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Study a Relationship between Manual and Function Pavement Condition

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ABSTRACT

The evaluation of pavement conditions is an important part of pavement management. Regularly scheduled pavement condition data collection is one the most important steps in implementing and sustaining a comprehensive pavement management system. Pavement condition data is used for monitoring the current condition of the highway system and for predicting future performance for identifying preservation needs and selecting rehabilitation projects. Traditionally, pavement condition data are gathered by human inspectors who walk or drive along the road to assess the distresses and subsequently produce report sheets. This visual survey method is not only time consuming and costly but more importantly it compromises the safety of the field personnel.

So, the aim of this paper is to study and investigate the possibility of correlating manual pavement condition index represented by Urban Distress Index (UDI) which are calculated based on pavement distress type, severity and quantity to the Function equipment evaluation Index like International Roughness Index (IRI) and Skid resistance factor (FN) for a sample of pavement sections or recommendation to use the new technology for pavement evaluation to save money, valuable time and safety for PMMS staff.

KEYWORDS:

Pavement Management System, Pavement Evaluation, International Roughness Index, Skid Resistance.

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1. INTRODUCTION

The urban roads network in any country is a huge network that was established during different periods of time, the fact that requires a special attention in order to preserve the good functional condition, and reach its expected performance during the assumed design life, that means we should inspect the pavement element at period time to reach to the perfect maintenance decision.

Pavement condition surveys play a vital role in the management of a pavement network. The pavement condition survey provides the most valuable information for pavement performance analysis, and is vital in order to forecast pavement performance, anticipate maintenance and rehabilitation needs, establish maintenance and rehabilitation priorities, and allocate funding. Therefore, it is critical to collect accurate pavement condition data in an efficient and safe manner. Accurate evaluations would result in a better chance that resources will be distributed normally. Thus, yielding a better service condition [1]. Pavement can be evaluated through the different types of distress experienced, such as cracking, disintegration and surface deformation. At present, there are various methods of conducting distress surveys, recording and analyzing distress survey data [2]. In the past the only method of completing a pavement condition survey was to walk or drive down the road and collect the data manually.

2. MANUAL PAVEMENT CONDITION SURVEY

While the use of automated pavement condition surveys are becoming more and more common, many agencies still rely on manual pavement condition surveys to provide their pavement condition data. There are two basic methods for conducting manual pavement condition surveys, walking and windshield surveys. Walking and windshield surveys are also commonly combined to provide a more complete pavement network survey [3].

Walking Survey

Walking surveys are completed by a rater who is trained to rate distresses according to the agency's distress identification specifications. The rater walks down the side of the pavement and fills out a pavement condition form that describes the amount, extent, and severity of each distress present on the roadway. Walking surveys provide the most precise data about the condition of the rated pavement [4], provided the raters are well trained an experienced.

Windshield Survey

A windshield survey is completed by driving along the road or on the shoulder of the road. The pavement is rated by a rater through the windshield of the vehicle. This method allows for a greater amount of coverage in less time; however, the quality of the pavement distress data is compromised. The entire network could possibly be surveyed using this method or samples may still be used.

Walking + Windshield Survey

Combining a walking survey with a windshield survey is a good method to achieve detailed pavement distress data and complete pavement surveys on a greater percentage of the network [4]. This method is acceptable only if the same procedure is used on every section in the network, and a random method is used for selecting the sample where the walking survey will be performed.

The Urban Distress Index (UDI) Method:

The Urban Distress Index is a numerical scale for distress survey of fifteen distresses and was developed for each section in the city street network [5]. The characteristics of the Urban Distress Index include:

- Rating method based on visual inspection of pavement distress. It involved a procedure to identify and describe the distress in term of type, severity and extent.
- The pavement rating is based on the numerical indicator of a scale from 0 to 100 (0 rating means very serious distress, 100 rating means excellent pavement condition and no distress appears). Four pavement condition ratings were adopted for the Urban Distress Index as shown in Table (1).

Table (1): Urban Distress Rating

UDI	Rating
90-100	Excellent
70-89	Good
40-69	Fair
0-39	Poor

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- Pavement distresses classified based on their effect on pavement condition into five groups.
- Each distress severity level is assigned a deduct value, ranging from zero to 5, where 5 mains a great effect and zero main no distress effect.
- The main equation used to calculate the Urban Distress Index is given by the formula:

$$UDI = 100 - 20 \sum \{(Tij * D i\backslash) \div 100\}$$

Where Tij is the deduct value for the distress type; and

D i\ is the adjusted density value for the distress type.

