Role of Pavement Age on Pavement Distress Propagation for High Volume Urban Roads

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Abstract
In this study, pavement deterioration recognizes three factors in defining distress propagation namely pavement age, traffic volumes, and availability of a drainage system. However, the three factors data were subjected to descriptive and inductive statistical tests to evaluate their level of significance. The descriptive analysis highlights the numerical summaries and scatter plots. The inductive analysis discusses the significance of the factors affecting pavement distress propagation, including experiment design, and tests of significance for both parametric test and nonparametric tests. The numerical summaries of the current study reveal that pavement distress density values for all types of distress considered in this study showed variations in distributions. Traffic and drainage data exhibited significant variations and dispersions. The data are not normally distributed, the scatter diagrams reveal that most points at different levels for different factors are mixed together randomly and nonlinearity exists. In conclusion, inferences from normality tests, parametric tests, and nonparametric tests showed that the data are among the three governing factors responsible for pavement distress, age of pavement stands out as a major factor in pavement distress propagation while traffic and drainage play statistically less important role in pavement deterioration for urban roads with high traffic volumes.

Keywords: Urban, Pavement, Distress, Descriptive Analysis, Inductive Analysis.

1. INTRODUCTION:
The cost of pavements represents one-half of total highway expenditure and moreover expenditures on pavements continue to grow as maintenance and rehabilitation are warranted (Haas et al. 1994). Pavements are complex structures involving many variables, such as materials’ characteristics, construction method, traffic loads, environment, performance, maintenance, and economics. Thus, various technical and economical factors must be well understood to design, build, and maintain better pavements. Moreover, the problems relating to road maintenance are still more complex due to the dynamic nature of road networks where elements of the network are constantly changing, being added or removed. These elements deteriorate with time and therefore to be maintained in good condition requires substantial expenditure. Also, the preparation and evaluation of the best ways to direct this expenditure is an extremely challenging task due to the numerous factors that affect the deterioration of these elements. Normality tests, parametric and nonparametric tests were used to explore which factors play more effect on the pavement deterioration.

The intervention of different factors on distress propagation for urban high volume roads is the focus of this paper in which factors have significant effect in the deterioration of urban roads will be studied. Data of pavement age, traffic volume, and drainage on urban high volume roads in different cities will be tested. To achieve this target, the parametric and nonparametric tests were performed to reach the right conclusions. Achievement of this objective will greatly assist in developing future pavement distress prediction models, which are not currently in the focus of this study. This paper aims to
test the primary factors affecting urban road network, mainly the high volume roads. In order to obtain reliable results for this study that can be utilized with a significant level of confidence, all possible and accessible pavement sections that satisfy the experiment design for the study have been covered.

2. EXPERIMENTAL DESIGN FOR THE STUDY

A specific database was developed for this study in a systematic and coherent way that included information on pavement characteristics, pavement distress data, and pavement maintenance data. Pavement characteristics data included information on pavement class, pavement type, pavement age, traffic volume, and availability of a drainage system. Pavement distress data included information on distress type, severity, extent and location. Seven common distress types (Muba�aki and Thom 2008) were considered as they occurred most frequently, namely; block cracks, longitudinal and transverse cracking, patching, potholes, depressions, weathering and ravelling, and cracking (due to patching). Pavement maintenance data included information about what type of maintenance strategy has been applied on the pavements and the maintenance date. The selection of independent variables for the prediction equation is based on experience suggesting that the prediction of pavement condition depends on the following factors: pavement age, traffic volume, and availability of a drainage system. Therefore, in this study, pavement deterioration recognizes three factors in defining distress propagation. However, the three factors will be subjected to tests of significance to determine the significant factors for distress models. As a basic principle, the form of the model is selected based on the boundary conditions and/or other variables that govern the deterioration of the pavements (Prozni and Madanat 2004). In order to have a good picture of a study, experimental design is a good approach to follow. A total of 701 overlaid main pavement sections were selected to be applicable for the study constraints. 2330 observations on all selected pavement sections for each distress type were used to study the significant factors. Therefore, the study is interested in the effect of different factors or the intervention of the pavement age, traffic, and drainage on distress density progression. Thus it can be concluded that the factors are the treatment and the distress density is the experiment unit (Montgomery and Peck 1982). The layout of the experimental design along with data included in the study is presented in Table 1. Experimental design of the study shows that the study is a multifactor experimental design. The independent variables are pavement age, traffic levels, and availability of a drainage system. These independent variables are called factors. Each single factor has different categories. All the factors will be investigated separately in the following subsections. The 2330 observations were distributed according to the design in Table 1, for example 1733 observations were selected on the network that has young pavement sections. 602 observations were selected on the network that the roads were drained. 463 observations were selected on the network that the roads were accommodating high traffic.

