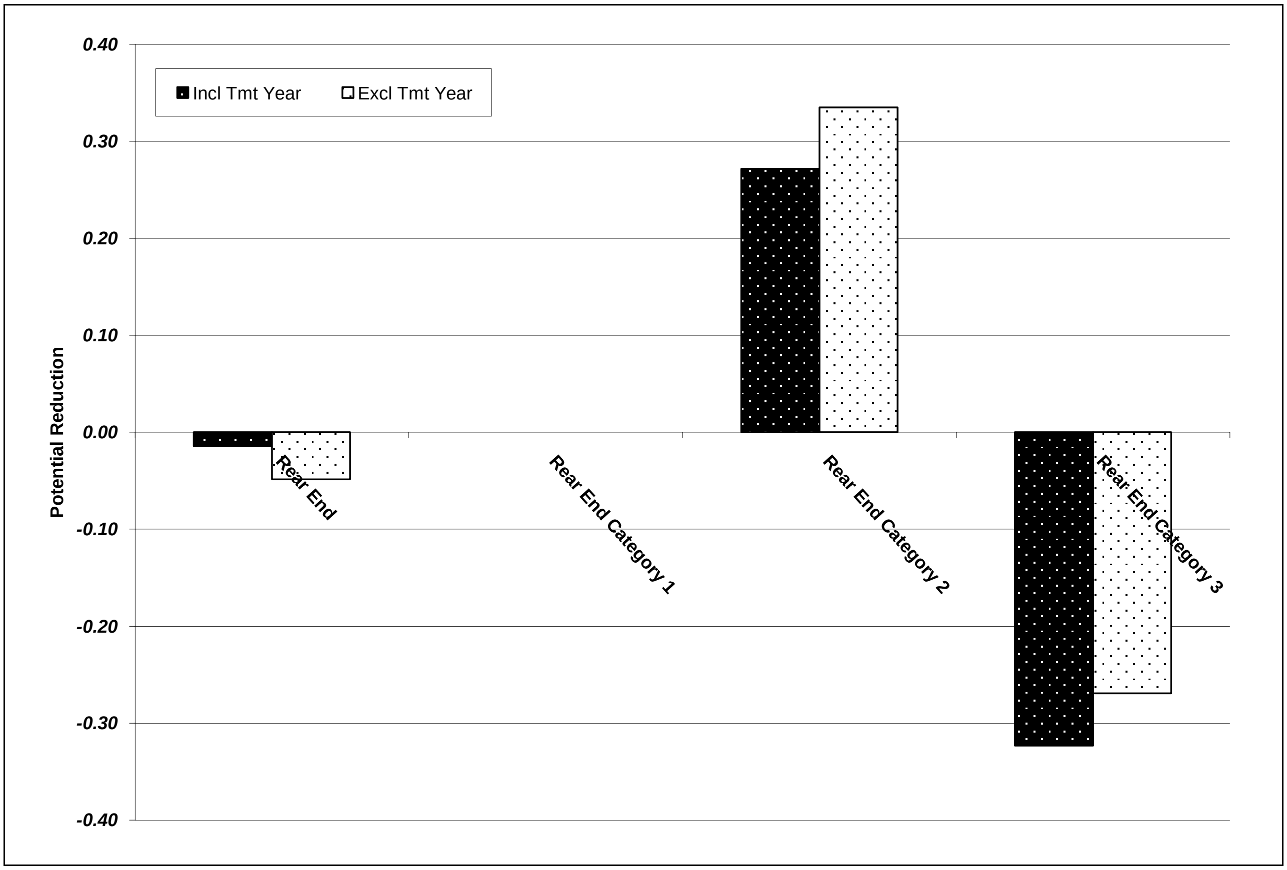


Figure 4.18 : Rear End Study Condition plotted for each data set

To get the big picture, it is important to separate and organize the data to highlight only the statistically significant findings. A tabular format makes it easy to compare microsurfacing and resurfacing results side by side; first with treatment year data included (Table 4.35) and then with treatment year data omitted (Table 4.36). At a quick glance, microsurfacing produced more applicable crash reduction factors and that number increased when treatment year data was omitted. This validates the hypothesis that treatment year is an anomaly and that omitting the data produces more statistically significant results.

Table 4.35: Summary of Crash Reduction Factors by Study Condition with Treatment Year Data

	Microsurfacing Statistically Significant Crash Reduction Factors			Resurfacing Statistically Significant Crash Reduction Factors		
	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)
Total	-	0.20	0.19	-	0.23	-
Dry	-	-	-	-	-	-
Wet	-	0.36	0.39	-	0.46	-
Not Dry	-	-	0.34	-	0.29	-
Severe	-	0.32	-	-	-	-
Intersection	-	0.25	0.24	-	0.31	-
Rear End	-	0.35	0.32	-	0.27	-

Table 4.36: Summary of Crash Reduction Factors by Study Condition without Treatment Year Data

	Microsurfacing Statistically Significant Crash Reduction Factors			Resurfacing Statistically Significant Crash Reduction Factors		
	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)
Total	-	0.37	0.26	-	0.26	-
Dry	0.36	0.38	0.16	-	-	-
Wet	-	0.54	0.46	-	0.51	-
Not Dry	-	0.37	0.42	-	0.34	-
Severe	-	0.43	0.26	-	-	-
Intersection	-	0.38	0.33	-	0.36	-
Rear End	-	0.50	0.41	-	0.33	-

The largest crash reduction factor was 54 percent for category 2 with AADT per lane between 3000 and 6999 in wet conditions and the smallest was for category 3 with AADT per lane greater than or equal to 7000 in dry road surface conditions, both for microsurfacing with treatment year data omitted.

Only one of the category 1 data sets with AADT per lane less than 3000 yielded a statistically significant result. For microsurfacing under dry road surface condition with treatment year data omitted the crash reduction factor is 36 percent. However the trend for both microsurfacing and resurfacing indicates that perhaps these treatments are not as effective at improving safety at locations with AADT per lane values less than 3000 veh/lane. It is noted that category 1 typically had the smallest sample size compared to categories 2 and 3, so further analysis may be necessary.

Crash reduction factors were produced for all the study conditions for microsurfacing using category 2 and 3 data with treatment year data omitted. This indicates that the treatment is most effective for locations with higher AADT values. In all but the not dry study condition, category 2 analysis resulted in crash reduction factors greater than category 3.

The same did not hold true for resurfacing where only category 2 with AADT per lane between 3000 and 6999 produced statistically significant crash reduction factors. One explanation is the fact that the category 3 data set with AADT per lane greater than or equal to 7000 provides reasonable sample sizes but all of the crashes for this category occurred at a single location. If the resurfacing was poorly done, or there were geometric or safety deficiencies associated with the site, this could have heavy influence on the results. Further analysis is required to conclude that resurfacing only has a safety effect where the AADT/lane is between 3000 and 6999 veh/lane.

In general, microsurfacing has been demonstrated to have a positive safety effect on locations with higher traffic volumes that are susceptible to any one or a combination of the following conditions:

- A regular occurrence of wet or slick (not dry) road surface conditions
- A trend in severe crashes
- Frequent intersection related crashes
- A high occurrence of rear end crashes.

5.0 APPLIED RESULTS

Research and analysis are valuable in understanding trends in data; however being able to apply the findings to assist engineers in their decision making process is invaluable. Road engineers faced with the task of assessing which sections receive maintenance treatments or rehabilitation often rely on past experience or engineering judgment because they do not have adequate decision making tools. Often because the data needed to develop the tools is not collected or it is not in a format that easily lends itself to further analysis. Furthermore safety data is not often used to make these types of decisions, rather they are made on a scheduling basis based on age or condition of the pavement itself.

If safety is used to prioritize maintenance locations, it is likely done based on what are considered black spots, which are locations with high accident occurrences, and little or no statistical analysis is carried out. Sites that have the most crashes are considered high priority, but may have a very high AADT and the true crash rate may actually not be disproportionate. From the literature review it is known that this method often neglects sites that are in need of attention and does not give consideration to severity of crashes.

Therefore it is necessary to step back and consider how this new found knowledge can be helpful to engineers and fulfill the needs of the driving public. There are two levels of decision making: network level and project level. The network level involves prioritizing treatment locations based on a specified budget; the goal is to improve the maximum number of sites within a defined monetary limit. The project level involves determining the most appropriate type of treatment for a location that has been identified at the network level. Good communication and cooperation between the two levels will result in a strong pavement and safety management system.

The following sections provide sample tools that could be adapted and used by road engineers to manage their pavement infrastructure. Some tweaking may be necessary if future analysis changes the statistical significance of the results. This is most likely to be the case with resurfaced sites that have an AADT/lane greater than 7000 veh/lane.

5.1 Network Level

At the network level, most decisions come down to budget. Therefore, it makes sense to prioritize treatment decisions based on a combined life-cycle cost and cost effectiveness analysis.

One method of attaining a life-cycle cost estimate is to bring the costs to date and anticipated in the future to the present worth of cost (PWC).

The PWC throughout the industry is calculated as follows.

$$\text{PWC} = \text{ICC} + \sum^{n} \frac{1}{(1+i)^n} * \text{Future Cost (n)}$$ **(Equation 5.1)**

where

i= discount rate

n = year

ICC = initial construction cost

Future Cost = maintenance costs plus rehabilitation costs

Based on knowledge gained in practice and through the literature review, it is understood that safety is a factor that should be considered when prioritizing locations to receive treatment. To account for this fact and to illustrate how the reduction factors developed in this study can be applied, Equation 6.1 has been modified as follows.

$$\text{PWC} = \text{ICC} + \sum^{n} \frac{1}{(1+i)^n} * \text{Future Cost (n)} - \sum_{n}^{n+tl} \frac{1}{(1+i)^{n+tl}} * \text{Safety Savings (n+ tl)}$$ **(Equation 5.2)**

where

tl = estimated treatment life in years

Safety Savings = potential monetary savings to the public as a result of treatment

where

Safety Savings = CRF * avg. no. crashes/year* avg. cost of crash * tl **(Equation 5.3)**

CRF = average crash reduction factor for treatment

It seems logical that since tax payers’ money is what funds road improvements, other public savings should be included in the decision making process. Vehicular crashes have a ripple effect on our public resources, aside from the invaluable loss of life; they impact our police enforcement, strain our healthcare system, and tie up our court system. In 2003 Transport Canada estimated that vehicle crashes have a cost to society of approximately $26 million each day which works out to approximately $14,400 per crash [TC 03]. The effect of improving road safety is far reaching and federal, provincial, and local officials should not minimize its role in road engineering. Instead they should be embracing it as a platform on which to build public support to improve our road infrastructure.

For example, a 12 year old, 4 lane, 0.5 km section of road under consideration for a microsurfacing treatment has an ICC of $100,000. The AADT is 16,800 and the history of the site produces and average of 17 annual crashes. Based on engineering practice in Ontario, a six percent discount rate, a cost for microsurfacing of \$8,438/lane/km, and average cost of \$14,400 per crash is assumed. The estimated service life for a microsurfacing treatment is 7 years.

The first step is to determine the PWC of the microsurfacing treatment.

Future Cost = $[1/(1+0.06)^{12}] * (8,438 * 4 * 0.5)$ = \$8386.86

The next step is to establish the Category classification and determine the appropriate CRF from Table 4.36.

16,800/4 = 4200 veh/lane which is Category 2 with AADT per lane between 3000 and 6999

From Table 4.36 the CRF is 0.37 and the Safety Savings can be calculated.

Safety Savings = $[1/(1+0.06)^{12+7}]\ 0.37 * 17 * 14,400 * 7$ = \$4763.78

Therefore the PWC is

PWC = 100,000 + 8386.86 - 4763.78 = \$103,623.10

The societal cost of the treatment is \$8386.86 - \$4763.78 = \$3,623.10; however, for budgeting purposes it is the treatment cost alone that must fall within a regions funding limits. At this stage decision makers may opt to compare the PWC values to maximize the number of treatments within a given budget or may chose to calculate and compare the cost effectiveness (CE).

CE = Effectiveness/PWC **(Equation 5.4)**

where

Effectiveness =

$$= \left\{ \sum_{\mathrm{Re}\,habYear}^{PQI_R \geq PQI_M} (PQI_R - PQI_M) - \left(\sum_{PQI_N \geq PQI_M}^{\mathrm{Re}\,habYear} (PQI_M - PQI_N) \right) \right\} * AADT * \text{Length of Section}$$

(Equation 5.5)

PWC = present worth of cost from Equation 5.2

PQI_R = pavement quality index (PQI) after rehabilitation (i.e., for the implementation year) and for each year until PQI_M is reached

PQI_M = minimum acceptable level of PQI

PQI_N = yearly PQI from the needs year to the implementation year

AADT = annual average daily traffic

Length of section = pavement length or road length in km

The CE calculation itself does not possess any physical meaning, but it can be used as a means to compare potential treatment sites. Engineers may develop their own crash reduction factors and average accident cost if they have the data available.

Another thing to consider is that contractors may negotiate better treatment prices for larger jobs. Microsurfacing was demonstrated to be very effective at reducing intersection related crashes and it would be advantageous when prioritizing treatment sites to group intersection locations and tendered out the microsurfacing work as single job. This type of foresight in the planning process can help agencies stretch their budgets farther while making the roads safer.

5.2 Project Level

Once sites have been identified at the network level, they must be verified for treatment type at the project level. This more detailed analysis is best done by an engineer that is familiar with the condition of the road network and can provide sound engineering judgment.

To facilitate this process, a concept decision model was developed to establish if microsurfacing or resurfacing is the most viable treatment based on the findings of this study and the literature review (Figure 5.1). The model guides the user through a number of questions that lead them to one of three results:

- Treat with microsurfacing
- Treat with resurfacing
- Seek another treatment option

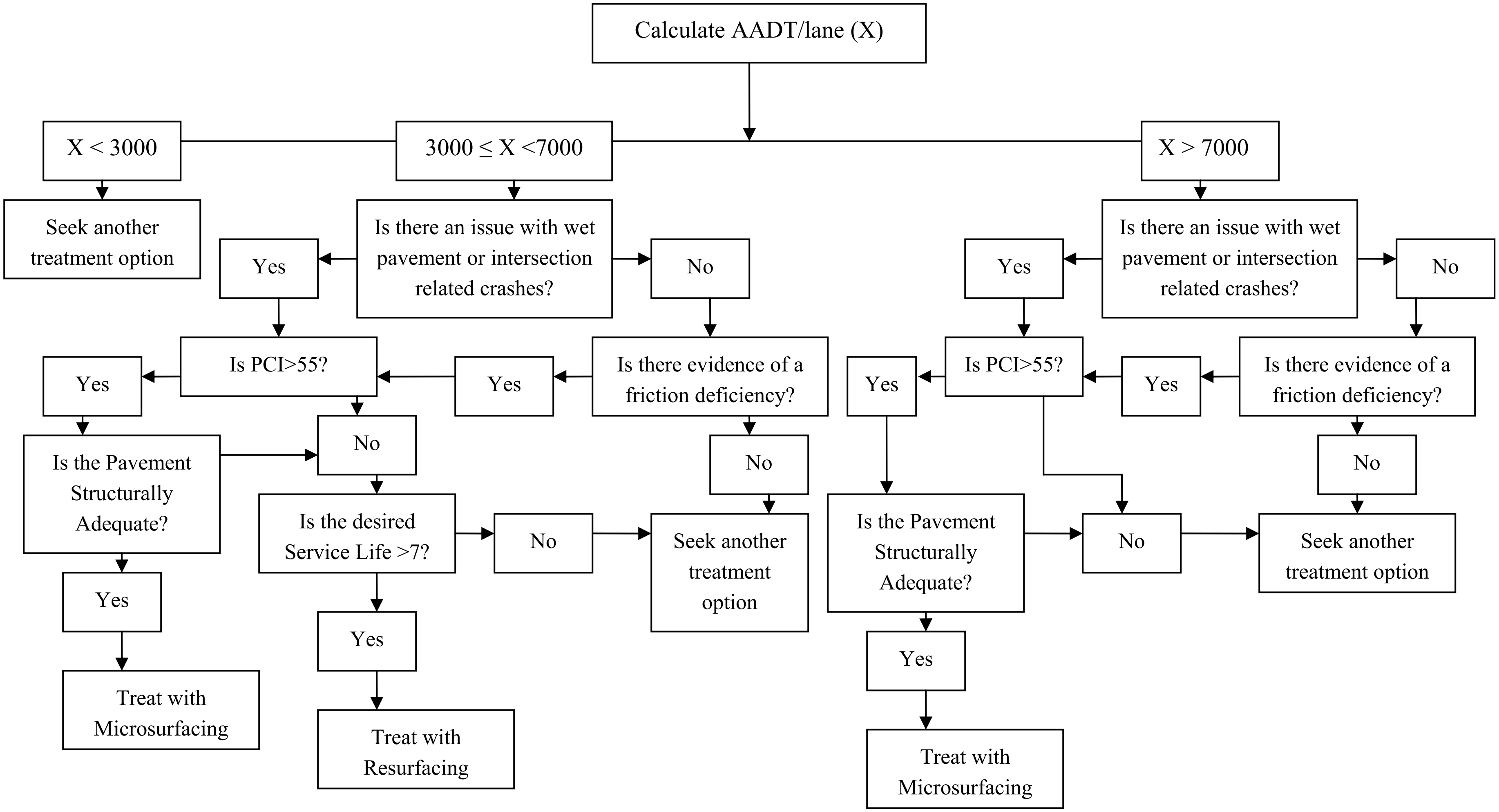


Figure 5.1 : Program level decision making model for microsurfacing and resurfacing

The model inputs include AADT per lane, evidence of wet pavement or intersection related crashes, pavement condition index (PCI), evidence of friction deficiency, structural adequacy of pavement, and the desired service life of the treatment.

For example, a site with an AADT per lane of 5,000 veh/lane has been short listed at the network level for treatment. The site has a PCI of 50 that has been declining for the last two years while there has been a rise in wet pavement crashes. The location has been passed over for treatment several times and needs to be brought back up to an acceptable level.

Applying the decision model through the centre path based on AADT/lane:

1. Is there evidence of wet pavement or intersection crashes: Yes
2. Is the PCI > 55: No
3. Is the desired service life>7: Yes (based on neglect a longer service life would be beneficial)
4. Outcome: Treat with Resurfacing

Therefore a resurfacing treatment is recommended.

As this is just a concept there is a great deal of potential for improvement with the provision of actual friction data and additional studies on surface treatments. Ultimately, there are practical and valuable opportunities created when road data and safety data are used together in a management system.

6.0 CONCLUSIONS

Many transportation agencies have been working towards the development of pavement preventative maintenance programs to ensure long-term pavement preservation; however none have considered the safety effects of the treatments they implement. Microsurfacing is a maintenance treatment that was introduced in Canada during the 1990's and quickly became popular because of its durability and quick curing time; however it has an expensive price tag.

Road related fatalities account for 90 percent of transportation related deaths in Canada despite safety measures such as stronger safety laws and public awareness campaigns. There is a need for engineers to think outside of the box and look at other ways to improve road safety. Given the high costs to society of crashes it only seems logical that safety should be a part of preventative maintenance decision making process.

From the literature review, it is apparent that there is a relationship between surface friction and road safety, but very few agencies collect skid data or monitor the safety effects of their surfacing treatments. York Region is a good example of an agency that applies surface treatments, such as microsurfacing, to improve the surface properties of the pavement but is unaware if the treatment is having a positive safety effect. Using the Region of York as a case study and performing a before-after analysis, the five objectives outlined in section 1.3 were attained.

First and foremost responding to the request of the Region of York, it was determined that microsurfacing has a positive safety effect when applied at locations with an Average Annual Daily Traffic (AADT) per land greater than 3000 veh/lane. This relationship was confirmed through data analysis to be statistically significant and sensitive to the treatment year data. Table 6.1 provides a list of statistically significant crash reduction factors that resulted from the study, excluding treatment year data.

Table 6.1: Summary of Microsurfacing Crash Reduction Factors by Study Condition without Treatment Year Data

	Microsurfacing Statistically Significant Crash Reduction Factors		
	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)
Total	-	0.37	0.26
Dry	0.36	0.38	0.16
Wet	-	0.54	0.46
Not Dry	-	0.37	0.42
Severe	-	0.43	0.26
Intersection	-	0.38	0.33
Rear End	-	0.50	0.41

The results were not as strong for resurfacing, although analysis revealed that resurfacing has a statistically significant safety effect where AADT per lane falls between 3000 and 6999 veh/lane. However, the results were often inconsistent possibly as a result of a difference in asphalt mixture or small sample size. Table 6.2 lists the handful of resurfacing crash reduction factors that were determined to be statistically significant.

Table 6.2: Summary of Resurfacing Crash Reduction Factors by Study Condition without Treatment Year Data

	Resurfacing Statistically Significant Crash Reduction Factors		
	Category 1 (AADT/lane 0-2999)	Category 2 (AADT/lane 3000-6999)	Category 3 (AADT/lane 7000+)
Total	-	0.26	-
Dry	-	-	-
Wet	-	0.51	-
Not Dry	-	0.34	-
Severe	-	-	-
Intersection	-	0.36	-
Rear End	-	0.33	-

Too many jurisdictions do not maintain a comprehensive safety database and rarely is that database able to link via a location I.D. or other attribute to a road construction database. Often the data are incommunicable as they exist in separate departments within an agency. York Region is among industry leaders in Canada when it comes to pavement management and road safety, given their extensive data management system, and yet they, like many other engineering agencies, have not recognized the potential benefits of integrating pavement management and safety management. If the data is being collected it is invaluable to take the time to ensure consistency in format and have linkable attributes between databases. Good data are hard to come by, however this research has illustrated that if agencies have a linkable data management system, it opens up the potential for research and the findings can be shared and applied between jurisdictions with similar characteristics.

The engineering code of ethics requires practicing engineers to hold public safety paramount. Agencies maintain their pavement infrastructure not only to uphold the condition of the asset but also to ensure our roads are safe to drive on. There is safety built into design guidelines so it is perplexing that safety is omitted from maintenance decisions. Safety has a role in preventative pavement maintenance because crashes, especially those considered severe, have a significant economic impact on all of society. The selection of a maintenance treatment should be one that is optimal when consideration is given to both structural preservation and driver safety. The Region of York had the foresight to make a connection between safety and pavement management and should continue to build on their success. Crash reduction factors are very useful at assisting engineers to forecast lives saved, which translates to dollars saved to society. They can be a big asset to municipal directors when they are seeking approval from government officials to increase their maintenance budget.

Research and analysis are valuable in understanding trends in data; however being able to apply the findings to assist engineers in their decision making process is invaluable. Road engineers faced with the task of assessing which sections receive maintenance treatments or rehabilitation often rely on past experience or engineering judgment because they do not have adequate decision making tools. The findings of this study are used herein to illustrate how decision making tools can be developed for both the network and project level. At the network level, potential safety savings can be integrated into a life cycle cost analysis, and at the project level, a decision flow chart can guide users to a recommended treatment. These concept decision making frameworks can be adopted by other jurisdictions with similar characteristics.

To conclude, the integration of safety under the pavement umbrella seems highly logical and yet has barely been explored. There is much potential for further research in the area of safety within a pavement management framework and the resulting studies will have a tremendous benefit to society.

7.0 RECOMMENDATIONS

It is believed that this study has only scratched the surface of that which can result from incorporating safety into a preventative maintenance program. The following recommendations are based on the findings of this study and fall into one of three categories: Data, Analysis, or Application.

7.1 Data

For this study it was vital to have access to real data that was of sound quality and organization. With this in mind, it is recommended that the following additional data be collected for use in future studies:

- Functional class of the roadway
- A more precise indication of when the treatment took place
- A larger sample size of data for category 1 with AADT per lane less than 3000 and category 3 with AADT greater than or equal to 7000, especially for further resurfacing analysis
- Friction or skid numbers

It is further recommended that both safety and road data be housed in one database that is accessible by all associated departments. Additionally, the police and collision reporting centre staff need to be reminded that the information they collect on crashes is very valuable and has an impact beyond the primary crash. For this reason, data managers need to maintain strict control over the data and how it is processed for use by the different municipalities. If these data are not accurate, it can be very damaging to the integrity of the research and could potential deem the findings useless.

7.2 Analysis

As discussed in section 3.3, due to data limitations there were analysis restrictions. A simple before-after study was conducted in lieu of preferred alternatives. It is recommended that further analysis be conducted using one of the following approaches.

- Before-after study with comparison group: it is expected that the crash reduction factors will likely be smaller but more accurate because using a comparison group can improve prediction by accounting for factors that are not recognized as affecting safety, that are recognized but not measured, or whose influence on safety is not understood.
- Empirical Bayes methodology: This method adjusts for the regression-to-the-mean bias and would result in a safety performance function that would include all of the statistically significant inputs that influence the safety of a maintenance treatment.

It is recommended that further analysis be conducted:

- On different maintenance treatments to see which ones have the greatest effect on safety and if similar trends can be seen
- To establish if there is a correlation between roughness and safety to determine if there is an alternative measure to use as an indicator when evaluating maintenance treatments
- On time sensitivity, to determine how long a microsurfacing treatment maintains its safety effectiveness and establish trigger values that indicate when to implement a treatment

7.3 Application

The application of the results presented earlier fulfilled the scope of the study. However, with more time and resources the applied decision making tools could be expanded as recommended below:

- Incorporate environmental costs into the life cycle cost analysis at the network level: Global warming is of great concern for this generation and studies are being conducted to evaluate how different maintenance treatments measure up in terms of emissions released into the atmosphere.
- Incorporate user delay costs into the life cycle cost analysis at the network level: Time is money and both truck and commuter drivers are becoming less tolerant of construction delays.
- Take the results a step further and incorporate them into a priority programming software: Such a software should dictate the data inputs required and work hand in hand with both the pavement and safety management databases.

It is further recommended that consideration be given to planning ahead and grouping maintenance treatments such as microsurfacing at multiple intersections throughout a region as a single project for the tendering process. This should result in a better overall price, as there are discounts in quantity and benefits in terms of contractor consistency for the treatment within the municipality.

