Usage Mobile Phone for Pavement Distresses Measurement in Irbid city – Jordan

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Abstract: *The main objective of this research work was to investigate the potential using camera of mobile phone system as one of the most common techniques for spatial distribution studies. This study aims to use mobile camera phone in different locations of Irbid city, it was very easy to located alligator cracking and longitudinal & transverse cracking for different locations in Irbid city as an attempt to investigate cracks quantities using automated validated process to help non-experienced people to perform a distress generation.*

Keywords: Pavement distresses, Alligator cracking, Longitudinal and transverse cracking.

Literature Review

In the past, pavement were maintained but not managed. The pavement engineer's experience tended to indicate the selection of maintenance and rehabilitation (M&R) techniques with little regard given to life-cycle costing or to priority as compared to other pavement requirements in network (SHAHIN, 1998).

Many traditional systems were used to evaluate and classify pavement surface distresses. Conventional visual and manual pavement distress analysis techniques are very costly, time-consuming, dangerous, labor-intensive, tedious, and subjective. They have a high degree of variability; are unable to provide meaningful quantitative information; and almost always lead to inconsistencies in distress detail over space and across evaluations (JASELSKIS, 2009). In this research work new technologies will be used for this purpose. It is anticipated the usage of mobile phone camera in order to collect and analyze different distress data at Irbid city roads.

The usage of this system is anticipated to: collect the distress data safely, perform real-time operation, extract highly accurate data, and develop a new high technology system that produces spatial and attribute data concerning distress evaluation and analysis, and introducing maintenance priorities according to distress severity and other integrated factors (SHUBINSKY, 2009).

Photogrammetry is defined as “The art, science, and technology of obtaining reliable information about physical objects and the environment by recording, measuring and interpreting photographic images”, when the maximum object-to-camera distance of about 300m, this is called close-range Photogrammetry. Close-range photogrammetry has many applications like, architecture, gauging, manufacturing, and industrial engineering (SMITH, 2007).

1. Introduction

The distribution of distresses cracks in Irbid city is one of most important issues for the society because there is a rapid increasing in the number of cracks locations in Irbid city. The collected variables in this study included: age of pavement, Average Annual Daily Traffic (AADT), section crack area, type of distresses, severity levels of distresses, and length & direction of distress cracks. Statistical regression were carried out to establish useful models to estimate cracking quantities from the mentioned data-base variables.

1.1 Significance of the study

- The Pavement Management System (PMS) is a set of tools or methods that can assist decision makers in finding cost effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition to provide the information necessary to make these decisions.
- The development of such an automated system was anticipated to open the door to automatically collect, classify, and predict pavement surface roads conditions. It will give the guidelines to the maintenance engineers to follow up technology trends rather than using manual measurements and operations. Therefore, real- time operations and maintenance prioritization are expected.
- The Fact that the usage of mobile phone camera adds more significance for the study.

1.2 Objectives of the study

This study has the following objectives relating distresses measurements in Irbid city

- To Investigate the potential of mobile camera systems setup in obtaining automated quantities of Alligator cracking and Longitudinal& Transverse cracking happening to some factors influencing crack behavior, such as age of section, Area of section and Average annual daily traffic(AADT) of the section.
- To Develop a statistical models using SPSS Package Software for distresses quantities involvement as function of variables affecting cracks behavior.
- To Identify of critical areas, if any, for future research and development.

