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Effect of Pavement Conditions on Urban Road Accidents

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ABSTRACT

Traffic accidents represent a serious problem in Jordan. The major objective of this study was to investigate the effect of pavement conditions on urban road accidents. To achieve the objective of the study, 25 urban pavement sections were selected. A comprehensive data base, including pavement conditions in terms of pavement condition index (PCI), traffic volume, and traffic accidents, for the selected sections, was developed. Regression analyses were carried out to explore possible relationships between PCI and the number of accidents and accident rates.

The results of the statistical analysis indicated that urban pavement conditions had a significant effect on accident occurrences and accident rates. The relationship between accidents and PCI had a parabolic shape. The regression models explained 69% and 61% of the variation in accident frequency and rate, respectively. It was found that urban pavement sections with PCI lower than 50 were consistently associated with higher accident frequency or accident rate. Also, a notable increase in accidents was observed for all sections having a PCI greater than 85. The results of the study are comparable with the results found for rural pavement sections. To provide a safe urban environment; therefore, municipal engineers should keep urban pavement in fair conditions and implement appropriate calming measures for good pavement conditions.

Keywords: Accident occurrence, Accident rate, Road safety, Pavement condition index (PCI), PAVER system, Pavement management system (PMS), Pavement distresses.

INTRODUCTION

Jordan is one of the Middle East countries and classified as a lower-middle income developing country. It has a serious road accident problem. In 2022, for example, the total number of road accidents was 169409, which resulted in 562 deaths and 17096 injuries, in addition to US$ 453 million as economic losses (JTI, 2023). These socio-economic losses are very huge for a country having limited resources. As such, different actions and policies have been undertaken to reduce this problem, including intensification of police enforcement, updating traffic laws, improvement of blackspot locations, and installation of speed cameras, among other related countermeasures. In fact, road accidents are caused by a set of contributing factors, including human errors, roadway environment, and vehicle related issues. The roadway environment may encompass geometric design limitations, poor pavement condition, as well as lack of roadway infrastructure. Although several studies and manuals have been developed and implemented to enhance roadway geometric design and infrastructure, limited studies have been carried out to investigate the impact of pavement condition on road safety.

Transportation agencies strive to enhance roadway safety through effective pavement engineering and maintenance. This approach is essential for economic competitiveness and is a critical transportation policy. Pavement conditions, especially roughness, rutting, and skid resistance, strongly influence accident risks. Poor pavement increases accident rates, with higher roughness and rutting linked to more accidents (Mkwata & Chong, 2022; Al-Zubaidi et al., 2023). Improved skid resistance lowers accident rates, particularly in bad weather and at night. The effect of pavement on accident severity differs by road type: high-speed roads see more severe single-vehicle crashes, while low-speed roads experience more severe multi-vehicle crashes. Precipitation increases accident frequency, but its impact on severity depends on factors, like fog, smoke, and accidents occurring before sunrise, which worsen severity (Sadeghi & Goli, 2024). Most studies on pavement condition and safety focus on skid resistance, but a comprehensive examination of all factors is necessary. For example, Al-Masaeid et al. (1998) explored the impact of pavement condition on the effectiveness of traffic operation on rural roads. They indicated that poor pavement condition, expressed in terms of international roughness index (IRI), pavement condition index (PCI), or pavement serviceability rating (PSR), has significantly reduced traffic speeds. Also, Al-Masaeid (1997) investigated the impact of pavement condition, expressed in terms of IRI and PSR, on rural primary road accidents. A comprehensive data base for 1130 km of two-lane rural roads in Jordan was developed in the study. He found that pavement condition had significant effects on single- and multiple-vehicle accident rates. The single-vehicle accidents included both rollover and fixed-object accidents. For each roadway segment, the study evaluated: single-vehicle accident rates, multiple-vehicle accident rates and total accident rate (which combines both single- and multiple-vehicle accidents). However, limited research has explored the relationship between pavement condition and accident rates in urban areas. In fact, urban roads are characterized by low speed levels with higher traffic volumes. Probably, the association between pavement condition and traffic accidents depends on the area type. For example, Yangsong et el. (2024) found that potholes are positively correlated with flat tire incidents. They also indicated that potholes in the central city were found to have a higher association with flat tire frequency than in rural areas. Thus, it is vital to explore the possible impact of pavement condition on urban road accident rates.

The objective of this study is to explore the impact of pavement condition on urban road accident rates. To achieve this objective, a major arterial urban road in Irbid city was taken as a case study. The city is considered as the second largest city in Jordan with a population of 350 thousand inhabitants. It is the center of the Irbid governorate, which has a population of about 2.2 million people. Data on pavement condition, road geometrics, traffic volume, and traffic accidents was obtained from related sources or through field measurements. The pavement conditions, expressed in term of pavement condition index (PCI), of 25 pavement sections were evaluated through field measurements. The study was carried out in 2022.