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Appendix A: Sample of Accident Report Template

r 1

Template
with
report

Accident Location

On Highway
01-Non intersection
02-Intersection related
03-At intersection
04-At/near private drive
05-At railway crossing
06-Underpass or tunnel
07-Overpass or bridge
98-Other

Off Highway
08-Trail
09-Frozen lake or river
10-Parking lot
99-Other

1

Impact Location

01-Within intersection
02-Thru lane
03-Left turn lane
04-Right turn lane
05-Right turn channel
06-Two-way left turn lane
07-Passing lane
08-Left shoulder
09-Right shoulder
10-Not on roadway-left side
11-Not on roadway-right side
12-Off highway
99-Other

2

3 If 02 used above, enter Thru Lane No.

Environment Condition Multiple Choices Allowed

01-Clear
02-Rain
03-Snow
04-Freezing rain
05-Drifting snow
06-Strong wind
07-Fog, mist, smoke, dust
99-Other

4
5

Light

01-Daylight
02-Daylight, artificial
03-Dawn
04-Dawn, artificial
05-Dusk
06-Dusk, artificial
07-Dark
08-Dark, artificial
99-Other

6

Traffic Control

01-Traffic signal
02-Stop sign
03-Yield sign
04-Ped. crossover
05-Police control
06-School guard
07-School bus
08-Traffic gate
09-Traffic controller
10-No control
99-Other

7

Traffic Control Condition

01-Functioning
02-Not functioning
03-Obscured
04-Missing/Damaged

8

Road Character

01-Undivided – one-way
02-Undivided – two-way
03-Divided with restraining barrier
04-Divided - no barrier
05-Ramp
06-Collector lane
07-Express lane
08-Transfer lane

9 R1
10 R2

Road Surface

01-Asphalt
02-Oil treated gravel
03-Gravel or crushed stone
04-Concrete
05-Earth
06-Wood
07-Steel
08-Brick/interlocking stone
99-Other

11 R1
12 R2

Road Condition

01-Good
02-Poor
03-Under repair or construction

13 R1
14 R2

Road Surface Condition

01-Dry
02-Wet
03-Loose snow
04-Slush
05-Packed snow
06-Ice
07-Mud
08-Loose sand or gravel
09-Spilled liquid
99-Other

15 R1
16 R2

Road Alignment

01-Straight on level
02-Straight on hill
03-Curve on level
04-Curve on hill

17 R1
18 R2

Road Pavement Markings

01-Exist
02-Non - existent
03-Obscured
04-Faded

19 R1
20 R2

Vehicle Type

01-Automobile, station wagon
02-Motorcycle
03-Moped
04-Passenger van
05-Pick-up truck
06-Delivery van
07-Tow truck
08-Truck - open
09-Truck - closed
10-Truck - tank
11-Truck - dump
12-Truck - car carrier
13-Truck - tractor
14-Municipal transit bus
15-Intercity bus
16-Bus (other)
17-School bus
18-School van
19-Other school vehicle/bus
20-Motor home
21-Off-road 2 wheels
22-Off-road 3 wheels
23-Off-road 4 wheels
24-Off-road – other
25-Motorized snow vehicle
26-Farm tractor
27-Other farm vehicle
28-Construction equipment
29-Railway train
30-Street car
31-Snow plow
32-Ambulance
33-Fire vehicle
34-Police vehicle
35-Other emergency vehicle
36-Bicycle
00-Unknown
98-Truck-other
99-Other

21 V1
22 V2

23 V1
24 V2 Enter code 01 here if code 32, 33, 34, or 35 used above, and vehicle light/siren activated

Towed Vehicle

01-Recreation trailer or semi-trailer — house, tent
02-Boat trailer
03-Small utility trailer
04-Wheeled device or apparatus
05-Large full trailer
06-Large semi-trailer
07-Double (semi-trailer – semi-trailer)
08-Double (semi-trailer- trailer)
09-Farm equipment
10-Towed motor vehicle
99-Other

25 V1
26 V2

Trailer Type - Single and Double Combination over 4600 kg. (codes 05,06,07,08 above)

01-Van
02-Flat bed/flat bed with racks
03-Low-bed/float
04-Tank
05-Dump
06-Car carrier
07-Livestock
99-Other

27 V1
28 V2

Trailer Connection -Double Semi-Trailers Only

01-single drawbar dolly (A Train)
02-5th wheel connection only (B Train)
03-double drawbar dolly (C Train)
99-Other

29 V1
30 V2

31 V1
32 V2 **Vehicle Condition** 01-No apparent defect 99-Defect

Apparent Driver Action

01-Driving properly
02-Following too close
03-Exceeding speed limit
07-Disobeyed traffic control
08-Failed to yield right-of-way
09-Improper passing
10-Lost control

Ver 1

Road Jurisdiction

01-Municipal (excl. Twp.Rd.)
02-Provincial highway
03-Township
04-County or district
05-Regional municipality
06-Private property
07-Federal
99-Other

41

Classification of Accident

01-Fatal injury
02-Non-fatal injury
03-P.D. only
04-Non-reportable
99-Other

42

Initial Direction of Travel

01-North
02-South
03-East
04-West

V1 43
V2 44

Initial Impact Type

01-Approaching
02-Angle
03-Rear end
04-Sideswipe
05-Turning movement
06-SMV unattended vehicle
07-SMV other
99-Other

45

Vehicle Manoeuver

01-Going ahead
02-Slowing or stopping
03-Overtaking
04-Turning left
05-Turning right
06-Making "U" turn
07-Changing lanes
08-Merging
09-Reversing
10-Stopped
11-Parked
12-Disabled
13-Pulling away from shoulder or curb
14-Pulling onto shoulder or toward curb
00-Unknown
99-Other

V1 46
V2 47

Sequence of Events Multiple Choices Allowed

Moveable Objects
01-Other motor vehicle
02-Unattended vehicle
03-Pedestrian
04-Cyclist
05-Railway train
06-Street car
07-Farm tractor
08-Animal — domestic
09-Animal — wild
97-Other

Other Events
20-Ran off road
21-Skidding/sliding
22-Jackknifing
23-Load spill
24-Fire/explosion
25-Submersion
26-Rollover
27-Debris on road
28-Debris falling off vehicle
98-Other

Fixed Objects
50-Cable guide rail
51-Concrete guide rail
52-Steel guide rail
53-Pole (utility, tower)
54-Pole (sign, parking meter)
55-Fence/noise barrier
56-Culvert
57-Bridge support
58-Rock face
59-Snowbank/drift
60-Ditch
61-Curb
62-Crash cush/end treat.
63-Building or wall
64-Water course
65-Construction marker
66-Tree, shrub, stump
99-Other

Fixed Object Offset

Left of Roadway	Right of Roadway
01- Less than 3.1m	05- Less than 3.1m
02- 3.1m to 6.0m	06- 3.1m to 6.0m
03- 6.1m to 9.0m	07- 6.1m to 9.0m
04- Greater than 9.0m	08- Greater than 9.0m

V1
1st 48
Offset 49
2nd 50
Offset 51
3rd 52
Offset 53

V2
1st 54
Offset 55
2nd 56
Offset 57
3rd 58
Offset 59

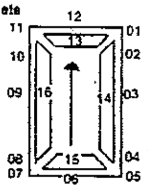
Vehicle Damage

01-None
02-Light
03-Moderate
04-Severe
05-Demolished

V1 60
V2 61

Location of Vehicle Damage or Area of Impact Multiple Choices Allowed

01-Right front corner
02-Right front
03-Right centre
04-Right rear
05-Right rear corner
06-Back centre
07-Left rear corner
08-Left rear
09-Left centre
10-Left front
11-Left front corner
12-Front centre
13-Front complete
14-Right side complete
15-Back complete
16-Left side complete
17-Top
18-Undercarriage
19-No contact
00-Unknown



V1 Initial impact 62
Secondary impact 63
V2 Initial impact 64
Secondary impact 65

Special Studies

66
67
68

Injury and Fatal Accident (Only) — All Involved Persons

Determination of Use
1 Involved driver/pass.
2 Investigating Officer
3 Witness

Safety Equipment Used

1 Lap and shoulder belt
2 Lap belt only
3 Lap belt only of combined assembly
8 Helmet
9 Equipment not used but

41		
42		
43	0	
44	0	
45		
46		
47		
48		
49	0	
50		
51	0	
52		
53	0	
54		
55	0	
56		
57	0	
58		
59	0	
60	0	
61	0	
62		
63		
64		
65		
66		
67		
68		

Appendix B: Microsurfacing Analysis

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	74	2001	9	12	15	10	10	10	8	0	21	53
10	2	6610	8950	10150	12180	11790		9611	9882	4941	10	2001	3	2	1	1	3	0	0	0	5	5
11	2	5590	5630	5220	3410	5090			4988	2494	9	2001	0	1	3	4	1	0	0	0	1	8
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	0	2001	0	0	0	0	0	0	0	0	0	0
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	90	2001	17	10	26	9	8	8	12	0	27	63
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001	0	0	0	0	0	0	0	0	0	0
*15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2002	0	0	0	0	0	0	0	0	0	0
16	2	9560	8590c	7240	10000	8960			8940	4470	33	2001	3	6	2	3	7	6	6	0	9	24
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	135	2001	17	20	22	25	20	21	10	0	37	98
25	4	27440	21870	24930	26570	25290	22422		24754	6188	41	2002	8	8	5	6	5	6	3	0	16	25
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0	0	0	0	0	0	0	0
27	2	9560	10180	10660	10580	10300		11633	10486	5243	46	2002	7	6	5	11	7	7	3	0	18	28
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	40	2002	5	9	3	8	7	8	0	0	17	23
29	4	29270	30000	30500		26240		27699	28742	7185	54	2002	11	8	8	9	8	7	3	0	27	27
30	6	42500	41560	40060	47110	48080	44172		43914	7319	352	2002	56	59	72	49	57	44	15	0	187	165
31	4	21995	23615	28780	22820	22550	22880		23773	5943	73	2004	14	13	19	11	9	6	1	0	66	7
32	2	n/a	5840	5950	6620	5940			6088	3044	28	2004	5	3	4	3	4	7	2	0	19	9
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	66	2004	12	12	10	14	5	9	4	0	53	13
34	4	27610	31760	35800	36440	38400	30841		33475	8369	64	2004	7	10	13	13	7	13	1	0	50	14
35	4	41160	38500	39320	38990	38660			39326	9832	34	2004	2	5	3	3	6	10	5	0	19	15
36	6	26190	31380	34200	36000	35000	32816		32598	5433	125	2004	18	20	21	18	25	19	4	0	102	23
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0	0	0	0	0	0
38	2	12670	8580	8580	6430	8390	7761		8735	4368	4	2004	0	0	0	0	2	1	1	0	2	2
40	2	9520	10480	8630	9730	10680	8623		9611	4805	12	2004	0	0	0	2	1	9	0	0	3	9
41	2	1940	3460	3620	3790	3360	2420		3098	1549	5	2003	1	0	0	2	0	0	2	0	3	2
42	4	28040	34440	31780	42640	39640	42853		36566	9141	104	2003	9	23	20	15	14	14	9	0	67	37
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	48	2003	3	10	4	12	8	11	0	0	29	19
48	2	16670	16630	15360	19110	16170		15978	16653	8327	26	2003	0	4	6	4	2	8	2	0	14	12

* Since project 14 is also on Keele St. the same AADT values were appliec

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	21	53	2.5	52.5	131.25
2	5	5	5	2.5	12.5	31.25
2	5	1	8	2.5	2.5	6.25
2	5	0	0	2.5	0	0
2	5	27	63	2.5	67.5	168.75
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	9	24	2.5	22.5	56.25
2	5	37	98	2.5	92.5	231.25
2	5	16	25	2.5	40	100
3	4	0	0	1.333333	0	0
3	4	18	28	1.333333	24	32
3	4	17	23	1.333333	22.66667	30.22222
3	4	27	27	1.333333	36	48
3	4	187	165	1.333333	249.3333	332.4444
5	2	66	7	0.4	26.4	10.56
5	2	19	9	0.4	7.6	3.04
5	2	53	13	0.4	21.2	8.48
5	2	50	14	0.4	20	8
5	2	19	15	0.4	7.6	3.04
5	2	102	23	0.4	40.8	16.32
5	2	0	0	0.4	0	0
5	2	2	2	0.4	0.8	0.32
5	2	3	9	0.4	1.2	0.48
4	3	3	2	0.75	2.25	1.6875
4	3	67	37	0.75	50.25	37.6875
4	3	29	19	0.75	21.75	16.3125
4	3	14	12	0.75	10.5	7.875
		$\Sigma L_{a(j)}=$	681	$\Sigma r_{d(j)}K_{b(j)}=$	832.35	1281.469

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	681	
	π	832.35	
STEP 2	$VAR(\lambda)$	681	
	$VAR(\pi)$	1281.469	
STEP 3	δ	151.35	
	θ	0.816655	0.183345
STEP 4	$VAR(\delta)$	1962.469	
	$VAR(\theta)$	0.002205	

Reduction	0.183345
std deviation	0.09391

18% +/- 9% result is statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		47	2001	8	6	9	7	5	6	6	0	14	33
10		8	2001	2	2	1	1	2	0	0	0	4	4
11		5	2001	0	1	3	1	0	0	0	0	1	4
12		53	2001	14	6	7	6	7	7	6	0	20	33
13		55	2001	11	7	17	3	3	3	11	0	18	37
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		17	2001	2	3	1	2	3	2	4	0	5	12
17		99	2001	14	14	17	19	13	15	7	0	28	71
25		27	2002	8	4	2	1	3	6	3	0	12	15
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		25	2002	0	2	3	5	7	5	3	0	5	20
28		27	2002	4	6	2	7	2	6	0	0	12	15
29		35	2002	6	6	7	3	5	5	3	0	19	16
30		212	2002	28	29	44	31	44	26	10	0	101	111
31		42	2004	11	7	11	6	2	4	1	0	37	5
32		22	2004	4	3	2	2	3	6	2	0	14	8
33		57	2004	10	10	9	11	5	8	4	0	45	12
34		42	2004	4	6	10	10	3	8	1	0	33	9
35		22	2004	2	2	2	1	3	8	4	0	10	12
36		100	2004	16	16	16	15	18	16	3	0	81	19
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		2	2004	0	0	0	0	1	0	1	0	1	1
40		7	2004	0	0	0	0	0	7	0	0	0	7
41		4	2003	0	0	0	2	0	0	2	0	2	2
42		66	2003	6	11	9	12	10	10	8	0	38	28
46		21	2003	3	4	1	3	4	6	0	0	11	10
48		24	2003	0	4	4	4	2	8	2	0	12	12

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	14	33	2.5	35	87.5
2	5	4	4	2.5	10	25
2	5	1	4	2.5	2.5	6.25
2	5	20	33	2.5	50	125
2	5	18	37	2.5	45	112.5
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	5	12	2.5	12.5	31.25
2	5	28	71	2.5	70	175
2	5	12	15	2.5	30	75
3	4	0	0	1.333333	0	0
3	4	5	20	1.333333	6.666667	8.888889
3	4	12	15	1.333333	16	21.33333
3	4	19	16	1.333333	25.33333	33.77778
3	4	101	111	1.333333	134.6667	179.5556
5	2	37	5	0.4	14.8	5.92
5	2	14	8	0.4	5.6	2.24
5	2	45	12	0.4	18	7.2
5	2	33	9	0.4	13.2	5.28
5	2	10	12	0.4	4	1.6
5	2	81	19	0.4	32.4	12.96
5	2	0	0	0.4	0	0
5	2	1	1	0.4	0.4	0.16
5	2	0	7	0.4	0	0
4	3	2	2	0.75	1.5	1.125
4	3	38	28	0.75	28.5	21.375
4	3	11	10	0.75	8.25	6.1875
4	3	12	12	0.75	9	6.75
		$\Sigma L_{a(j)}=$	496	$\Sigma r_{d(j)}K_{b(j)}=$	573.3167	951.8531

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	496
	π	573.3167
STEP 2	$VAR(\lambda)$	496
	$VAR(\pi)$	951.8531
STEP 3	δ	77.31667
	θ	0.862643
STEP 4	$VAR(\delta)$	1447.853
	$VAR(\theta)$	0.003634

Reduction	0.137357
std deviation	0.120569

14% +/- 12% result is statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		16	2001	0	1	4	3	3	3	2	0	1	15
10		2	2001	1	0	0	0	1	0	0	0	1	1
11		2	2001	0	0	0	2	0	0	0	0	0	2
12		26	2001	2	3	6	1	8	6	0	0	5	21
13		23	2001	6	2	6	3	3	3	0	0	8	15
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		7	2001	1	1	1	0	2	1	1	0	2	5
17		22	2001	2	5	3	3	3	5	1	0	7	15
25		11	2002	0	3	2	5	1	0	0	0	3	8
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		15	2002	5	3	2	4	0	1	0	0	10	5
28		9	2002	0	2	1	1	3	2	0	0	3	6
29		15	2002	4	1	1	5	3	1	0	0	6	9
30		113	2002	25	21	26	15	8	16	2	0	72	41
31		23	2004	3	5	7	3	3	2	0	0	21	2
32		5	2004	0	0	2	1	1	1	0	0	4	1
33		8	2004	2	2	1	2	0	1	0	0	7	1
34		15	2004	1	3	2	3	3	3	0	0	12	3
35		9	2004	0	2	0	2	3	1	1	0	7	2
36		21	2004	2	3	3	2	7	3	1	0	17	4
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		1	2004	0	0	0	0	0	1	0	0	0	1
40		1	2004	0	0	0	0	0	1	0	0	0	1
41		0	2003	0	0	0	0	0	0	0	0	0	0
42		28	2003	2	8	9	3	2	3	1	0	22	6
46		12	2003	0	3	2	5	0	2	0	0	10	2
48		2	2003	0	0	2	0	0	0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	15	2.5	2.5	6.25
2	5	1	1	2.5	2.5	6.25
2	5	0	2	2.5	0	0
2	5	5	21	2.5	12.5	31.25
2	5	8	15	2.5	20	50
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	2	5	2.5	5	12.5
2	5	7	15	2.5	17.5	43.75
2	5	3	8	2.5	7.5	18.75
3	4	0	0	1.333333	0	0
3	4	10	5	1.333333	13.33333	17.77778
3	4	3	6	1.333333	4	5.333333
3	4	6	9	1.333333	8	10.66667
3	4	72	41	1.333333	96	128
5	2	21	2	0.4	8.4	3.36
5	2	4	1	0.4	1.6	0.64
5	2	7	1	0.4	2.8	1.12
5	2	12	3	0.4	4.8	1.92
5	2	7	2	0.4	2.8	1.12
5	2	17	4	0.4	6.8	2.72
5	2	0	0	0.4	0	0
5	2	0	1	0.4	0	0
5	2	0	1	0.4	0	0
4	3	0	0	0.75	0	0
4	3	22	6	0.75	16.5	12.375
4	3	10	2	0.75	7.5	5.625
4	3	2	0	0.75	1.5	1.125
		$\Sigma L_{a(j)}=$	166	$\Sigma r_{d(j)}K_{b(j)}=$	241.5333	360.5328

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	166
	π	241.5333
STEP 2	$VAR(\lambda)$	166
	$VAR(\pi)$	360.5328
STEP 3	δ	75.53333
	θ	0.683054
STEP 4	$VAR(\delta)$	526.5328
	$VAR(\theta)$	0.005624

Reduction	0.316946
std deviation	0.14999

32% +/- 15% result is statistically significant

not dry

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		27	2001	1	6	6	3	5	4	2	0	7	20
10		2	2001	1	0	0	0	1	0	0	0	1	1
11		4	2001	0	0	0	3	1	0	0	0	0	4
12		34	2001	5	3	6	1	10	9	0	0	8	26
13		35	2001	6	3	9	6	5	5	1	0	9	26
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		16	2001	1	3	1	1	4	4	2	0	4	12
17		36	2001	3	6	5	6	7	6	3	0	9	27
25		14	2002	0	4	3	5	2	0	0	0	4	10
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		21	2002	7	4	2	6	0	2	0	0	13	8
28		13	2002	1	3	1	1	5	2	0	0	5	8
29		19	2002	5	2	1	6	3	2	0	0	8	11
30		140	2002	28	30	28	18	13	18	5	0	86	54
31		31	2004	3	6	8	5	7	2	0	0	29	2
32		6	2004	1	0	2	1	1	1	0	0	5	1
33		9	2004	2	2	1	3	0	1	0	0	8	1
34		22	2004	3	4	3	3	4	5	0	0	17	5
35		12	2004	0	3	1	2	3	2	1	0	9	3
36		25	2004	2	4	5	3	7	3	1	0	21	4
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		2	2004	0	0	0	0	1	1	0	0	1	1
40		5	2004	0	0	0	2	1	2	0	0	3	2
41		1	2003	1	0	0	0	0	0	0	0	1	0
42		38	2003	3	12	11	3	4	4	1	0	29	9
46		27	2003	0	6	3	9	4	5	0	0	18	9
48		2	2003	0	0	2	0	0	0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	7	20	2.5	17.5	43.75
2	5	1	1	2.5	2.5	6.25
2	5	0	4	2.5	0	0
2	5	8	26	2.5	20	50
2	5	9	26	2.5	22.5	56.25
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	4	12	2.5	10	25
2	5	9	27	2.5	22.5	56.25
2	5	4	10	2.5	10	25
3	4	0	0	1.333333	0	0
3	4	13	8	1.333333	17.33333	23.11111
3	4	5	8	1.333333	6.666667	8.888889
3	4	8	11	1.333333	10.66667	14.22222
3	4	86	54	1.333333	114.6667	152.8889
5	2	29	2	0.4	11.6	4.64
5	2	5	1	0.4	2	0.8
5	2	8	1	0.4	3.2	1.28
5	2	17	5	0.4	6.8	2.72
5	2	9	3	0.4	3.6	1.44
5	2	21	4	0.4	8.4	3.36
5	2	0	0	0.4	0	0
5	2	1	1	0.4	0.4	0.16
5	2	3	2	0.4	1.2	0.48
4	3	1	0	0.75	0.75	0.5625
4	3	29	9	0.75	21.75	16.3125
4	3	18	9	0.75	13.5	10.125
4	3	2	0	0.75	1.5	1.125
		$\Sigma L_{a(j)}=$	244	$\Sigma r_{d(j)}K_{b(j)}=$	329.0333	504.6161

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	244
	π	329.0333
STEP 2	$VAR(\lambda)$	244
	$VAR(\pi)$	504.6161
STEP 3	δ	85.03333
	θ	0.738126
STEP 4	$VAR(\delta)$	748.6161
	$VAR(\theta)$	0.004728

Reduction	0.261874
std deviation	0.137524

26% +/- 14% result is statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		12	2001	2	2	1	3	1	0	3	0	4	8
10		3	2001	2	0	0	1	0	0	0	0	2	1
11		3	2001	0	0	2	1	0	0	0	0	0	3
12		25	2001	6	2	2	2	6	3	4	0	8	17
13		21	2001	5	2	5	1	3	1	4	0	7	14
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		1	2001	0	1	0	0	0	0	0	0	1	0
17		25	2001	4	3	2	2	4	5	5	0	7	18
25		13	2002	3	2	0	1	3	3	1	0	5	8
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		13	2002	0	2	2	4	2	2	1	0	4	9
28		9	2002	0	2	1	2	1	3	0	0	3	6
29		6	2002	2	0	0	2	0	2	0	0	2	4
30		85	2002	14	19	14	17	9	9	3	0	47	38
31		17	2004	3	5	2	3	2	2	0	0	15	2
32		7	2004	0	1	1	2	3	0	0	0	7	0
33		13	2004	2	3	1	2	0	3	2	0	8	5
34		19	2004	3	1	4	5	2	4	0	0	15	4
35		8	2004	0	1	0	0	1	3	3	0	2	6
36		25	2004	3	4	3	4	6	3	2	0	20	5
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		1	2004	0	0	0	0	0	1	0	0	0	1
40		3	2004	0	0	0	0	1	2	0	0	1	2
41		1	2003	0	0	0	1	0	0	0	0	1	0
42		27	2003	2	5	5	1	2	9	3	0	13	14
46		13	2003	1	2	1	4	3	2	0	0	8	5
48		8	2003	0	2	2	2	2	0	0	0	6	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	4	8	2.5	10	25
2	5	2	1	2.5	5	12.5
2	5	0	3	2.5	0	0
2	5	8	17	2.5	20	50
2	5	7	14	2.5	17.5	43.75
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	1	0	2.5	2.5	6.25
2	5	7	18	2.5	17.5	43.75
2	5	5	8	2.5	12.5	31.25
3	4	0	0	1.333333	0	0
3	4	4	9	1.333333	5.333333	7.111111
3	4	3	6	1.333333	4	5.333333
3	4	2	4	1.333333	2.666667	3.555556
3	4	47	38	1.333333	62.66667	83.55556
5	2	15	2	0.4	6	2.4
5	2	7	0	0.4	2.8	1.12
5	2	8	5	0.4	3.2	1.28
5	2	15	4	0.4	6	2.4
5	2	2	6	0.4	0.8	0.32
5	2	20	5	0.4	8	3.2
5	2	0	0	0.4	0	0
5	2	0	1	0.4	0	0
5	2	1	2	0.4	0.4	0.16
4	3	1	0	0.75	0.75	0.5625
4	3	13	14	0.75	9.75	7.3125
4	3	8	5	0.75	6	4.5
4	3	6	2	0.75	4.5	3.375
		$\Sigma L_{a(j)}=$	172	$\Sigma r_{d(j)}K_{b(j)}=$	207.8667	338.6856

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	172
	π	207.8667
STEP 2	$VAR(\lambda)$	172
	$VAR(\pi)$	338.6856
STEP 3	δ	35.86667
	θ	0.821018
STEP 4	$VAR(\delta)$	510.6856
	$VAR(\theta)$	0.00906

Reduction	0.178982
std deviation	0.190369

18% +/- 19% result is **NOT** statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		63	2001	7	12	13	8	9	10	4	0	19	44
10		9	2001	3	2	1	1	2	0	0	0	5	4
11		6	2001	0	0	2	3	1	0	0	0	0	6
12		73	2001	17	9	13	7	14	11	2	0	26	47
13		80	2001	16	8	22	8	8	7	11	0	24	56
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		27	2001	3	4	2	3	7	5	3	0	7	20
17		93	2001	10	15	18	18	14	12	6	0	25	68
25		38	2002	8	7	3	6	5	6	3	0	15	23
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		38	2002	6	5	5	10	5	4	3	0	16	22
28		34	2002	4	8	3	6	6	7	0	0	15	19
29		46	2002	10	6	8	8	7	5	2	0	24	22
30		291	2002	47	51	60	42	45	35	11	0	158	133
31		64	2004	11	11	17	11	8	5	1	0	58	6
32		20	2004	3	2	4	2	4	4	1	0	15	5
33		47	2004	8	11	8	8	4	5	3	0	39	8
34		50	2004	5	8	12	10	5	9	1	0	40	10
35		22	2004	1	4	3	2	4	5	3	0	14	8
36		107	2004	16	17	15	16	22	17	4	0	86	21
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		4	2004	0	0	0	0	2	1	1	0	2	2
40		3	2004	0	0	0	0	0	3	0	0	0	3
41		3	2003	0	0	0	2	0	0	1	0	2	1
42		93	2003	7	23	18	13	14	10	8	0	61	32
46		40	2003	2	8	4	11	7	8	0	0	25	15
48		18	2003	0	2	6	2	2	4	2	0	10	8

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	19	44	2.5	47.5	118.75
2	5	5	4	2.5	12.5	31.25
2	5	0	6	2.5	0	0
2	5	26	47	2.5	65	162.5
2	5	24	56	2.5	60	150
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	7	20	2.5	17.5	43.75
2	5	25	68	2.5	62.5	156.25
2	5	15	23	2.5	37.5	93.75
3	4	0	0	1.333333	0	0
3	4	16	22	1.333333	21.33333	28.44444
3	4	15	19	1.333333	20	26.66667
3	4	24	22	1.333333	32	42.66667
3	4	158	133	1.333333	210.6667	280.8889
5	2	58	6	0.4	23.2	9.28
5	2	15	5	0.4	6	2.4
5	2	39	8	0.4	15.6	6.24
5	2	40	10	0.4	16	6.4
5	2	14	8	0.4	5.6	2.24
5	2	86	21	0.4	34.4	13.76
5	2	0	0	0.4	0	0
5	2	2	2	0.4	0.8	0.32
5	2	0	3	0.4	0	0
4	3	2	1	0.75	1.5	1.125
4	3	61	32	0.75	45.75	34.3125
4	3	25	15	0.75	18.75	14.0625
4	3	10	8	0.75	7.5	5.625
		$\Sigma L_{a(j)}$=	583	$\Sigma r_{d(j)}K_{b(j)}$=	761.6	1230.682