1.3 Study area

- Irbid city was being selected to be the study area.
- Irbid city which is located Longitude 35º 45˙ and 36º 00˙ east and between Latitudes 32º 30˙ and 32º 45˙ north, as shown in figure 1.1

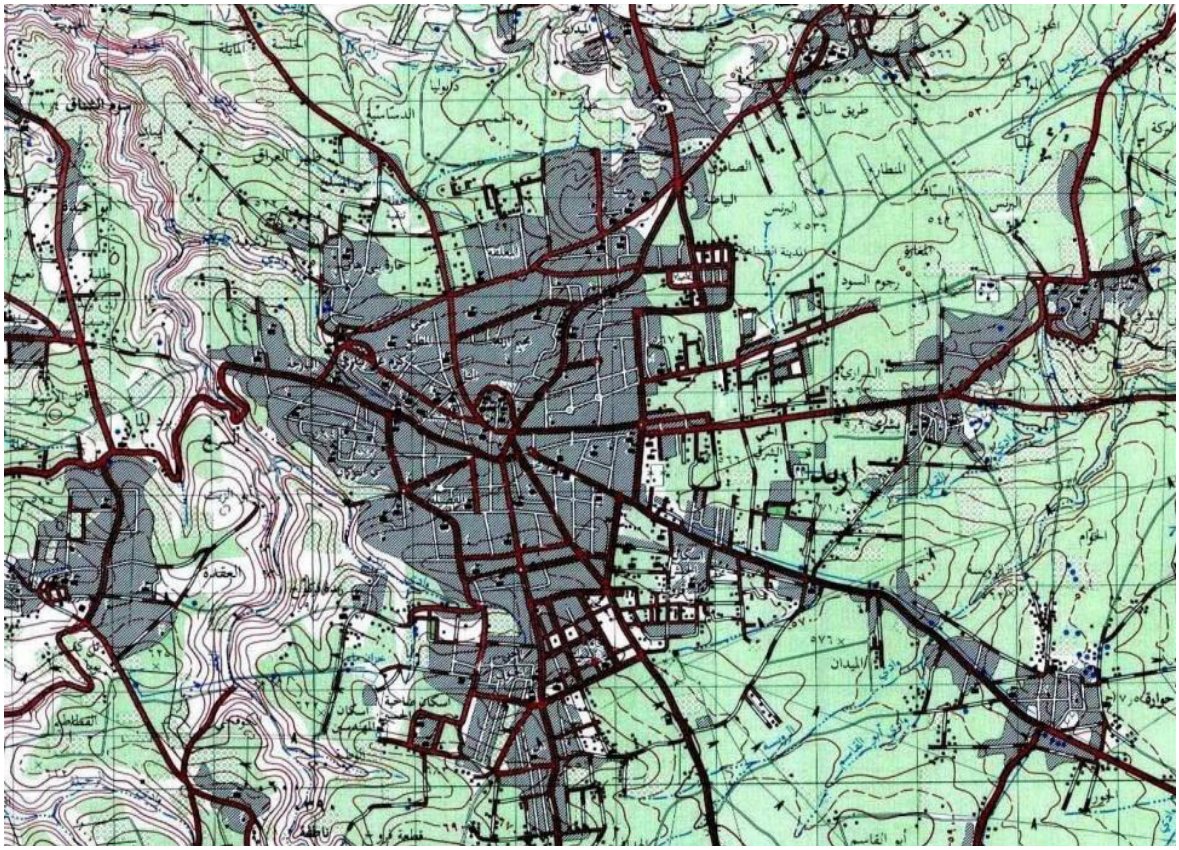

Figure 1.1: Irbid Study area

2 Research data and Methodology

The research data and methodology can be divided into components:

- Data acquisition and collection: Real digital images were collected using mobile phone camera for specific locations at various times (peak hours and off-peak hours). Random locations were selected in Irbid city for the purpose of implementation of this study.
- Image analysis: The captured images were used for two purposes: 1) to visualize the type of distress and 2) to quantify length and direction of cracks.
- Statistical Analysis: SPSS statistical package was used to develop models that show the relation between automated quantities of cracks as function of age of crack section, AADT of crack section, and area of section. Statistical analysis scheme was performed to predict quantities of cracks as function of the previously mentioned independent variables.
- Results Analysis, Conclusions, and Recommendations: The findings were discussed and analyzed in order to study the feasibility, potential and limitations of the proposed research work. Proper conclusions and recommendations were drawn.