2.1. PROBLEM STATEMENT

Manual visual inspection of pavement surface condition is costly and time consuming. In many cases, work has to be done along fast moving traffic. Such condition would endanger the safety of the personnel involved. In the wake of tedious manual measurements and safety issues, various types of automated equipments have been developed for the purpose of pavement monitoring and evaluation. Visual observation of pavement distress is the most common method for monitoring pavement surface condition. This has been traditionally performed by trained engineers who work or drive along the road and counts the distresses [6]. However this method of field inspection poses several drawbacks [7], such as:

(i) Slow, labour intensive and expensive.

(ii) Inflexible and does not provide an absolute measure of the surface.

(iii) Has poor repeatability since the assessment of given pavement section may be differ from one survey to the next.

(iv) Could expose a serious safety hazard to the surveyors due to high speed and high volume traffic.

Therefore, over the past two decades an effort has been made to fully automate the data collection process.

3. AUTOMATED PAVEMENT CONDITION SURVEY

Over the past two decades the concept of a fully automated pavement condition survey has grown closer to a reality through research and major technological advancements. An automated pavement condition survey consists of driving down the road at or near highway speeds while collecting data. The vehicles used to collect the data are outfitted with numerous technologically complex systems. Each system is designed to collect a specific type of data and some of the systems work in conjunction with each other. Some of the data that are commonly collected by automated data collection vehicles include, but are not limited to: rut depth, ride quality, global positioning, position orientation, and numerous types of surface distress. Surface distresses such as cracking are commonly the most difficult type of data to detect and classify. Hence, the most widely used method of detecting and classifying surface distresses is still with the human eye. However, in recent years, technological advancements in computer hardware and imaging recognition techniques have provided the means to successfully detect and classify surface distresses automatically in a cost-effective manner [3]. The ideal automated survey would provide less subjective and more accurate data, the ability to survey the entire network in a time efficient manner, and a safer means of collection.

Ride Quality

How rough a road feels to the passenger when riding down the road is commonly referred to as "ride". There are several indices used to describe ride; however, the index used presently by nearly every agency is International Roughness Index (IRI). IRI was proposed in Brazil by the World Bank in 1982, as a standard statistic to correlate and to calibrate roughness measurements. IRI is a statistic used to estimate the amount of roughness in a measured longitudinal profile [8]. IRI is computed from a single longitudinal profile using differential equations and algorithms [9]. The longitudinal profile is measured using a laser or other device to measure the vehicle's height above the roadway. An accelerometer is also used to measure the vertical forces caused by surface deformities [10] as Figure (1). The longitudinal profile and the vertical force data are used to calculate IRI for the roadway. The IRI calculation is completed in real time.

Figure (1): Road Surface Profilometer

Skid Tester

Pavement skid resistance or surface friction is measured to evaluate pavement safety. Skid resistance varies with many factors such as pavement material, texture, aggregate type and amount of polish, temperature, such as rubber, oil, grease, type and dust on the pavement surface, water film thickness, and tire type, condition, and material composition. Pavement skid resistance is usually measured directly through the use of locked wheel skid trailers. The trailer is towed over the pavement surface at a speed of 40 mph and water is applied in front of the test wheel. The test wheel is locked by a brake, and after it has been sliding along the pavement for a certain distance the force that the friction in the tire contact patch produces or the resulting torque on the test wheel is measured and recorded for a specified length of time. Either a ribbed tire or a smooth tire can be used to perform the test. The ribbed tire 'is insensitive to the pavement macrotexture, allowing water dissipation through the tire grooves. The smooth tire is sensitive to the macrotexture. Standard procedures (ASTM E 274-85) have been developed for the performance of skid testing with the locked wheel skid trailer. The result of the test is reported as a skid number. On-board computers are now being used to record and calculate the skid number, as well as to plot skid number versus speed, and peak incipient friction, [11] as Figure (2).