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j) K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2 Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	583
	π	761.6
STEP 2	$VAR(\lambda)$	583
	$VAR(\pi)$	1230.682
STEP 3	δ	178.6
	θ	0.763873
STEP 4	$VAR(\delta)$	1813.682
	$VAR(\theta)$	0.002229

Reduction	0.236127
std deviation	0.094434

24% +/- 9% result is statistically significant

Rear End

Before Treatment

After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		19	2001	2	4	4	1	0	4	4	0	6	13
10		2	2001	0	1	1	0	0	0	0	0	1	1
11		3	2001	0	0	2	1	0	0	0	0	0	3
12		25	2001	4	1	5	3	5	6	1	0	5	20
13		35	2001	9	4	9	3	1	4	5	0	13	22
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		14	2001	2	2	0	0	3	4	3	0	4	10
17		62	2001	5	10	15	9	11	10	2	0	15	47
25		8	2002	1	3	1	1	0	1	1	0	4	4
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		21	2002	2	3	3	6	1	3	3	0	8	13
28		21	2002	3	6	1	4	2	5	0	0	10	11
29		22	2002	5	6	2	4	2	1	2	0	13	9
30		164	2002	29	34	36	18	15	24	8	0	99	65
31		33	2004	8	5	8	5	1	5	1	0	27	6
32		14	2004	3	3	3	1	2	2	0	0	12	2
33		33	2004	4	8	6	8	1	5	1	0	27	6
34		21	2004	2	4	6	3	1	5	0	0	16	5
35		23	2004	2	2	2	2	5	8	2	0	13	10
36		39	2004	6	9	7	5	8	4	0	0	35	4
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		0	2004	0	0	0	0	0	0	0	0	0	0
40		1	2004	0	0	0	0	0	1	0	0	0	1
41		0	2003	0	0	0	0	0	0	0	0	0	0
42		44	2003	6	9	9	6	3	6	5	0	30	14
46		16	2003	1	3	3	3	4	2	0	0	10	6
48		12	2003	0	4	4	2	0	2	0	0	10	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	6	13	2.5	15	37.5
2	5	1	1	2.5	2.5	6.25
2	5	0	3	2.5	0	0
2	5	5	20	2.5	12.5	31.25
2	5	13	22	2.5	32.5	81.25
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	4	10	2.5	10	25
2	5	15	47	2.5	37.5	93.75
2	5	4	4	2.5	10	25
3	4	0	0	1.333333	0	0
3	4	8	13	1.333333	10.66667	14.22222
3	4	10	11	1.333333	13.33333	17.77778
3	4	13	9	1.333333	17.33333	23.11111
3	4	99	65	1.333333	132	176
5	2	27	6	0.4	10.8	4.32
5	2	12	2	0.4	4.8	1.92
5	2	27	6	0.4	10.8	4.32
5	2	16	5	0.4	6.4	2.56
5	2	13	10	0.4	5.2	2.08
5	2	35	4	0.4	14	5.6
5	2	0	0	0.4	0	0
5	2	0	0	0.4	0	0
5	2	0	1	0.4	0	0
4	3	0	0	0.75	0	0
4	3	30	14	0.75	22.5	16.875
4	3	10	6	0.75	7.5	5.625
4	3	10	2	0.75	7.5	5.625
		$\Sigma L_{a(j)}=$	274	$\Sigma r_{d(j)}K_{b(j)}=$	382.8333	580.0361

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	274
	π	382.8333
STEP 2	$VAR(\lambda)$	274
	$VAR(\pi)$	580.0361
STEP 3	δ	108.8333
	θ	0.712895
STEP 4	$VAR(\delta)$	854.0361
	$VAR(\theta)$	0.003836

Reduction	0.287105
std deviation	0.123867

29% +/- 12% result is statistically significant

Appendix C: Resurfacing Analysis

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	7	2001
3	2	5890	6050	5880	5990	6930		13952	7449	3724	13	2001
4	2	3640	3890	3170	3490	3920			3622	1811	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	22	2001
6	4	17650	18870	18610	23640	23250			20404	5101	34	2001
7	4	3670	4860	5670	7050	3460			4942	1236	2	2001
18	6	49540	49180	48875	50535	52180	49753		50011	8335	388	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	324	2001
21	2								4762	2381	15	2001
22	2			1280	2280	1700		1986	1812	906	2	2002
23	2	5450	5410c	7320	6610	6510			6473	3236	20	2002
24	2		940	1010	1020	930		967	973	487	3	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	2	0	0	1	0	1	6
1	1	2	2	2	4	1	0	1	12
0	1	2	0	3	0	4	0	0	10
3	3	2	3	2	5	4	0	3	19
6	4	6	1	4	9	4	0	6	28
0	0	0	1	0	0	1	0	0	2
41	61	67	57	65	69	28	0	102	286
63	52	56	38	52	43	20	0	115	209
0	1	2	2	6	2	2	0	1	14
0	0	0	0	0	1	1	0	0	2
2	4	0	3	3	4	4	0	6	14
0	0	0	0	1	2	0	0	0	3
								235	605

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	6	6	6	36
1	6	1	12	6	6	36
1	6	0	10	6	0	0
1	6	3	19	6	18	108
1	6	6	28	6	36	216
1	6	0	2	6	0	0
2	5	102	286	2.5	255	637.5
2	5	115	209	2.5	287.5	718.75
2	5	1	14	2.5	2.5	6.25
2	5	0	2	2.5	0	0
2	5	6	14	2.5	15	37.5
2	5	0	3	2.5	0	0
		$\Sigma L_{a(j)}=$	605	$\Sigma r_{d(j)}K_{b(j)}=$	626	1796

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	605
	π	626
STEP 2	$VAR(\lambda)$	605
	$VAR(\pi)$	1796
STEP 3	δ	21
	θ	0.962045
STEP 4	$VAR(\delta)$	2401
	$VAR(\theta)$	0.005719

0.037955

Reduction 0.037955

std deviation 0.151249

4% +/- 15% result is NOT statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	1	1	2	1	0	0	0	0	1	4
3		10	2001	0	1	0	1	2	3	0	0	0	7
4		9	2001	0	1	1	0	2	0	0	0	0	4
5		87	2001	1	2	1	3	1	4	3	0	1	14
6		90	2001	4	2	4	0	2	4	2	0	4	14
7		0	2001	0	0	0	1	0	0	1	0	0	2
18		0	2001	37	49	57	42	49	49	21	0	86	218
19		33	2001	40	34	33	28	34	29	12	0	74	136
21		135	2001	0	0	1	2	2	1	2	0	0	8
22		41	2002	0	0	0	0	0	1	1	0	0	2
23		0	2002	1	2	0	2	1	3	3	0	3	9
24		46	2002	0	0	0	0	1	2	0	0	0	3
												169	421

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	4	6	6	36
1	6	0	7	6	0	0
1	6	0	4	6	0	0
1	6	1	14	6	6	36
1	6	4	14	6	24	144
1	6	0	2	6	0	0
2	5	86	218	2.5	215	537.5
2	5	74	136	2.5	185	462.5
2	5	0	8	2.5	0	0
2	5	0	2	2.5	0	0
2	5	3	9	2.5	7.5	18.75
2	5	0	3	2.5	0	0
		$\Sigma L_{a(j)}=$	421	$\Sigma r_{d(j)}K_{b(j)}=$	443.5	1234.75

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	421	
	π	443.5	
STEP 2	VAR(λ)	421	
	VAR(π)	1234.75	
STEP 3	δ	22.5	
	θ	0.943345	0.056655
STEP 4	VAR(δ)	1655.75	
	VAR(θ)	0.007604	

Reduction	0.056655
std deviation	0.174407

6% +/- 17% result is NOT statistically significant

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	0	0	0	1	0	0	0	0	0	1
3		10	2001	1	0	1	1	0	1	0	0	1	3
4		9	2001	0	0	1	0	1	0	2	0	0	4
5		87	2001	2	1	1	0	1	0	0	0	2	3
6		90	2001	2	2	2	0	0	3	2	0	2	9
7		0	2001	0	0	0	0	0	0	0	0	0	0
18		0	2001	2	10	8	11	9	12	4	0	12	44
19		33	2001	18	15	15	6	13	9	5	0	33	48
21		135	2001	0	0	1	0	3	0	0	0	0	4
22		41	2002	0	0	0	0	0	0	0	0	0	0
23		0	2002	1	2	0	0	2	1	1	0	3	4
24		46	2002	0	0	0	0	0	0	0	0	0	0
												53	120

🟨 Before Treatment
🟩 After Treatment

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	1	6	0	0
1	6	1	3	6	6	36
1	6	0	4	6	0	0
1	6	2	3	6	12	72
1	6	2	9	6	12	72
1	6	0	0	6	0	0
2	5	12	44	2.5	30	75
2	5	33	48	2.5	82.5	206.25
2	5	0	4	2.5	0	0
2	5	0	0	2.5	0	0
2	5	3	4	2.5	7.5	18.75
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}=$	120	$\Sigma r_{d(j)}K_{b(j)}=$	150	480

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	120	
	π	150	
STEP 2	$VAR(\lambda)$	120	
	$VAR(\pi)$	480	
STEP 3	δ	30	
	θ	0.78329	0.21671
STEP 4	$VAR(\delta)$	600	
	$VAR(\theta)$	0.017449	

Reduction	0.21671
std deviation	0.264192

22%+/-26% result is NOT statistically significant

Not Dry

Before Treatment
After Treatment

Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
1		74	2001	0	0	0	1	0	0	1	0	0	2
3		10	2001	1	0	2	1	0	1	1	0	1	5
4		9	2001	0	0	1	0	1	0	4	0	0	6
5		87	2001	2	1	1	0	1	1	1	0	2	5
6		90	2001	2	2	2	1	2	5	2	0	2	14
7		0	2001	0	0	0	0	0	0	0	0	0	0
18		0	2001	4	12	10	15	16	20	7	0	16	68
19		33	2001	23	18	23	10	18	14	8	0	41	73
21		135	2001	0	1	1	0	4	1	0	0	1	6
22		41	2002	0	0	0	0	0	0	0	0	0	0
23		0	2002	1	2	0	1	2	1	1	0	3	5
24		46	2002	0	0	0	0	0	0	0	0	0	0
												66	184

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	2	6	0	0
1	6	1	5	6	6	36
1	6	0	6	6	0	0
1	6	2	5	6	12	72
1	6	2	14	6	12	72
1	6	0	0	6	0	0
2	5	16	68	2.5	40	100
2	5	41	73	2.5	102.5	256.25
2	5	1	6	2.5	2.5	6.25
2	5	0	0	2.5	0	0
2	5	3	5	2.5	7.5	18.75
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}=$	184	$\Sigma r_{d(j)}K_{b(j)}=$	182.5	561.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	184
	π	182.5
STEP 2	$VAR(\lambda)$	184
	$VAR(\pi)$	561.25
STEP 3	δ	-1.5
	θ	0.991511
STEP 4	$VAR(\delta)$	745.25
	$VAR(\theta)$	0.021189

0.008489

Reduction	0.008489
std deviation	0.291129

1% +/- 30% result is NOT statistically significant

Severe

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	1	0	1	0	0	0	1	0	1	2
3		10	2001	0	1	2	1	0	0	0	0	0	4
4		9	2001	0	0	1	0	0	0	1	0	0	2
5		87	2001	0	0	1	1	0	0	1	0	0	3
6		90	2001	2	1	0	0	0	1	1	0	2	3
7		0	2001	0	0	0	0	0	0	1	0	0	1
18		0	2001	11	13	16	10	10	17	10	0	24	63
19		33	2001	12	4	12	4	8	8	8	0	16	40
21		135	2001	0	0	2	1	3	0	1	0	0	7
22		41	2002	0	0	0	0	0	0	0	0	0	0
23		0	2002	0	0	0	0	0	2	0	0	0	2
24		46	2002	0	0	0	0	0	1	0	0	0	1
												43	128

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	2	6	6	36
1	6	0	4	6	0	0
1	6	0	2	6	0	0
1	6	0	3	6	0	0
1	6	2	3	6	12	72
1	6	0	1	6	0	0
2	5	24	63	2.5	60	150
2	5	16	40	2.5	40	100
2	5	0	7	2.5	0	0
2	5	0	0	2.5	0	0
2	5	0	2	2.5	0	0
2	5	0	1	2.5	0	0
		$\Sigma L_{a(j)}=$	128	$\Sigma r_{d(j)}K_{b(j)}=$	118	358

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$\mathrm{VAR}(\lambda) = \Sigma La(j)$

$\mathrm{VAR}(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + \mathrm{VAR}(\pi)/\pi^2]^{-1}$

$\mathrm{VAR}(\delta) = \mathrm{VAR}(\pi) + \mathrm{VAR}(\lambda)$

$\mathrm{VAR}(\theta) = \theta^2[\mathrm{VAR}(\lambda)/\lambda^2 + \mathrm{VAR}(\pi)/\pi^2]/[1 + \mathrm{VAR}(\pi)/\pi^2]^2$

		Results
STEP 1	λ	128
	π	118
STEP 2	VAR(λ)	128
	VAR(π)	358
STEP 3	δ	-10
	θ	1.057555
STEP 4	VAR(δ)	486
	VAR(θ)	0.035637

-0.05755

Reduction	-0.05755
std deviation	0.377557

-6%+-38% result is NOT statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	1	1	2	2	0	0	0	0	1	5
3		10	2001	1	1	2	2	2	3	0	0	1	10
4		9	2001	0	0	2	0	1	0	2	0	0	5
5		87	2001	2	3	2	3	2	2	3	0	2	15
6		90	2001	3	3	5	1	3	5	2	0	3	19
7		0	2001	0	0	0	0	0	0	0	0	0	0
18		0	2001	34	53	51	43	50	51	21	0	87	216
19		33	2001	53	45	44	26	42	24	15	0	98	151
21		135	2001	0	1	2	2	5	2	1	0	1	12
22		41	2002	0	0	0	0	0	0	1	0	0	1
23		0	2002	2	4	0	3	3	3	2	0	6	11
24		46	2002	0	0	0	0	1	1	0	0	0	2
												199	447

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	5	6	6	36
1	6	1	10	6	6	36
1	6	0	5	6	0	0
1	6	2	15	6	12	72
1	6	3	19	6	18	108
1	6	0	0	6	0	0
2	5	87	216	2.5	217.5	543.75
2	5	98	151	2.5	245	612.5
2	5	1	12	2.5	2.5	6.25
2	5	0	1	2.5	0	0
2	5	6	11	2.5	15	37.5
2	5	0	2	2.5	0	0
		$\Sigma L_{a(j)}=$	447	$\Sigma r_{d(j)}K_{b(j)}=$	522	1452

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	447	
	π	522	
STEP 2	VAR(λ)	447	
	VAR(π)	1452	
STEP 3	δ	75	
	θ	0.851783	0.148217
STEP 4	VAR(δ)	1899	
	VAR(θ)	0.005431	

Reduction	0.148217
std deviation	0.147394

15% +/- 15% result is NOT statistically significant

Rear End

Before Treatment

After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	0	1	0	0	0	0	0	0	0	1
3		10	2001	0	0	1	0	0	2	0	0	0	3
4		9	2001	0	1	0	0	1	0	2	0	0	4
5		87	2001	1	1	1	1	1	2	1	0	1	7
6		90	2001	5	1	2	1	1	4	0	0	5	9
7		0	2001	0	0	0	0	0	0	1	0	0	1
18		0	2001	14	24	30	30	30	27	12	0	38	129
19		33	2001	26	16	26	16	16	16	9	0	42	83
21		135	2001	0	0	0	0	1	0	1	0	0	2
22		41	2002	0	0	0	0	0	0	1	0	0	1
23		0	2002	1	0	0	2	0	1	2	0	1	5
24		46	2002	0	0	0	0	0	0	0	0	0	0
												87	245

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	1	6	0	0
1	6	0	3	6	0	0
1	6	0	4	6	0	0
1	6	1	7	6	6	36
1	6	5	9	6	30	180
1	6	0	1	6	0	0
2	5	38	129	2.5	95	237.5
2	5	42	83	2.5	105	262.5
2	5	0	2	2.5	0	0
2	5	0	1	2.5	0	0
2	5	1	5	2.5	2.5	6.25
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}=$	245	$\Sigma r_{d(j)}K_{b(j)}=$	238.5	722.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	245
	π	238.5
STEP 2	$VAR(\lambda)$	245
	$VAR(\pi)$	722.25
STEP 3	δ	-6.5
	θ	1.014374
STEP 4	$VAR(\delta)$	967.25
	$VAR(\theta)$	0.016835

-0.01437

Reduction	-0.01437
std deviation	0.259496

-1% +/- 26% result is NOT statistically significant

Appendix D: Microsurfacing Analysis – With Treatment Year Omitted

Summary Total

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		74	2001	9	12		10	10	10	8	0	21	38
10		10	2001	3	2		1	3	0	0	0	5	4
11		9	2001	0	1		4	1	0	0	0	1	5
12		87	2001	19	9		7	17	16	6	0	28	46
13		90	2001	17	10		9	8	8	12	0	27	37
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		33	2001	3	6		3	7	6	6	0	9	22
17		135	2001	17	20		25	20	21	10	0	37	76
25		41	2002	8	8		6	5	6	3	0	16	20
26		0	2002	0	0	0		0	0	0	0	0	0
27		46	2002	7	6	5		7	7	3	0	18	17
28		40	2002	5	9	3		7	8	0	0	17	15
29		54	2002	11	8	8		8	7	3	0	27	18
30		352	2002	56	59	72		57	44	15	0	187	116
31		73	2004	14	13	19	11	9		1	0	66	1
32		28	2004	5	3	4	3	4		2	0	19	2
33		66	2004	12	12	10	14	5		4	0	53	4
34		64	2004	7	10	13	13	7		1	0	50	1
35		34	2004	2	5	3	3	6		5	0	19	5
36		125	2004	18	20	21	18	25		4	0	102	4
37		0	2004	0	0	0	0	0		0	0	0	0
38		4	2004	0	0	0	0	2		1	0	2	1
40		12	2004	0	0	0	2	1		0	0	3	0
41		5	2003	1	0	0	2		0	2	0	3	2
42		104	2003	9	23	20	15		14	9	0	67	23
46		48	2003	3	10	4	12		11	0	0	29	11
48		26	2003	0	4	6	4		8	2	0	14	10

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	21	38	2	42	84
2	4	5	4	2	10	20
2	4	1	5	2	2	4
2	4	28	46	2	56	112
2	4	27	37	2	54	108
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	9	22	2	18	36
2	4	37	76	2	74	148
2	4	16	20	2	32	64
3	3	0	0	1	0	0
3	3	18	17	1	18	18
3	3	17	15	1	17	17
3	3	27	18	1	27	27
3	3	187	116	1	187	187
5	1	66	1	0.2	13.2	2.64
5	1	19	2	0.2	3.8	0.76
5	1	53	4	0.2	10.6	2.12
5	1	50	1	0.2	10	2
5	1	19	5	0.2	3.8	0.76
5	1	102	4	0.2	20.4	4.08
5	1	0	0	0.2	0	0
5	1	2	1	0.2	0.4	0.08
5	1	3	0	0.2	0.6	0.12
4	2	3	2	0.5	1.5	0.75
4	2	67	23	0.5	33.5	16.75
4	2	29	11	0.5	14.5	7.25
4	2	14	10	0.5	7	3.5
		$\Sigma L_{a(j)}=$	478	$\Sigma r_{d(j)}K_{b(j)}=$	656.3	865.81

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	478	
	π	656.3	
STEP 2	VAR(λ)	478	
	VAR(π)	865.81	
STEP 3	δ	178.3	
	θ	0.726864	0.273136
STEP 4	VAR(δ)	1343.81	
	VAR(θ)	0.002159	

Reduction	0.273136
std deviation	0.092922

28% +/- 10%	result is statistically significant

Summary Dry

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		47	2001	8	6		7	5	6	6	0	14	24
10		8	2001	2	2		1	2	0	0	0	4	3
11		5	2001	0	1		1	0	0	0	0	1	1
12		53	2001	14	6		6	7	7	6	0	20	26
13		55	2001	11	7		3	3	3	11	0	18	20
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		17	2001	2	3		2	3	2	4	0	5	11
17		99	2001	14	14		19	13	15	7	0	28	54
25		27	2002	8	4		1	3	6	3	0	12	13
26		0	2002	0	0	0		0	0	0	0	0	0
27		25	2002	0	2	3		7	5	3	0	5	15
28		27	2002	4	6	2		2	6	0	0	12	8
29		35	2002	6	6	7		5	5	3	0	19	13
30		212	2002	28	29	44		44	26	10	0	101	80
31		42	2004	11	7	11	6	2		1	0	37	1
32		22	2004	4	3	2	2	3		2	0	14	2
33		57	2004	10	10	9	11	5		4	0	45	4
34		42	2004	4	6	10	10	3		1	0	33	1
35		22	2004	2	2	2	1	3		4	0	10	4
36		100	2004	16	16	16	15	18		3	0	81	3
37		0	2004	0	0	0	0	0		0	0	0	0
38		2	2004	0	0	0	0	1		1	0	1	1
40		7	2004	0	0	0	0	0		0	0	0	0
41		4	2003	0	0	0	2		0	2	0	2	2
42		66	2003	6	11	9	12		10	8	0	38	18
46		21	2003	3	4	1	3		6	0	0	11	6
48		24	2003	0	4	4	4		8	2	0	12	10

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	14	24	2	28	56
2	4	4	3	2	8	16
2	4	1	1	2	2	4
2	4	20	26	2	40	80
2	4	18	20	2	36	72
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	5	11	2	10	20
2	4	28	54	2	56	112
2	4	12	13	2	24	48
3	3	0	0	1	0	0
3	3	5	15	1	5	5
3	3	12	8	1	12	12
3	3	19	13	1	19	19
3	3	101	80	1	101	101
5	1	37	1	0.2	7.4	1.48
5	1	14	2	0.2	2.8	0.56
5	1	45	4	0.2	9	1.8
5	1	33	1	0.2	6.6	1.32
5	1	10	4	0.2	2	0.4
5	1	81	3	0.2	16.2	3.24
5	1	0	0	0.2	0	0
5	1	1	1	0.2	0.2	0.04
5	1	0	0	0.2	0	0
4	2	2	2	0.5	1	0.5
4	2	38	18	0.5	19	9.5
4	2	11	6	0.5	5.5	2.75
4	2	12	10	0.5	6	3
		$\Sigma L_{a(j)}=$	320	$\Sigma r_{d(j)}K_{b(j)}=$	416.7	569.59

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	320
	π	416.7
STEP 2	VAR(λ)	320
	VAR(π)	569.59
STEP 3	δ	96.7
	θ	0.765428
STEP 4	VAR(δ)	889.59
	VAR(θ)	0.003728

Reduction	0.234572
std deviation	0.122119

23% +/- 12% result is statistically significant

Summary Wet

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		16	2001	0	1		3	3	3	2	0	1	11
10		2	2001	1	0		0	1	0	0	0	1	1
11		2	2001	0	0		2	0	0	0	0	0	2
12		26	2001	2	3		1	8	6	0	0	5	15
13		23	2001	6	2		3	3	3	0	0	8	9
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		7	2001	1	1		0	2	1	1	0	2	4
17		22	2001	2	5		3	3	5	1	0	7	12
25		11	2002	0	3		5	1	0	0	0	3	6
26		0	2002	0	0	0		0	0	0	0	0	0
27		15	2002	5	3	2		0	1	0	0	10	1
28		9	2002	0	2	1		3	2	0	0	3	5
29		15	2002	4	1	1		3	1	0	0	6	4
30		113	2002	25	21	26		8	16	2	0	72	26
31		23	2004	3	5	7	3	3		0	0	21	0
32		5	2004	0	0	2	1	1		0	0	4	0
33		8	2004	2	2	1	2	0		0	0	7	0
34		15	2004	1	3	2	3	3		0	0	12	0
35		9	2004	0	2	0	2	3		1	0	7	1
36		21	2004	2	3	3	2	7		1	0	17	1
37		0	2004	0	0	0	0	0		0	0	0	0
38		1	2004	0	0	0	0	0		0	0	0	0
40		1	2004	0	0	0	0	0		0	0	0	0
41		0	2003	0	0	0	0		0	0	0	0	0
42		28	2003	2	8	9	3		3	1	0	22	4
46		12	2003	0	3	2	5		2	0	0	10	2
48		2	2003	0	0	2	0		0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	11	2	2	4
2	4	1	1	2	2	4
2	4	0	2	2	0	0
2	4	5	15	2	10	20
2	4	8	9	2	16	32
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	2	4	2	4	8
2	4	7	12	2	14	28
2	4	3	6	2	6	12
3	3	0	0	1	0	0
3	3	10	1	1	10	10
3	3	3	5	1	3	3
3	3	6	4	1	6	6
3	3	72	26	1	72	72
5	1	21	0	0.2	4.2	0.84
5	1	4	0	0.2	0.8	0.16
5	1	7	0	0.2	1.4	0.28
5	1	12	0	0.2	2.4	0.48
5	1	7	1	0.2	1.4	0.28
5	1	17	1	0.2	3.4	0.68
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
4	2	0	0	0.5	0	0
4	2	22	4	0.5	11	5.5
4	2	10	2	0.5	5	2.5
4	2	2	0	0.5	1	0.5
		$\Sigma L_{a(j)}=$	104	$\Sigma r_{d(j)}K_{b(j)}=$	175.6	210.22

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	104
	π	175.6
STEP 2	$VAR(\lambda)$	104
	$VAR(\pi)$	210.22
STEP 3	δ	71.6
	θ	0.588245
STEP 4	$VAR(\delta)$	314.22
	$VAR(\theta)$	0.00561