3. 1. PAVEMENT AGE

Pavement age is measured from the date of construction or from the date of the last major maintenance. However, only last major maintenance sections were considered in this study due to lack of construction date data. Urban main road sections were grouped into three categories as follows: young (0 to 4 years), moderate (4.1 to 8 years), and old (>8 years). The average distress density values of each distress within each group are shown in Figure 1 (a-g). As expected, all distress types tend to increase with time. However, this increase is relatively varied
from distress to distress. More details will be presented using suitable statistical tests.

Table 1 Experimental Design

<table>
<thead>
<tr>
<th>Pavement Age</th>
<th>Old Sections</th>
<th>Moderate Sections</th>
<th>Young Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>147</td>
<td>450</td>
<td>1733</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drainage Condition</th>
<th>With Drainage System</th>
<th>Without Drainage System</th>
</tr>
</thead>
<tbody>
<tr>
<td>602</td>
<td>1728</td>
<td></td>
</tr>
</tbody>
</table>

(a) Effect of Pavement Age on Distress Density

(b) Effect of Pavement Age on Distress Density

(c) Effect of Pavement Age on Distress Density

(d) Effect of Pavement Age on Distress Density

(e) Effect of Pavement Age on Distress Density

(f) Effect of Pavement Age on Distress Density

(g) Effect of Pavement Age on Distress Density
Role of Pavement Age on Pavement Distress Propagation

Figure 1 Effect of Pavement Age on (a) Block Cracking, (b) Longitudinal and Transverse Cracking, (c) Patching, (d) Potholes, (e) Depressions, (f) Weathering & Raveling, and (g) Cracking (due to patching).

3.2 Traffic

The ADT was used to classify the traffic into three levels, low, medium, high. Low traffic level ranged from 0 to 1500 ADT, medium traffic level ranged from 1500 to 10000 ADT, and high traffic level is more than 10000 ADT. The average distress density values for different traffic levels of each distress type are shown in Figure 2 (a-g). In general, the difference in mean values is not clear. There appears to be little difference between the different levels of traffic on distress propagation. However, this small difference will be examined by suitable statistical tests.
Figure 2 Effect of Traffic on (a) Block Crack, (b) Longitudinal and Transverse Cracking, (c) Patching, (d) Potholes, (e) Depressions, (f) Weathering & Reversing, and (g) Cracking (due to patching).

3.3 Drainage

The availability of a drainage system can affect distress propagation. Therefore, pavement sections were grouped into those sections with a drainage system and those sections without a drainage system. It was expected that distress on drained sections would propagate less than distress on not drained sections. However, Figure 3 (a-g) shows small differences in average values of distress density.
5. TEST OF SIGNIFICANCE

5.1. Nonparametric Tests

Classification of variables into factors and levels as was mentioned before shows that the factors have to be tested in two different tests. Tests for several independent samples were performed for pavement age and traffic, where there were three levels, whereas two independent tests were performed for drainage where two levels were used. Therefore, the Kruskal-Wallis H-test would be appropriate for pavement age and traffic factors three levels in each factor under investigation, and the Mann-Whitney U test would be appropriate for drainage factors where only two levels were investigated (Moore 2003 and Williams 2004). However, tests for pavement age and traffic factors must only be performed into two steps if the first step is significant. The first step is the Kruskal-Wallis H-test. If this test is significant, the second step is to do the Mann-Whitney U only for pavement age and traffic factors. And then finally based on both steps, a conclusion could be drawn. The null hypothesis (Ho) would be that there is no difference between the means of levels of factor, whereas the alternative hypothesis (Ha) is that there is a difference in at least one of the means. Tables 2, 3, and 4 show