Figure (2): Skid tester

4. METHODOLOGY

The methodology of the study consists of main steps. The first step is to collect the required data and filter it for a selected sample of street sections. The data includes the Urban Distress Index (UDI), the International Roughness Index (IRI), skid resistance Factor (FN) and maintenance date for each included pavement lane per section, the Automatic Road Analyzer (ARAN) was used for roughness measurements and Dynatest Skid tester was used for pavement skid resistance measurements. The second step of the methodology is to investigate the correlation between UDI and IRI observations and find the most appropriate models that relate UDI and IRI. The third step of the methodology is to investigate the correlation between UDI and FN observations and find the most appropriate models that relate UDI and FN. The fourth step is to draw a conclusion of the analysis and recommendations obtained from the collected data. The work flow of the study is illustrated in Figure (3).

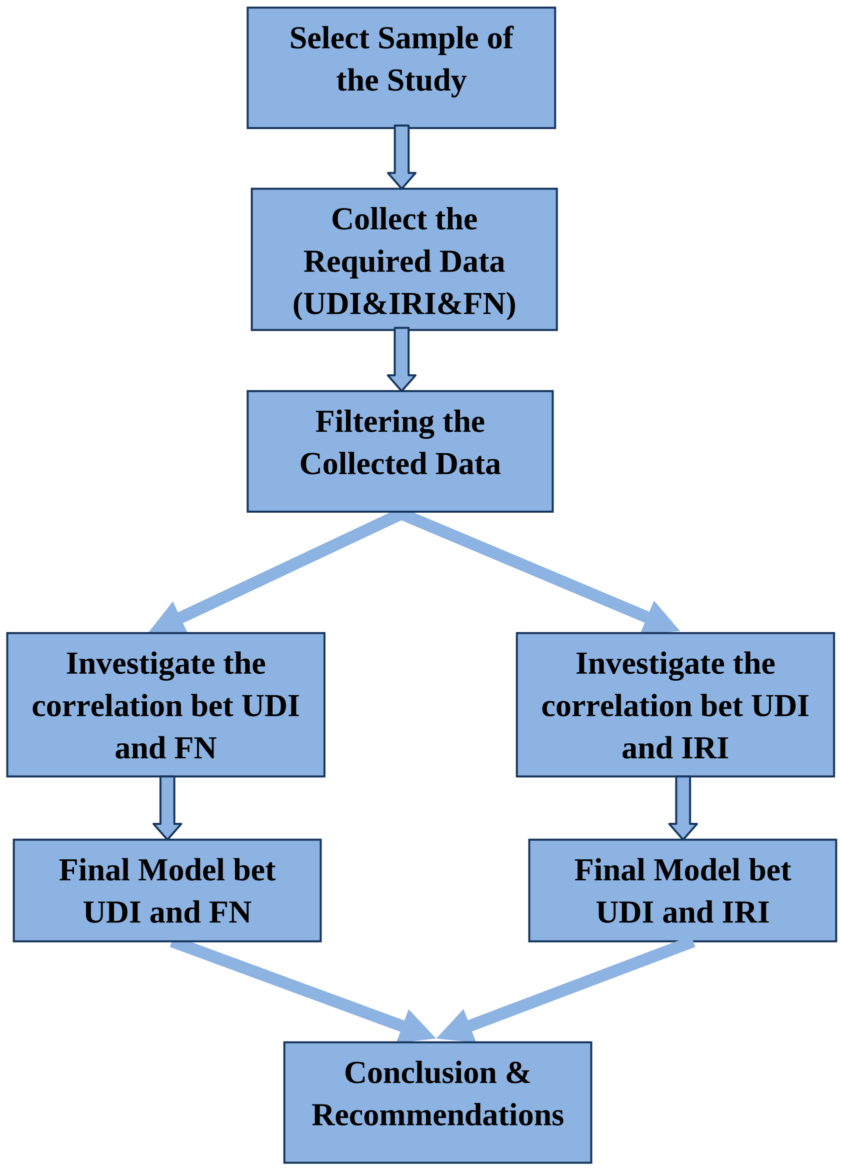

Figure (3): Flow chart for study methodology

5. ANALYSIS OF DATA

A representative sample of pavement sections from main streets was randomly selected and included all main streets category, different type and volume of traffic, various pavement conditions. A more than 2000 lane of main street sections included in the study. In main streets each observation represents pavement condition index, IRI, FN and maintenance date for one lane per section. A section may have two to three lanes. After that, the data was filtered according to the following Considerations:

1 - Data collection for various main street types.

2 - Data collection for various pavement conditions.