Reduction	0.411755
std deviation	0.149794

41% +/- 15% result is statistically significant

Summary Not Dry

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		27	2001	1	6		3	5	4	2	0	7	14
10		2	2001	1	0		0	1	0	0	0	1	1
11		4	2001	0	0		3	1	0	0	0	0	4
12		34	2001	5	3		1	10	9	0	0	8	20
13		35	2001	6	3		6	5	5	1	0	9	17
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		16	2001	1	3		1	4	4	2	0	4	11
17		36	2001	3	6		6	7	6	3	0	9	22
25		14	2002	0	4		5	2	0	0	0	4	7
26		0	2002	0	0	0		0	0	0	0	0	0
27		21	2002	7	4	2		0	2	0	0	13	2
28		13	2002	1	3	1		5	2	0	0	5	7
29		19	2002	5	2	1		3	2	0	0	8	5
30		140	2002	28	30	28		13	18	5	0	86	36
31		31	2004	3	6	8	5	7		0	0	29	0
32		6	2004	1	0	2	1	1		0	0	5	0
33		9	2004	2	2	1	3	0		0	0	8	0
34		22	2004	3	4	3	3	4		0	0	17	0
35		12	2004	0	3	1	2	3		1	0	9	1
36		25	2004	2	4	5	3	7		1	0	21	1
37		0	2004	0	0	0	0	0		0	0	0	0
38		2	2004	0	0	0	0	1		0	0	1	0
40		5	2004	0	0	0	2	1		0	0	3	0
41		1	2003	1	0	0	0		0	0	0	1	0
42		38	2003	3	12	11	3		4	1	0	29	5
46		27	2003	0	6	3	9		5	0	0	18	5
48		2	2003	0	0	2	0		0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	7	14	2	14	28
2	4	1	1	2	2	4
2	4	0	4	2	0	0
2	4	8	20	2	16	32
2	4	9	17	2	18	36
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	4	11	2	8	16
2	4	9	22	2	18	36
2	4	4	7	2	8	16
3	3	0	0	1	0	0
3	3	13	2	1	13	13
3	3	5	7	1	5	5
3	3	8	5	1	8	8
3	3	86	36	1	86	86
5	1	29	0	0.2	5.8	1.16
5	1	5	0	0.2	1	0.2
5	1	8	0	0.2	1.6	0.32
5	1	17	0	0.2	3.4	0.68
5	1	9	1	0.2	1.8	0.36
5	1	21	1	0.2	4.2	0.84
5	1	0	0	0.2	0	0
5	1	1	0	0.2	0.2	0.04
5	1	3	0	0.2	0.6	0.12
4	2	1	0	0.5	0.5	0.25
4	2	29	5	0.5	14.5	7.25
4	2	18	5	0.5	9	4.5
4	2	2	0	0.5	1	0.5
		$\Sigma L_{a(j)}=$	158	$\Sigma r_{d(j)}K_{b(j)}=$	239.6	296.22

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	158
	π	239.6
STEP 2	VAR(λ)	158
	VAR(π)	296.22
STEP 3	δ	81.6
	θ	0.656047
STEP 4	VAR(δ)	454.22
	VAR(θ)	0.004894

Reduction	0.343953
std deviation	0.139917

34% +/- 14% result is statistically significant

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		12	2001	2	2		3	1	0	3	0	4	7
10		3	2001	2	0		1	0	0	0	0	2	1
11		3	2001	0	0		1	0	0	0	0	0	1
12		25	2001	6	2		2	6	3	4	0	8	15
13		21	2001	5	2		1	3	1	4	0	7	9
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		1	2001	0	1		0	0	0	0	0	1	0
17		25	2001	4	3		2	4	5	5	0	7	16
25		13	2002	3	2		1	3	3	1	0	5	8
26		0	2002	0	0	0		0	0	0	0	0	0
27		13	2002	0	2	2		2	2	1	0	4	5
28		9	2002	0	2	1		1	3	0	0	3	4
29		6	2002	2	0	0		0	2	0	0	2	2
30		85	2002	14	19	14		9	9	3	0	47	21
31		17	2004	3	5	2	3	2		0	0	15	0
32		7	2004	0	1	1	2	3		0	0	7	0
33		13	2004	2	3	1	2	0		2	0	8	2
34		19	2004	3	1	4	5	2		0	0	15	0
35		8	2004	0	1	0	0	1		3	0	2	3
36		25	2004	3	4	3	4	6		2	0	20	2
37		0	2004	0	0	0	0	0		0	0	0	0
38		1	2004	0	0	0	0	0		0	0	0	0
40		3	2004	0	0	0	0	1		0	0	1	0
41		1	2003	0	0	0	1		0	0	0	1	0
42		27	2003	2	5	5	1		9	3	0	13	12
46		13	2003	1	2	1	4		2	0	0	8	2
48		8	2003	0	2	2	2		0	0	0	6	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	4	7	2	8	16
2	4	2	1	2	4	8
2	4	0	1	2	0	0
2	4	8	15	2	16	32
2	4	7	9	2	14	28
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	1	0	2	2	4
2	4	7	16	2	14	28
2	4	5	8	2	10	20
3	3	0	0	1	0	0
3	3	4	5	1	4	4
3	3	3	4	1	3	3
3	3	2	2	1	2	2
3	3	47	21	1	47	47
5	1	15	0	0.2	3	0.6
5	1	7	0	0.2	1.4	0.28
5	1	8	2	0.2	1.6	0.32
5	1	15	0	0.2	3	0.6
5	1	2	3	0.2	0.4	0.08
5	1	20	2	0.2	4	0.8
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
5	1	1	0	0.2	0.2	0.04
4	2	1	0	0.5	0.5	0.25
4	2	13	12	0.5	6.5	3.25
4	2	8	2	0.5	4	2
4	2	6	0	0.5	3	1.5
		$\Sigma L_{a(j)}=$	110	$\Sigma r_{d(j)}K_{b(j)}=$	151.6	201.72

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	110
	π	151.6
STEP 2	VAR(λ)	110
	VAR(π)	201.72
STEP 3	δ	41.6
	θ	0.71928
STEP 4	VAR(δ)	311.72
	VAR(θ)	0.009084

Reduction	0.28072
std deviation	0.190621

28% +/- 19% result is statistically significant

Summary Intersection Only

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		63	2001	7	12		8	9	10	4	0	19	31
10		9	2001	3	2		1	2	0	0	0	5	3
11		6	2001	0	0		3	1	0	0	0	0	4
12		73	2001	17	9		7	14	11	2	0	26	34
13		80	2001	16	8		8	8	7	11	0	24	34
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		27	2001	3	4		3	7	5	3	0	7	18
17		93	2001	10	15		18	14	12	6	0	25	50
25		38	2002	8	7		6	5	6	3	0	15	20
26		0	2002	0	0	0		0	0	0	0	0	0
27		38	2002	6	5	5		5	4	3	0	16	12
28		34	2002	4	8	3		6	7	0	0	15	13
29		46	2002	10	6	8		7	5	2	0	24	14
30		291	2002	47	51	60		45	35	11	0	158	91
31		64	2004	11	11	17	11	8		1	0	58	1
32		20	2004	3	2	4	2	4		1	0	15	1
33		47	2004	8	11	8	8	4		3	0	39	3
34		50	2004	5	8	12	10	5		1	0	40	1
35		22	2004	1	4	3	2	4		3	0	14	3
36		107	2004	16	17	15	16	22		4	0	86	4
37		0	2004	0	0	0	0	0		0	0	0	0
38		4	2004	0	0	0	0	2		1	0	2	1
40		3	2004	0	0	0	0	0		0	0	0	0
41		3	2003	0	0	0	2		0	1	0	2	1
42		93	2003	7	23	18	13		10	8	0	61	18
46		40	2003	2	8	4	11		8	0	0	25	8
48		18	2003	0	2	6	2		4	2	0	10	6

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	19	31	2	38	76
2	4	5	3	2	10	20
2	4	0	4	2	0	0
2	4	26	34	2	52	104
2	4	24	34	2	48	96
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	7	18	2	14	28
2	4	25	50	2	50	100
2	4	15	20	2	30	60
3	3	0	0	1	0	0
3	3	16	12	1	16	16
3	3	15	13	1	15	15
3	3	24	14	1	24	24
3	3	158	91	1	158	158
5	1	58	1	0.2	11.6	2.32
5	1	15	1	0.2	3	0.6
5	1	39	3	0.2	7.8	1.56
5	1	40	1	0.2	8	1.6
5	1	14	3	0.2	2.8	0.56
5	1	86	4	0.2	17.2	3.44
5	1	0	0	0.2	0	0
5	1	2	1	0.2	0.4	0.08
5	1	0	0	0.2	0	0
4	2	2	1	0.5	1	0.5
4	2	61	18	0.5	30.5	15.25
4	2	25	8	0.5	12.5	6.25
4	2	10	6	0.5	5	2.5
		$\Sigma L_{a(j)}=$	371	$\Sigma r_{d(j)}K_{b(j)}=$	554.8	731.66

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	371
	π	554.8
STEP 2	VAR(λ)	371
	VAR(π)	731.66
STEP 3	δ	183.8
	θ	0.667124
STEP 4	VAR(δ)	1102.66
	VAR(θ)	0.002247

Reduction	0.332876
std deviation	0.094801

33% +/- 9% result is statistically significant

Summary Rear End

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		19	2001	2	4		1	0	4	4	0	6	9
10		2	2001	0	1		0	0	0	0	0	1	0
11		3	2001	0	0		1	0	0	0	0	0	1
12		25	2001	4	1		3	5	6	1	0	5	15
13		35	2001	9	4		3	1	4	5	0	13	13
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		14	2001	2	2		0	3	4	3	0	4	10
17		62	2001	5	10		9	11	10	2	0	15	32
25		8	2002	1	3		1	0	1	1	0	4	3
26		0	2002	0	0	0		0	0	0	0	0	0
27		21	2002	2	3	3		1	3	3	0	8	7
28		21	2002	3	6	1		2	5	0	0	10	7
29		22	2002	5	6	2		2	1	2	0	13	5
30		164	2002	29	34	36		15	24	8	0	99	47
31		33	2004	8	5	8	5	1		1	0	27	1
32		14	2004	3	3	3	1	2		0	0	12	0
33		33	2004	4	8	6	8	1		1	0	27	1
34		21	2004	2	4	6	3	1		0	0	16	0
35		23	2004	2	2	2	2	5		2	0	13	2
36		39	2004	6	9	7	5	8		0	0	35	0
37		0	2004	0	0	0	0	0		0	0	0	0
38		0	2004	0	0	0	0	0		0	0	0	0
40		1	2004	0	0	0	0	0		0	0	0	0
41		0	2003	0	0	0	0		0	0	0	0	0
42		44	2003	6	9	9	6		6	5	0	30	11
46		16	2003	1	3	3	3		2	0	0	10	2
48		12	2003	0	4	4	2		2	0	0	10	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	6	9	2	12	24
2	4	1	0	2	2	4
2	4	0	1	2	0	0
2	4	5	15	2	10	20
2	4	13	13	2	26	52
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	4	10	2	8	16
2	4	15	32	2	30	60
2	4	4	3	2	8	16
3	3	0	0	1	0	0
3	3	8	7	1	8	8
3	3	10	7	1	10	10
3	3	13	5	1	13	13
3	3	99	47	1	99	99
5	1	27	1	0.2	5.4	1.08
5	1	12	0	0.2	2.4	0.48
5	1	27	1	0.2	5.4	1.08
5	1	16	0	0.2	3.2	0.64
5	1	13	2	0.2	2.6	0.52
5	1	35	0	0.2	7	1.4
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
4	2	0	0	0.5	0	0
4	2	30	11	0.5	15	7.5
4	2	10	2	0.5	5	2.5
4	2	10	2	0.5	5	2.5
		$\Sigma L_{a(j)}=$	168	$\Sigma r_{d(j)}K_{b(j)}=$	277	339.7

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	168
	π	277
STEP 2	VAR(λ)	168
	VAR(π)	339.7
STEP 3	δ	109
	θ	0.603825
STEP 4	VAR(δ)	507.7
	VAR(θ)	0.003751

Reduction	0.396175
std deviation	0.122494

40% +/- 12% result is statistically significant

Appendix E: Resurfacing Analysis – With Treatment Year Omitted

Summary (Treatment year omit)

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		2	2	0	0	1	0	1	5
1		2	2	2	4	1	0	1	11
0		2	0	3	0	4	0	0	9
3		2	3	2	5	4	0	3	16
6		6	1	4	9	4	0	6	24
0		0	1	0	0	1	0	0	2
41	61		57	65	69	28	0	102	219
63	52		38	52	43	20	0	115	153
0	1		2	6	2	2	0	1	12
0	0		0	0	1	1	0	0	2
2	4		3	3	4	4	0	6	14
0	0		0	1	2	0	0	0	3
								235	470

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	5	5	5	25
1	5	1	11	5	5	25
1	5	0	9	5	0	0
1	5	3	16	5	15	75
1	5	6	24	5	30	150
1	5	0	2	5	0	0
2	4	102	219	2	204	408
2	4	115	153	2	230	460
2	4	1	12	2	2	4
2	4	0	2	2	0	0
2	4	6	14	2	12	24
2	4	0	3	2	0	0
		$\Sigma L_{a(j)}=$	470	$\Sigma r_{d(j)}K_{b(j)}=$	503	1171

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2 Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	470
	π	503
STEP 2	$VAR(\lambda)$	470
	$VAR(\pi)$	1171
STEP 3	δ	33
	θ	0.930089
STEP 4	$VAR(\delta)$	1641
	$VAR(\theta)$	0.005791

0.069911

Reduction	0.069911
std deviation	0.152192

7% +/- 15% result is NOT statistically significar

				Before Treatment									
				After Treatment									
Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
1		74	2001	1		2	1	0	0	0	0	1	3
3		10	2001	0		0	1	2	3	0	0	0	6
4		9	2001	0		1	0	2	0	0	0	0	3
5		87	2001	1		1	3	1	4	3	0	1	12
6		90	2001	4		4	0	2	4	2	0	4	12
7		0	2001	0		0	1	0	0	1	0	0	2
18		0	2001	37	49		42	49	49	21	0	86	161
19		33	2001	40	34		28	34	29	12	0	74	103
21		135	2001	0	0		2	2	1	2	0	0	7
22		41	2002	0	0		0	0	1	1	0	0	2
23		0	2002	1	2		2	1	3	3	0	3	9
24		46	2002	0	0		0	1	2	0	0	0	3
												169	323

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	3	5	5	25
1	5	0	6	5	0	0
1	5	0	3	5	0	0
1	5	1	12	5	5	25
1	5	4	12	5	20	100
1	5	0	2	5	0	0
2	4	86	161	2	172	344
2	4	74	103	2	148	296
2	4	0	7	2	0	0
2	4	0	2	2	0	0
2	4	3	9	2	6	12
2	4	0	3	2	0	0
		$\Sigma L_{a(j)}=$	323	$\Sigma r_{d(j)}K_{b(j)}=$	356	802

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	323	
	π	356	
STEP 2	VAR(λ)	323	
	VAR(π)	802	
STEP 3	δ	33	
	θ	0.901598	0.098402
STEP 4	VAR(δ)	1125	
	VAR(θ)	0.007565	

Reduction	0.098402
std deviation	0.173949

10% +/- 17% result is NOT statistically significar

				Before Treatment									
				After Treatment									
Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
1		74	2001	0		0	1	0	0	0	0	0	1
3		10	2001	1		1	1	0	1	0	0	1	3
4		9	2001	0		1	0	1	0	2	0	0	4
5		87	2001	2		1	0	1	0	0	0	2	2
6		90	2001	2		2	0	0	3	2	0	2	7
7		0	2001	0		0	0	0	0	0	0	0	0
18		0	2001	2	10		11	9	12	4	0	12	36
19		33	2001	18	15		6	13	9	5	0	33	33
21		135	2001	0	0		0	3	0	0	0	0	3
22		41	2002	0	0		0	0	0	0	0	0	0
23		0	2002	1	2		0	2	1	1	0	3	4
24		46	2002	0	0		0	0	0	0	0	0	0
												53	93

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	1	5	0	0
1	5	1	3	5	5	25
1	5	0	4	5	0	0
1	5	2	2	5	10	50
1	5	2	7	5	10	50
1	5	0	0	5	0	0
2	4	12	36	2	24	48
2	4	33	33	2	66	132
2	4	0	3	2	0	0
2	4	0	0	2	0	0
2	4	3	4	2	6	12
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	93	$\Sigma r_{d(j)}K_{b(j)}=$	121	317

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	93	
	π	121	
STEP 2	$VAR(\lambda)$	93	
	$VAR(\pi)$	317	
STEP 3	δ	28	
	θ	0.752306	0.247694
STEP 4	$VAR(\delta)$	410	
	$VAR(\theta)$	0.017571	

Reduction	0.247694
std deviation	0.265108

25% +/- 27% result is NOT statistically significar

Not Dry

Before Treatment
After Treatment

Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
1		74	2001	0		0	1	0	0	1	0	0	2
3		10	2001	1		2	1	0	1	1	0	1	5
4		9	2001	0		1	0	1	0	4	0	0	6
5		87	2001	2		1	0	1	1	1	0	2	4
6		90	2001	2		2	1	2	5	2	0	2	12
7		0	2001	0		0	0	0	0	0	0	0	0
18		0	2001	4	12		15	16	20	7	0	16	58
19		33	2001	23	18		10	18	14	8	0	41	50
21		135	2001	0	1		0	4	1	0	0	1	5
22		41	2002	0	0		0	0	0	0	0	0	0
23		0	2002	1	2		1	2	1	1	0	3	5
24		46	2002	0	0		0	0	0	0	0	0	0
												66	147

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	2	5	0	0
1	5	1	5	5	5	25
1	5	0	6	5	0	0
1	5	2	4	5	10	50
1	5	2	12	5	10	50
1	5	0	0	5	0	0
2	4	16	58	2	32	64
2	4	41	50	2	82	164
2	4	1	5	2	2	4
2	4	0	0	2	0	0
2	4	3	5	2	6	12
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	147	$\Sigma r_{d(j)}K_{b(j)}=$	147	369

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2 Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	147
	π	147
STEP 2	VAR(λ)	147
	VAR(π)	369
STEP 3	δ	0
	θ	0.98321
STEP 4	VAR(δ)	516
	VAR(θ)	0.022315

0.01679

Reduction	0.01679
std deviation	0.298766

2% +/- 30% result is NOT statistically significar

Severe

🟨 Before Treatment
🟩 After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	1		1	0	0	0	1	0	1	2
3		10	2001	0		2	1	0	0	0	0	0	3
4		9	2001	0		1	0	0	0	1	0	0	2
5		87	2001	0		1	1	0	0	1	0	0	3
6		90	2001	2		0	0	0	1	1	0	2	2
7		0	2001	0		0	0	0	0	1	0	0	1
18		0	2001	11	13		10	10	17	10	0	24	47
19		33	2001	12	4		4	8	8	8	0	16	28
21		135	2001	0	0		1	3	0	1	0	0	5
22		41	2002	0	0		0	0	0	0	0	0	0
23		0	2002	0	0		0	0	2	0	0	0	2
24		46	2002	0	0		0	0	1	0	0	0	1
												43	96

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	2	5	5	25
1	5	0	3	5	0	0
1	5	0	2	5	0	0
1	5	0	3	5	0	0
1	5	2	2	5	10	50
1	5	0	1	5	0	0
2	4	24	47	2	48	96
2	4	16	28	2	32	64
2	4	0	5	2	0	0
2	4	0	0	2	0	0
2	4	0	2	2	0	0
2	4	0	1	2	0	0
		$\Sigma L_{a(j)}=$	96	$\Sigma r_{d(j)}K_{b(j)}=$	95	235

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	96	
	π	95	
STEP 2	VAR(λ)	96	
	VAR(π)	235	
STEP 3	δ	-1	
	θ	0.984881	0.015119
STEP 4	VAR(δ)	331	
	VAR(θ)	0.033589	

Reduction	0.015119
std deviation	0.366548

2% +/- 37% result is NOT statistically significar

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	1		2	2	0	0	0	0	1	4
3		10	2001	1		2	2	2	3	0	0	1	9
4		9	2001	0		2	0	1	0	2	0	0	5
5		87	2001	2		2	3	2	2	3	0	2	12
6		90	2001	3		5	1	3	5	2	0	3	16
7		0	2001	0		0	0	0	0	0	0	0	0
18		0	2001	34	53		43	50	51	21	0	87	165
19		33	2001	53	45		26	42	24	15	0	98	107
21		135	2001	0	1		2	5	2	1	0	1	10
22		41	2002	0	0		0	0	0	1	0	0	1
23		0	2002	2	4		3	3	3	2	0	6	11
24		46	2002	0	0		0	1	1	0	0	0	2
												199	342

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	4	5	5	25
1	5	1	9	5	5	25
1	5	0	5	5	0	0
1	5	2	12	5	10	50
1	5	3	16	5	15	75
1	5	0	0	5	0	0
2	4	87	165	2	174	348
2	4	98	107	2	196	392
2	4	1	10	2	2	4
2	4	0	1	2	0	0
2	4	6	11	2	12	24
2	4	0	2	2	0	0
		$\Sigma L_{a(j)}=$	342	$\Sigma r_{d(j)}K_{b(j)}=$	419	943

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	342	
	π	419	
STEP 2	$VAR(\lambda)$	342	
	$VAR(\pi)$	943	
STEP 3	δ	77	
	θ	0.811868	0.188132
STEP 4	$VAR(\delta)$	1285	
	$VAR(\theta)$	0.005409	

Reduction	0.188132
std deviation	0.147098

19% +/- 15% result is NOT statistically significar

Rear End

Before Treatment 🟨
After Treatment 🟩

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		74	2001	0		0	0	0	0	0	0	0	0
3		10	2001	0		1	0	0	2	0	0	0	3
4		9	2001	0		0	0	1	0	2	0	0	3
5		87	2001	1		1	1	1	2	1	0	1	6
6		90	2001	5		2	1	1	4	0	0	5	8
7		0	2001	0		0	0	0	0	1	0	0	1
18		0	2001	14	24		30	30	27	12	0	38	99
19		33	2001	26	16		16	16	16	9	0	42	57
21		135	2001	0	0		0	1	0	1	0	0	2
22		41	2002	0	0		0	0	0	1	0	0	1
23		0	2002	1	0		2	0	1	2	0	1	5
24		46	2002	0	0		0	0	0	0	0	0	0
												87	185

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	0	5	0	0
1	5	0	3	5	0	0
1	5	0	3	5	0	0
1	5	1	6	5	5	25
1	5	5	8	5	25	125
1	5	0	1	5	0	0
2	4	38	99	2	76	152
2	4	42	57	2	84	168
2	4	0	2	2	0	0
2	4	0	1	2	0	0
2	4	1	5	2	2	4
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	185	$\Sigma r_{d(j)}K_{b(j)}=$	192	474

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	185	
	π	192	
STEP 2	$VAR(\lambda)$	185	
	$VAR(\pi)$	474	
STEP 3	δ	7	
	θ	0.95131	0.04869
STEP 4	$VAR(\delta)$	659	
	$VAR(\theta)$	0.016111	

Reduction	0.04869
std deviation	0.25386

5% +/- 25% result is NOT statistically significar

Appendix F: Microsurfacing and Resurfacing Combined Analysis With and Without Treatment Year

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		74	2001	9	12	15	10	10	10	8	0	21	53
10		10	2001	3	2	1	1	3	0	0	0	5	5
11		9	2001	0	1	3	4	1	0	0	0	1	8
12		0	2001	0	0	0	0	0	0	0	0	0	0
13		90	2001	17	10	26	9	8	8	12	0	27	63
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
16		33	2001	3	6	2	3	7	6	6	0	9	24
17		135	2001	17	20	22	25	20	21	10	0	37	98
25		41	2002	8	8	5	6	5	6	3	0	16	25
26		0	2002	0	0	0	0	0	0	0	0	0	0
27		46	2002	7	6	5	11	7	7	3	0	18	28
28		40	2002	5	9	3	8	7	8	0	0	17	23
29		54	2002	11	8	8	9	8	7	3	0	27	27
30		352	2002	56	59	72	49	57	44	15	0	187	165
31		73	2004	14	13	19	11	9	6	1	0	66	7
32		28	2004	5	3	4	3	4	7	2	0	19	9
33		66	2004	12	12	10	14	5	9	4	0	53	13
34		64	2004	7	10	13	13	7	13	1	0	50	14
35		34	2004	2	5	3	3	6	10	5	0	19	15
36		125	2004	18	20	21	18	25	19	4	0	102	23
37		0	2004	0	0	0	0	0	0	0	0	0	0
38		4	2004	0	0	0	0	2	1	1	0	2	2
40		12	2004	0	0	0	2	1	9	0	0	3	9
41		5	2003	1	0	0	2	0	0	2	0	3	2
42		104	2003	9	23	20	15	14	14	9	0	67	37
46		48	2003	3	10	4	12	8	11	0	0	29	19
48		26	2003	0	4	6	4	2	8	2	0	14	12
1		74	2001	1	1	2	2	0	0	1	0	1	6
3		10	2001	1	1	2	2	2	4	1	0	1	12
4		9	2001	0	1	2	0	3	0	4	0	0	10
5		0	2001	3	3	2	3	2	5	4	0	3	19
6		90	2001	6	4	6	1	4	9	4	0	6	28
7		0	2001	0	0	0	1	0	0	1	0	0	2
18		0	2001	41	61	67	57	65	69	28	0	102	286
19		33	2001	63	52	56	38	52	43	20	0	115	209
21		135	2001	0	1	2	2	6	2	2	0	1	14
22		41	2002	0	0	0	0	0	1	1	0	0	2
23		0	2002	2	4	0	3	3	4	4	0	6	14
24		46	2002	0	0	0	0	1	2	0	0	0	3
												1027	1286

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	21	53	2.5	52.5	131.25
2	5	5	5	2.5	12.5	31.25
2	5	1	8	2.5	2.5	6.25
2	5	0	0	2.5	0	0
2	5	27	63	2.5	67.5	168.75
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
2	5	9	24	2.5	22.5	56.25
2	5	37	98	2.5	92.5	231.25
2	5	16	25	2.5	40	100
3	4	0	0	1.333333	0	0
3	4	18	28	1.333333	24	32
3	4	17	23	1.333333	22.66667	30.22222
3	4	27	27	1.333333	36	48
3	4	187	165	1.333333	249.3333	332.4444
5	2	66	7	0.4	26.4	10.56
5	2	19	9	0.4	7.6	3.04
5	2	53	13	0.4	21.2	8.48
5	2	50	14	0.4	20	8
5	2	19	15	0.4	7.6	3.04
5	2	102	23	0.4	40.8	16.32
5	2	0	0	0.4	0	0
5	2	2	2	0.4	0.8	0.32
5	2	3	9	0.4	1.2	0.48
4	3	3	2	0.75	2.25	1.6875
4	3	67	37	0.75	50.25	37.6875
4	3	29	19	0.75	21.75	16.3125
4	3	14	12	0.75	10.5	7.875
1	6	1	6	6	6	36
1	6	1	12	6	6	36
1	6	0	10	6	0	0
1	6	3	19	6	18	108
1	6	6	28	6	36	216
1	6	0	2	6	0	0
2	5	102	286	2.5	255	637.5
2	5	115	209	2.5	287.5	718.75
2	5	1	14	2.5	2.5	6.25
2	5	0	2	2.5	0	0
2	5	6	14	2.5	15	37.5
2	5	0	3	2.5	0	0
		$\Sigma L_{a(j)}=$	1286	$\Sigma r_{d(j)}K_{b(j)}=$	1458.35	3077.469

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	1286	
	π	1458.35	
STEP 2	VAR(λ)	1286	
	VAR(π)	3077.469	
STEP 3	δ	172.35	
	θ	0.880544	0.119456
STEP 4	VAR(δ)	4363.469	
	VAR(θ)	0.00172	

Reduction	0.119456
std deviation	0.082943

12% +/- 8% result is statistically significant

Summary (treatment year omit)