LITERATURE REVIEW

Pavement surface conditions, particularly roughness and rutting, have a strong positive effect on accident risks, with increased roughness and rutting associated with higher accident rates. Increased pavement skid resistance is associated with lower accident rates, and the effect is more pronounced in poor weather conditions and at night (Mkwata & Chong, 2022, Al-Zubaidiet al., 2023). Pavement friction, roughness, and rutting, particularly during rain and at night, are key factors influencing road accidents. The effect of pavement conditions on accident safety differs based on road type and classification. Poor pavement conditions tend to result in more severe single-vehicle crashes on high-speed roads, while on low-speed, low-level roads, they lead to less severe single-vehicle accidents, but more severe multi-vehicle crashes. Additionally, precipitation has a direct, linear relationship with accident frequency, though its impact on accident severity varies. This variation is influenced by multiple factors, including fog, smoke, and accidents occurring before sunrise, which exacerbate the severity of accidents (Sadeghi & Goli, 2024).

Pavement is considered prone to accidents if it has a rut depth exceeding 23.5 mm and an IRI value greater than 3.2 m/km. The pavement roughness is defined as irregularities in the pavement surface that adversely affect vehicle ride quality, playing a critical role in highway condition analysis. Road roughness directly impacts ride quality, vehicle delay costs, and fuel consumption. Due to its importance, highway agencies regularly measure and monitor road roughness. Roughness can be assessed subjectively in terms of Present Serviceability Index (PSI) or PSR, or objectively using cumulative measures of vertical displacements, like the International Roughness Index (IRI), and reported in units of inches/mile or m/km. On the other hand, the PCI is a numerical index which varies from 0 to 100, giving an indication of a pavement structural integrity and operational condition. The PCI is determined based on the type, severity, and quantity of pavement distress. It is worth mentioning that IRI and PCI are pavement performance indicators. Furthermore, for the same road type and regional area, both IRI and PCI are strongly related (Priyonesi & El-Diraby, 2021). A study by Sati et al. (2024) investigated advanced methodologies for assessing and managing pavement deterioration, focusing on the International Roughness Index (IRI) as a key performance indicator. The research employed predictive modeling and reliability analysis to evaluate pavement performance, identifying critical factors such as axle loads and environmental conditions that impact IRI and the overall pavement serviceability. The findings emphasized the importance of data-driven approaches for optimizing maintenance and rehabilitation strategies in pavement management systems, contributing to sustainable infrastructure management (Sati et al., 2024).

Previous research has extensively analyzed the impact of pavement condition on accident rates. Pavement distresses, such as rutting, significantly influence accident occurrence. Numerous studies have demonstrated strong correlations between pavement friction and accident rates, with a notable emphasis on the role of friction loss in skidding, particularly on wet pavements (Kuttesch,2004). Research has consistently shown that a reduction in skid resistance correlates with an increase in wet crash rates, with this relationship being either linear or non-linear (Noyce et al., 2005). The highest number of crashes typically occurs when the friction factor is below 0.15 (Hall et al., 2009).

While pavement condition contributes a smaller percentage to overall accidents compared to human factors, maintaining good pavements can still significantly reduce accident rates. There is a robust relationship between road roughness and road safety, with higher accident rates associated with increased pavement roughness. Light vehicles, in particular, are more affected by increased roughness than heavy vehicles. It is recommended that agencies reduce rural road roughness to an International Roughness Index (IRI) value of 120 in./mile to enhance road safety (King, 2014). In Jordan, Al-Masaeid (1997) found that the rate of reduction in single-vehicle accident decreases with the increase in the IRI level. In contrast, he found that multiple-vehicle accidents increase with the increase in the IRI level. In Jordan, single- and multiple-vehicle accidents are approximately equal. Thus, he concluded that it would be beneficial to keep IRI below 5 m/km on Jordanian primary rural roads.

Li et al. conducted a study in Texas exploring the relationship between accident severity and pavement condition, finding that higher severity accidents occurred more frequently on roads with poor pavement conditions compared to those with fair conditions. Interestingly, higher severity accidents also occurred on roads with very good pavement conditions (Zhou & Wang, 2008). Li further stated that poor pavement surface conditions are responsible for higher crash rates (Li,2014). In Malaysia, Baskara et al. (2023) conducted a study on the impact of the International Roughness Index (IRI) on accident severity on Malaysian highways. The results revealed that IRI had the most significant effect on accident severity compared to other pavement characteristics, such as rut depth and mean texture depth. The study found that when pavement characteristics (IRI, rut depth, and mean texture depth) exceed certain thresholds, the likelihood of fatal accidents increases significantly. Therefore, maintaining pavement conditions within these identified thresholds is essential for improving road safety and reducing the severity of accidents. (Baskara et al., 2023).