3 - Take the (UDI & IRI or FN) data only which was in the same year

4 - Take the (UDI & IRI or FN) data only which was in the same side from a maintenance final and which in the same period.

5 – Delete the Up normal Data.

Table (2) and table (3) show a sample of the data selected for UDI and IRI before and after filtering (row data and final data) for lane of main street sections, Figure (4) represent the row data between UDI & IRI (before filtering) and Figure (5) represent the final data between UDI & IRI (after filtering). Table (4) and table (5) show a sample of the data selected for UDI and FN before and after filtering (row data and final data) for lane of main street sections Figure (6) represent the row data between UDI & FN (before filtering) and Figure (7) represent the final data between UDI & FN (after filtering).

Table (2): Sample of the Row Data selected for UDI and IRI (Before Filtering)

UDI_VALUE	UDI_RATE	UDI_DATE	IRI_VALUE	IRI_DATE	MAINT_DATE
98	Excellent	18/08/2008	2.67	18/03/2009	05/08/2008
61	Fair	31/07/2006	4.03	04/11/2009	21/08/1996
72	Good	09/08/2006	3.87	28/10/2009	02/04/2004
58	Fair	07/08/2006	2.65	22/11/2008	07/09/2004
64	Fair	14/08/2008	3.14	27/10/2009	05/08/2008
52	Fair	02/08/2006	3.49	28/10/2009	01/03/2004
100	Excellent	07/02/2010	1.80	01/03/2010	07/02/2010
100	Excellent	07/02/2010	1.55	01/03/2010	07/02/2010
86	Good	13/03/2011	2	18/08/2011	27/06/2005
76	Good	25/06/2011	3	16/08/2011	04/07/2005
63	Fair	10/06/2012	3	14/01/2012	23/11/1996
59	Fair	12/03/2012	3	24/01/2012	29/04/2004

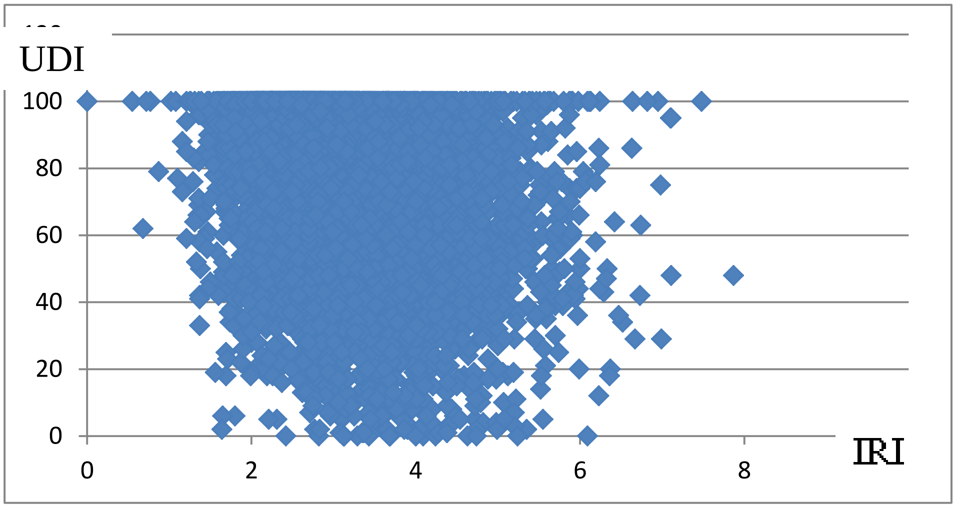

Figure (4): The Row Data Between UDI & IRI (Before Filtering)

Table (3): Sample of Final Data selected for UDI and IRI (After Filtering)

UDI_VALUE	UDI_RATE	UDI_DATE	IRI_VALUE	IRI_DATE	MAINT_DATE
49	Fair	06/02/2012	6	24/01/2012	24/05/2000
93	Excellent	26/06/2011	1	15/08/2011	26/07/2005
86	Good	13/03/2011	2	18/08/2011	27/06/2005
86	Good	26/06/2011	2	15/08/2011	16/07/2005
100	Excellent	21/09/2011	2	26/09/2011	21/09/2011
79	Good	04/11/2011	2	29/11/2011	04/11/2011
100	Excellent	05/11/2011	2	12/12/2011	05/11/2011
63	Fair	10/06/2012	3	14/01/2012	23/11/1996
59	Fair	12/03/2012	3	24/01/2012	29/04/2004
70	Good	23/04/2012	4	14/12/2011	02/04/2004