🟨 Before Treatment
🟩 After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		74	2001	9	12		10	10	10	8	0	21	38
10		10	2001	3	2		1	3	0	0	0	5	4
11		9	2001	0	1		4	1	0	0	0	1	5
12		0	2001	0	0		0	0	0	0	0	0	0
13		90	2001	17	10		9	8	8	12	0	27	37
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
16		33	2001	3	6		3	7	6	6	0	9	22
17		135	2001	17	20		25	20	21	10	0	37	76
25		41	2002	8	8		6	5	6	3	0	16	20
26		0	2002	0	0	0		0	0	0	0	0	0
27		46	2002	7	6	5		7	7	3	0	18	17
28		40	2002	5	9	3		7	8	0	0	17	15
29		54	2002	11	8	8		8	7	3	0	27	18
30		352	2002	56	59	72		57	44	15	0	187	116
31		73	2004	14	13	19	11	9		1	0	66	1
32		28	2004	5	3	4	3	4		2	0	19	2
33		66	2004	12	12	10	14	5		4	0	53	4
34		64	2004	7	10	13	13	7		1	0	50	1
35		34	2004	2	5	3	3	6		5	0	19	5
36		125	2004	18	20	21	18	25		4	0	102	4
37		0	2004	0	0	0	0	0		0	0	0	0
38		4	2004	0	0	0	0	2		1	0	2	1
40		12	2004	0	0	0	2	1		0	0	3	0
41		5	2003	1	0	0	2		0	2	0	3	2
42		104	2003	9	23	20	15		14	9	0	67	23
46		48	2003	3	10	4	12		11	0	0	29	11
48		26	2003	0	4	6	4		8	2	0	14	10
1		74	2001	1		2	2	0	0	1	0	1	5
3		10	2001	1		2	2	2	4	1	0	1	11
4		9	2001	0		2	0	3	0	4	0	0	9
5		0	2001	3		2	3	2	5	4	0	3	16
6		90	2001	6		6	1	4	9	4	0	6	24
7		0	2001	0		0	1	0	0	1	0	0	2
18		0	2001	41	61		57	65	69	28	0	102	219
19		33	2001	63	52		38	52	43	20	0	115	153
21		135	2001	0	1		2	6	2	2	0	1	12
22		41	2002	0	0		0	0	1	1	0	0	2
23		0	2002	2	4		3	3	4	4	0	6	14
24		46	2002	0	0		0	1	2	0	0	0	3
												1027	902

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	21	38	2	42	84
2	4	5	4	2	10	20
2	4	1	5	2	2	4
2	4	0	0	2	0	0
2	4	27	37	2	54	108
2	4	0	0	2	0	0
2	4	0	0	2	0	0
2	4	9	22	2	18	36
2	4	37	76	2	74	148
2	4	16	20	2	32	64
3	3	0	0	1	0	0
3	3	18	17	1	18	18
3	3	17	15	1	17	17
3	3	27	18	1	27	27
3	3	187	116	1	187	187
5	1	66	1	0.2	13.2	2.64
5	1	19	2	0.2	3.8	0.76
5	1	53	4	0.2	10.6	2.12
5	1	50	1	0.2	10	2
5	1	19	5	0.2	3.8	0.76
5	1	102	4	0.2	20.4	4.08
5	1	0	0	0.2	0	0
5	1	2	1	0.2	0.4	0.08
5	1	3	0	0.2	0.6	0.12
4	2	3	2	0.5	1.5	0.75
4	2	67	23	0.5	33.5	16.75
4	2	29	11	0.5	14.5	7.25
4	2	14	10	0.5	7	3.5
1	5	1	5	5	5	25
1	5	1	11	5	5	25
1	5	0	9	5	0	0
1	5	3	16	5	15	75
1	5	6	24	5	30	150
1	5	0	2	5	0	0
2	4	102	219	2	204	408
2	4	115	153	2	230	460
2	4	1	12	2	2	4
2	4	0	2	2	0	0
2	4	6	14	2	12	24
2	4	0	3	2	0	0
		$\Sigma L_{a(j)}=$	902	$\Sigma r_{d(j)}K_{b(j)}=$	1103.3	1924.81

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	902	
	π	1103.3	
STEP 2	VAR(λ)	902	
	VAR(π)	1924.81	
STEP 3	δ	201.3	
	θ	0.816257	0.183743
STEP 4	VAR(δ)	2826.81	
	VAR(θ)	0.001787	

Reduction	0.183743
std deviation	0.084535

18% +/- 8% result is statistically significant

Appendix G: Microsurfacing Normalized Analysis

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	9	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	87	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	5	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	1	3	4	1	0	0	0	1	8
12	19	9	13	7	17	16	6	0	28	59
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
41	1	0	0	2	0	0	2	0	3	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	8	2.5	2.5	6.25
2	5	28	59	2.5	70	175
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	3	2	0.75	2.25	1.6875
		$\Sigma L_{a(j)}=$	69	$\Sigma r_{d(j)}K_{b(j)}=$	74.75	182.9375

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	69
	π	74.75
STEP 2	$VAR(\lambda)$	69
	$VAR(\pi)$	182.9375
STEP 3	δ	5.75
	θ	0.893813
STEP 4	$VAR(\delta)$	251.9375
	$VAR(\theta)$	0.03538

0.106187

Reduction 0.106187
std deviation 0.376191

-56% +/- 155% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	5	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	53	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	4	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	1	3	1	0	0	0	0	1	4
12	14	6	7	6	7	7	6	0	20	33
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	2	0	2	0	0	4

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	4	2.5	2.5	6.25
2	5	20	33	2.5	50	125
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	0	4	0.75	0	0
		$\Sigma L_{a(j)}=$	41	$\Sigma r_{d(j)}K_{b(j)}=$	52.5	131.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	41
	π	52.5
STEP 2	$VAR(\lambda)$	41
	$VAR(\pi)$	131.25
STEP 3	δ	11.5
	θ	0.745455
STEP 4	$VAR(\delta)$	172.25
	$VAR(\theta)$	0.036461

Reduction	0.254545
std deviation	0.381893

25% +/- 38% result is NOT statistically significant

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	2	5590	5630	5220	3410	5090			4988	2494	2	2001	0	0	0	2	0	0	0	0	0	2
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	26	2001	2	3	6	1	8	6	0	0	5	21
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001	0	0	0	0	0	0	0	0	0	0
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001	0	0	0	0	0	0	0	0	0	0
41	2	1940	3460	3620	3790	3360	2420		3098	1549	0	2003	0	0	0	0	0	0	0	0	0	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	0	2	2.5	0	0
2	5	5	21	2.5	12.5	31.25
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	0	0	0.75	0	0
		$\Sigma L_{a(j)}=$	23	$\Sigma r_{d(j)}K_{b(j)}=$	12.5	31.25

Formulas:
$r_d(j) = T_a(j)/T_b(j)$
$\lambda = \Sigma L_a(j)$
$\pi = \Sigma r_d(j)K_b(j)$
$VAR(\lambda) = \Sigma La(j)$
$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*
$\delta = \pi - \lambda$
$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$
$VAR(\delta) = VAR(\pi) + VAR(\lambda)$
$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	23
	π	12.5
STEP 2	VAR(λ)	23
	VAR(π)	31.25
STEP 3	δ	-10.5
	θ	1.533333
STEP 4	VAR(δ)	54.25
	VAR(θ)	0.397531

Reduction	-0.53333
std deviation	1.261001

-53% +/- 126% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	4	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	34	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	1	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	0	0	3	1	0	0	0	0	4
12	5	3	6	1	10	9	0	0	8	26
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
41	1	0	0	0	0	0	0	0	1	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	0	4	2.5	0	0
2	5	8	26	2.5	20	50
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	1	0	0.75	0.75	0.5625
		$\Sigma L_{a(j)}=$	30	$\Sigma r_{d(j)}K_{b(j)}=$	20.75	50.5625

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	30
	π	20.75
STEP 2	VAR(λ)	30
	VAR(π)	50.5625
STEP 3	δ	-9.25
	θ	1.293843
STEP 4	VAR(δ)	80.5625
	VAR(θ)	0.202128

Reduction	-0.29384
std deviation	0.899172

-29% +/- 90% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	3	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	25	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	1	2003

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	0	2	1	0	0	0	0	0	3
6	2	2	2	6	3	4	0	8	17
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	1	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	0	3	2.5	0	0
2	5	8	17	2.5	20	50
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	1	0	0.75	0.75	0.5625
		$\Sigma L_{a(j)}$=	20	$\Sigma r_{d(j)}K_{b(j)}$=	20.75	50.5625

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	20
	π	20.75
STEP 2	VAR(λ)	20
	VAR(π)	50.5625
STEP 3	δ	0.75
	θ	0.862562
STEP 4	VAR(δ)	70.5625
	VAR(θ)	0.099765

Reduction	0.137438
std deviation	0.631713

14% +/- 63% result is NOT statistically significant

Summary Intersection Only

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	6	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	73	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	3	2003

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	0	2	3	1	0	0	0	0	6
17	9	13	7	14	11	2	0	26	47
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	2	0	0	1	0	2	1

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	0	6	2.5	0	0
2	5	26	47	2.5	65	162.5
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	2	1	0.75	1.5	1.125
		$\Sigma L_{a(j)}=$	54	$\Sigma r_{d(j)}K_{b(j)}=$	66.5	163.625

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	54
	π	66.5
STEP 2	VAR(λ)	54
	VAR(π)	163.625
STEP 3	δ	12.5
	θ	0.783057
STEP 4	VAR(δ)	217.625
	VAR(θ)	0.031657

Reduction	0.216943
std deviation	0.355848

22% +/- 36% result is NOT statistically significant

Summary Rear End

Before Treatment
After Treatment

Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
11		3	2001	0	0	2	1	0	0	0	0	0	3
12		25	2001	4	1	5	3	5	6	1	0	5	20
14		0	2001	0	0	0	0	0	0	0	0	0	0
15		0	2001	0	0	0	0	0	0	0	0	0	0
41		0	2003	0	0	0	0	0	0	0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	0	3	2.5	0	0
2	5	5	20	2.5	12.5	31.25
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
4	3	0	0	0.75	0	0
		$\Sigma L_{a(j)}=$	23	$\Sigma r_{d(j)}K_{b(j)}=$	12.5	31.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	23
	π	12.5
STEP 2	$VAR(\lambda)$	23
	$VAR(\pi)$	31.25
STEP 3	δ	-10.5
	θ	1.533333
STEP 4	$VAR(\delta)$	54.25
	$VAR(\theta)$	0.397531

Reduction	-0.53333
std deviation	1.261001

-53% +/- 126% result is statistically significant

Summary Total Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	6610	8950	10150	12180	11790		9611	9882	4941	10	2001	3	2	1	1	3	0	0	0	5	5
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	90	2001	17	10	26	9	8	8	12	0	27	63
16	2	9560	8590c	7240	10000	8960			8940	4470	33	2001	3	6	2	3	7	6	6	0	9	24
25	4	27440	21870	24930	26570	25290	22422		24754	6188	41	2002	8	8	5	6	5	6	3	0	16	25
27	2	9560	10180	10660	10580	10300		11633	10486	5243	46	2002	7	6	5	11	7	7	3	0	18	28
31	4	21995	23615	28780	22820	22550	22880		23773	5943	73	2004	14	13	19	11	9	6	1	0	66	7
32	2	n/a	5840	5950	6620	5940			6088	3044	28	2004	5	3	4	3	4	7	2	0	19	9
36	6	26190	31380	34200	36000	35000	32816		32598	5433	125	2004	18	20	21	18	25	19	4	0	102	23
38	2	12670	8580	8580	6430	8390	7761		8735	4368	4	2004	0	0	0	0	2	1	1	0	2	2
40	2	9520	10480	8630	9730	10680	8623		9611	4805	12	2004	0	0	0	2	1	9	0	0	3	9

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	5	5	2.5	12.5	31.25
2	5	27	63	2.5	67.5	168.75
2	5	9	24	2.5	22.5	56.25
2	5	16	25	2.5	40	100
3	4	18	28	1.333333	24	32
5	2	66	7	0.4	26.4	10.56
5	2	19	9	0.4	7.6	3.04
5	2	102	23	0.4	40.8	16.32
5	2	2	2	0.4	0.8	0.32
5	2	3	9	0.4	1.2	0.48
		$\Sigma L_{a(j)}$=	195	$\Sigma r_{d(j)}K_{b(j)}$=	243.3	418.97

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	195
	π	243.3
STEP 2	$VAR(\lambda)$	195
	$VAR(\pi)$	418.97
STEP 3	δ	48.3
	θ	0.795847
STEP 4	$VAR(\delta)$	613.97
	$VAR(\theta)$	0.007623

0.204153

Reduction 0.204153
std deviation 0.174616

20% +/- 17% result is statistically significant

Summary Dry Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	6610	8950	10150	12180	11790		9611	9882	4941	8	2001	2	2	1	1	2	0	0	0	4	4
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	55	2001	11	7	17	3	3	3	11	0	18	37
16	2	9560	8590c	7240	10000	8960			8940	4470	17	2001	2	3	1	2	3	2	4	0	5	12
25	4	27440	21870	24930	26570	25290	22422		24754	6188	27	2002	8	4	2	1	3	6	3	0	12	15
27	2	9560	10180	10660	10580	10300		11633	10486	5243	25	2002	0	2	3	5	7	5	3	0	5	20
31	4	21995	23615	28780	22820	22550	22880		23773	5943	42	2004	11	7	11	6	2	4	1	0	37	5
32	2	n/a	5840	5950	6620	5940			6088	3044	22	2004	4	3	2	2	3	6	2	0	14	8
36	6	26190	31380	34200	36000	35000	32816		32598	5433	100	2004	16	16	16	15	18	16	3	0	81	19
38	2	12670	8580	8580	6430	8390	7761		8735	4368	2	2004	0	0	0	0	1	0	1	0	1	1
40	2	9520	10480	8630	9730	10680	8623		9611	4805	7	2004	0	0	0	0	0	7	0	0	0	7

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	4	4	2.5	10	25
2	5	18	37	2.5	45	112.5
2	5	5	12	2.5	12.5	31.25
2	5	12	15	2.5	30	75
3	4	5	20	1.333333	6.666667	8.888889
5	2	37	5	0.4	14.8	5.92
5	2	14	8	0.4	5.6	2.24
5	2	81	19	0.4	32.4	12.96
5	2	1	1	0.4	0.4	0.16
5	2	0	7	0.4	0	0
		$\Sigma L_{a(j)}=$	128	$\Sigma r_{d(j)}K_{b(j)}=$	157.3667	273.9189

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	128
	π	157.3667
STEP 2	VAR(λ)	128
	VAR(π)	273.9189
STEP 3	δ	29.36667
	θ	0.804489
STEP 4	VAR(δ)	401.9189
	VAR(θ)	0.011949

Reduction	0.195511
std deviation	0.218625

20% +/- 22% result is NOT statistically significant

Summary Wet Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	2	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	23	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	7	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	11	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	15	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	23	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	5	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	21	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	1	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	1	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	1	0	0	0	1	0	0	0	1	1
13	6	2	6	3	3	3	0	0	8	15
16	1	1	1	0	2	1	1	0	2	5
25	0	3	2	5	1	0	0	0	3	8
27	5	3	2	4	0	1	0	0	10	5
31	3	5	7	3	3	2	0	0	21	2
32	0	0	2	1	1	1	0	0	4	1
36	2	3	3	2	7	3	1	0	17	4
38	0	0	0	0	0	1	0	0	0	1
40	0	0	0	0	0	1	0	0	0	1

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	1	2.5	2.5	6.25
2	5	8	15	2.5	20	50
2	5	2	5	2.5	5	12.5
2	5	3	8	2.5	7.5	18.75
3	4	10	5	1.333333	13.33333	17.77778
5	2	21	2	0.4	8.4	3.36
5	2	4	1	0.4	1.6	0.64
5	2	17	4	0.4	6.8	2.72
5	2	0	1	0.4	0	0
5	2	0	1	0.4	0	0
		$\Sigma L_{a(j)}=$	43	$\Sigma r_{d(j)}K_{b(j)}=$	65.13333	111.9978

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	43
	π	65.13333
STEP 2	VAR(λ)	43
	VAR(π)	111.9978
STEP 3	δ	22.13333
	θ	0.643204
STEP 4	VAR(δ)	154.9978
	VAR(θ)	0.0195

Reduction 0.356796
std deviation 0.279284

36% +/- 28% result is statistically significant

Summary Not Dry Bin 2

Before Treatment

After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	6610	8950	10150	12180	11790		9611	9882	4941	2	2001	1	0	0	0	1	0	0	0	1	1
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	35	2001	6	3	9	6	5	5	1	0	9	26
16	2	9560	8590c	7240	10000	8960			8940	4470	16	2001	1	3	1	1	4	4	2	0	4	12
25	4	27440	21870	24930	26570	25290	22422		24754	6188	14	2002	0	4	3	5	2	0	0	0	4	10
27	2	9560	10180	10660	10580	10300		11633	10486	5243	21	2002	7	4	2	6	0	2	0	0	13	8
31	4	21995	23615	28780	22820	22550	22880		23773	5943	31	2004	3	6	8	5	7	2	0	0	29	2
32	2	n/a	5840	5950	6620	5940			6088	3044	6	2004	1	0	2	1	1	1	0	0	5	1
36	6	26190	31380	34200	36000	35000	32816		32598	5433	25	2004	2	4	5	3	7	3	1	0	21	4
38	2	12670	8580	8580	6430	8390	7761		8735	4368	2	2004	0	0	0	0	1	1	0	0	1	1
40	2	9520	10480	8630	9730	10680	8623		9611	4805	5	2004	0	0	0	2	1	2	0	0	3	2

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	1	2.5	2.5	6.25
2	5	9	26	2.5	22.5	56.25
2	5	4	12	2.5	10	25
2	5	4	10	2.5	10	25
3	4	13	8	1.333333	17.33333	23.11111
5	2	29	2	0.4	11.6	4.64
5	2	5	1	0.4	2	0.8
5	2	21	4	0.4	8.4	3.36
5	2	1	1	0.4	0.4	0.16
5	2	3	2	0.4	1.2	0.48
		$\Sigma L_{a(j)}=$	67	$\Sigma r_{d(j)}K_{b(j)}=$	85.93333	145.0511

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	67
	π	85.93333
STEP 2	$VAR(\lambda)$	67
	$VAR(\pi)$	145.0511
STEP 3	δ	18.93333
	θ	0.764654
STEP 4	$VAR(\delta)$	212.0511
	$VAR(\theta)$	0.019441

Reduction	0.235346
std deviation	0.278858

24% +/- 28% result is statistically significant

Summary Severe Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	6610	8950	10150	12180	11790		9611	9882	4941	3	2001	2	0	0	1	0	0	0	0	2	1
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	21	2001	5	2	5	1	3	1	4	0	7	14
16	2	9560	8590c	7240	10000	8960			8940	4470	1	2001	0	1	0	0	0	0	0	0	1	0
25	4	27440	21870	24930	26570	25290	22422		24754	6188	13	2002	3	2	0	1	3	3	1	0	5	8
27	2	9560	10180	10660	10580	10300		11633	10486	5243	13	2002	0	2	2	4	2	2	1	0	4	9
31	4	21995	23615	28780	22820	22550	22880		23773	5943	17	2004	3	5	2	3	2	2	0	0	15	2
32	2	n/a	5840	5950	6620	5940			6088	3044	7	2004	0	1	1	2	3	0	0	0	7	0
36	6	26190	31380	34200	36000	35000	32816		32598	5433	25	2004	3	4	3	4	6	3	2	0	20	5
38	2	12670	8580	8580	6430	8390	7761		8735	4368	1	2004	0	0	0	0	0	1	0	0	0	1
40	2	9520	10480	8630	9730	10680	8623		9611	4805	3	2004	0	0	0	0	1	2	0	0	1	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	2	1	2.5	5	12.5
2	5	7	14	2.5	17.5	43.75
2	5	1	0	2.5	2.5	6.25
2	5	5	8	2.5	12.5	31.25
3	4	4	9	1.333333	5.333333	7.111111
5	2	15	2	0.4	6	2.4
5	2	7	0	0.4	2.8	1.12
5	2	20	5	0.4	8	3.2
5	2	0	1	0.4	0	0
5	2	1	2	0.4	0.4	0.16
		$\Sigma L_{a(j)}=$	42	$\Sigma r_{d(j)}K_{b(j)}=$	60.03333	107.7411

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	42
	π	60.03333
STEP 2	VAR(λ)	42
	VAR(π)	107.7411
STEP 3	δ	18.03333
	θ	0.679304
STEP 4	VAR(δ)	149.7411
	VAR(θ)	0.023364

Reduction	0.320696
std deviation	0.305707

32% +/- 31% result is statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	9	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	80	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	27	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	38	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	38	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	64	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	20	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	107	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	4	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	3	2004

🟨 Before Treatment
🟩 After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	3	2	1	1	2	0	0	0	5	4
13	16	8	22	8	8	7	11	0	24	56
16	3	4	2	3	7	5	3	0	7	20
25	8	7	3	6	5	6	3	0	15	23
27	6	5	5	10	5	4	3	0	16	22
31	11	11	17	11	8	5	1	0	58	6
32	3	2	4	2	4	4	1	0	15	5
36	16	17	15	16	22	17	4	0	86	21
38	0	0	0	0	2	1	1	0	2	2
40	0	0	0	0	0	3	0	0	0	3

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	5	4	2.5	12.5	31.25
2	5	24	56	2.5	60	150
2	5	7	20	2.5	17.5	43.75
2	5	15	23	2.5	37.5	93.75
3	4	16	22	1.333333	21.33333	28.44444
5	2	58	6	0.4	23.2	9.28
5	2	15	5	0.4	6	2.4
5	2	86	21	0.4	34.4	13.76
5	2	2	2	0.4	0.8	0.32
5	2	0	3	0.4	0	0
		$\Sigma L_{a(j)}=$	162	$\Sigma r_{d(j)}K_{b(j)}=$	213.2333	372.9544

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	162
	π	213.2333
STEP 2	$VAR(\lambda)$	162
	$VAR(\pi)$	372.9544
STEP 3	δ	51.23333
	θ	0.75355
STEP 4	$VAR(\delta)$	534.9544
	$VAR(\theta)$	0.008031

Reduction	0.24645
std deviation	0.179227

25% +/- 18% result is statistically significant

Summary Rear End Bin 2

🟨 Before Treatment
🟩 After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10		2	2001	0	1	1	0	0	0	0	0	1	1
13		35	2001	9	4	9	3	1	4	5	0	13	22
16		14	2001	2	2	0	0	3	4	3	0	4	10
25		8	2002	1	3	1	1	0	1	1	0	4	4
27		21	2002	2	3	3	6	1	3	3	0	8	13
31		33	2004	8	5	8	5	1	5	1	0	27	6
32		14	2004	3	3	3	1	2	2	0	0	12	2
36		39	2004	6	9	7	5	8	4	0	0	35	4
38		0	2004	0	0	0	0	0	0	0	0	0	0
40		1	2004	0	0	0	0	0	1	0	0	0	1

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	1	2.5	2.5	6.25
2	5	13	22	2.5	32.5	81.25
2	5	4	10	2.5	10	25
2	5	4	4	2.5	10	25
3	4	8	13	1.333333	10.66667	14.22222
5	2	27	6	0.4	10.8	4.32
5	2	12	2	0.4	4.8	1.92
5	2	35	4	0.4	14	5.6
5	2	0	0	0.4	0	0
5	2	0	1	0.4	0	0
		$\Sigma L_{a(j)}=$	63	$\Sigma r_{d(j)}K_{b(j)}=$	95.26667	163.5622

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	63
	π	95.26667
STEP 2	VAR(λ)	63
	VAR(π)	163.5622
STEP 3	δ	32.26667
	θ	0.649595
STEP 4	VAR(δ)	226.5622
	VAR(θ)	0.013801

Reduction	0.350405
std deviation	0.234954

35% +/- 23% result is statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	74	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	135	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	40	2002
29	4	29270	30000	30500		26240		27699	28742	7185	54	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	352	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	66	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	64	2004
35	4	41160	38500	39320	38990	38660			39326	9832	34	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	104	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	48	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	26	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	9	12	15	10	10	10	8	0	21	53
17	17	20	22	25	20	21	10	0	37	98
26	0	0	0	0	0	0	0	0	0	0
28	5	9	3	8	7	8	0	0	17	23
29	11	8	8	9	8	7	3	0	27	27
30	56	59	72	49	57	44	15	0	187	165
33	12	12	10	14	5	9	4	0	53	13
34	7	10	13	13	7	13	1	0	50	14
35	2	5	3	3	6	10	5	0	19	15
37	0	0	0	0	0	0	0	0	0	0
42	9	23	20	15	14	14	9	0	67	37
46	3	10	4	12	8	11	0	0	29	19
48	0	4	6	4	2	8	2	0	14	12

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	21	53	2.5	52.5	131.25
2	5	37	98	2.5	92.5	231.25
3	4	0	0	1.333333	0	0
3	4	17	23	1.333333	22.66667	30.22222
3	4	27	27	1.333333	36	48
3	4	187	165	1.333333	249.3333	332.4444
5	2	53	13	0.4	21.2	8.48
5	2	50	14	0.4	20	8
5	2	19	15	0.4	7.6	3.04
5	2	0	0	0.4	0	0
4	3	67	37	0.75	50.25	37.6875
4	3	29	19	0.75	21.75	16.3125
4	3	14	12	0.75	10.5	7.875
		$\Sigma L_{a(j)}$=	476	$\Sigma r_{d(j)}K_{b(j)}$=	584.3	854.5617

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	476
	π	584.3
STEP 2	VAR(λ)	476
	VAR(π)	854.5617
STEP 3	δ	108.3
	θ	0.812616
STEP 4	VAR(δ)	1330.562
	VAR(θ)	0.003025

0.187384

Reduction	0.187384
std deviation	0.11

19% +/- 11% result is statistically significant

Summary Dry Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	47	2001	8	6	9	7	5	6	6	0	14	33
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	99	2001	14	14	17	19	13	15	7	0	28	71
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0	0	0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	27	2002	4	6	2	7	2	6	0	0	12	15
29	4	29270	30000	30500		26240		27699	28742	7185	35	2002	6	6	7	3	5	5	3	0	19	16
30	6	42500	41560	40060	47110	48080	44172		43914	7319	212	2002	28	29	44	31	44	26	10	0	101	111
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	57	2004	10	10	9	11	5	8	4	0	45	12
34	4	27610	31760	35800	36440	38400	30841		33475	8369	42	2004	4	6	10	10	3	8	1	0	33	9
35	4	41160	38500	39320	38990	38660			39326	9832	22	2004	2	2	2	1	3	8	4	0	10	12
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0	0	0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	66	2003	6	11	9	12	10	10	8	0	38	28
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	21	2003	3	4	1	3	4	6	0	0	11	10
48	2	16670	16630	15360	19110	16170		15978	16653	8327	24	2003	0	4	4	4	2	8	2	0	12	12