In Canada, the relationship between IRI values and accident numbers revealed that sections with high IRI values experienced more crashes compared to those with low IRI values. Additionally, a significant correlation was found between rut depth and accident numbers (Tehrani, 2014). A study in New Zealand developed a statistical model to predict the correlation between rut depths and fatal and injury accidents on the state highway network, finding an increased accident rate where rut depth exceeded 10 mm (Cenek and Davies, 2004). Another study demonstrated the relationship between accident frequency and pavement condition using IRI, rut depth, and Present Serviceability Index (PSI) as parameters. The results indicated that IRI and PSI were significant across all model types, while the rut depth model was particularly effective in predicting night-time accidents (Chan et al., 2010). A statistical relationship between IRI and driving comfort and safety further highlighted that pavement condition is a contributing factor to traffic safety and accident occurrence (Hu et al., 2013).

Pavement roughness affects not only ride quality, but also vehicle lifespan, fuel consumption, delay costs, and traffic noise level (Al-Masaeid & Bani-Hani, 2023). Importantly, increased roughness can cause loss of vehicle control during braking or turning (Chan et al., 2010). As pavement roughness increases, the contact area between the vehicle tire and pavement decreases, leading to reduced braking friction (Wambold et al., 1973). Research has found that pavement distresses, like potholes, cracks, and raveling significantly impact pavement roughness. Rut depth and patching also severely affect road roughness (Chandra et al., 2012). Distress characteristics influence IRI values, with one study reporting a correlation factor (R^2) of 0.944 between IRI and distress factors (Zhou & Wang, 2008; Li et al., 2013). These findings indicate that IRI and pavement distresses are closely linked, making IRI a reliable measure of pavement distress.

Moreover, rutting is characterized by longitudinal depressions in the wheel path of paved surfaces, caused by deformation of the pavement surface, base, sub-base, or sub-grade (Huang, 1993). Rutting data is measured and reported in inches or millimeters. In dry conditions, rutting acts as a wheel path, requiring drivers to exert extra effort to exit the rut if its depth is significant. Rutting is more hazardous in wet weather, as water accumulation in the rut path can lead to hydroplaning.

Most previous studies on the impact of pavement condition on safety primarily focus on skid resistance, with limited research available on how pavement distresses affect safety. This study examines the influence of pavement condition, as measured by PCI, on accident occurrence. The most challenging aspect of this research involved collecting PCI data from the field and organizing the available accident data to establish a common basis for data correlation.

METHODOLOGY

This paper outlines a comprehensive methodology for analyzing the relationship between pavement condition and accident rates. The initial step involved defining the study location. Each selected street was treated as a separate segment, which was then divided into multiple sections based on various factors, such as pavement structure, rank, condition, traffic volume, drainage facilities, and construction history, including the date of construction or last major maintenance.

To facilitate the pavement condition survey, each selected section was further divided into smaller management units known as sample units. Detailed inspections were conducted for every sample unit within each section. The types, severity levels, and quantities of collected pavement distresses were entered into the Micro-PAVER system to determine the PCI value for each section. Additionally, data on age (in years) and length (in kilometers) of each selected section was collected to calculate PCI and accident rates.

The number of accidents in each selected section was also determined to establish accident rates. This data was used to identify the relationships between the PCI values of pavement sections and accident frequencies. The aim was to uncover the logical correlation between pavement condition and accident occurrence, as illustrated in Figure 1.