value ranging from zero to one. It is a measure of how much evidence against the null hypothesis. The null hypothesis, traditionally represented by the symbol Ho, represents the hypothesis of no change or no effect. Normality tests shows that all seven distress types’ data are not normally distributed. The data violate the required conditions to use parametric tests like the two sample test and analysis of variance. This means that to do statistical tests on the factors, tests that are designed for data with a non normal (non parametric) distribution would be used. Therefore, non parametric tests were performed to determine which variables are significant in the prediction of each distress type.
the results of significance factors using non-parametric tests for pavement age, traffic, and drainage.

5.2. Parametric test

The Central Limit Theorem (CLT) says “The sampling distribution of the mean of a random sample from any population is approximately normal for a sufficiently large sample size. The larger the sample size, the more closely the sampling distribution will resemble a normal distribution”. The accuracy of the approximation alluded to in the CLT depends on the probability distribution and on the sample size. If the population is normal, then the data is normally distributed for all values of \( n \). If the population is non-normal, then the data is approximately normal only for large values of \( n \). In many practical situations, a sample size of 30 may be sufficiently large to allow the researcher to use the normal distribution as an approximation for the sampling distribution (Keller 2009). To conclude based on the CLT, the data is considered to be normal as each individual in the data set has a sample size of 2330 points. As mentioned before, the pavement age and traffic factors have three levels, whereas drainage factor has only two levels. Therefore the test of significance for the factors could be examined by different approaches. The test statistic value will be used to evaluate the hypotheses. Test statistics take into account the amount of variability inherent in the averages and the size of the samples (Moore 2003, and Keller 2009).

The \( t \) statistic will be used because the sample standard deviation \( (s) \) will be considered in the experimental design study. Therefore, hypothesis testing with \( t \) statistics will be compared to \( t \) distributions. However, because of the large sample in the comparison, the \( t \) distribution should look almost identical to the normal distribution, and this is stated clearly in the Central Limit Theorem (CLT) as it mentioned before. Table 2 shows that all the three factors have more than one level. Therefore, the study involved two or more independent samples. Consequently hypothesis testing for single samples with \( t \) statistic will not be appropriate in this study. So, hypothesis testing two samples \( t \) statistic will be appropriate for drainage factor because this factor has two levels (with drainage and without drainage) provided that the samples meet its condition. To perform the two samples \( t \) statistic test (Moore 2003), there are two main conditions. First, the sampling distribution must be approximately normal. Second, both sample variances are not too far from each other. Both conditions are met, the first condition can be counted by the (CLT) because the sample size is large, so normality is guaranteed, and the test for equality of variances will be conducted by Levene’s test (SPSS Manual version 16). This test is shown in the output of \( t \)-test. Therefore, hypothesis testing independent samples \( t \) statistic will be conducted on availability of drainage factor to test its significance on distress behaviour.

The null hypothesis \( Ho \) and the alternative hypothesis \( Ha \) can be stated in statistical terminology as;

\[
Ho: \; \mu_1 = \mu_2 \; \text{versus} \; Ha: \; \mu_1 \neq \mu_2
\]

The confidence level used was 95 percent. The two samples \( t \) statistic hypothesis was calculated by the following formula (Walpole et al. 2001).

\[
t = \frac{\mu_1 - \mu_2}{\left(\frac{S^2}{n_1} + \frac{S^2}{n_2}\right)^{1/2}}
\]

Where

- \( \mu_1 \) = mean of first sample,
- \( \mu_2 \) = mean of second sample,
- \( S^2 \) = first sample variance,
- and \( S_2^2 \) = second sample variance.