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	14	33	2.5	35	87.5
2	5	28	71	2.5	70	175
3	4	0	0	1.333333	0	0
3	4	12	15	1.333333	16	21.33333
3	4	19	16	1.333333	25.33333	33.77778
3	4	101	111	1.333333	134.6667	179.5556
5	2	45	12	0.4	18	7.2
5	2	33	9	0.4	13.2	5.28
5	2	10	12	0.4	4	1.6
5	2	0	0	0.4	0	0
4	3	38	28	0.75	28.5	21.375
4	3	11	10	0.75	8.25	6.1875
4	3	12	12	0.75	9	6.75
		$\Sigma L_{a(j)}=$	329	$\Sigma r_{d(j)}K_{b(j)}=$	361.95	545.5592

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	329
	π	361.95
STEP 2	VAR(λ)	329
	VAR(π)	545.5592
STEP 3	δ	32.95
	θ	0.905196
STEP 4	VAR(δ)	874.5592
	VAR(θ)	0.005854

Reduction	0.094804
std deviation	0.153021

9% +/- 15% result is NOT statistically significant

Summary Wet Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	16	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	22	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	9	2002
29	4	29270	30000	30500		26240		27699	28742	7185	15	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	113	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	8	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	15	2004
35	4	41160	38500	39320	38990	38660			39326	9832	9	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	28	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	12	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	2	2003

Before Treatment

After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	0	1	4	3	3	3	2	0	1	15
17	2	5	3	3	3	5	1	0	7	15
26	0	0	0	0	0	0	0	0	0	0
28	0	2	1	1	3	2	0	0	3	6
29	4	1	1	5	3	1	0	0	6	9
30	25	21	26	15	8	16	2	0	72	41
33	2	2	1	2	0	1	0	0	7	1
34	1	3	2	3	3	3	0	0	12	3
35	0	2	0	2	3	1	1	0	7	2
37	0	0	0	0	0	0	0	0	0	0
42	2	8	9	3	2	3	1	0	22	6
46	0	3	2	5	0	2	0	0	10	2
48	0	0	2	0	0	0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	1	15	2.5	2.5	6.25
2	5	7	15	2.5	17.5	43.75
3	4	0	0	1.333333	0	0
3	4	3	6	1.333333	4	5.333333
3	4	6	9	1.333333	8	10.66667
3	4	72	41	1.333333	96	128
5	2	7	1	0.4	2.8	1.12
5	2	12	3	0.4	4.8	1.92
5	2	7	2	0.4	2.8	1.12
5	2	0	0	0.4	0	0
4	3	22	6	0.75	16.5	12.375
4	3	10	2	0.75	7.5	5.625
4	3	2	0	0.75	1.5	1.125
		$\Sigma L_{a(j)}=$	100	$\Sigma r_{d(j)}K_{b(j)}=$	163.9	217.285

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	100
	π	163.9
STEP 2	VAR(λ)	100
	VAR(π)	217.285
STEP 3	δ	63.9
	θ	0.605233
STEP 4	VAR(δ)	317.285
	VAR(θ)	0.00652

Reduction 0.394767

std deviation 0.161494

40% +/- 16% result is statistically significant

Summary Not Dry Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	27	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	36	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	13	2002
29	4	29270	30000	30500		26240		27699	28742	7185	19	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	140	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	9	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	22	2004
35	4	41160	38500	39320	38990	38660			39326	9832	12	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	38	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	27	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	2	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	1	6	6	3	5	4	2	0	7	20
17	3	6	5	6	7	6	3	0	9	27
26	0	0	0	0	0	0	0	0	0	0
28	1	3	1	1	5	2	0	0	5	8
29	5	2	1	6	3	2	0	0	8	11
30	28	30	28	18	13	18	5	0	86	54
33	2	2	1	3	0	1	0	0	8	1
34	3	4	3	3	4	5	0	0	17	5
35	0	3	1	2	3	2	1	0	9	3
37	0	0	0	0	0	0	0	0	0	0
42	3	12	11	3	4	4	1	0	29	9
46	0	6	3	9	4	5	0	0	18	9
48	0	0	2	0	0	0	0	0	2	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	7	20	2.5	17.5	43.75
2	5	9	27	2.5	22.5	56.25
3	4	0	0	1.333333	0	0
3	4	5	8	1.333333	6.666667	8.888889
3	4	8	11	1.333333	10.66667	14.22222
3	4	86	54	1.333333	114.6667	152.8889
5	2	8	1	0.4	3.2	1.28
5	2	17	5	0.4	6.8	2.72
5	2	9	3	0.4	3.6	1.44
5	2	0	0	0.4	0	0
4	3	29	9	0.75	21.75	16.3125
4	3	18	9	0.75	13.5	10.125
4	3	2	0	0.75	1.5	1.125
		$\Sigma L_{a(j)}=$	147	$\Sigma r_{d(j)}K_{b(j)}=$	222.35	309.0025

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	147
	π	222.35
STEP 2	$VAR(\lambda)$	147
	$VAR(\pi)$	309.0025
STEP 3	δ	75.35
	θ	0.657013
STEP 4	$VAR(\delta)$	456.0025
	$VAR(\theta)$	0.005565

Reduction 0.342987
std deviation 0.149194

34% +/- 15% result is statistically significant

Summary Severe Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	12	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	25	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	9	2002
29	4	29270	30000	30500		26240		27699	28742	7185	6	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	85	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	13	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	19	2004
35	4	41160	38500	39320	38990	38660			39326	9832	8	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	27	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	13	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	8	2003

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
2	2	1	3	1	0	3	0	4	8
4	3	2	2	4	5	5	0	7	18
0	0	0	0	0	0	0	0	0	0
0	2	1	2	1	3	0	0	3	6
2	0	0	2	0	2	0	0	2	4
14	19	14	17	9	9	3	0	47	38
2	3	1	2	0	3	2	0	8	5
3	1	4	5	2	4	0	0	15	4
0	1	0	0	1	3	3	0	2	6
0	0	0	0	0	0	0	0	0	0
2	5	5	1	2	9	3	0	13	14
1	2	1	4	3	2	0	0	8	5
0	2	2	2	2	0	0	0	6	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	4	8	2.5	10	25
2	5	7	18	2.5	17.5	43.75
3	4	0	0	1.333333	0	0
3	4	3	6	1.333333	4	5.333333
3	4	2	4	1.333333	2.666667	3.555556
3	4	47	38	1.333333	62.66667	83.55556
5	2	8	5	0.4	3.2	1.28
5	2	15	4	0.4	6	2.4
5	2	2	6	0.4	0.8	0.32
5	2	0	0	0.4	0	0
4	3	13	14	0.75	9.75	7.3125
4	3	8	5	0.75	6	4.5
4	3	6	2	0.75	4.5	3.375
		$\Sigma L_{a(j)}=$	110	$\Sigma r_{d(j)}K_{b(j)}=$	127.0833	180.3819

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	110
	π	127.0833
STEP 2	VAR(λ)	110
	VAR(π)	180.3819
STEP 3	δ	17.08333
	θ	0.856013
STEP 4	VAR(δ)	290.3819
	VAR(θ)	0.014519

Reduction 0.143987
std deviation 0.240994

14% +/- 24% result is NOT statistically significant

Summary Intersection Only Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	63	2001	7	12	13	8	9	10	4	0	19	44
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	93	2001	10	15	18	18	14	12	6	0	25	68
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0	0	0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	34	2002	4	8	3	6	6	7	0	0	15	19
29	4	29270	30000	30500		26240		27699	28742	7185	46	2002	10	6	8	8	7	5	2	0	24	22
30	6	42500	41560	40060	47110	48080	44172		43914	7319	291	2002	47	51	60	42	45	35	11	0	158	133
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	47	2004	8	11	8	8	4	5	3	0	39	8
34	4	27610	31760	35800	36440	38400	30841		33475	8369	50	2004	5	8	12	10	5	9	1	0	40	10
35	4	41160	38500	39320	38990	38660			39326	9832	22	2004	1	4	3	2	4	5	3	0	14	8
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0	0	0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	93	2003	7	23	18	13	14	10	8	0	61	32
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	40	2003	2	8	4	11	7	8	0	0	25	15
48	2	16670	16630	15360	19110	16170		15978	16653	8327	18	2003	0	2	6	2	2	4	2	0	10	8

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	19	44	2.5	47.5	118.75
2	5	25	68	2.5	62.5	156.25
3	4	0	0	1.333333	0	0
3	4	15	19	1.333333	20	26.66667
3	4	24	22	1.333333	32	42.66667
3	4	158	133	1.333333	210.6667	280.8889
5	2	39	8	0.4	15.6	6.24
5	2	40	10	0.4	16	6.4
5	2	14	8	0.4	5.6	2.24
5	2	0	0	0.4	0	0
4	3	61	32	0.75	45.75	34.3125
4	3	25	15	0.75	18.75	14.0625
4	3	10	8	0.75	7.5	5.625
		$\Sigma L_{a(j)}=$	367	$\Sigma r_{d(j)}K_{b(j)}=$	481.8667	694.1022

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	367
	π	481.8667
STEP 2	VAR(λ)	367
	VAR(π)	694.1022
STEP 3	δ	114.8667
	θ	0.759352
STEP 4	VAR(δ)	1061.102
	VAR(θ)	0.003275

Reduction	0.240648
std deviation	0.114459

24% +/- 11% result is statistically significant

Summary Rear End Bin 3

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		19	2001	2	4	4	1	0	4	4	0	6	13
17		62	2001	5	10	15	9	11	10	2	0	15	47
26		0	2002	0	0	0	0	0	0	0	0	0	0
28		21	2002	3	6	1	4	2	5	0	0	10	11
29		22	2002	5	6	2	4	2	1	2	0	13	9
30		164	2002	29	34	36	18	15	24	8	0	99	65
33		33	2004	4	8	6	8	1	5	1	0	27	6
34		21	2004	2	4	6	3	1	5	0	0	16	5
35		23	2004	2	2	2	2	5	8	2	0	13	10
37		0	2004	0	0	0	0	0	0	0	0	0	0
42		44	2003	6	9	9	6	3	6	5	0	30	14
46		16	2003	1	3	3	3	4	2	0	0	10	6
48		12	2003	0	4	4	2	0	2	0	0	10	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	6	13	2.5	15	37.5
2	5	15	47	2.5	37.5	93.75
3	4	0	0	1.333333	0	0
3	4	10	11	1.333333	13.33333	17.77778
3	4	13	9	1.333333	17.33333	23.11111
3	4	99	65	1.333333	132	176
5	2	27	6	0.4	10.8	4.32
5	2	16	5	0.4	6.4	2.56
5	2	13	10	0.4	5.2	2.08
5	2	0	0	0.4	0	0
4	3	30	14	0.75	22.5	16.875
4	3	10	6	0.75	7.5	5.625
4	3	10	2	0.75	7.5	5.625
		$\Sigma L_{a(j)}=$	188	$\Sigma r_{d(j)}K_{b(j)}=$	275.0667	385.2239

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	188
	π	275.0667
STEP 2	VAR(λ)	188
	VAR(π)	385.2239
STEP 3	δ	87.06667
	θ	0.680008
STEP 4	VAR(δ)	573.2239
	VAR(θ)	0.004765

Reduction	0.319992
std deviation	0.138062

32% +/- 14% result is statistically significant

Appendix H: Microsurfacing Normalized Analysis – With Treatment Year Omitted

Summary Total Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	9	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	87	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	5	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	1		4	1	0	0	0	1	5
12	19	9		7	17	16	6	0	28	46
14	0	0		0	0	0	0	0	0	0
15	0	0		0	0	0	0	0	0	0
41	1	0	0	2		0	2	0	3	2

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	5	2	2	4
2	4	28	46	2	56	112
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	3	2	0.5	1.5	0.75
		$\Sigma L_{a(j)}=$	53	$\Sigma r_{d(j)}K_{b(j)}=$	59.5	116.75

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	53
	π	59.5
STEP 2	VAR(λ)	53
	VAR(π)	116.75
STEP 3	δ	6.5
	θ	0.862319
STEP 4	VAR(δ)	169.75
	VAR(θ)	0.03613

0.137681

Reduction 0.137681
std deviation 0.380158

-44% +/- 151% result is NOT statistically significant

Summary Dry Bin 1

Project	**No. Lane**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Average A**	**Avg. AAD'**	**No. Collisions**	**Year of Treatment**
11	2	5590	5630	5220	3410	5090			4988	2494	5	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	53	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	4	2003

Before Treatment
After Treatment

Project	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
11	0	1		1	0	0	0	0	1	1
12	14	6		6	7	7	6	0	20	26
14	0	0		0	0	0	0	0	0	0
15	0	0		0	0	0	0	0	0	0
41	0	0	0	2		0	2	0	2	2

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	1	2	2	4
2	4	20	26	2	40	80
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	2	2	0.5	1	0.5
		$\Sigma L_{a(j)}=$	29	$\Sigma r_{d(j)}K_{b(j)}=$	43	84.5

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	29
	π	43
STEP 2	VAR(λ)	29
	VAR(π)	84.5
STEP 3	δ	14
	θ	0.644944
STEP 4	VAR(δ)	113.5
	VAR(θ)	0.030501

Reduction	0.355056
std deviation	0.34929

36% +/- 35% result is statistically significant

Summary Wet Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	2	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	26	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	0	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	0		2	0	0	0	0	0	2
12	2	3		1	8	6	0	0	5	15
14	0	0		0	0	0	0	0	0	0
15	0	0		0	0	0	0	0	0	0
41	0	0	0	0		0	0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	0	2	2	0	0
2	4	5	15	2	10	20
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	0	0	0.5	0	0
		$\Sigma L_{a(j)}=$	17	$\Sigma r_{d(j)}K_{b(j)}=$	10	20

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	17
	π	10
STEP 2	VAR(λ)	17
	VAR(π)	20
STEP 3	δ	-7
	θ	1.416667
STEP 4	VAR(δ)	37
	VAR(θ)	0.360725

Reduction	-0.41667
std deviation	1.201208

-42% +/- 120% result is NOT statistically significant

Summary Not Dry Bin 1

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	2	5590	5630	5220	3410	5090			4988	2494	4	2001	0	0		3	1	0	0	0	0	4
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	34	2001	5	3		1	10	9	0	0	8	20
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001	0	0		0	0	0	0	0	0	0
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001	0	0		0	0	0	0	0	0	0
41	2	1940	3460	3620	3790	3360	2420		3098	1549	1	2003	1	0	0	0		0	0	0	1	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	0	4	2	0	0
2	4	8	20	2	16	32
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	1	0	0.5	0.5	0.25
		$\Sigma L_{a(j)}=$	24	$\Sigma r_{d(j)}K_{b(j)}=$	16.5	32.25

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	24
	π	16.5
STEP 2	VAR(λ)	24
	VAR(π)	32.25
STEP 3	δ	-7.5
	θ	1.300493
STEP 4	VAR(δ)	56.25
	VAR(θ)	0.216488

Reduction	-0.30049
std deviation	0.930565

-30% +/- 96% result is NOT statistically significant

Summary Severe Bin 1

Project	**No. Lane**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Average A**	**Avg. AADT**	**No. Collisions**	**Year of Treatment**
11	2	5590	5630	5220	3410	5090			4988	2494	3	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	25	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	1	2003

Before Treatment

After Treatment

1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
0	0		1	0	0	0	0	0	1
6	2		2	6	3	4	0	8	15
0	0		0	0	0	0	0	0	0
0	0		0	0	0	0	0	0	0
0	0	0	1		0	0	0	1	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	0	1	2	0	0
2	4	8	15	2	16	32
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	1	0	0.5	0.5	0.25
		$\Sigma L_{a(j)}=$	16	$\Sigma r_{d(j)}K_{b(j)}=$	16.5	32.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	16
	π	16.5
STEP 2	VAR(λ)	16
	VAR(π)	32.25
STEP 3	δ	0.5
	θ	0.866995
STEP 4	VAR(δ)	48.25
	VAR(θ)	0.108735

Reduction	0.133005
std deviation	0.659501

13% +/- 67% result is NOT statistically significant

Summary Intersection Only Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
11	2	5590	5630	5220	3410	5090			4988	2494	6	2001
12	6	14830	16080	16200c	17330	14660	15798		15740	2623	73	2001
14	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
15	2	n/a	2490	2140	2210	2410	1550		2160	1080	0	2001
41	2	1940	3460	3620	3790	3360	2420		3098	1549	3	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	0	0		3	1	0	0	0	0	4
12	17	9		7	14	11	2	0	26	34
14	0	0		0	0	0	0	0	0	0
15	0	0		0	0	0	0	0	0	0
41	0	0	0	2		0	1	0	2	1

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	0	4	2	0	0
2	4	26	34	2	52	104
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	2	1	0.5	1	0.5
		$\Sigma L_{a(j)}=$	39	$\Sigma r_{d(j)}K_{b(j)}=$	53	104.5

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	39
	π	53
STEP 2	VAR(λ)	39
	VAR(π)	104.5
STEP 3	δ	14
	θ	0.709456
STEP 4	VAR(δ)	143.5
	VAR(θ)	0.029402

Reduction	0.290544
std deviation	0.342942

29% +/- 34% result is NOT statistically significant

Summary Rear End Bin 1

				Before Treatment After Treatment									
Project	**AADT**	**No. Collisions**	**Year of Treatment**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Before**	**After**
11		3	2001	0	0		1	0	0	0	0	0	1
12		25	2001	4	1		3	5	6	1	0	5	15
14		0	2001	0	0		0	0	0	0	0	0	0
15		0	2001	0	0		0	0	0	0	0	0	0
41		0	2003	0	0	0	0		0	0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	0	1	2	0	0
2	4	5	15	2	10	20
2	4	0	0	2	0	0
2	4	0	0	2	0	0
4	2	0	0	0.5	0	0
		$\Sigma L_{a(j)}$=	16	$\Sigma r_{d(j)}K_{b(j)}$=	10	20

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	16
	π	10
STEP 2	VAR(λ)	16
	VAR(π)	20
STEP 3	δ	-6
	θ	1.333333
STEP 4	VAR(δ)	36
	VAR(θ)	0.324074

Reduction	-0.33333
std deviation	1.13855

-33% +/- 114% result is statistically significant

Summary Total Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	10	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	90	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	33	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	41	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	46	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	73	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	28	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	125	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	4	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	12	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	3	2		1	3	0	0	0	5	4
13	17	10		9	8	8	12	0	27	37
16	3	6		3	7	6	6	0	9	22
25	8	8		6	5	6	3	0	16	20
27	7	6	5		7	7	3	0	18	17
31	14	13	19	11	9		1	0	66	1
32	5	3	4	3	4		2	0	19	2
36	18	20	21	18	25		4	0	102	4
38	0	0	0	0	2		1	0	2	1
40	0	0	0	2	1		0	0	3	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	5	4	2	10	20
2	4	27	37	2	54	108
2	4	9	22	2	18	36
2	4	16	20	2	32	64
3	3	18	17	1	18	18
5	1	66	1	0.2	13.2	2.64
5	1	19	2	0.2	3.8	0.76
5	1	102	4	0.2	20.4	4.08
5	1	2	1	0.2	0.4	0.08
5	1	3	0	0.2	0.6	0.12
		$\Sigma L_{a(j)}=$	108	$\Sigma r_{d(j)}K_{b(j)}=$	170.4	253.68

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	108	
	π	170.4	
STEP 2	VAR(λ)	108	
	VAR(π)	253.68	
STEP 3	δ	62.4	
	θ	0.628313	0.371687
STEP 4	VAR(δ)	361.68	
	VAR(θ)	0.006982	

Reduction 0.371687
std deviation 0.167115

37% +/- 17% result is statistically significant

Summary Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	8	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	55	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	17	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	27	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	25	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	42	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	22	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	100	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	2	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	7	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	2		1	2	0	0	0	4	3
13	11	7		3	3	3	11	0	18	20
16	2	3		2	3	2	4	0	5	11
25	8	4		1	3	6	3	0	12	13
27	0	2	3		7	5	3	0	5	15
31	11	7	11	6	2		1	0	37	1
32	4	3	2	2	3		2	0	14	2
36	16	16	16	15	18		3	0	81	3
38	0	0	0	0	1		1	0	1	1
40	0	0	0	0	0		0	0	0	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	4	3	2	8	16
2	4	18	20	2	36	72
2	4	5	11	2	10	20
2	4	12	13	2	24	48
3	3	5	15	1	5	5
5	1	37	1	0.2	7.4	1.48
5	1	14	2	0.2	2.8	0.56
5	1	81	3	0.2	16.2	3.24
5	1	1	1	0.2	0.2	0.04
5	1	0	0	0.2	0	0
		$\Sigma L_{a(j)}=$	69	$\Sigma r_{d(j)}K_{b(j)}=$	109.6	166.32

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	69
	π	109.6
STEP 2	$VAR(\lambda)$	69
	$VAR(\pi)$	166.32
STEP 3	δ	40.6
	θ	0.620964
STEP 4	$VAR(\delta)$	235.32
	$VAR(\theta)$	0.010631

Reduction	0.379036
std deviation	0.206212

37% +/- 21% result is statistically significant

Summary Wet Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	2	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	23	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	7	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	11	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	15	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	23	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	5	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	21	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	1	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	1	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	1	0		0	1	0	0	0	1	1
13	6	2		3	3	3	0	0	8	9
16	1	1		0	2	1	1	0	2	4
25	0	3		5	1	0	0	0	3	6
27	5	3	2		0	1	0	0	10	1
31	3	5	7	3	3		0	0	21	0
32	0	0	2	1	1		0	0	4	0
36	2	3	3	2	7		1	0	17	1
38	0	0	0	0	0		0	0	0	0
40	0	0	0	0	0		0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	1	2	2	4
2	4	8	9	2	16	32
2	4	2	4	2	4	8
2	4	3	6	2	6	12
3	3	10	1	1	10	10
5	1	21	0	0.2	4.2	0.84
5	1	4	0	0.2	0.8	0.16
5	1	17	1	0.2	3.4	0.68
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
		$\Sigma L_{a(j)}=$	22	$\Sigma r_{d(j)}K_{b(j)}=$	46.4	67.68

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	22
	π	46.4
STEP 2	VAR(λ)	22
	VAR(π)	67.68
STEP 3	δ	24.4
	θ	0.459687
STEP 4	VAR(δ)	89.68
	VAR(θ)	0.015273

Reduction	0.540313
std deviation	0.247165

54% +/- 25% result is statistically significant

Summary Not Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	2	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	35	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	16	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	14	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	21	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	31	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	6	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	25	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	2	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	5	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	1	0		0	1	0	0	0	1	1
13	6	3		6	5	5	1	0	9	17
16	1	3		1	4	4	2	0	4	11
25	0	4		5	2	0	0	0	4	7
27	7	4	2		0	2	0	0	13	2
31	3	6	8	5	7		0	0	29	0
32	1	0	2	1	1		0	0	5	0
36	2	4	5	3	7		1	0	21	1
38	0	0	0	0	1		0	0	1	0
40	0	0	0	2	1		0	0	3	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before $T_b(j)$	Years After $T_a(j)$	Before (B) $K_b(j)$	After (A) $L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	1	2	2	4
2	4	9	17	2	18	36
2	4	4	11	2	8	16
2	4	4	7	2	8	16
3	3	13	2	1	13	13
5	1	29	0	0.2	5.8	1.16
5	1	5	0	0.2	1	0.2
5	1	21	1	0.2	4.2	0.84
5	1	1	0	0.2	0.2	0.04
5	1	3	0	0.2	0.6	0.12
		$\Sigma L_{a(j)}=$	39	$\Sigma r_{d(j)}K_{b(j)}=$	60.8	87.36

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	39
	π	60.8
STEP 2	$VAR(\lambda)$	39
	$VAR(\pi)$	87.36
STEP 3	δ	21.8
	θ	0.626638
STEP 4	$VAR(\delta)$	126.36
	$VAR(\theta)$	0.018465

Reduction	0.373362
std deviation	0.271775

37% +/- 27% result is statistically significant

Summary Severe Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	2	6610	8950	10150	12180	11790		9611	9882	4941	3	2001	2	0		1	0	0	0	0	2	1
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	21	2001	5	2		1	3	1	4	0	7	9
16	2	9560	8590c	7240	10000	8960			8940	4470	1	2001	0	1		0	0	0	0	0	1	0
25	4	27440	21870	24930	26570	25290	22422		24754	6188	13	2002	3	2		1	3	3	1	0	5	8
27	2	9560	10180	10660	10580	10300		11633	10486	5243	13	2002	0	2	2		2	2	1	0	4	5
31	4	21995	23615	28780	22820	22550	22880		23773	5943	17	2004	3	5	2	3	2		0	0	15	0
32	2	n/a	5840	5950	6620	5940			6088	3044	7	2004	0	1	1	2	3		0	0	7	0
36	6	26190	31380	34200	36000	35000	32816		32598	5433	25	2004	3	4	3	4	6		2	0	20	2
38	2	12670	8580	8580	6430	8390	7761		8735	4368	1	2004	0	0	0	0	0		0	0	0	0
40	2	9520	10480	8630	9730	10680	8623		9611	4805	3	2004	0	0	0	0	1		0	0	1	0

Treatment						
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	2	1	2	4	8
2	4	7	9	2	14	28
2	4	1	0	2	2	4
2	4	5	8	2	10	20
3	3	4	5	1	4	4
5	1	15	0	0.2	3	0.6
5	1	7	0	0.2	1.4	0.28
5	1	20	2	0.2	4	0.8
5	1	0	0	0.2	0	0
5	1	1	0	0.2	0.2	0.04
		$\Sigma L_{a(j)}=$	25	$\Sigma r_{d(j)}K_{b(j)}=$	42.6	65.72

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin	Range		
Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	25
	π	42.6
STEP 2	$VAR(\lambda)$	25
	$VAR(\pi)$	65.72
STEP 3	δ	17.6
	θ	0.566345
STEP 4	$VAR(\delta)$	90.72
	$VAR(\theta)$	0.022767

Reduction	0.433655
std deviation	0.301772

43% +/- 30% result is statistically significant

Summary Intersection Only Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
10	2	6610	8950	10150	12180	11790		9611	9882	4941	9	2001
13	4	18910	20880	18680	22890	22020	~22880		20676	5169	80	2001
16	2	9560	8590c	7240	10000	8960			8940	4470	27	2001
25	4	27440	21870	24930	26570	25290	22422		24754	6188	38	2002
27	2	9560	10180	10660	10580	10300		11633	10486	5243	38	2002
31	4	21995	23615	28780	22820	22550	22880		23773	5943	64	2004
32	2	n/a	5840	5950	6620	5940			6088	3044	20	2004
36	6	26190	31380	34200	36000	35000	32816		32598	5433	107	2004
38	2	12670	8580	8580	6430	8390	7761		8735	4368	4	2004
40	2	9520	10480	8630	9730	10680	8623		9611	4805	3	2004

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10	3	2		1	2	0	0	0	5	3
13	16	8		8	8	7	11	0	24	34
16	3	4		3	7	5	3	0	7	18
25	8	7		6	5	6	3	0	15	20
27	6	5	5		5	4	3	0	16	12
31	11	11	17	11	8		1	0	58	1
32	3	2	4	2	4		1	0	15	1
36	16	17	15	16	22		4	0	86	4
38	0	0	0	0	2		1	0	2	1
40	0	0	0	0	0		0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	5	3	2	10	20
2	4	24	34	2	48	96
2	4	7	18	2	14	28
2	4	15	20	2	30	60
3	3	16	12	1	16	16
5	1	58	1	0.2	11.6	2.32
5	1	15	1	0.2	3	0.6
5	1	86	4	0.2	17.2	3.44
5	1	2	1	0.2	0.4	0.08
5	1	0	0	0.2	0	0
		$\Sigma L_{a(j)}=$	94	$\Sigma r_{d(j)}K_{b(j)}=$	150.2	226.44

