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An-Najah National University

Faculty of Graduate Studies

Developing a Pavement Performance Function for Palestinian Roadway Network

Case Study: Nablus Province

By

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إهداء

أهدي هذا البحث الذي أعانني الله على إنجازه، بكل ما أمدني به من علم نافع وصبر وجهد ومثابرة

لأعز وأقرب الناس إلى قلبي أمي الحنونة وأبي الحكيم

لزوجي الحبيب الذي سار الدرب معي وكان خير عون لي

لأخوتي لما قدموه لي من دعم ومساعدة

ولكافة الأصدقاء المخلصين

شكر وتقدير

بعد الشكر لله سبحانه وتعالى، أتقدم بالشكر والعرفان إلى أساتذتي الأفاضل في كلية الهندسة في جامعة النجاح الوطنية، وأخص بالشكر والتقدير الدكتور أسامة أباظة الذي كان خير مرشد لي وجزاه الله عني كل خير.

كما وأتقدم بالشكر والتقدير إلى كل المؤسسات التي زودتني بالمعلومات اللازمة لإتمام هذا البحث، وأخص بالشكر المجلس الاقتصادي الفلسطيني للتنمية والاعمار (بكدار) وبلدية نابلس.

كما وأتقدم بالشكر لكافة الزملاء الذين قدموا لي المساعدة في جمع البيانات اللازمة.

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ABSTRACT

Successful implementation of a pavement management system requires the necessary simulation tools, among which pavement performance prediction models form an important part. The measurement and prediction of pavement performance condition is an essential component of any pavement management system. The pavement performance life provides information on how long a particular pavement type will typically last before it needs maintenance or rehabilitation that is important for overall planning and budgeting activities.

In this study, a performance evaluation method for Palestinian roadways was developed. Estimating the flexible pavement performance life for maintenance and rehabilitation was also presented. Data for model development was collected based on pavement evaluation methods that were offered by World Bank for developing countries.

Performance model development in this study was based on evaluating various deterministic and probabilistic models using surveyed data for arterial and village-access roadways in Nablus Province.

In this study, various mathematical models for predicting pavement performance were used including deterministic regression polynomial model of second degree, deterministic logistic growth model, and probabilistic Markov model.

The pavement performance models were developed based on calibrating surveyed pavement condition rating data. The results of the analysis showed that polynomial model of the second degree performed well in fitting the calibrated data using logistic growth model.

The major-maintained arterial roadway system had longer average performance life than the resurfacing arterial and village-access roadway system. This study shows the importance of establishing pavement performance curves for applying maintenance and repair in the slow rate of deterioration phase so as to reduce the life cycle cost of pavement.

ملخص

تعتبر شبكة الطرق في أي دولة في العالم من ضروريــات التطــور الحضــري والاقتصــادي.

وللحفاظ على أداء جيد لهذه الطرق فقد تم وضع نظام لإدارة رصفات الطرق منذ منتصف القرن العشرين (Pavement Management System) ، وأهم بنود هذا النظام هو كيفيــة وصــف حالة رصفات الطرق وتحديد أدائها (Pavement Performance) وكذلك التنبؤ عــن أدائــها بمرور الزمن. فتحديد هذا الأداء ضروري لمن هم في موقع القرار ولمصمم الطرق ولـــلهيئات المسؤولة عن صيانة هذه الطرق. إن التطبيق الناجح والفعال لنظام إدارة رصفات الطرق يتطلــب تحديد هذا الأداء لمعرفة المدة الزمنية التي تقضيها الرصفات وهي في حالة جيدة قبل أن تحتــاج إلى صيانة.

وبناءاً على ما تقدم فقد تم عمل دراسة مفصلة لتحديد أداء الرصفات الإسفلتية لشبكة الطرق فـــي المناطق الفلسطينية. تم تطبيق هذا البحث من خلال المعلومات التي تم جمعها عن حالة الطـــرق التي أجريت لها أعمال صيانة رئيسية منذ عام ١٩٩٥ بأخذ عينة ممثلة للطرق الرئيســـية فـــي مدينة نابلس وللطرق القروية في المحافظة.