However, before interpreting the \( t \) test result, the variance has to be checked to insure that the variance within the two groups is equal. Therefore, the Levene’s test result must be read before interpreting the two samples \( t \) statistic (SPSS Manual version 16). The null hypothesis for Levene’s test is
that there is no difference between the variance of the two levels in drainage factor. If the significance value is greater than 0.05, equal variances are assumed, if the significance value is less than 0.05, equal variances are not assumed. Then, the mean difference between the two levels must be checked; if the mean difference is high, there is significance, otherwise not (SPSS Manual version 16). Although the other two factors (pavement age and traffic) have three levels, two samples t statistic can be conducted on each level of the experimental conditions. However, this strategy would require 3 separate hypotheses tests. This would cause serious problem. This problem with analyzing a single experiment using 3 t tests has to do with the chances of incorrectly rejecting a true null hypothesis. The analysis of variance (ANOVA) (Walpole et al. 2001) analyzes whether or not there are significant differences between three condition means considering the total amount of variability in distress values. This variability is caused by differences between conditions and within condition. Therefore, the ANOVA will account for independent samples and then ANOVA F can be calculated and then p-value can be found to check the significance of the independent variables together. Although this test can give an answer whether the pavement age and the traffic factors are significant or not, it does not reveal which conditions are significantly different from which. In other words, there are significant differences between the levels but which levels differ significantly from each other. For instance which levels among the three levels of pavement age differ most significantly, young sections, moderate sections, or old sections for each distress behaviour. To consider the interaction between all combinations, analysis of multi-condition must be performed (Moor 2003, and SPSS Manual version 16). A good statistical test to tackle such a situation is to use post hoc tests. The post hoc tests are tests to check the difference in means when there are more than two factors in the study. They are only valid when done after obtaining a significant result with the ANOVA F test. Therefore, the analysis of variance (ANOVA) will be performed for the pavement age and traffic volume factors in order to do the post hoc tests if the ANOVA F test is significant (Moore 2003). Similarly to perform the ANOVA F test (Walpole et al. 2001), two main conditions must be met. First, the sampling distribution must be approximately normal. Second, both sample standard deviation variances are not too far from each other. Both conditions are met. Therefore, Hypothesis testing ANOVA F test will be performed on pavement age and traffic volume to check their significance on distress behaviour.

The null hypothesis \( H_0 \) and the alternative hypothesis \( H_a \) can be stated in statistical terminology as:

\[ H_0: \mu_1=\mu_2=\mu_3 \]

versus

\[ H_a: \mu_1\neq\mu_2\neq\mu_3 \]

The confidence level used was 95 percent. The Hypothesis testing \( ANOVA \ F \) test was calculated by the following formula.

\[ F=\frac{MSG}{MSE} \]

Where

\( MSG= \text{the mean square for the groups} \)

\( MSE= \text{the mean square for error} \)
After finding out the ANOVA F value, the Post hoc test can be investigated. Post hoc tests are two of the ways to infer and assess the significance of the difference between one of conditions. However, there is no one standard way to do a post hoc test.
test. There are, for example, 18 different types of post hoc tests. There is evidence from old studies to support use of the Tukey HSD procedure. The HSD is based on the mean square for error (MSE), the total number of conditions in the study, the sample size, and a modified distribution of t statistics. Any pair of means whose difference is greater than the HSD is declared significant (Williams 2004). Table 5, 6, 7 show the results for ANOVA, F Test, and Post Hoc Test results.

Table 5 ANOVA F test and Post Hoc test Results for Pavement Age

<table>
<thead>
<tr>
<th>Output of the Test</th>
<th>First Step</th>
<th>Second Step</th>
<th>Final Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Age</td>
<td></td>
<td>F-TEST</td>
<td></td>
</tr>
<tr>
<td>Categories</td>
<td>Overall (Low to High)</td>
<td>Young-Moderate (Tukey HSD)</td>
<td>Moderate-Old (Tukey HSD)</td>
</tr>
<tr>
<td>Distress</td>
<td>P-value</td>
<td>Test Result</td>
<td>P-value</td>
</tr>
<tr>
<td>Block Cracks</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Longitudinal &amp; Transverse Cracking</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Patching</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Potholes</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Depressions</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Weathering &amp; Ravelling</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
<tr>
<td>Cracking (due to patching)</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 6 ANOVA F test and Post Hoc test Results for Traffic