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	94
	π	150.2
STEP 2	VAR(λ)	94
	VAR(π)	226.44
STEP 3	δ	56.2
	θ	0.619613
STEP 4	VAR(δ)	320.44
	VAR(θ)	0.007781

Reduction	0.380387
std deviation	0.176417

38% +/- 18% result is statistically significant

Summary Rear End Bin 2

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
10		2	2001	0	1		0	0	0	0	0	1	0
13		35	2001	9	4		3	1	4	5	0	13	13
16		14	2001	2	2		0	3	4	3	0	4	10
25		8	2002	1	3		1	0	1	1	0	4	3
27		21	2002	2	3	3		1	3	3	0	8	7
31		33	2004	8	5	8	5	1		1	0	27	1
32		14	2004	3	3	3	1	2		0	0	12	0
36		39	2004	6	9	7	5	8		0	0	35	0
38		0	2004	0	0	0	0	0		0	0	0	0
40		1	2004	0	0	0	0	0		0	0	0	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	0	2	2	4
2	4	13	13	2	26	52
2	4	4	10	2	8	16
2	4	4	3	2	8	16
3	3	8	7	1	8	8
5	1	27	1	0.2	5.4	1.08
5	1	12	0	0.2	2.4	0.48
5	1	35	0	0.2	7	1.4
5	1	0	0	0.2	0	0
5	1	0	0	0.2	0	0
		$\Sigma L_{a(j)}=$	34	$\Sigma r_{d(j)}K_{b(j)}=$	66.8	98.96

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	34
	π	66.8
STEP 2	$VAR(\lambda)$	34
	$VAR(\pi)$	98.96
STEP 3	δ	32.8
	θ	0.497939
STEP 4	$VAR(\delta)$	132.96
	$VAR(\theta)$	0.012242

Reduction	0.502061
std deviation	0.221288

50% +/- 22% result is statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	74	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	135	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	40	2002
29	4	29270	30000	30500		26240		27699	28742	7185	54	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	352	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	66	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	64	2004
35	4	41160	38500	39320	38990	38660			39326	9832	34	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	104	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	48	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	26	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	9	12		10	10	10	8	0	21	38
17	17	20		25	20	21	10	0	37	76
26	0	0	0		0	0	0	0	0	0
28	5	9	3		7	8	0	0	17	15
29	11	8	8		8	7	3	0	27	18
30	56	59	72		57	44	15	0	187	116
33	12	12	10	14	5		4	0	53	4
34	7	10	13	13	7		1	0	50	1
35	2	5	3	3	6		5	0	19	5
37	0	0	0	0	0		0	0	0	0
42	9	23	20	15		14	9	0	67	23
46	3	10	4	12		11	0	0	29	11
48	0	4	6	4		8	2	0	14	10

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	21	38	2	42	84
2	4	37	76	2	74	148
3	3	0	0	1	0	0
3	3	17	15	1	17	17
3	3	27	18	1	27	27
3	3	187	116	1	187	187
5	1	53	4	0.2	10.6	2.12
5	1	50	1	0.2	10	2
5	1	19	5	0.2	3.8	0.76
5	1	0	0	0.2	0	0
4	2	67	23	0.5	33.5	16.75
4	2	29	11	0.5	14.5	7.25
4	2	14	10	0.5	7	3.5
		$\Sigma L_{a(j)}$=	317	$\Sigma r_{d(j)}K_{b(j)}$=	426.4	495.38

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	317
	π	426.4
STEP 2	VAR(λ)	317
	VAR(π)	495.38
STEP 3	δ	109.4
	θ	0.741413
STEP 4	VAR(δ)	812.38
	VAR(θ)	0.003214

0.258587

Reduction	0.258587
std deviation	0.113388

26% +/- 11% result is statistically significant

Summary Dry Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
9	4	25000	25230	30670	28860	30170		28182	28019	7005	47	2001
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	99	2001
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	27	2002
29	4	29270	30000	30500		26240		27699	28742	7185	35	2002
30	6	42500	41560	40060	47110	48080	44172		43914	7319	212	2002
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	57	2004
34	4	27610	31760	35800	36440	38400	30841		33475	8369	42	2004
35	4	41160	38500	39320	38990	38660			39326	9832	22	2004
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004
42	4	28040	34440	31780	42640	39640	42853		36566	9141	66	2003
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	21	2003
48	2	16670	16630	15360	19110	16170		15978	16653	8327	24	2003

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	8	6		7	5	6	6	0	14	24
17	14	14		19	13	15	7	0	28	54
26	0	0	0		0	0	0	0	0	0
28	4	6	2		2	6	0	0	12	8
29	6	6	7		5	5	3	0	19	13
30	28	29	44		44	26	10	0	101	80
33	10	10	9	11	5		4	0	45	4
34	4	6	10	10	3		1	0	33	1
35	2	2	2	1	3		4	0	10	4
37	0	0	0	0	0		0	0	0	0
42	6	11	9	12		10	8	0	38	18
46	3	4	1	3		6	0	0	11	6
48	0	4	4	4		8	2	0	12	10

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	14	24	2	28	56
2	4	28	54	2	56	112
3	3	0	0	1	0	0
3	3	12	8	1	12	12
3	3	19	13	1	19	19
3	3	101	80	1	101	101
5	1	45	4	0.2	9	1.8
5	1	33	1	0.2	6.6	1.32
5	1	10	4	0.2	2	0.4
5	1	0	0	0.2	0	0
4	2	38	18	0.5	19	9.5
4	2	11	6	0.5	5.5	2.75
4	2	12	10	0.5	6	3
		$\Sigma L_{a(j)}=$	222	$\Sigma r_{d(j)}K_{b(j)}=$	264.1	318.77

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	222
	π	264.1
STEP 2	$VAR(\lambda)$	222
	$VAR(\pi)$	318.77
STEP 3	δ	42.1
	θ	0.836766
STEP 4	$VAR(\delta)$	540.77
	$VAR(\theta)$	0.006296

Reduction	0.163234
std deviation	0.158698

16% +/- 16% result is statistically significant

Summary Wet Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	16	2001	0	1		3	3	3	2	0	1	11
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	22	2001	2	5		3	3	5	1	0	7	12
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0		0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	9	2002	0	2	1		3	2	0	0	3	5
29	4	29270	30000	30500		26240		27699	28742	7185	15	2002	4	1	1		3	1	0	0	6	4
30	6	42500	41560	40060	47110	48080	44172		43914	7319	113	2002	25	21	26		8	16	2	0	72	26
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	8	2004	2	2	1	2	0		0	0	7	0
34	4	27610	31760	35800	36440	38400	30841		33475	8369	15	2004	1	3	2	3	3		0	0	12	0
35	4	41160	38500	39320	38990	38660			39326	9832	9	2004	0	2	0	2	3		1	0	7	1
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0		0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	28	2003	2	8	9	3		3	1	0	22	4
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	12	2003	0	3	2	5		2	0	0	10	2
48	2	16670	16630	15360	19110	16170		15978	16653	8327	2	2003	0	0	2	0		0	0	0	2	0

Years before	Years After	Treatment				
		Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	1	11	2	2	4
2	4	7	12	2	14	28
3	3	0	0	1	0	0
3	3	3	5	1	3	3
3	3	6	4	1	6	6
3	3	72	26	1	72	72
5	1	7	0	0.2	1.4	0.28
5	1	12	0	0.2	2.4	0.48
5	1	7	1	0.2	1.4	0.28
5	1	0	0	0.2	0	0
4	2	22	4	0.5	11	5.5
4	2	10	2	0.5	5	2.5
4	2	2	0	0.5	1	0.5
		$\Sigma L_{a(j)}$=	65	$\Sigma r_{d(j)}K_{b(j)}$=	119.2	122.54

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2 Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	65
	π	119.2
STEP 2	VAR(λ)	65
	VAR(π)	122.54
STEP 3	δ	54.2
	θ	0.540639
STEP 4	VAR(δ)	187.54
	VAR(θ)	0.006898

Reduction	0.459361
std deviation	0.16611

46% +/- 17% result is statistically significant

Summary Not Dry Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	27	2001	1	6		3	5	4	2	0	7	14
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	36	2001	3	6		6	7	6	3	0	9	22
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0		0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	13	2002	1	3	1		5	2	0	0	5	7
29	4	29270	30000	30500		26240		27699	28742	7185	19	2002	5	2	1		3	2	0	0	8	5
30	6	42500	41560	40060	47110	48080	44172		43914	7319	140	2002	28	30	28		13	18	5	0	86	36
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	9	2004	2	2	1	3	0		0	0	8	0
34	4	27610	31760	35800	36440	38400	30841		33475	8369	22	2004	3	4	3	3	4		0	0	17	0
35	4	41160	38500	39320	38990	38660			39326	9832	12	2004	0	3	1	2	3		1	0	9	1
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0		0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	38	2003	3	12	11	3		4	1	0	29	5
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	27	2003	0	6	3	9		5	0	0	18	5
48	2	16670	16630	15360	19110	16170		15978	16653	8327	2	2003	0	0	2	0		0	0	0	2	0

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	7	14	2	14	28
2	4	9	22	2	18	36
3	3	0	0	1	0	0
3	3	5	7	1	5	5
3	3	8	5	1	8	8
3	3	86	36	1	86	86
5	1	8	0	0.2	1.6	0.32
5	1	17	0	0.2	3.4	0.68
5	1	9	1	0.2	1.8	0.36
5	1	0	0	0.2	0	0
4	2	29	5	0.5	14.5	7.25
4	2	18	5	0.5	9	4.5
4	2	2	0	0.5	1	0.5
		$\Sigma L_{a(j)}$=	95	$\Sigma r_{d(j)}K_{b(j)}$=	162.3	176.61

Formulas:
$r_d(j) = T_a(j)/T_b(j)$
$\lambda = \Sigma L_a(j)$
$\pi = \Sigma r_d(j)K_b(j)$
$VAR(\lambda) = \Sigma La(j)$
$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*
$\delta = \pi - \lambda$
$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$
$VAR(\delta) = VAR(\pi) + VAR(\lambda)$
$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	95
	π	162.3
STEP 2	VAR(λ)	95
	VAR(π)	176.61
STEP 3	δ	67.3
	θ	0.581437
STEP 4	VAR(δ)	271.61
	VAR(θ)	0.005748

Reduction	0.418563
std deviation	0.15163

42% +/- 15% result is statistically significant

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	12	2001	2	2		3	1	0	3	0	4	7
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	25	2001	4	3		2	4	5	5	0	7	16
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0		0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	9	2002	0	2	1		1	3	0	0	3	4
29	4	29270	30000	30500		26240		27699	28742	7185	6	2002	2	0	0		0	2	0	0	2	2
30	6	42500	41560	40060	47110	48080	44172		43914	7319	85	2002	14	19	14		9	9	3	0	47	21
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	13	2004	2	3	1	2	0		2	0	8	2
34	4	27610	31760	35800	36440	38400	30841		33475	8369	19	2004	3	1	4	5	2		0	0	15	0
35	4	41160	38500	39320	38990	38660			39326	9832	8	2004	0	1	0	0	1		3	0	2	3
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0		0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	27	2003	2	5	5	1		9	3	0	13	12
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	13	2003	1	2	1	4		2	0	0	8	2
48	2	16670	16630	15360	19110	16170		15978	16653	8327	8	2003	0	2	2	2		0	0	0	6	0

Years before	Years After	Treatment Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	4	7	2	8	16
2	4	7	16	2	14	28
3	3	0	0	1	0	0
3	3	3	4	1	3	3
3	3	2	2	1	2	2
3	3	47	21	1	47	47
5	1	8	2	0.2	1.6	0.32
5	1	15	0	0.2	3	0.6
5	1	2	3	0.2	0.4	0.08
5	1	0	0	0.2	0	0
4	2	13	12	0.5	6.5	3.25
4	2	8	2	0.5	4	2
4	2	6	0	0.5	3	1.5
		$\Sigma L_{a(j)}=$	69	$\Sigma r_{d(j)}K_{b(j)}=$	92.5	103.75

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	69
	π	92.5
STEP 2	VAR(λ)	69
	VAR(π)	103.75
STEP 3	δ	23.5
	θ	0.737009
STEP 4	VAR(δ)	172.75
	VAR(θ)	0.014114

Reduction	0.262991
std deviation	0.237607

26% +/- 24% result is statistically significant

Summary Intersection Only Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9	4	25000	25230	30670	28860	30170		28182	28019	7005	63	2001	7	12		8	9	10	4	0	19	31
17	6	46160	49500	45430c	52290	53120	55406		51295	8549	93	2001	10	15		18	14	12	6	0	25	50
26	4	33050	33500	36540	34440	32460	31713		33617	8404	0	2002	0	0	0		0	0	0	0	0	0
28	6	46960	31160c	43500	38690	43120		47700	43994	7332	34	2002	4	8	3		6	7	0	0	15	13
29	4	29270	30000	30500		26240		27699	28742	7185	46	2002	10	6	8		7	5	2	0	24	14
30	6	42500	41560	40060	47110	48080	44172		43914	7319	291	2002	47	51	60		45	35	11	0	158	91
33	4	41660	44000	43465	41825	42705	~52007		42731	10683	47	2004	8	11	8	8	4		3	0	39	3
34	4	27610	31760	35800	36440	38400	30841		33475	8369	50	2004	5	8	12	10	5		1	0	40	1
35	4	41160	38500	39320	38990	38660			39326	9832	22	2004	1	4	3	2	4		3	0	14	3
37	2	26250	29850	34110	34460	36670		33930	32545	16273	0	2004	0	0	0	0	0		0	0	0	0
42	4	28040	34440	31780	42640	39640	42853		36566	9141	93	2003	7	23	18	13		10	8	0	61	18
46	4	25940	27360	26220	32460	31000	~30295		28596	7149	40	2003	2	8	4	11		8	0	0	25	8
48	2	16670	16630	15360	19110	16170		15978	16653	8327	18	2003	0	2	6	2		4	2	0	10	6

* Since project 14 is also on Keele St. the same AADT values were applied.

Bin 1	0<aadt/lane < 3000	🟩	5
Bin 2	3000=<aadt/lane <7000	🟩	10
Bin 3	7000 <=aadt/lane	🟩	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	19	31	2	38	76
2	4	25	50	2	50	100
3	3	0	0	1	0	0
3	3	15	13	1	15	15
3	3	24	14	1	24	24
3	3	158	91	1	158	158
5	1	39	3	0.2	7.8	1.56
5	1	40	1	0.2	8	1.6
5	1	14	3	0.2	2.8	0.56
5	1	0	0	0.2	0	0
4	2	61	18	0.5	30.5	15.25
4	2	25	8	0.5	12.5	6.25
4	2	10	6	0.5	5	2.5
		$\Sigma L_{a(j)}=$	238	$\Sigma r_{d(j)}K_{b(j)}=$	351.6	400.72

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	238
	π	351.6
STEP 2	VAR(λ)	238
	VAR(π)	400.72
STEP 3	δ	113.6
	θ	0.674718
STEP 4	VAR(δ)	638.72
	VAR(θ)	0.003367

Reduction 0.325282
std deviation 0.116045

33% +/- 12% result is statistically significant

Summary Rear End Bin 3

Before Treatment
After Treatment

Project	AADT	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
9		19	2001	2	4		1	0	4	4	0	6	9
17		62	2001	5	10		9	11	10	2	0	15	32
26		0	2002	0	0	0		0	0	0	0	0	0
28		21	2002	3	6	1		2	5	0	0	10	7
29		22	2002	5	6	2		2	1	2	0	13	5
30		164	2002	29	34	36		15	24	8	0	99	47
33		33	2004	4	8	6	8	1		1	0	27	1
34		21	2004	2	4	6	3	1		0	0	16	0
35		23	2004	2	2	2	2	5		2	0	13	2
37		0	2004	0	0	0	0	0		0	0	0	0
42		44	2003	6	9	9	6		6	5	0	30	11
46		16	2003	1	3	3	3		2	0	0	10	2
48		12	2003	0	4	4	2		2	0	0	10	2

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	6	9	2	12	24
2	4	15	32	2	30	60
3	3	0	0	1	0	0
3	3	10	7	1	10	10
3	3	13	5	1	13	13
3	3	99	47	1	99	99
5	1	27	1	0.2	5.4	1.08
5	1	16	0	0.2	3.2	0.64
5	1	13	2	0.2	2.6	0.52
5	1	0	0	0.2	0	0
4	2	30	11	0.5	15	7.5
4	2	10	2	0.5	5	2.5
4	2	10	2	0.5	5	2.5
		$\Sigma L_{a(j)}=$	118	$\Sigma r_{d(j)}K_{b(j)}=$	200.2	220.74

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	118
	π	200.2
STEP 2	$VAR(\lambda)$	118
	$VAR(\pi)$	220.74
STEP 3	δ	82.2
	θ	0.586182
STEP 4	$VAR(\delta)$	338.74
	$VAR(\theta)$	0.004752

Reduction	0.413818
std deviation	0.137868

41% +/- 14% result is statistically significant

Appendix I: Resurfacing Normalized Analysis

Summary Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	7	2001
4	2	3640	3890	3170	3490	3920			3622	1811	10	2001
7	4	3670	4860	5670	7050	3460			4942	1236	2	2001
21	2								4762	2381	15	2001
22	2			1280	2280	1700		1986	1812	906	2	2002
24	2		940	1010	1020	930		967	973	487	3	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	2	0	0	1	0	1	6
0	1	2	0	3	0	4	0	0	10
0	0	0	1	0	0	1	0	0	2
0	1	2	2	6	2	2	0	1	14
0	0	0	0	0	1	1	0	0	2
0	0	0	0	1	2	0	0	0	3
								2	37

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	6	6	6	36
1	6	0	10	6	0	0
1	6	0	2	6	0	0
2	5	1	14	2.5	2.5	6.25
2	5	0	2	2.5	0	0
2	5	0	3	2.5	0	0
		$\Sigma L_{a(j)}=$	37	$\Sigma r_{d(j)}K_{b(j)}=$	8.5	42.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	37
	π	8.5
STEP 2	VAR(λ)	37
	VAR(π)	42.25
STEP 3	δ	-28.5
	θ	2.746725
STEP 4	VAR(δ)	79.25
	VAR(θ)	1.837833

-1.74672

Reduction -1.74672
std deviation 2.711334

-175% +/- 271% result is NOT statistically significant

Dry Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	1	0	0	0	0	1	4
0	1	1	0	2	0	0	0	0	4
0	0	0	1	0	0	1	0	0	2
0	0	1	2	2	1	2	0	0	8
0	0	0	0	0	1	1	0	0	2
0	0	0	0	1	2	0	0	0	3
								1	23

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	4	6	6	36
1	6	0	4	6	0	0
1	6	0	2	6	0	0
2	5	0	8	2.5	0	0
2	5	0	2	2.5	0	0
2	5	0	3	2.5	0	0
		$\Sigma L_{a(j)}=$	23	$\Sigma r_{d(j)}K_{b(j)}=$	6	36

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	23	
	π	6	
STEP 2	$VAR(\lambda)$	23	
	$VAR(\pi)$	36	
STEP 3	δ	-17	
	θ	1.916667	-0.91667
STEP 4	$VAR(\delta)$	59	
	$VAR(\theta)$	0.958333	

Reduction	-0.91667
std deviation	1.95789

92% +/- 196% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	0	0	1	0	0	0	0	0	1
0	0	1	0	1	0	2	0	0	4
0	0	0	0	0	0	0	0	0	0
0	0	1	0	3	0	0	0	0	4
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
								0	9

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	1	6	0	0
1	6	0	4	6	0	0
1	6	0	0	6	0	0
2	5	0	4	2.5	0	0
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}=$	9	$\Sigma r_{d(j)}K_{b(j)}=$	0	0

Formulas:
$r_d(j) = T_a(j)/T_b(j)$
$\lambda = \Sigma L_a(j)$
$\pi = \Sigma r_d(j)K_b(j)$
$VAR(\lambda) = \Sigma La(j)$
$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*
$\delta = \pi - \lambda$
$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$
$VAR(\delta) = VAR(\pi) + VAR(\lambda)$
$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	9	
	π	0	
STEP 2	VAR(λ)	9	
	VAR(π)	0	
STEP 3	δ	-9	
	θ	#DIV/0!	#DIV/0!
STEP 4	VAR(δ)	9	
	VAR(θ)	#DIV/0!	

Reduction	#DIV/0!
std deviation	#DIV/0!

result is NOT statistically significant

*not possible to calculate because no collisions in the before period

Not Dry Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	0	0	1	0	0	1	0	0	2
0	0	1	0	1	0	4	0	0	6
0	0	0	0	0	0	0	0	0	0
0	1	1	0	4	1	0	0	1	6
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
								1	14

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	2	6	0	0
1	6	0	6	6	0	0
1	6	0	0	6	0	0
2	5	1	6	2.5	2.5	6.25
2	5	0	0	2.5	0	0
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}=$	14	$\Sigma r_{d(j)}K_{b(j)}=$	2.5	6.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	14
	π	2.5
STEP 2	VAR(λ)	14
	VAR(π)	6.25
STEP 3	δ	-11.5
	θ	2.8
STEP 4	VAR(δ)	20.25
	VAR(θ)	2.1

-1.8

Reduction -1.8

std deviation 2.898275

-180% +/- 290% result is NOT statistically significant

Severe Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	0	1	0	0	0	1	0	1	2
0	0	1	0	0	0	1	0	0	2
0	0	0	0	0	0	1	0	0	1
0	0	2	1	3	0	1	0	0	7
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	1
								1	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	2	6	6	36
1	6	0	2	6	0	0
1	6	0	1	6	0	0
2	5	0	7	2.5	0	0
2	5	0	0	2.5	0	0
2	5	0	1	2.5	0	0
		$\Sigma L_{a(j)}=$	13	$\Sigma r_{d(j)}K_{b(j)}=$	6	36

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	13
	π	6
STEP 2	VAR(λ)	13
	VAR(π)	36
STEP 3	δ	-7
	θ	1.083333
STEP 4	VAR(δ)	49
	VAR(θ)	0.315972

-0.08333

Reduction -0.08333
std deviation 1.124228

-8%+-112% result is NOT statistically significant

Intersection Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	2	0	0	0	0	1	5
0	0	2	0	1	0	2	0	0	5
0	0	0	0	0	0	0	0	0	0
0	1	2	2	5	2	1	0	1	12
0	0	0	0	0	0	1	0	0	1
0	0	0	0	1	1	0	0	0	2
								2	25

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	5	6	6	36
1	6	0	5	6	0	0
1	6	0	0	6	0	0
2	5	1	12	2.5	2.5	6.25
2	5	0	1	2.5	0	0
2	5	0	2	2.5	0	0
		$\Sigma L_{a(j)}=$	25	$\Sigma r_{d(j)}K_{b(j)}=$	8.5	42.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	25
	π	8.5
STEP 2	VAR(λ)	25
	VAR(π)	42.25
STEP 3	δ	-16.5
	θ	1.855895
STEP 4	VAR(δ)	67.25
	VAR(θ)	0.856831

-0.8559

Reduction	-0.8559
std deviation	1.851304

-86% +/- 185% result is NOT statistically significant

Rear End Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	1	0	0	0	0	0	0	0	1
0	1	0	0	1	0	2	0	0	4
0	0	0	0	0	0	1	0	0	1
0	0	0	0	1	0	1	0	0	2
0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	0
								0	9

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	1	6	0	0
1	6	0	4	6	0	0
1	6	0	1	6	0	0
2	5	0	2	2.5	0	0
2	5	0	1	2.5	0	0
2	5	0	0	2.5	0	0
		$\Sigma L_{a(j)}$=	9	$\Sigma r_{d(j)}K_{b(j)}$=	0	0

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	9	
	π	0	
STEP 2	VAR(λ)	9	
	VAR(π)	0	
STEP 3	δ	-9	
	θ	#DIV/0!	#DIV/0!
STEP 4	VAR(δ)	9	
	VAR(θ)	#DIV/0!	

Reduction	#DIV/0!
std deviation	#DIV/0!