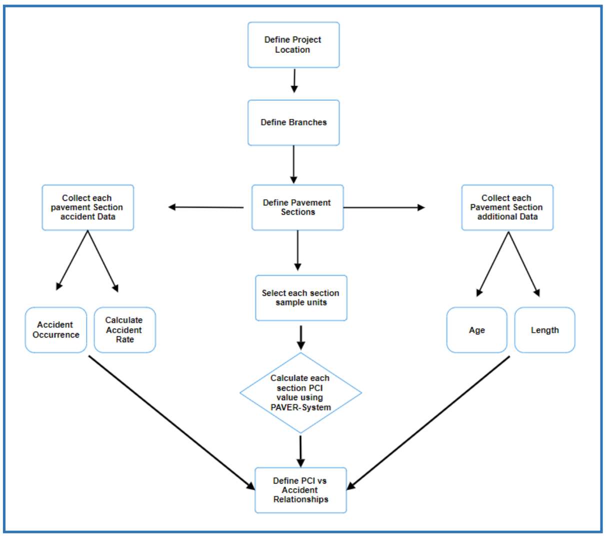

Figure (1): Research methodology

Site Location

The western entrance of Irbid city features one of its most active roads, connecting multiple districts to the downtown area. This main arterial street, approximately 3 km long, links two major traffic signals with a central rotary. The entrance area is a popular destination due to its many tourist attractions. The street exhibits significant variations in surrounding land use. A large portion is lined with car repair shops, where oil spills and deterioration significantly impact pavement conditions. Other sections are place to public amenities, such as large supermarkets, restaurants, commercial markets, a comprehensive secondary school, and a police station. These areas receive more attention and maintenance, resulting in better pavement conditions compared to other sections. The traffic signals and roundabout experience high traffic volumes due to their role in managing major intersections, leading to worse pavement conditions. Given the diversity in pavement conditions, accident occurrences, and traffic volumes, the western entrance of Irbid city in addition to many arterial roads that serve large traffic volumes through Irbid city were selected for this study in order to explore the possible relationship between the Pavement Condition Index (PCI) and accident rates for Irbid city, starting from the western entrance to the other vital arterial roads. Figure 2 shows an aerial photography of Irbid city.

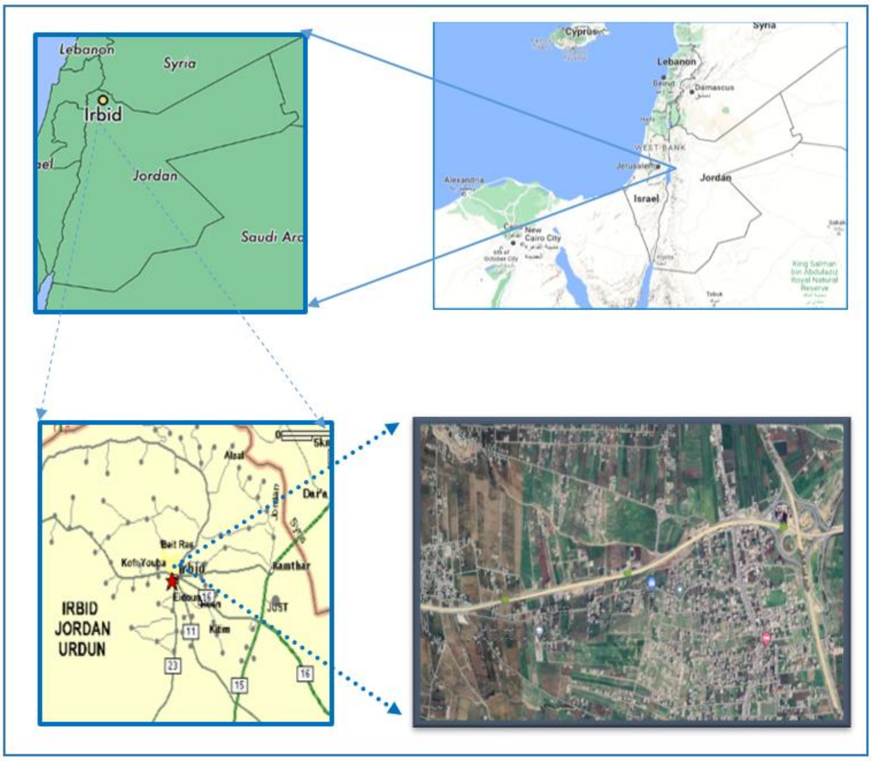

Figure (2): An aerial photography for Irbid city with the sections in the western entrance

Data Collection

Accident Data

Traffic accident data was collected from different locations and agencies, especially from Irbid Municipality and Jordan Traffic Institute (JTI). The data was collected, organized and then separated for each road section according to its time, location, and detailed information. All accidents that occurred at the same road section were collected together and accident occurrence or frequency was found according to its definition; which is the number of accidents that occur at a particular location over a given period of time. Accident frequency or occurrence was obtained from the data source by summing up the total number of accidents that occur at a particular section. The analysis period for the study was selected to be one year (2022).

In order to consider the impact of traffic factors or length of the road segments on the accident occurrances, accident rates are generally used. Accident data need to be normalized to obtain accident rate that can be used to provide better judgments and help in prioritizing locations for safety analysis. A widely used approach to calculate accident rate can be performed using Eq. (1) (Huang, 1993):

$$R = \frac{C*100{,}000{,}000}{V*365*L*N} \quad (1)$$

where:

C: Average number of crashes in the study period.

V: Average traffic volume entering the study area daily or average-annual-daily-traffic (AADT).

L: Length of the road segment used for analysis.

N: Number of years of data.

The accident rate can be calculated by using the average number of crashes in each study period multiplied by 1 million, then dividing the result due to the AADT, segment length, number of years and number of days within the year.

Traffic Data

Some major street sections within Irbid city were selected, because they experienced most of the daily trips. These sections include some sections at the western entrance of Irbid city, in addition to many major roads through the city. An arterial road is designed for high speed, to realize high traffic volume, and create connection routes between the major residential and commercial locations. A collector street is designed for moderate speed, to realize moderate traffic volume and create connections between local streets and arterial streets (Huang, 1993). Each road type was determined and sections were categorized into arterial or collector roads.