<table>
<thead>
<tr>
<th>Output of the Test</th>
<th>First Step</th>
<th>Second Step</th>
<th>Final Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td></td>
<td>F-TEST</td>
<td></td>
</tr>
<tr>
<td>Categories</td>
<td>Overall (Low to High)</td>
<td>Low-Medium (Tukey HSD)</td>
<td>Low-High (Tukey HSD)</td>
</tr>
<tr>
<td>Distress</td>
<td>P-value</td>
<td>Test Result</td>
<td>P-value</td>
</tr>
<tr>
<td>Block Cracks</td>
<td>0.000</td>
<td>Significant</td>
<td>0.001</td>
</tr>
<tr>
<td>Longitudinal &amp; Transverse Cracking</td>
<td>0.078</td>
<td>Not Significant</td>
<td>-</td>
</tr>
<tr>
<td>Patching</td>
<td>0.002</td>
<td>Significant</td>
<td>0.033</td>
</tr>
<tr>
<td>Potholes</td>
<td>0.011</td>
<td>Not Significant</td>
<td>-</td>
</tr>
<tr>
<td>Depressions</td>
<td>0.000</td>
<td>Significant</td>
<td>0.006</td>
</tr>
<tr>
<td>Weathering &amp; Ravelling</td>
<td>0.002</td>
<td>Significant</td>
<td>0.033</td>
</tr>
<tr>
<td>Cracking (due to patching)</td>
<td>0.000</td>
<td>Significant</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Table 7 Two Samples t- test Results for Drainage

<table>
<thead>
<tr>
<th>Factor</th>
<th>Drained - Not Drained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output of the Test</td>
<td>Two samples t test</td>
</tr>
<tr>
<td>Distress</td>
<td>Mean Difference (%)</td>
</tr>
<tr>
<td>Block Cracks</td>
<td>1.012</td>
</tr>
<tr>
<td>Longitudinal &amp; Transverse Cracking</td>
<td>0.889</td>
</tr>
<tr>
<td>Patching</td>
<td>1.735</td>
</tr>
<tr>
<td>Potholes</td>
<td>0.359</td>
</tr>
<tr>
<td>Depressions</td>
<td>-0.480</td>
</tr>
<tr>
<td>Weathering &amp; Ravelling</td>
<td>1.823</td>
</tr>
<tr>
<td>Cracking (due to patching)</td>
<td>0.493</td>
</tr>
</tbody>
</table>

5.3 Significance tests results

Inferences and descriptive analyses from normality tests, parametric tests, nonparametric, numerical summaries, and scatter plots showed the following points:
- The variation in the data is noticeable,
- Data are not normal,
- Nonlinearity is clear more than linearity,
- Among the three factors pavement age, traffic, and drainage, only pavement age affects the prediction models. However, in the modelling process this point will be investigated further.

6. IMPORTANCE OF PAVEMENT AGE

The question now arises of why pavement age is so significant in the predicting pavement deterioration. As indicated earlier the prediction equation recognizes two causal factors in defining pavement deterioration. They are age in years since last overlay, and drainage, with being pavement age the most significant factor. The traffic and drainage are of only minor importance can clearly be seen from different results including descriptive analysis, inductive analysis, modelling analysis. This was clear through numerical values, scatter plots, and sections significance tests.