تضمن هذا البحث دراسة عدة نماذج رياضية لتطبيقها على البيانات التي تـــم جمعــها، ومنــها نمـــوذج Deterministic Regression Polynomial مـــن الدرجـــة الثانيـــة ونمـــوذج

Deterministic Logistic Growth ونمــوذج Probabilistic Markov لتحديـــد أداء الرصفات الإسفلتية.

تبين من نتائج هذا البحث أن تطبيق نموذج Logistic Growth هو الأفضل من حيث مطابقتـه للبيانات الخاصة بحالة الطرق لتحديد أدائها.

تبين نتائج تطبيق نموذج Logistic Growth أن الشوارع الشريانية التي تلقت صيانة رئيســية لها عمر أطول من الشوارع الشريانية التي تم صيانتها بوضع طبقـــة إســفلتية ومــن المداخــل الرئيسية للقرى التي تلقت صيانة رئيسية. وعليه فإن هذه الدراسة تبين أهمية المنحنيـــات التــي تصف أداء الطرق لضرورة استخدامها في برامج الصيانة لأجل تقليل تكلفة صيانة الطرق.

Chapter One

Introduction

1.1 Background

Pavement condition and performance are issues of central concern in the multidisciplinary aspects of pavement management system that is essential for roadway development of any country. They are essential for decision-makers, pavement designers, and maintenance personnel.

The foundation and alignment of some existing roads in Palestine were established during the British mandate. A considerable portion of these roads were constructed as Macadam roads following old footpaths with relatively tortured alignment due to the prevailing mountainous terrain and limited resources.

During the thirty-three years of Israeli occupation, most roads in the occupied territories have deteriorated, while some urban streets received some kind of unorganized maintenance activities. The polices of the Israeli occupation focused only on the construction and rehabilitation of settlement's main and access roads ignoring all other roadways.

Since 1995, the Palestinian National Authority played a crucial role in the multi-disciplinary fields of planning, construction, rehabilitation, and maintenance of roads infrastructure. Various roads have been rehabilitated and constructed by the Palestinian Economic Council for Development and Reconstruction (PECDAR), related governmental agencies, and municipalities. Other roads are under rehabilitation, while other roads are under design and study. Their policy's included construction and rehabilitation of several roads such as arterial, collector and local urban streets, interurban roads, and many village access roads distributed all over Palestinian Provinces for which donor countries and World Bank finance most of those road projects.

To meet the increasing demand for new pavements and to save a lot of money in pavement investment, there is a need to establish a pavement management system for Palestinian roadway network. A pavement management system consists of a comprehensive set of activities including planning, design, construction, maintenance, evaluation, and pavement's research, all of which depend on data evaluation. Pavement management indicated that evaluation process provides roadway condition data to the planning group for assessing road deficiencies, and pavement performance behavior on the network level, and to the design group for detailed project analysis.

The pavement condition has always been of central concern in pavement management. Such questions as "Has the contractor done an adequate job of construction? Does this road need maintenance? Should this pavement be rebuilt? Should the job be overlaid?" All those issues are related to pavement condition, either the current or the expected condition of the pavement at some future time, which is defined as pavement performance. There are many reasons for evaluating the condition and performance of pavement.

Pavement condition involves four main components; riding comfort, load-carrying capacity, safety, and aesthetics. In a complete sense, a "good" pavement rides well, carries traffic satisfactorily, provides a safe tire interface for both rolling and stopping, and looks pleasing to the "pavement manager" and "user".

1.2 Aims and Objectives

The general aim of this study is to establish pavement performance models through the assessment of current conditions of roadway pavements to predict future pavement conditions. Since roadway performance is an essential input to any decision making process concerning pavement rehabilitation policy of related governmental agencies, road condition survey was performed on several arterial and village access roads for Nablus province. The following are the specific objectives of this study:

1. Establishing of an integral database of roadway condition and related pavement characteristics for sample roads.
2. Assessment of roadway condition by developing pavement performance trends for flexible pavements that fit the observed roadway condition data.
3. Prediction of future roadway performance trends through the use of deterministic and probabilistic approaches for modeling pavement performance.
4. Developing pavement performance life cycles for the representative arterial and village access roads that were analyzed in this research.
5. Evaluation of pavement life cycle related to the developed pavement performance model.