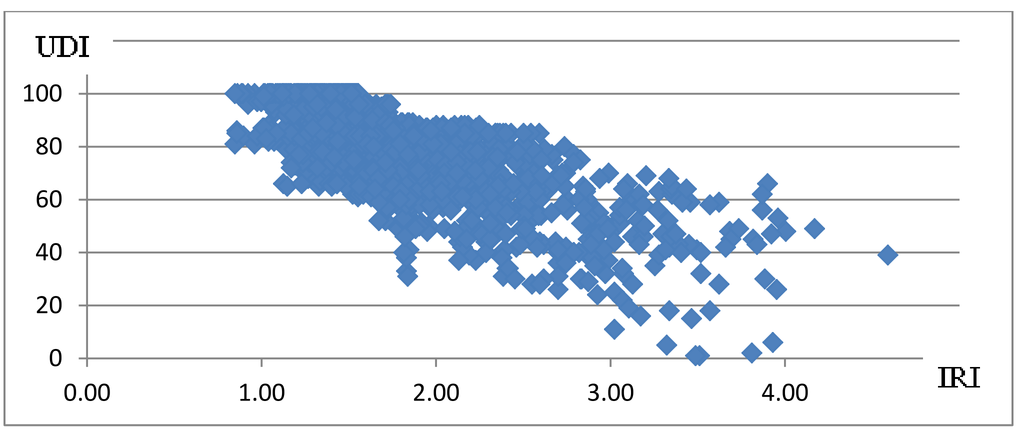

Figure (5): The Final Data Between UDI & IRI (After Filtering)

Table (4): Sample of Row Data selected for UDI and FN (Before Filtering)

UDI_VALUE	UDI_RATE	UDI_DATE	SKID_VALUE	SKID_DATE	MAINT_DATE
99	Excellent	10/06/2007	15	23/01/2007	11/05/2005
91	Excellent	29/06/2011	47	14/10/2006	07/08/2005
46	Fair	05/01/2012	14	26/08/2009	26/02/1998
81	Good	04/07/2006	26	16/03/2007	04/07/2006
100	Excellent	20/07/2006	8	16/09/2009	20/07/2006
86	Good	14/03/2011	47	14/10/2006	19/07/2005
82	Good	28/05/2007	19	06/09/2009	20/10/2000
49	Fair	06/02/2012	31	09/03/2007	24/05/2000
69	Fair	19/02/2012	8	02/07/2009	31/12/2000
97	Excellent	24/04/2011	17	25/01/2007	11/07/1999
39	Poor	06/10/2012	15	21/03/2007	19/08/1997
80	Good	05/05/2012	11	27/08/2009	15/08/2006

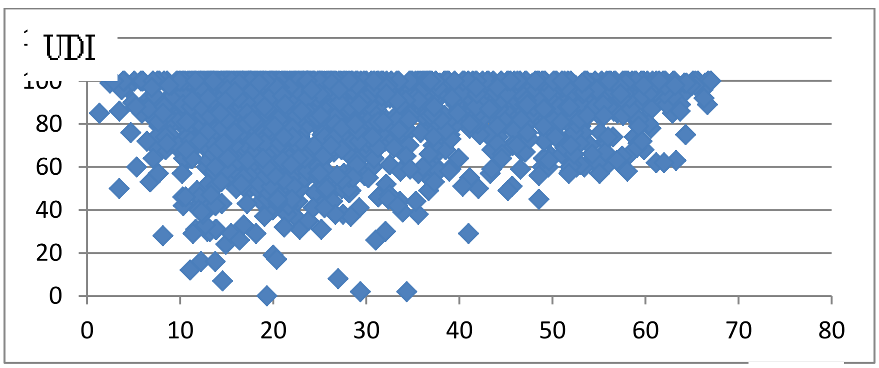

Figure (6): The Row Data Between UDI & FN (Before ng)

Table (5): Sample of Final Data selected for UDI and FN (After Filtering)