Each selected section's location was exactly determined and indicated by its related road name. Traffic volume data also was collected from Dar Al-Omran Consulting Company and Irbid Municipality. Then, the data was checked, reviewed and organized in term of average daily traffic (ADT).

Every section's age was determined since construction or last maintenance or rehabilitation, and all of the available records and documents from Irbid Municipality were collected, reviewed, organized and extracted for each pavement section in order to insert them for Micro-Paver in order to find section PCI or use that information in statistical model development as a contributing factor. Every section length was measured in order to exactly determine the pavement condition, to use it in finding the accident rate and in the modeling process to insert it as a contributing factor.

Pavement Sections

Dealing with the same area use, the same funding source and the same acceptable operational standard ensures dealing with the same network only; dealing with the same geographical area ensures dealing with same zone only. A branch is a defined portion of the network associated with the same function, which leads us to deal with the whole main street as one branch. The branch does not always contain consistent characteristics, which makes it better to divide it into sections according to many considerations, as: pavement structure, rank and condition, traffic volume, drainage facilities and construction histories since construction or last major maintenance. A traffic signal rotary section had a total pavement condition survey, and each sample unit in these sections was inspected and the exact PCI value was determined using Micro-Paver. The rest of sections were inspected randomly and additional samples were taken, since significant conditions were noticed. Detailed information for the selected sections is provided in Table 1. Figures (3) and (4) show the locations and sample units of the first six sections.

Table 1. Detailed information for the sections

Section Number	Number of Total Sample Units	Number of Inspected Sample Units	Number of Randomly Sampled Units	Number of Additionally Sampled Units	Length (m)	Area (m^2)
1	4	4	4	0	15.3	229.5
2	11	11	11	0	350	2450
3	11	11	11	0	350	2450
4	4	4	4	0	Dia.=16.5	140.4
5	90	18	16	2	2700	18900
6	90	16	16	0	2700	18900
7	89	20	20	0	3170	450
8	146	30	30	0	5200	743
9	62	15	14	1	2200	314

10	58	15	15	0	2060	295
11	93	19	19	0	3300	470
12	93	19	19	0	3300	470
13	20	12	12	0	700	100
14	76	18	18	0	2700	385
15	37	9	9	0	1300	185
16	70	16	16	0	2500	357
17	37	13	12	1	1320	188
18	84	19	19	0	3000	428
19	108	22	20	2	3850	550
20	55	15	15	0	1950	279
21	70	16	16	0	2500	357
22	119	25	25	0	4200	600
23	95	21	21	0	3400	485
24	37	13	12	1	1300	180
25	42	14	14	0	1500	215

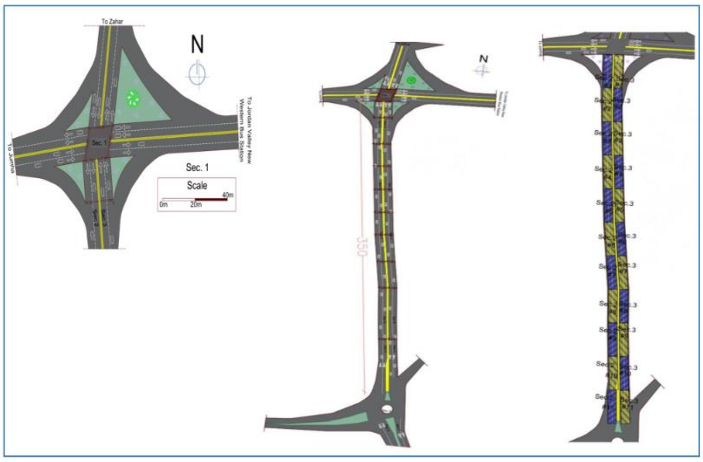

Figure (3): Location and sample unit illustration of sections 1, 2 and 3

The number of inspected sample units was determined systematically, the number of random samples was determined for every section, and then, additional samples were added if there is any unusual sample unit condition.