2.1 Data acquisition and collection

Collected data could be divided into:

1. Data measured using the Mobile Phone Camera;
2. Data collected by visualization with the aid of Mobile Phone Camera
3. Data collected from Irbid-Municipality like age of section and AADT of that section.

2.2 Image Analysis

- The measured data using Mobile Phone Camera for every location included:

1. Image coordinates of vehicles through its path a long the road, in the field of view of the mobile camera. The x-coordinates of vehicle image was recorded while having the camera in the play. The x-coordinate was representing the direction movement in the mobile camera. Normally a point on the hood of the vehicle was selected as a reference point for measurements.
2. Thus, knowing the coordinates, length and direction of cracks

- The Data collected by visualization with the aid of mobile camera included:

1. Type of distress.

- Data-base of the Study

For the purpose of checking the precision and accuracy of the collected distresses data that include distress type, distress quantity and severity level of the observed distress that was obtained through analyzing the obtained photographs from the camera for the distressed locations .The results of analysis, comparison and validation between manually collected distresses data and photogrammetric ally analyzed data are summarized in table 2.1 below. This table contains the following pieces of information:

1. Types of distresses visible through images associated with there severity levels.
2. Distresses quantity obtained through camera analysis in m, m^2 or number units.
3. Distresses quantity obtained manually in m, m^2 or number units
4. Difference between manual and automated collected distress quantities:

$$Difference = |(camera\text{-}based\ quantity) - (manual\text{-}based\ quantity)| \quad 2.1$$

5. Error or Bias percentages of the automatically collected data from accurate manual data:

$$\%\ Bias = (Difference \div Manual\ Measurement) \times 100\% \quad 2.2$$

6. Percentages of accuracy of the automatically collected data:

$$\%\ Accuracy = 100 - \%\ Bias \quad 2.3$$

Table 2.1

Sample Output of Validation Process

Types of Distresses in Photograph & Severity	Camera Analysis Quantity	Manually Identified Quantity	Diff	% bias	% Accuracy
Alligator Cracking (H)	46.28m^2	10.72*4.25 =45.56 m^2	0.72	1.58	98.42
Alligator Cracking (H)	11.79m^2	2.75*4.1 = 11.28 m^2	0.52	4.57	95.43
L&T Cracking (M)	24.98 m, w=2.5cm	24.45m, w=2.3cm	0.53	2.17	97.83
L&T Cracking (M)	15.39m, w=3.6cm	15.2m, w=3.3cm	0.19	1.25	98.75
Alligator Cracking (M)	5.55m^2	1.42*3.75 = 5.33 m^2	0.22	4.13	95.87
L&T Cracking (M)	13.49m, w=1.45cm	13.25m, w=1.6cm	0.24	1.82	98.18
Alligator Cracking (H)	5.63 m^2	3.62*1.49 = 5.4 m^2	0.23	4.26	95.74
L&T Cracking (M)	5.87m, w=1.3cm	5.82m, w=1.45cm	0.05	.86	99.14

7. Estimate Average of Accuracy, Standard Deviation of Accuracy, and coefficient of Variation of Accuracy as shown in table 2.2 below.

Table 2.2

Validation Process Accuracy Results

Average of Accuracy	96.49%
Standard Deviation of Accuracy	2.21%
Coefficient of Variation of Accuracy (COV)	2.29

Obviously, from table 2.2 and because the average accuracy of the system was about 96.5% in the measurements mode, this validation process showed a promising usage of this system so this system is a step toward full automation point in order to relieve the entire hazard that accompanied the traditional manual data collection techniques.

2.3 Development of Alligator Cracking and Longitudinal and Transverse Cracking Model

Model development was a major part of this study. Therefore, statistical regression analysis was adopted to develop predictable models that can be utilized to estimate quantities of cracks from the studied variables.

The previous independent variables were selected and identified based on the following criteria:

1- Regression analysis using SPSS Package software in order to select the most significant variables

2- Drawing of scatter plots to show the pattern of relationships among variables and various observations related to investigated variables.

