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Impact of pavement conditions on crash severity

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ABSTRACT

Pavement condition has been known as a key factor related to ride quality, but it is less clear how exactly pavement conditions are related to traffic crashes. The researchers used Geographic Information System (GIS) to link Texas Department of Transportation (TxDOT) Crash Record Information System (CRIS) data and Pavement Management Information System (PMIS) data, which provided an opportunity to examine the impact of pavement conditions on traffic crashes in depth. The study analyzed the correlation between several key pavement condition ratings or scores and crash severity based on a large number of crashes in Texas between 2008 and 2009. The results in general suggested that poor pavement condition scores and ratings were associated with proportionally more severe crashes, but very poor pavement conditions were actually associated with less severe crashes. Very good pavement conditions might induce speeding behaviors and therefore could have caused more severe crashes, especially on non-freeway arterials and during favorable driving conditions. In addition, the results showed that the effects of pavement conditions on crash severity were more evident for passenger vehicles than for commercial vehicles. These results provide insights on how pavement conditions may have contributed to crashes, which may be valuable for safety improvement during pavement design and maintenance. Readers should notice that, although the study found statistically significant effects of pavement variables on crash severity, the effects were rather minor in reality as suggested by frequency analyses.

1. Introduction

Traffic safety is one of the most important study areas among transportation engineers and researchers. Research individuals have devoted significant efforts to develop good understanding of factors contributing to traffic crashes. The implementation of many meaningful findings have resulted in significant safety improvements, evidenced by decreased fatalities, injuries, and property losses associated with traffic crashes.

Pavement condition has been known as a key factor related to ride quality, but it is less clear how pavement conditions are related to traffic crashes. During a literature review, the researchers did not find comprehensive studies that examined the relationship between key pavement condition indicators and traffic crashes. Several earlier studies investigated the impacts of pavement conditions on vehicle maneuvers mostly due to skidding (Nakatsuji et al., 1990; Burns, 1981; Chandra, 2004). A recent Tennessee study attempted to examine the safety impact of pavement conditions but did not find strong relationships between crash frequency and key pavement condition measures (Chan et al., 2010). The study was limited to crashes of four unban interstate highways with asphalt pavements and a 55 mph speed limit. A study of selected highway segments in Wisconsin showed that longitudinally ground cement pavements seemed to have lower overall crash rates than transversely tined concrete pavements (Drakopoulos et al., 1998).

State highway agencies (SHAs) have implemented relatively mature traffic crash databases that describe crashes with a large number of dimensions. Many SHAs routinely inspect pavement conditions of their on-system roadways and store key scores and ratings in pavement information databases. Traditionally, there has been a lack of direct linkages between these two types of databases, which, as found during the literature review, has been a primary factor for the lack of in-depth research on the impact of pavement conditions on traffic crashes. On the other hand, advances in computer technology and the increasing availability of geographic information systems (GIS) have provided a possibility to integrate crash and pavement data with a much higher degree of efficiency.

This paper investigates the correlations between crash severity and several key pavement condition scores and ratings. The study analyzed traffic crashes occurred on Texas highways between 2008 and 2009. In a GIS environment, the researchers integrated

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the Crash Record Information System (CRIS) and Pavement Management Information System (PMIS) at the Texas Department of Transportation (TxDOT) and generated a data repository with abundant information describing crash events and the crash roadway conditions. Using multiple comparison procedures (MCPs) and Chi-Square statistics, the research team examined potential relationship between crash severity and each of the selected pavement condition variables.

2. Data collection

During this study, the researchers analyzed traffic crashes that occurred between 2008 and 2009 on TxDOT on-system highways (highways on the TxDOT-designated highway system). The data collection and processing efforts involved the following three major steps:

- Crash data collection,
- Pavement data collection, and
- Crash and pavement data integration.

2.1. Crash data collection

Crash data were obtained from TxDOT CRIS data system, which contained detailed information about traffic crashes on all Texas highways based on reports from Texas Department of Public Safety (DPS). The CRIS data were organized in three data files:

- Crash, which included variables depicting the crash events, such as crash date/time, number of vehicles, environmental condition, and crash location.
- Person, which included variables depicting each person who was involved in the crash, such as gender, age, human factor, and role in the crash.
- Vehicle, which included variables depicting each vehicle that was involved in the crash, such as vehicle type, make, model, year, and harmful maneuver.