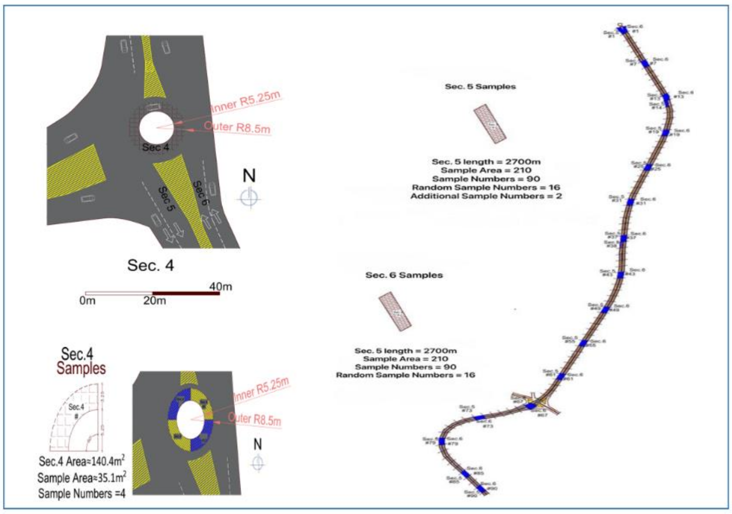

Figure (4): Location and sample unit illustration of sections 4, 5 and 6

Procedure of Visual Inspection

It was observed that the road experienced the lowest traffic volumes in the early mornings. So, it was selected for conducting a comprehensive visual inspection survey for the selected sections using the necessary tools. Every identified distress in the pavement was carefully located, marked with chalk, and measured accurately. The corresponding number, severity level, and quantity of each distress were then recorded on the inspection sheet. The collected data was subsequently entered into the PAVER system to determine the PCI for each sample unit and section, and to quantify the extent of each distress within each section.

Pavement Condition Index (PCI)

PCI of Sample Units

After dividing each section into sample units, each selected sample is analyzed separately. The results from the visual survey are used to calculate the PCI for each sample unit using the PAVER system. Each distress type, area, length or number is recorded on the corresponding data sheet along with its severity level. These combinations are then entered into PAVER, which assigns a specific value for each type of distress combined with its severity level (low, medium, or high) and quantity. Table 2 illustrates this process, showing data for all samples in Section 1 as an example (see Table 3 and Figure 2).

Table 2. Sample units / section 1 distress information

Sample Number	Distress	Description	Severity	Quantity	Units	Density	Deduct
1	1	ALLIGATOR CR	H	4	Sqm	7.02	56.96
	10	L & T CR	M	3	M	1.6	11.93
	11	PATCH/UT CUT	M	3	Sqm	5.26	22.91
2	1	ALLIGATOR CR	H	5	Sqm	8.77	59.96
	10	L & T CR	M	3	M	1.6	11.93
	13	POTHOLE	M	1	Count	0.16	44.17
3	1	ALLIGATOR CR	H	4	Sqm	7.02	56.96
	10	L & T CR	M	2	M	1.07	8.89
4	1	ALLIGATOR CR	H	4	Sqm	7.02	56.96
	13	POTHOLE	M	1	Count	0.16	44.17

Table 3. Section one sample unit PCI values

Sample Number	Sample Type	Sample Size (m^2)	PCI
1	Random	57	39
2	Random	57	27
3	Random	57	41
4	Random	57	30

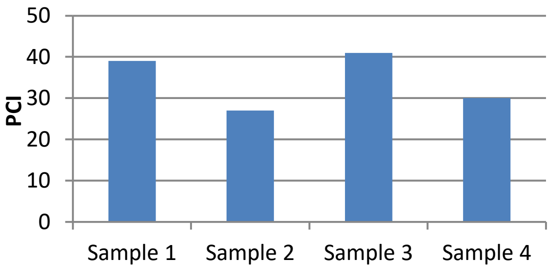

Figure (5): Section-1 sample unit PCI illustration

PCI of Pavement Sections

PCI for each pavement section represents the weighted average for all of pavement sample unit PCI values. It can be calculated by determining the total, random and additional sample unit numbers and PCIs, as mentioned in Equation (2).

$$PCIsection = [(N - A) * (PCIr) + A * (PCIa)]/N \quad (2)$$

where:

PCIs: PCI of pavement section.

PCI_r: PCI for random sample units.

PCI_a: PCI for additional sample units.

A: Number of additional sample units.

N: Number of total sample units in the section.

N: Number of inspected sample units in the section.

Then, the section's PCI value can be obtained directly from PAVER.

Pavement Condition Rating

The condition rating of a pavement section depends on a score that reflects performance. It is used to compare the performance of the sections and help agencies confine the extent and severity of each pavement distress and then estimate the cost of establishing priorities, according to PAVER system. Figure (6) shows the standard rating (Shah et al., 2013).

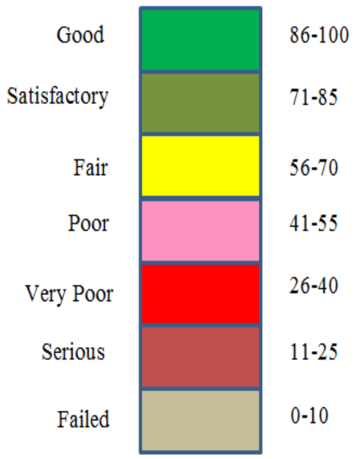

Figure (6): PCI rating according to PAVER standard and custom rating scale system classifications (Shah et al., 2013)