2.3.1 Modeling and Results of Analysis

2.3.1.1 Linear Multiple Regression of Alligator Cracking

The following model was developed to predict Alligator cracking distress quantities on different sections:

Alligator Cracking Quantity = 16.123* (Area of section) +136.695* (Age) -103.532*(AADT) 2.4

Where;

Area of section = Area of section contain cracks

Age= Age of section contains cracks

AADT=Average Annual Daily Traffic of section contains cracks.

Table 2.3 lists the statistical characteristics of this model. As shown in this table, the developed model is statistically significant with coefficient of multiple regression determination (R2) = 0.416 This means that about 41.6% of alligator cracking quantities variation can be explained by the included independent variables. The coefficient of multiple determination was very close to adjusted coefficient of multiple determination, which suggests that the model is strong and predictable. Table 2.4 list the variables entered in the model and their T- value. The model had a small standard error of estimates. Figure 2.1 predicts the predicated values of this model versus the measured values.

This model shows that the overtake alligator cracking quantities, which is a measure for crack behavior, could be predicted if the following variables are known: Area of crack section, Age of section, and AADT of crack section.

Table 2.3

Statistical characteristics of the linear model

Multiple R	0.645
R-square	0.416
Adjusted R-square	0.319
Standard error	22.8979
DF	18
Sum of Squares	9437.655
Mean Square	524.314
F- Value	4.278
α - Level	0.0002

Table 2.4

Variables entered in the model and their T- value

Variable	T-value
Area of section	-0.559
Age of section	1.953
AADT	1.667
Constant	1.645

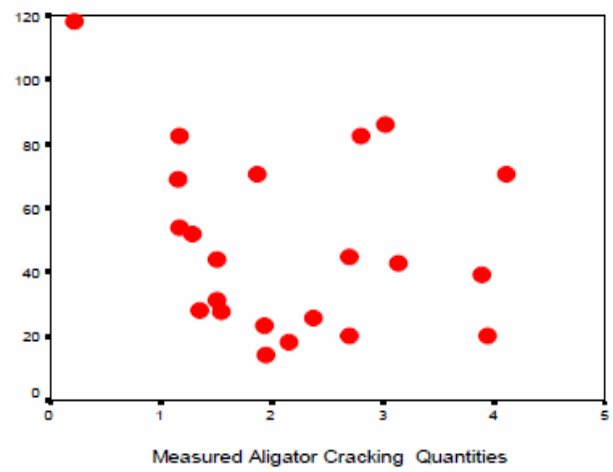

Figure 2.1: Scatter Plot of Alligator Cracking Quantities Measured v.s Alligator Cracking Quantities Predicated of the linear model

2.3.1.2 Linear Multiple Regression of Longitudinal and Transverse Cracking

The following model was developed to predict Longitudinal and Transverse (L&T) cracking distress quantities on different sections:

(L&T) Cracking Quantity= 4.258*10-4 *(AADT) + 17.103*(Age0 -3.185*10 -4 *(Section Area)-89.478 2.5

Where;

Area of section = Area of section contain cracks

Age= Age of section contains cracks

AADT = Average Annual Daily Traffic of section contains cracks.

Table 2.5 lists the statistical characteristics of this model. As shown in this table, the developed model is statistically significant with coefficient of multiple regression determination (R2) = 0.347 This means that about 34.7% of alligator cracking quantities variation can be explained by the included independent variables. The coefficient of multiple determination was very close to adjusted coefficient of multiple determination, which suggests that the model is strong and predictable. Table 2.6 list the variables entered in the model and their T- value. The model had a small standard error of estimates. Figure 2.2 predicts the predicated values of this model versus the measured values.