Among the data files, this study was focused on the crash file that included most pertinent variables interesting to this research. Due to the large number of variables (148 fields in total) available in this data file and to ensure depth, the researchers selected the following variables for further analysis based on engineering judgment and previous research experience:

- CMV_INVOLV, which indicated if commercial vehicles were involved in the crash.
- SURFACE_COND, which described the pavement surface condition (e.g., dry or wet) during the crash. The original field included 11 values, which were further grouped to four general groups including dry, wet, snowy/icy, and other to increase effective sample sizes.
- CRASH_SEV, which described the severity of the crash including fatal, incapacitating injury, non-incapacitating injury, possible injury, not injured, and unknown. During this analysis, the researchers assigned an index number to each of the different severities to indicate the level of a severity as compared to other severity outcomes:
  - 1 = not injured,
  - 2 = possible injury,
  - 3 = non-incapacitating injury,
  - 4 = incapacitating injury, and
  - 5 = fatal.
- LIGHT_COND, which described the light condition when the crash took place. The original field included nine values, which were further grouped to four general groups including daylight, dawn/dusk, dark, and unknown during the analysis to increase effective sample sizes.
- VEH_COUNT, which was the number of vehicles involved in the crash.
- MONTH, which was the month during which the crash took place.

2.2. Pavement data collection

Pavement data were extracted from TxDOT PMIS. PMIS is an automated system used by TxDOT for storing, retrieving, analyzing, and reporting pavement condition information. For the purpose of this study, the researchers obtained PMIS data for the same years as for the crash data. The PMIS database included a large number of tables. The research team focused on the PMIS_CONDITION_SUMMARY and PMIS_DATA_COLLECTION_SECTION tables.

The PMIS_CONDITION_SUMMARY table included a summary of the major pavement condition scores and ratings. This study focused on the following PMIS scores and ratings in the table (TxDOT, 1997; Wu et al., 2010):

- Distress score, which is a value between 1 (most distress) and 100 (least distress) that describes the overall amount of surface distress on the data collection section. This score combines the scores for each type of distress and measures the overall cracking and rutting. TxDOT uses a multiplicative utility analysis approach to calculate distress scores. To calculate the overall distress score, the distress score of each type of distress for a pavement section is converted into a utility value between 0 and 1 using the following formula:

  $$U_i = 1 - \alpha e^{-(\rho/L_i)^{\beta}}$$

  where U_i is the utility value for distress type i; L_i is the length of the ith distress type; a, ρ, β are coefficients controlling the shape of the associated curve and the value of U_i. The overall distress score is the product of 100 and the utility values for all distress types applicable to the pavement type of the data collection segment.

  During this analysis and in accordance with how TxDOT classifies distress scores, the researchers divided the distress scores into four groups including very poor (1–49), poor (50–69), fair or good (70–89), and very good (90–100).
- Condition score, which describes the average person's opinion of a pavement's condition by combining distress ratings, ride quality measurements, average daily traffic, and speed limit into a single value from 1 (worst) to 100 (best). During this analysis, the research team divided the condition scores into four groups using the same criteria of distress scores.
- Skid score, which is a value between 1 (least skid resistance) and 99 (most skid resistance) that describes the overall skid resistance of the data collection section. Skid scores are useful for engineers to evaluate surface friction properties of aggregate types, asphalt mix design, and pavement construction methods. Scores generally range from 10 to 40, with the higher number indicating greater skid resistance. During this study, the researchers grouped skid scores into three groups including good (51–99), fair (26–50), and poor (1–25).
- Ride score, which is a value from 0.1 (roughest) to 5.0 (smoothest) calculated as the length-weighted average of the raw serviceability index (SI) values measured in a data collection section. It describes the overall ride quality of the data collection section. During this analysis, the researchers used the following groups for ride scores: rough (0.1–2.5), fair (2.6–3.5), and smooth (3.6–5).