RESULTS AND ANALYSIS

The relationship between accidents and urban pavement condition was explored through scatter plots, correlation matrix, and regression analysis. Figure (7) shows that the number of accidents (N) decreases with the increase in PCI level up to about 85 and then, accidents tend to increase with the increase in the PCI value. The same relationship is shown in Figure (8), where accident rate (R) decreases with the increase in the PCI value up to about 85 and then, the accident rate tends to increase beyond that level. Clearly, the relationship between the number of accidents or accident rate is parabolic. Using multiple regression analysis, the following regression equations were obtained:

$$N= 0.0119*(PCI)^2 - 2.2833*PCI + 174.34 \quad (3)$$

$$R= 0.0009*(PCI)^2 - 0.1684PCI + 8.4622 \quad (4)$$

Equations (3) and (4) and their parameters were found to be significant at the 95% confidence level. Coefficients of multiple determination for Equations (3) and (4) were 0.689 and 0.611, respectively.

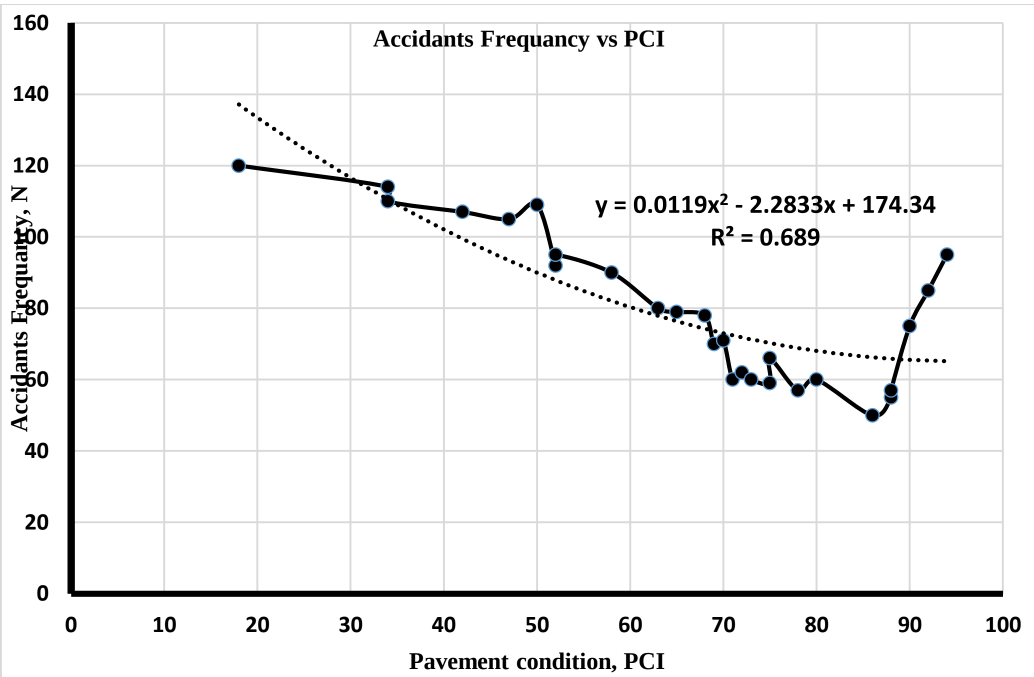

Figure (7): Accident frequency *vs.* pavement condition

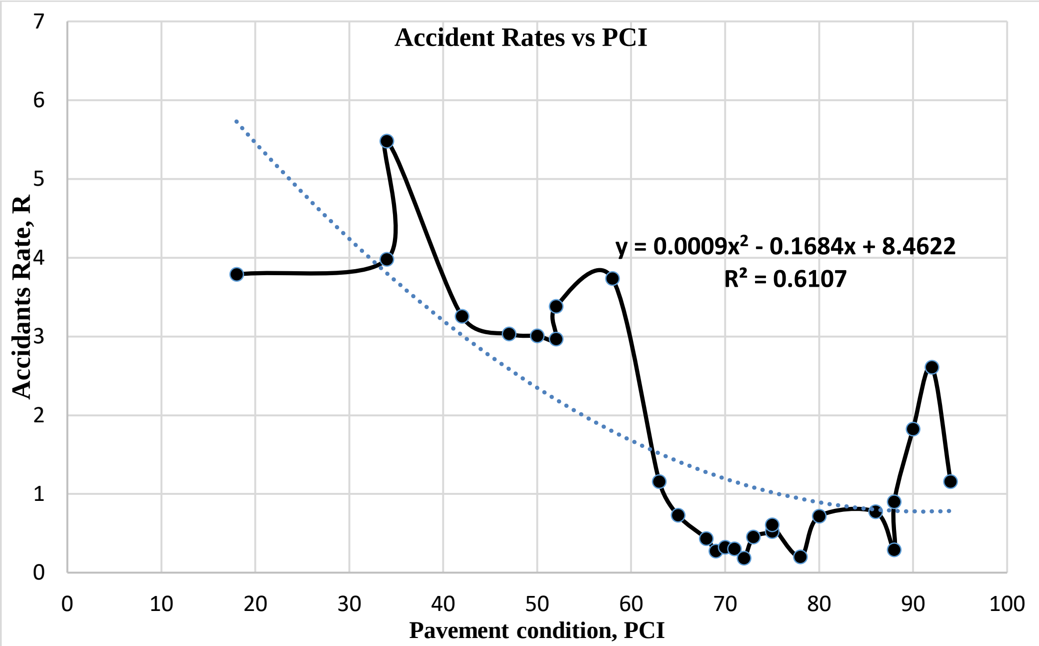

Figure (8): Accident rate *vs.* pavement condition

DISCUSSION

This study investigates the possible impact of pavement on traffic accidents or accident rate in an urban environment. The results of analysis confirm this impact. The results of analysis indicated that the relationship between the number of accidents or accident rate and pavement condition had a parabolic shape. Also, pavement condition explained about 69 and 61% of the number of accidents or accident rate variations, respectively. The study highlights that when PCI values exceed 85, there is a noticeable increase in the number of accidents or accident rate, which suggests that drivers may feel more confident on smoother urban roads, leading to higher speeds and consequently, to more accidents. The significant effect of PCI on accidents is particularly noteworthy, since the model did not account for other engineering elements, emphasizing the critical role of pavement condition alone. On the other end of the spectrum, roads with a PCI below 30 also experience higher accident rates. This is likely due to the hazardous driving conditions created by deteriorated pavement, such as potholes, alligator cracks, and utility cut patch defects, which can cause drivers to lose control or react unpredictably. Field observations show that lateral variations in the vehicle's path increase with the increase in pavement deteriorations. Probably, drivers tend to avoid severe distresses. As such, side-swipe accidents may occur. On the other hand, an increase in the potholes, alligator cracks or cut patch defects may force drivers to change their driving speed abruptly and this behavior may cause rear-end accidents.

To address the identified risks, especially on newly paved roads with high PCI values, it is essential to enforce more effective speed control measures. Reducing speed limits on these roads could counteract the tendency of drivers to speed, thereby reducing the number of accidents. Additionally, for sections with low PCI values, a systematic approach to pavement evaluation is crucial. Regular surveys should be conducted to assess the condition of the pavement, and timely maintenance should be carried out to improve safety and reduce accidents due to pavement deterioration, specifically potholes, alligator cracks, and utility cut patch defects.