UDI_VALUE	UDI_RATE	UDI_DATE	SKID_VALUE	SKID_DATE	MAINT_DATE
95	Excellent	23/04/2007	34	07/02/2007	03/05/2004
62	Fair	20/03/2007	27	10/02/2007	11/03/2006
99	Excellent	01/05/2007	18	28/01/2007	30/09/2004
100	Excellent	21/09/2006	29	15/02/2007	21/09/2006
79	Good	03/04/2007	32	07/02/2007	10/08/2000
93	Excellent	04/04/2007	21	07/02/2007	23/12/2001
85	Good	14/04/2006	27	08/03/2007	14/04/2006
98	Excellent	02/06/2007	14	14/02/2007	11/04/1998
87	Good	03/04/2007	19	07/02/2007	23/12/2001
99	Excellent	23/04/2007	24	07/02/2007	26/05/2004
29	Poor	11/06/2007	27	14/05/2007	25/02/2002

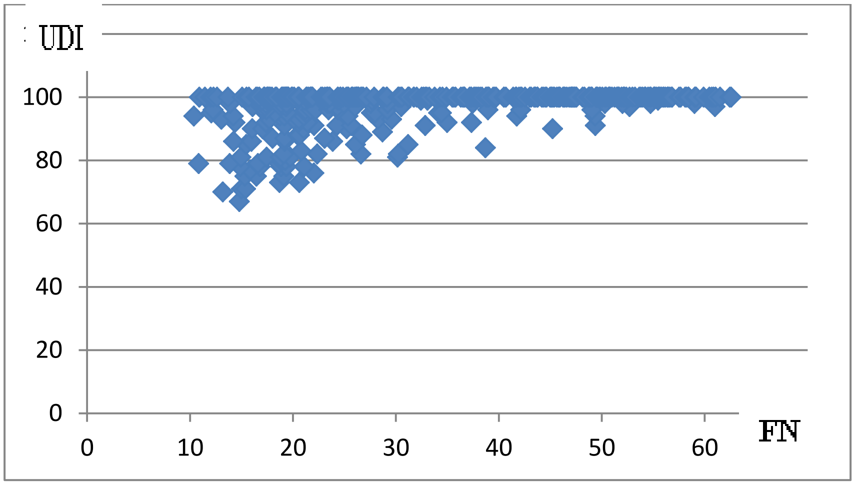

Figure (7): The Final Data Between UDI & FN (After Filtering)

After filtering the data, the process of analyzing the relation between IRI & UDI or FN & UDI can be summarized into four main steps:

1- Final data (after filtering) of UDI and IRI or FN is plotted to determine the trend of relation between the two variables. The plot is a useful tool to spot and delete any abnormal observations.

2- Statistical correlation analysis is used to find the degree of correlation between IRI or FN and UDI. As a result of this analysis a decision for the significant relationship between the two pavement indices is determined.

3- A number of statistical regression models to relate IRI or FN and UDI, based on the Final data plot, are investigated.

4- The final and the most suitable regression models for the available data are then selected.

Figure (8) represents the relationship between (UDI & IRI) and Figure (9) represents the relationship between (UDI & FN).