1.3 Study Area

Road transport is an important sector for economic activity and investment, and functions as a catalyst to the overall economic and social development process. The role of road transport is relatively more important in developing countries because of limitations in other sectors of their national transport systems. Road infrastructure in Palestine is likewise important for providing access to health, education, trade, and agriculture sectors. Fast growth of vehicle fleets and burst of growth in road construction and upgrading projects in the last ten years, have been common characteristics of past developments in road transport in Palestine

Nablus Province was selected as a case study for the purpose of this research. Nablus City is located at the innermost of the northern area of West Bank, where considerable traffic motion is generated through south-north and east-west regions. In addition, it is considered the economic capital of the West Bank. Nablus Province population for mid-year 2000 was 317,556 individuals, which forms 17.8 percent of total population in West Bank (Palestinian Central Bureau of Statistics, 1999).

Most of roadway pavements in Palestine are flexible pavement while others are unpaved roads for agricultural use. Total length of roadway network for Nablus City is approximately three hundred and eighty-five kilometers (Nablus Municipality, 2001).

The total investment in roadway construction and rehabilitation projects executed by PECDAR for Nablus Province until January, 2000 was 17,021,104 US Dollars for roadway length of two hundred and ten kilometers (PECDAR, 2000). Nablus Municipality investment in city road projects was ten million US Dollars (Nablus Municipality, 2001).

This large investments in road projects indicate the importance of establishing a Pavement Management System (PMS). So the assessment of road condition data obtained by regular road condition survey, is very important for establishing roadway performance trend which is an essential aspect of the multidisciplinary aspects of PMS.

The considerable traffic volume for the main urban roads in the city will affect negatively pavement condition and performance. In addition, most developing countries, as Palestine, have agriculturally-based economic. Road transport plays an essential role in marketing village production and people necessity for city services. A representative sample of main urban and village access roads that have been rehabilitated were chosen for this study. Figure 1-1 shows the roadway network in Nablus City while Figure 1-2 shows roadway network in Nablus Province.