The answer for this question can be expressed from three standpoints. The first is the data, the second is the designed traffic level, and the third comes through the literature and the possible causes of pavement distresses under study. The data show that the age alone can account for a substantial portion of the decline in serviceability. Age is significant because it is a common factor in the estimation the effect of drainage over the life cycle period. Therefore, age can be a surrogate for the effect of drainage in prediction model. So it can be concluded that age plays a pivotal role in predicting pavement deterioration. The second possible reason behind this is the fact that the pavements were designed to perform for the expected traffic level. The third standpoint concerns the possible causes of flexible pavement distress from the literature (Al-Swailmi and Al-Abdal Whab 2001, FHWA 2002, RRM 1998b, Shain 2002, USCERL 1990, and WSDT 1988). As mentioned before, the common pavement distress types on the network are; block cracking, longitudinal and transverse cracks, patching, potholes, depressions, and cracking due to patching. The block cracking takes the form of inter-connected cracks that divide the pavement up into rectangular pieces. A possible cause is an
inability of asphalt binder to expand and contract with temperature cycles because of asphalt binder aging or poor choice of asphalt binder. Longitudinal cracks are parallel to the pavement’s centreline or laying direction. The possible causes are poor joint construction. Transverse cracks are perpendicular cracks to the pavement’s centreline or laying direction. The possible causes are shrink-age of the asphalt surface due to low temperatures or asphalt binder hardening, reflective crack caused by cracks beneath the surface asphalt layer, and top down cracking. Depressions are localized pavement surface areas with slightly lower elevations than the surrounding pavement. The possible cause is subgrade settlement resulting from inadequate compaction during construction. Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course. A possible cause is determination of alligator cracking. As alligator cracking becomes severe, the interconnected cracks create small elements of pavement, which can be dislodged as vehicles drive over them, and the remaining hole is called a pothole. Patching is an area of pavement that has been replaced with new material to repair the existing pavement. The possible causes are previous localized pavement deterioration that has been removed and patched, and utility cuts. Ravelling is the progressive disintegration of an asphalt layer from the surface downward as a result of the dislodgement of aggregate particles. The possible cause is loss of bond between aggregate particles and the asphalt binder. Therefore, distress propagation on urban road network due to climatic problems, material problems, construction problems, and utility cuts. Urban roads are not rural roads. Beneath the city roads a large number of utility lines run parallel to and across the roads. Therefore, all utility agencies share the network with the municipalities (Al-Mansour and Al-Swilim 1997, Al-Swailmi 1994, Al-Swailmi and Al-Abd Whab 2001). So distress propagation comes from different factors, it is not only traffic problem and/or drainage. To conclude, the traffic and drainage have minor affect compared to pavement age, in this study, because age surrogates for the effect of traffic and drainage in the prediction model. The pavements were designed to accommodate the expected traffic level, the effect of climate, the effect of material problem, the effect of construction problem, and the effect of utility cuts.

7. CONCLUSION

Inferences and descriptive analyses showed that the traffic and drainage have minor affect compared to pavement age, in this study, because age surrogates for the effect of traffic and drainage in the prediction model. The pavements were designed to accommodate the expected traffic level, the effect of climate, the effect of material problem, the effect of construction problem, and the effect of utility cuts.

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دور عمر الرصف الأسفلتي على تنامي عيوب الرصف للطرق الحضرية ذات الأحمال المرورية العالية

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المتخصص

تدهور الرصف الأسفلتي يرجع فهمه من خلال تحديد ثلاثة عوامل لفهم تنامي العيوب على الطريق مثل عمر الطريق. أحجام المرور، وتوفر نظام صرف. إلا إن هذه الثلاثة عوامل ت تعرضت لدراسة إحصائية وصفية واستدلالية لتحقيق مستوى أثرها على تدهور الطريق. التحليل الوصفي ركز على عرض خلاصة البيانات مع عرض رسومات توضيحية. التحليل الإحصائي الإستدلال ناقش العوامل المؤثرة ذات الاستدلال الإحصائي التي تؤثر على تنامي عيوب الرصف عن طريق ترتيب البيانات بأسلوب تجريبية والإختبارات ذات الدلالة. النتائج كشفت عن تباين كبير بين قيم كثافة العيوب، وحجم الأحمال المرورية والتصريف تبانيته من طريق إلى آخر، أيضا أظهر التحليل الإحصائي الاستدلال من الاختبارات تقدم عمر الطريق هو العامل الأهم في تدهور الطريق وهو ذات دلالة إحصائية عالية جدا بينما حجم المرور وتصريف الطريق لم يعند درا احصائيا أقل. يُتَدْهُر الرصف الأسفلتي للطرق الحضرية صاحبة الأحمال المرورية العالية.

الكلمات المفتاحية: حضري - الرصف الأسفلتي - عيوب الرصف - التحليل الإحصائي الوصفي - التحليل الإحصائي الاستدلال