This model shows that the overtake alligator cracking quantities, which is a measure for crack behavior, could be predicted if the following variables are known: Area of crack section, Age of section, and AADT of crack section

Table 2.5

Statistical characteristics of the linear model

Multiple R	0.589
R-square	0.347
Adjusted R-square	0.238
Standard error	24.2122
DF	18
Sum of Squares	10552.166
Mean Square	586.231
F- Value	3.192
α - Level	0.0002

Table 2.6

Variables entered in the model and their T- value

Variable	T-value
Area of section	-0.267
Age of section	2.597
AADT	0.764
Constant	1.028

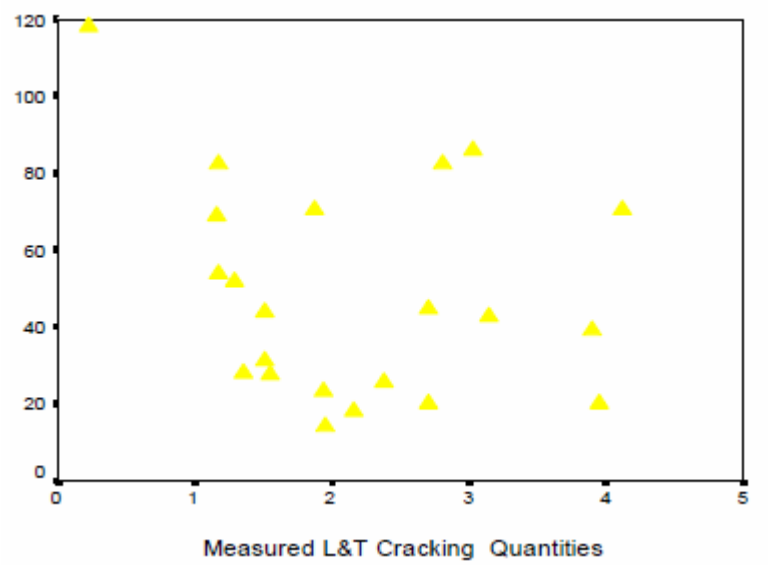

Figure 2.2: Scatter Plot of L&T Cracking Quantities Measured v.s L&T Cracking Quantities Predicated of the linear model

3. Discussion of the results

Results of this investigation indicated that

- Various predication models for each type of distresses were developed. Number of variables that include {Average Daily Traffic(ADT), Pavement Age, and Section Area} were selected to show their effect on distress generation using the Linear multiple regression model.
- Results indicted that in most of the developed predication models, ADT and Pavement age variables play the most important role in the distresses development with higher effect of the pavement age variable in distress generation.
- Area of section contains cracking is found to have non significant contribution to distresses quantities.
- Its worth to mention that all above distresses predication models were developed through utilizing ADT, section area, and pavement age variables with suitable transformations. Other variables may be important such as pavement materials characteristics, pavement structure, foundation properties and other variables were not included in these models. The absence of such variables was due to lack of available data concerning these variables on Irbid Municipality. So research needs

to be preformed to provide the required data for these variables to build stronger models.

- Most of Irbid sections suffering from alligator cracking distress type. Since this type of distress is mostly related to traffic repetition this might indicated a traffic management problem over the city where they are exposed to higher traffic levels than they designed for.

4. Conclusions and Recommendations

- Data acquisition for pavement distresses using such automatic system proved to be quick, unlike manual data collection which consumes time, money and labor. This in turn showed a great potential of time saving through the use of digital data reduction procedures.
- Surface measurements as well as decision making have been validated and actually tested for all distresses types. The developed system showed a great accuracy potential in both measurement mode and decision making phase. This result opened the door for automatic distresses classification potential without any human intervention.
- The analysis dealt with issues related to the objectives mentioned in this study. I hope that this study will help both government municipalities related to distresses maintenance and people who concern in order to take right decisions about this problem & its relationship to transportation issues in society of Irbid city and other factors.
- Usage of Mobile camera phone setup was proven to be useful, practical, and accurate camera configuration and data acquisition system for distresses studies.
- Futher studies are needed to expand the usage of mobile camera phone setup in transportation engineering.
- It is recommended to make use of the developed system to perform more iterations in order to reach the full automation case of pavement condition recognition and collection.

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