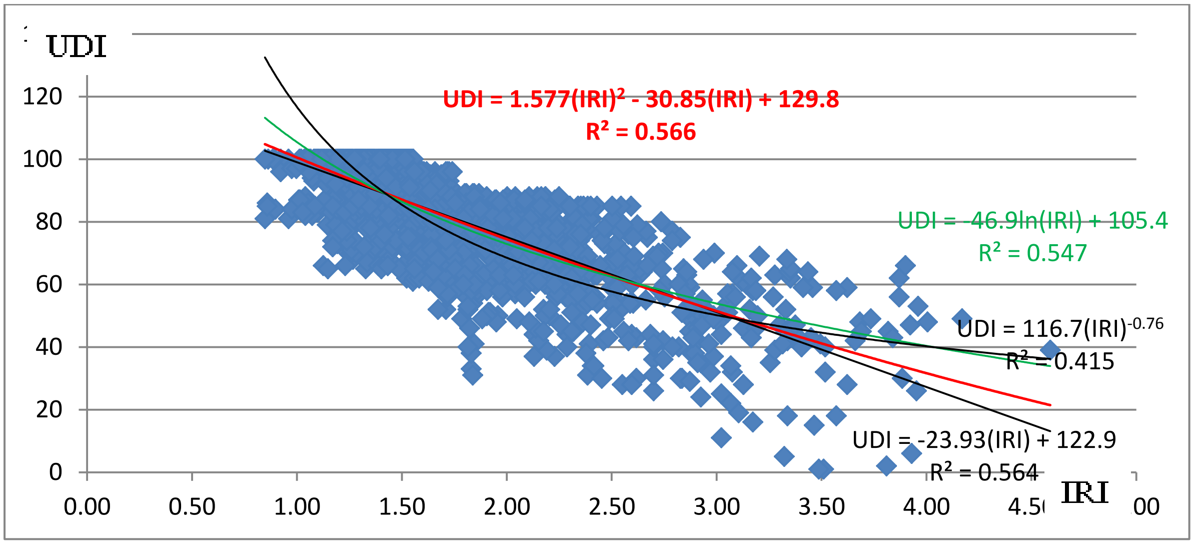

Figure (8): Relationship Between UDI & IRI

According to the above chart and statistical analysis, the most suitable regression models for the available data is

$$UDI = 1.577(IRI)^2 - 30.85(IRI) + 129.8 \quad \text{with } R^2 = 0.566 \qquad \text{Eq. (1)}$$

And according to the value of R^2 the correlation is fair.

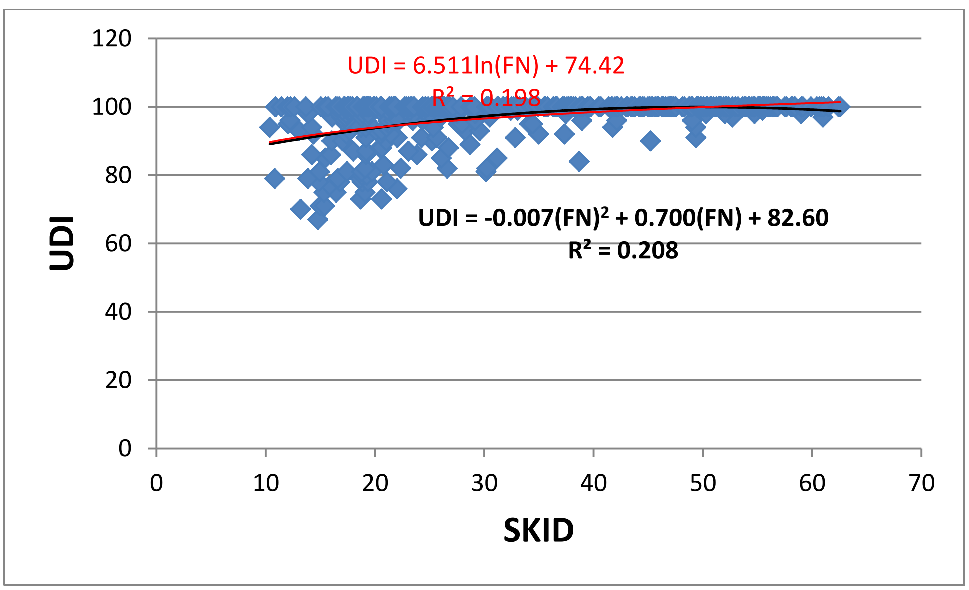

Figure (9): Relationship Between UDI & FN

According to the above chart and statistical analysis, the suitable regression models for the available data is

$$\mathbf{UDI = -0.007(FN)^2 + 0.700(FN) + 82.60 \text{ with } R^2 = 0.208 \qquad Eq. (2)}$$

And according to the value of R^2 the correlation is poor.

6. CONCLUSION & RECOMMENDATION

The pavement condition survey provides the most valuable information for pavement. In the past the only method of completing a pavement condition survey was collected the data manually. This method is time consuming, hazardous, and subjective. Therefore, this study was investigated the possibility of correlating manual pavement condition index (UDI) to the Function equipment evaluation Index, International Roughness Index (IRI) and Skid resistance factor (FN). It enables derivation of the following conclusions regarding the relationship of IRI or FN to UDI:

1. A power regression model, as depicted in Eq. (1), can more or less predict UDI values for asphalt pavements. However, IRI cannot be a unique predictor of pavement condition ratings. Some 43.4% of the variation in UDI remains unaccounted by IRI.
2. A power regression model, as depicted in Eq. (2), can't predict UDI values because the correlation is poor.
3. If used, the prediction model derived in Eq. (1), should be applied to known general network evaluation and not recommended for maintenance purposes.
4. Future studies will address the transition from manual to automated pavement condition surveys by line scan (2D) or Laser Crack Measurement System (LCMS)(3D).

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