-1% +/- 26% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	13	2001
5	2	12530	10630	10840	13490	11780			11854	5927	22	2001
6	4	17650	18870	18610	23640	23250			20404	5101	34	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	324	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	20	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	2	2	4	1	0	1	12
3	3	2	3	2	5	4	0	3	19
6	4	6	1	4	9	4	0	6	28
63	52	56	38	52	43	20	0	115	209
2	4	0	3	3	4	4	0	6	14
								131	282

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	12	6	6	36
1	6	3	19	6	18	108
1	6	6	28	6	36	216
2	5	115	209	2.5	287.5	718.75
2	5	6	14	2.5	15	37.5
		$\Sigma L_{a(j)}$=	282	$\Sigma r_{d(j)}K_{b(j)}$=	362.5	1116.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$
$\lambda = \Sigma L_a(j)$
$\pi = \Sigma r_d(j)K_b(j)$
$VAR(\lambda) = \Sigma La(j)$
$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*
$\delta = \pi - \lambda$
$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$
$VAR(\delta) = VAR(\pi) + VAR(\lambda)$
$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	282	
	π	362.5	
STEP 2	VAR(λ)	282	
	VAR(π)	1116.25	
STEP 3	δ	80.5	
	θ	0.771378	0.228622
STEP 4	VAR(δ)	1398.25	
	VAR(θ)	0.007044	

Reduction	0.228622
std deviation	0.167861

23% +/- 17% result is statistically significant

Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	1	0	1	2	3	0	0	0	7
1	2	1	3	1	4	3	0	1	14
4	2	4	0	2	4	2	0	4	14
40	34	33	28	34	29	12	0	74	136
1	2	0	2	1	3	3	0	3	9
								82	180

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	7	6	0	0
1	6	1	14	6	6	36
1	6	4	14	6	24	144
2	5	74	136	2.5	185	462.5
2	5	3	9	2.5	7.5	18.75
		$\Sigma L_{a(j)}$=	180	$\Sigma r_{d(j)}K_{b(j)}$=	222.5	661.25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	180
	π	222.5
STEP 2	VAR(λ)	180
	VAR(π)	661.25
STEP 3	δ	42.5
	θ	0.798326
STEP 4	VAR(δ)	841.25
	VAR(θ)	0.011738

0.201674

Reduction	0.201674
std deviation	0.216681

20% +/- 22% result is NOT statistically significant

Wet Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	0	1	1	0	1	0	0	1	3
2	1	1	0	1	0	0	0	2	3
2	2	2	0	0	3	2	0	2	9
18	15	15	6	13	9	5	0	33	48
1	2	0	0	2	1	1	0	3	4
								41	67

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	3	6	6	36
1	6	2	3	6	12	72
1	6	2	9	6	12	72
2	5	33	48	2.5	82.5	206.25
2	5	3	4	2.5	7.5	18.75
		$\Sigma L_{a(j)}=$	67	$\Sigma r_{d(j)}K_{b(j)}=$	120	405

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	67
	π	120
STEP 2	VAR(λ)	67
	VAR(π)	405
STEP 3	δ	53
	θ	0.54306
STEP 4	VAR(δ)	472
	VAR(θ)	0.012011

0.45694

Reduction 0.45694
std deviation 0.21919

46%+/-22% result isstatistically significant

Not Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD⁊	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	0	2	1	0	1	1	0	1	5
2	1	1	0	1	1	1	0	2	5
2	2	2	1	2	5	2	0	2	14
23	18	23	10	18	14	8	0	41	73
1	2	0	1	2	1	1	0	3	5
								49	102

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	5	6	6	36
1	6	2	5	6	12	72
1	6	2	14	6	12	72
2	5	41	73	2.5	102.5	256.25
2	5	3	5	2.5	7.5	18.75
		$\Sigma L_{a(j)}=$	102	$\Sigma r_{d(j)}K_{b(j)}=$	140	455

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	102	
	π	140	
STEP 2	$VAR(\lambda)$	102	
	$VAR(\pi)$	455	
STEP 3	δ	38	
	θ	0.712042	0.287958
STEP 4	$VAR(\delta)$	557	
	$VAR(\theta)$	0.015989	

Reduction	0.287958
std deviation	0.252898

29% +/- 25% result is statistically significant

Severe Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	1	2	1	0	0	0	0	0	4
0	0	1	1	0	0	1	0	0	3
2	1	0	0	0	1	1	0	2	3
12	4	12	4	8	8	8	0	16	40
0	0	0	0	0	2	0	0	0	2
								18	52

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	4	6	0	0
1	6	0	3	6	0	0
1	6	2	3	6	12	72
2	5	16	40	2.5	40	100
2	5	0	2	2.5	0	0
		$\Sigma L_{a(j)}=$	52	$\Sigma r_{d(j)}K_{b(j)}=$	52	172

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	52
	π	52
STEP 2	VAR(λ)	52
	VAR(π)	172
STEP 3	δ	0
	θ	0.940195
STEP 4	VAR(δ)	224
	VAR(θ)	0.064731

0.059805

Reduction	0.059805
std deviation	0.508846

6%+-51% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AADT	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1	1	2	2	2	3	0	0	1	10
2	3	2	3	2	2	3	0	2	15
3	3	5	1	3	5	2	0	3	19
53	45	44	26	42	24	15	0	98	151
2	4	0	3	3	3	2	0	6	11
								110	206

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	1	10	6	6	36
1	6	2	15	6	12	72
1	6	3	19	6	18	108
2	5	98	151	2.5	245	612.5
2	5	6	11	2.5	15	37.5
		$\Sigma L_{a(j)}=$	206	$\Sigma r_{d(j)}K_{b(j)}=$	296	866

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	206
	π	296
STEP 2	VAR(λ)	206
	VAR(π)	866
STEP 3	δ	90
	θ	0.689135
STEP 4	VAR(δ)	1072
	VAR(θ)	0.006863

0.310865

Reduction	0.310865
std deviation	0.165687

31% +/- 17% result is statistically significant

Rear End Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0	0	1	0	0	2	0	0	0	3
1	1	1	1	1	2	1	0	1	7
5	1	2	1	1	4	0	0	5	9
26	16	26	16	16	16	9	0	42	83
1	0	0	2	0	1	2	0	1	5
								49	107

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	6	0	3	6	0	0
1	6	1	7	6	6	36
1	6	5	9	6	30	180
2	5	42	83	2.5	105	262.5
2	5	1	5	2.5	2.5	6.25
		$\Sigma L_{a(j)}=$	107	$\Sigma r_{d(j)}K_{b(j)}=$	143.5	484.75

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	107	
	π	143.5	
STEP 2	VAR(λ)	107	
	VAR(π)	484.75	
STEP 3	δ	36.5	
	θ	0.728496	0.271504
STEP 4	VAR(δ)	591.75	
	VAR(θ)	0.016659	

Reduction	0.271504
std deviation	0.258142

27% +/- 26% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	388	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
41	61	67	57	65	69	28	0	102	286
								102	286

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	102	286	2.5	255	637.5
		$\Sigma L_{a(j)}=$	286	$\Sigma r_{d(j)}K_{b(j)}=$	255	637.5

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	286
	π	255
STEP 2	VAR(λ)	286
	VAR(π)	637.5
STEP 3	δ	-31
	θ	1.11068
STEP 4	VAR(δ)	923.5
	VAR(θ)	0.01609

-0.11068

Reduction -0.11068
std deviation 0.253697

-11% +/- 25% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
37	49	57	42	49	49	21	0	86	218
								86	218

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	86	218	2.5	215	537.5
		$\Sigma L_{a(j)}=$	218	$\Sigma r_{d(j)}K_{b(j)}=$	215	537.5

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	218	
	π	215	
STEP 2	$VAR(\lambda)$	218	
	$VAR(\pi)$	537.5	
STEP 3	δ	-3	
	θ	1.002299	-0.0023
STEP 4	$VAR(\delta)$	755.5	
	$VAR(\theta)$	0.015917	

Reduction	-0.0023
std deviation	0.252328

0% +/- 25% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
2	10	8	11	9	12	4	0	12	44
								12	44

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	12	44	2.5	30	75
		$\Sigma L_{a(j)}=$	44	$\Sigma r_{d(j)}K_{b(j)}=$	30	75

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	44	
	π	30	
STEP 2	VAR(λ)	44	
	VAR(π)	75	
STEP 3	δ	-14	
	θ	1.353846	-0.35385
STEP 4	VAR(δ)	119	
	VAR(θ)	0.165641	

Reduction	-0.35385
std deviation	0.813981

-35%+/-81% result is NOT statistically significant

Not Dry Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
4	12	10	15	16	20	7	0	16	68
								16	68

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	16	68	2.5	40	100
		$\Sigma L_{a(j)}$=	68	$\Sigma r_{d(j)}K_{b(j)}$=	40	100

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	68	
	π	40	
STEP 2	$VAR(\lambda)$	68	
	$VAR(\pi)$	100	
STEP 3	δ	-28	
	θ	1.6	-0.6
STEP 4	$VAR(\delta)$	168	
	$VAR(\theta)$	0.175078	

Reduction	-0.6
std deviation	0.836847

-60% +/- 84% result is NOT statistically significant

Severe Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	13	16	10	10	17	10	0	24	63
								24	63

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	24	63	2.5	60	150
		$\Sigma L_{a(j)}=$	63	$\Sigma r_{d(j)}K_{b(j)}=$	60	150

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	63	
	π	60	
STEP 2	VAR(λ)	63	
	VAR(π)	150	
STEP 3	δ	-3	
	θ	1.008	-0.008
STEP 4	VAR(δ)	213	
	VAR(θ)	0.05388	

Reduction	-0.008
std deviation	0.464243

-1%+-46% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
34	53	51	43	50	51	21	0	87	216
								87	216

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	87	216	2.5	217.5	543.75
		$\Sigma L_{a(j)}$=	216	$\Sigma r_{d(j)}K_{b(j)}$=	217.5	543.75

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	216	
	π	217.5	
STEP 2	$VAR(\lambda)$	216	
	$VAR(\pi)$	543.75	
STEP 3	δ	1.5	
	θ	0.981818	0.018182
STEP 4	$VAR(\delta)$	759.75	
	$VAR(\theta)$	0.015192	

Reduction	0.018182
std deviation	0.246509

2% +/- 25% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
14	24	30	30	30	27	12	0	38	129
								38	129

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	5	38	129	2.5	95	237.5
		$\Sigma L_{a(j)}$=	129	$\Sigma r_{d(j)}K_{b(j)}$=	95	237.5

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	129	
	π	95	
STEP 2	VAR(λ)	129	
	VAR(π)	237.5	
STEP 3	δ	-34	
	θ	1.323077	-0.32308
STEP 4	VAR(δ)	366.5	
	VAR(θ)	0.056618	

Reduction	-0.32308
std deviation	0.475889

-32% +/- 48% result is NOT statistically significant

Appendix J: Resurfacing Normalized Analysis – With Treatment Year Omitted

Summary (Treatment year omit) Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		2	2	0	0	1	0	1	5
0		2	0	3	0	4	0	0	9
0		0	1	0	0	1	0	0	2
0	1		2	6	2	2	0	1	12
0	0		0	0	1	1	0	0	2
0	0		0	1	2	0	0	0	3
								2	33

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	5	5	5	25
1	5	0	9	5	0	0
1	5	0	2	5	0	0
2	4	1	12	2	2	4
2	4	0	2	2	0	0
2	4	0	3	2	0	0
		$\Sigma L_{a(j)}=$	33	$\Sigma r_{d(j)}K_{b(j)}=$	7	29

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	33
	π	7
STEP 2	VAR(λ)	33
	VAR(π)	29
STEP 3	δ	-26
	θ	2.961538
STEP 4	VAR(δ)	62
	VAR(θ)	2.153405

-1.96154

Reduction -1.96154
std deviation 2.934897

-196% +/- 293% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		2	1	0	0	0	0	1	3
0		1	0	2	0	0	0	0	3
0		0	1	0	0	1	0	0	2
0	0		2	2	1	2	0	0	7
0	0		0	0	1	1	0	0	2
0	0		0	1	2	0	0	0	3
								1	20

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	3	5	5	25
1	5	0	3	5	0	0
1	5	0	2	5	0	0
2	4	0	7	2	0	0
2	4	0	2	2	0	0
2	4	0	3	2	0	0
		$\Sigma L_{a(j)}$=	20	$\Sigma r_{d(j)}K_{b(j)}$=	5	25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	20
	π	5
STEP 2	VAR(λ)	20
	VAR(π)	25
STEP 3	δ	-15
	θ	2
STEP 4	VAR(δ)	45
	VAR(θ)	1.05

-1

Reduction -1
std deviation 2.04939

-100% +/- 205% result is NOT statistically significant

Wet Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		0	1	0	0	0	0	0	1
0		1	0	1	0	2	0	0	4
0		0	0	0	0	0	0	0	0
0	0		0	3	0	0	0	0	3
0	0		0	0	0	0	0	0	0
0	0		0	0	0	0	0	0	0
								0	8

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	1	5	0	0
1	5	0	4	5	0	0
1	5	0	0	5	0	0
2	4	0	3	2	0	0
2	4	0	0	2	0	0
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	8	$\Sigma r_{d(j)}K_{b(j)}=$	0	0

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	8	
	π	0	
STEP 2	$VAR(\lambda)$	8	
	$VAR(\pi)$	0	
STEP 3	δ	-8	
	θ	#DIV/0!	#DIV/0!
STEP 4	$VAR(\delta)$	8	
	$VAR(\theta)$	#DIV/0!	

Reduction	#DIV/0!
std deviation	#DIV/0!

result is NOT statistically significant

*not possible to calculate because no collisions in the before period

Not Dry Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		0	1	0	0	1	0	0	2
0		1	0	1	0	4	0	0	6
0		0	0	0	0	0	0	0	0
0	1		0	4	1	0	0	1	5
0	0		0	0	0	0	0	0	0
0	0		0	0	0	0	0	0	0
								1	13

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	2	5	0	0
1	5	0	6	5	0	0
1	5	0	0	5	0	0
2	4	1	5	2	2	4
2	4	0	0	2	0	0
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	13	$\Sigma r_{d(j)}K_{b(j)}=$	2	4

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	13
	π	2
STEP 2	$VAR(\lambda)$	13
	$VAR(\pi)$	4
STEP 3	δ	-11
	θ	3.25
STEP 4	$VAR(\delta)$	17
	$VAR(\theta)$	2.84375

-2.25

Reduction	-2.25
std deviation	3.372684

-225% +/- 337% result is NOT statistically significant

Severe Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		1	0	0	0	1	0	1	2
0		1	0	0	0	1	0	0	2
0		0	0	0	0	1	0	0	1
0	0		1	3	0	1	0	0	5
0	0		0	0	0	0	0	0	0
0	0		0	0	1	0	0	0	1
								1	11

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	2	5	5	25
1	5	0	2	5	0	0
1	5	0	1	5	0	0
2	4	0	5	2	0	0
2	4	0	0	2	0	0
2	4	0	1	2	0	0
		$\Sigma L_{a(j)}=$	11	$\Sigma r_{d(j)}K_{b(j)}=$	5	25

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	11
	π	5
STEP 2	$VAR(\lambda)$	11
	$VAR(\pi)$	25
STEP 3	δ	-6
	θ	1.1
STEP 4	$VAR(\delta)$	36
	$VAR(\theta)$	0.33

-0.1

Reduction	-0.1
std deviation	1.148913

-10% +/- 115% result is NOT statistically significant

Intersection Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		2	2	0	0	0	0	1	4
0		2	0	1	0	2	0	0	5
0		0	0	0	0	0	0	0	0
0	1		2	5	2	1	0	1	10
0	0		0	0	0	1	0	0	1
0	0		0	1	1	0	0	0	2
								2	22

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	4	5	5	25
1	5	0	5	5	0	0
1	5	0	0	5	0	0
2	4	1	10	2	2	4
2	4	0	1	2	0	0
2	4	0	2	2	0	0
		$\Sigma L_{a(j)}=$	22	$\Sigma r_{d(j)}K_{b(j)}=$	7	29

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	22
	π	7
STEP 2	VAR(λ)	22
	VAR(π)	29
STEP 3	δ	-15
	θ	1.974359
STEP 4	VAR(δ)	51
	VAR(θ)	0.980377

-0.97436

Reduction -0.97436
std deviation 1.98028

-97% +/- 198% result is NOT statistically significant

Rear End Bin 1

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
1	2	1280	1190	1140	1160	1290	836	n/a	1149	575	74	2001
4	2	3640	3890	3170	3490	3920			3622	1811	9	2001
7	4	3670	4860	5670	7050	3460			4942	1236	0	2001
21	2								4762	2381	135	2001
22	2			1280	2280	1700		1986	1812	906	41	2002
24	2		940	1010	1020	930		967	973	487	46	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	6
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		0	0	0	0	0	0	0	0
0		0	0	1	0	2	0	0	3
0		0	0	0	0	1	0	0	1
0	0		0	1	0	1	0	0	2
0	0		0	0	0	1	0	0	1
0	0		0	0	0	0	0	0	0
								0	7

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	0	5	0	0
1	5	0	3	5	0	0
1	5	0	1	5	0	0
2	4	0	2	2	0	0
2	4	0	1	2	0	0
2	4	0	0	2	0	0
		$\Sigma L_{a(j)}=$	7	$\Sigma r_{d(j)}K_{b(j)}=$	0	0

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	7	
	π	0	
STEP 2	VAR(λ)	7	
	VAR(π)	0	
STEP 3	δ	-7	
	θ	#DIV/0!	#DIV/0!
STEP 4	VAR(δ)	7	
	VAR(θ)	#DIV/0!	

Reduction	#DIV/0!
std deviation	#DIV/0!

5% +/- 25% result is NOT statistically significant

Summary (Treatment year omit) Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001	1		2	2	2	4	1	0	1	11
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001	3		2	3	2	5	4	0	3	16
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001	6		6	1	4	9	4	0	6	24
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001	63	52		38	52	43	20	0	115	153
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002	2	4		3	3	4	4	0	6	14
																					131	218

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	11	5	5	25
1	5	3	16	5	15	75
1	5	6	24	5	30	150
2	4	115	153	2	230	460
2	4	6	14	2	12	24
		$\Sigma L_{a(j)}$=	218	$\Sigma r_{d(j)}K_{b(j)}$=	292	734

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	218	
	π	292	
STEP 2	$VAR(\lambda)$	218	
	$VAR(\pi)$	734	
STEP 3	δ	74	
	θ	0.740203	0.259797
STEP 4	$VAR(\delta)$	952	
	$VAR(\theta)$	0.007107	

Reduction	0.259797
std deviation	0.168607

26% +/- 17% result is NOT statistically significant

Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		0	1	2	3	0	0	0	6
1		1	3	1	4	3	0	1	12
4		4	0	2	4	2	0	4	12
40	34		28	34	29	12	0	74	103
1	2		2	1	3	3	0	3	9
								82	142

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	6	5	0	0
1	5	1	12	5	5	25
1	5	4	12	5	20	100
2	4	74	103	2	148	296
2	4	3	9	2	6	12
		$\Sigma L_{a(j)}=$	142	$\Sigma r_{d(j)}K_{b(j)}=$	179	433

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	142	
	π	179	
STEP 2	$VAR(\lambda)$	142	
	$VAR(\pi)$	433	
STEP 3	δ	37	
	θ	0.782718	0.217282
STEP 4	$VAR(\delta)$	575	
	$VAR(\theta)$	0.01226	

Reduction	0.217282
std deviation	0.221451

22% +/- 22% result is NOT statistically significant

Wet Bin 2

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001	1		1	1	0	1	0	0	1	3
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001	2		1	0	1	0	0	0	2	2
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001	2		2	0	0	3	2	0	2	7
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001	18	15		6	13	9	5	0	33	33
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002	1	2		0	2	1	1	0	3	4
																					41	49

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	3	5	5	25
1	5	2	2	5	10	50
1	5	2	7	5	10	50
2	4	33	33	2	66	132
2	4	3	4	2	6	12
		$\Sigma L_{a(j)}=$	49	$\Sigma r_{d(j)}K_{b(j)}=$	97	269

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	49	
	π	97	
STEP 2	VAR(λ)	49	
	VAR(π)	269	
STEP 3	δ	48	
	θ	0.491114	0.508886
STEP 4	VAR(δ)	318	
	VAR(θ)	0.01117	

Reduction	0.508886
std deviation	0.211377

51% +/- 21% result is statistically significant

Not Dry Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

Project	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
3	1		2	1	0	1	1	0	1	5
5	2		1	0	1	1	1	0	2	4
6	2		2	1	2	5	2	0	2	12
19	23	18		10	18	14	8	0	41	50
23	1	2		1	2	1	1	0	3	5
									49	76

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	5	5	5	25
1	5	2	4	5	10	50
1	5	2	12	5	10	50
2	4	41	50	2	82	164
2	4	3	5	2	6	12
		$\Sigma L_{a(j)}=$	76	$\Sigma r_{d(j)}K_{b(j)}=$	113	301

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results
STEP 1	λ	76
	π	113
STEP 2	VAR(λ)	76
	VAR(π)	301
STEP 3	δ	37
	θ	0.657077
STEP 4	VAR(δ)	377
	VAR(θ)	0.015136

0.342923

Reduction 0.342923
std deviation 0.24606

34% +/- 25% result is NOT statistically significant

Severe Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		2	1	0	0	0	0	0	3
0		1	1	0	0	1	0	0	3
2		0	0	0	1	1	0	2	2
12	4		4	8	8	8	0	16	28
0	0		0	0	2	0	0	0	2
								18	38

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	3	5	0	0
1	5	0	3	5	0	0
1	5	2	2	5	10	50
2	4	16	28	2	32	64
2	4	0	2	2	0	0
		$\Sigma L_{a(j)}$=	38	$\Sigma r_{d(j)}K_{b(j)}$=	42	114

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	38	
	π	42	
STEP 2	VAR(λ)	38	
	VAR(π)	114	
STEP 3	δ	4	
	θ	0.84984	0.15016
STEP 4	VAR(δ)	152	
	VAR(θ)	0.057949	

Reduction	0.15016
std deviation	0.481451

15% +/- 48% result is NOT statistically significant

Intersection Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
1		2	2	2	3	0	0	1	9
2		2	3	2	2	3	0	2	12
3		5	1	3	5	2	0	3	16
53	45		26	42	24	15	0	98	107
2	4		3	3	3	2	0	6	11
								110	155

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	1	9	5	5	25
1	5	2	12	5	10	50
1	5	3	16	5	15	75
2	4	98	107	2	196	392
2	4	6	11	2	12	24
		$\Sigma L_{a(j)}=$	155	$\Sigma r_{d(j)}K_{b(j)}=$	238	566

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	155	
	π	238	
STEP 2	$VAR(\lambda)$	155	
	$VAR(\pi)$	566	
STEP 3	δ	83	
	θ	0.644817	0.355183
STEP 4	$VAR(\delta)$	721	
	$VAR(\theta)$	0.006703	

Reduction	0.355183
std deviation	0.163738

36% +/- 16% result is statistically significant

Rear End Bin 2

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
3	2	5890	6050	5880	5990	6930		13952	7449	3724	10	2001
5	2	12530	10630	10840	13490	11780			11854	5927	87	2001
6	4	17650	18870	18610	23640	23250			20404	5101	90	2001
19	4	20800	21000	22500	28740	24970		29028	24506	6127	33	2001
23	2	5450	5410c	7320	6610	6510			6473	3236	0	2002

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	5
Bin 3	7000 <=aadt/lane	🟩	0

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
0		1	0	0	2	0	0	0	3
1		1	1	1	2	1	0	1	6
5		2	1	1	4	0	0	5	8
26	16		16	16	16	9	0	42	57
1	0		2	0	1	2	0	1	5
								49	79

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
1	5	0	3	5	0	0
1	5	1	6	5	5	25
1	5	5	8	5	25	125
2	4	42	57	2	84	168
2	4	1	5	2	2	4
		$\Sigma L_{a(j)}=$	79	$\Sigma r_{d(j)}K_{b(j)}=$	116	322

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	79	
	π	116	
STEP 2	VAR(λ)	79	
	VAR(π)	322	
STEP 3	δ	37	
	θ	0.665118	0.334882
STEP 4	VAR(δ)	401	
	VAR(θ)	0.015438	

Reduction	0.334882
std deviation	0.248501

33% +/- 25% result is NOT statistically significant

Summary (Treatment year omit) Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
41	61		57	65	69	28	0	102	219
								102	219

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	102	219	2	204	408
		$\Sigma L_{a(j)}=$	219	$\Sigma r_{d(j)}K_{b(j)}=$	204	408

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	219	
	π	204	
STEP 2	VAR(λ)	219	
	VAR(π)	408	
STEP 3	δ	-15	
	θ	1.063107	-0.06311
STEP 4	VAR(δ)	627	
	VAR(θ)	0.015927	

Reduction	-0.06311
std deviation	0.252406

-6% +/- 25% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
37	49		42	49	49	21	0	86	161
								86	161

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	86	161	2	172	344
		$\Sigma L_{a(j)}$=	161	$\Sigma r_{d(j)}K_{b(j)}$=	172	344

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	161	
	π	172	
STEP 2	VAR(λ)	161	
	VAR(π)	344	
STEP 3	δ	11	
	θ	0.925287	0.074713
STEP 4	VAR(δ)	505	
	VAR(θ)	0.014924	

Reduction	0.074713
std deviation	0.244327

8% +/- 24% result is NOT statistically significant

Wet Bin 3

Before Treatment
After Treatment

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment	1999	2000	2001	2002	2003	2004	2005	2006	Before	After
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001	2	10		11	9	12	4	0	12	36
																					12	36

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	12	36	2	24	48
		$\Sigma L_{a(j)}=$	36	$\Sigma r_{d(j)}K_{b(j)}=$	24	48

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2 Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	36	
	π	24	
STEP 2	VAR(λ)	36	
	VAR(π)	48	
STEP 3	δ	-12	
	θ	1.384615	-0.38462
STEP 4	VAR(δ)	84	
	VAR(θ)	0.181506	

Reduction	-0.38462
std deviation	0.852071

-39% +/- 85% result is NOT statistically significant

Not Dry Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
4	12		15	16	20	7	0	16	58
								16	58

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	16	58	2	32	64
		$\Sigma L_{a(j)}=$	58	$\Sigma r_{d(j)}K_{b(j)}=$	32	64

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	58	
	π	32	
STEP 2	$VAR(\lambda)$	58	
	$VAR(\pi)$	64	
STEP 3	δ	-26	
	θ	1.705882	-0.70588
STEP 4	$VAR(\delta)$	122	
	$VAR(\theta)$	0.205553	

Reduction	-0.70588
std deviation	0.906759

-71% +/- 91% result is NOT statistically significant

Severe Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment

After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
11	13		10	10	17	10	0	24	47
								24	47

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	24	47	2	48	96
		$\Sigma L_{a(j)}$=	47	$\Sigma r_{d(j)}K_{b(j)}$=	48	96

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	47	
	π	48	
STEP 2	$VAR(\lambda)$	47	
	$VAR(\pi)$	96	
STEP 3	δ	1	
	θ	0.94	0.06
STEP 4	$VAR(\delta)$	143	
	$VAR(\theta)$	0.051256	

Reduction	0.06
std deviation	0.452797

6% +/- 45% result is NOT statistically significant

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD'	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
34	53		43	50	51	21	0	87	165
								87	165

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	87	165	2	174	348
		$\Sigma L_{a(j)}=$	165	$\Sigma r_{d(j)}K_{b(j)}=$	174	348

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	165	
	π	174	
STEP 2	VAR(λ)	165	
	VAR(π)	348	
STEP 3	δ	9	
	θ	0.9375	0.0625
STEP 4	VAR(δ)	513	
	VAR(θ)	0.01508	

Reduction	0.0625
std deviation	0.245605

6% +/- 25% result is NOT statistically significant

Rear End Bin 3

Project	No. Lane	1999	2000	2001	2002	2003	2004	2005	Average A	Avg. AAD	No. Collisions	Year of Treatment
18	6	49540	49180	48875	50535	52180	49753		50011	8335	0	2001

* assumed 2 lane and took average aadt for resurfaced 2 lane

Bin 1	0<aadt/lane < 3000	🟩	0
Bin 2	3000=<aadt/lane <7000	🟩	0
Bin 3	7000 <=aadt/lane	🟩	1

Before Treatment
After Treatment

1999	2000	2001	2002	2003	2004	2005	2006	Before	After
14	24		30	30	27	12	0	38	99
								38	99

		Treatment				
Years before	Years After	Before (B)	After (A)			
$T_b(j)$	$T_a(j)$	$K_b(j)$	$L_a(j)$	$r_d(j)$	$r_d(j)K_b(j)$	$r_d(j)^2K_b(j)$
2	4	38	99	2	76	152
		$\Sigma L_{a(j)}=$	99	$\Sigma r_{d(j)}K_{b(j)}=$	76	152

Formulas:

$r_d(j) = T_a(j)/T_b(j)$

$\lambda = \Sigma L_a(j)$

$\pi = \Sigma r_d(j)K_b(j)$

$VAR(\lambda) = \Sigma La(j)$

$VAR(\pi) = \Sigma rd(j)^2Kb(j)$ *Assumes Poisson distribution*

$\delta = \pi - \lambda$

$\theta = (\lambda/\pi)[1 + VAR(\pi)/\pi^2]^{-1}$

$VAR(\delta) = VAR(\pi) + VAR(\lambda)$

$VAR(\theta) = \theta^2[VAR(\lambda)/\lambda^2 + VAR(\pi)/\pi^2]/[1 + VAR(\pi)/\pi^2]^2$

		Results	
STEP 1	λ	99	
	π	76	
STEP 2	$VAR(\lambda)$	99	
	$VAR(\pi)$	152	
STEP 3	δ	-23	
	θ	1.269231	-0.26923
STEP 4	$VAR(\delta)$	251	
	$VAR(\theta)$	0.055696	

Reduction	-0.26923
std deviation	0.471998

-27% +/- 47% result is NOT statistically significant