The study findings are in line with those of previous studies that also found an increase in accident rates on roads with extreme pavement conditions. Roads in both very good and very poor conditions are more prone to accidents, underlining the importance of balanced road maintenance strategies (Al-Masaeid,1997). This consistency with existing literature reinforces the need for targeted interventions that address the specific risks associated with different pavement conditions.

The findings can be tested and ensured by defining a relationship between pavement roughness and accident number in the same pavement section. Also, many parameters can be added to the pavement condition to address the accident rates in all situations and seasons, such as the pavement section drainage.

Policymakers should consider adjusting speed limits based on the PCI of road sections, with stricter limits on newly paved or well-maintained roads to mitigate the risk of accidents. Moreover, public awareness campaigns should be conducted to educate drivers about the dangers of speeding on smooth roads and the risks posed by deteriorated pavements. For deteriorated sections, regular pavement condition assessments and timely maintenance measures are necessary to ensure road safety and reduce accident rates.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicated that there is a strong correlation between the PCI and accident occurrence across all sections, showing that lower PCI values increase the likelihood of accident rates. This trend is consistent across all levels of accident severity. Additionally, accident occurrence data is notably significant for PCI values above 85 and below 50, suggesting critical points for pavement condition. Furthermore, the results of this study are compatible with findings of previous studies conducted on rural roads.

To enhance road safety, newly constructed or maintained roads should include speed calming measures to enforce reduced speeds, thereby decreasing the number of accidents and improving the overall safety. Also, it is important to keep urban pavements in fair conditions or better to avoid the increase in traffic accidents. Thus, municipal engineers should be aware of these effects in order to make urban environment much safer.

It is recommended to develop comprehensive accident models that incorporate factors, such as highway geometry, traffic volume, and pavement condition to explore the share of each factor in accident occurrences. Furthermore, performing cost analyses is essential to compare the total cost of accidents with the cost of pavement maintenance using a detailed Pavement Management System (PMS) will provide valuable insights for decision-making.

Abbreviation	**Meaning**
Pavement Condition Index	PCI
Pavement Management System	PMS
Jordan Traffic Institute	JTI
Maintenance and Rehabilitation	M&R
Average Annual Daily Traffic	AADT
Average Daily Traffic	ADT

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