Figure 1-1: Roadway Network in Nablus City

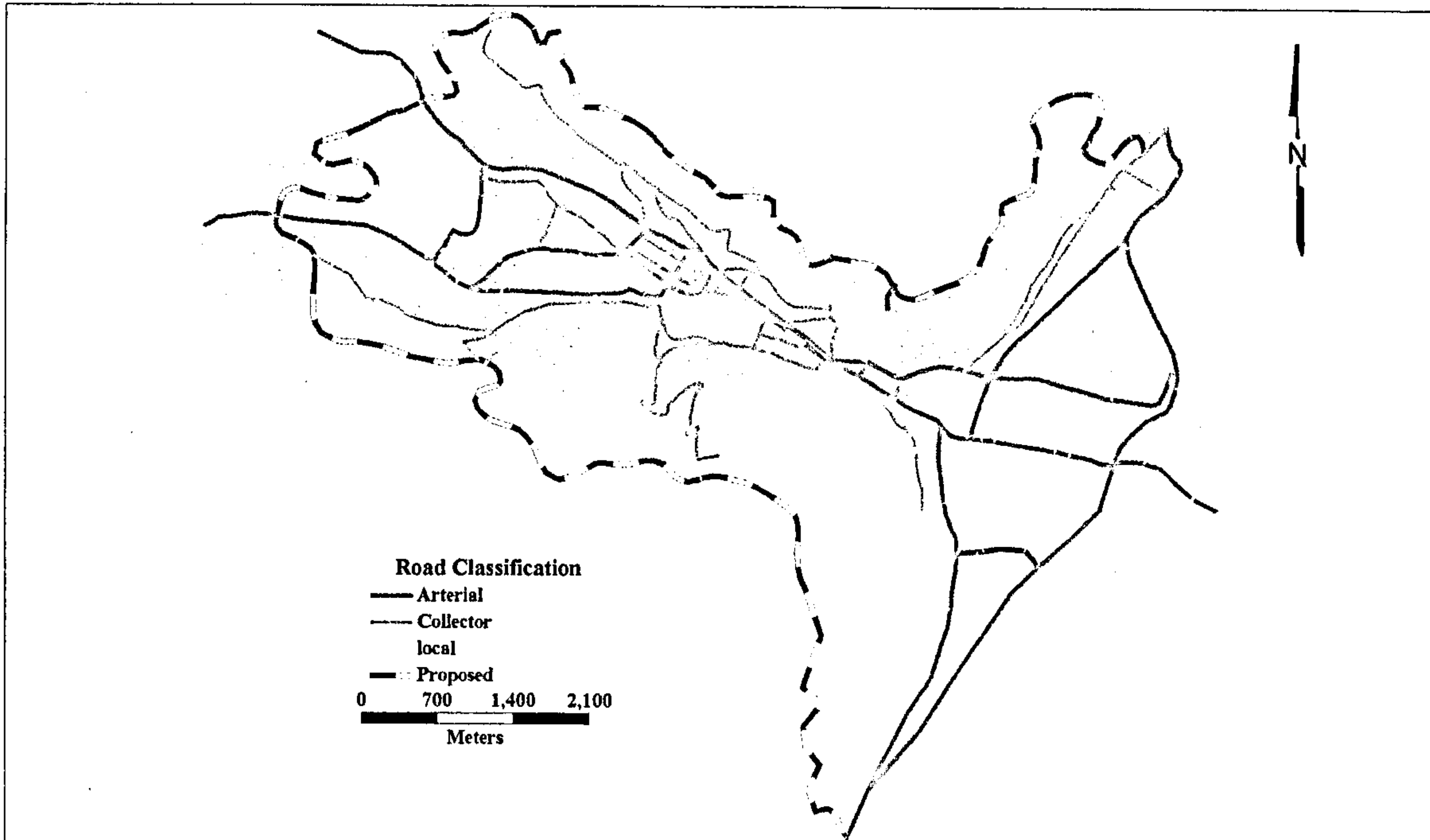


Figure 1–2: Roadway Network in Nablus Province

1.4 Thesis Outline

This thesis is composed of six chapters. Chapter One contains the background of pavement condition and performance, aims and objectives, study area, and the report outline.

Chapter two is the literature review of previous researches related to this study in the assessment of serviceability performance concept, and pavement performance models.

Chapter three deals with the methodology adopted in this thesis. It consists of an introduction to the modeling concept, deterministic polynomial regression model, deterministic logistic growth model, and Markov probabilistic model for developing pavement performance trend.

Road condition data is presented in Chapter Four. It consists of road monitoring scheme, sampling method and sample size, road condition survey, detailed visual inspection, and data processing.

Data analysis and model formation is presented in Chapter Five. It consists of applying deterministic polynomial regression model, logistic growth model, and Markov model to road condition data.

Finally, Chapter Six presents conclusions and recommendations based on results of the model.

Chapter Two

Literature Review

2.1 Introduction

Pavement management was defined by the Federal Highway Administration (FHWA) as the process of coordinating and controlling all activities related to pavements in an attempt to best utilize public funds for providing and maintaining pavements in a serviceable condition on a continuing basis. Effective pavement management, by necessity, involves the utilization of the feedback of information on pavement performance, pavement maintenance, pavement rehabilitation activities, and the cost of providing and maintaining pavement (Hass, Hudson, & Pedigo, 1980).

Pavement management system was defined by FHWA as a comprehensive and ordered set of activities, which describe the entire process of pavement management. A pavement management system or program encompasses all of many highway agency activities that pertain to pavements, including those normally associated with planning, programming, design, materials, construction, maintenance, and research; and the management process utilized to ensure coordination of these many pavement related activities (Hass, Hudson, & Pedigo, 1980).

Pavement management subsystem was defined by FHWA as an ordered set of activities or actions, which describe only part of the total process of pavement management. Pavement management subsystems typically are tools which provide input for pavement related decisions or which assist decision-makers in comparing alternatives and identifying the optimum strategies for one or more pavements related activities (Hass, Hudson, & Pedigo, 1980).

The primary operating characteristic of a pavement is the level of service it provides to the users, both today and in the future. It is important to measure or evaluate this level of service to establish the current status of a pavement, and to predict the change of this level in the future. This level of serviceability can change slowly or relatively quickly with time, depending on such factors as traffic, type and thickness of structure, surface distress, original construction quality, climatic factors, type, and degree of maintenance performed. When the change of serviceability over time is considered, pavement managers refer to it as pavement performance, which has always been of central concern in pavement management system.

Different relevant papers, reports, and articles were reviewed which considered pavement serviceability-performance concept, pavement performance evaluation, and development of performance models. Some of the studies were summarized in the following sections. Other studies mentioned through the next chapters are found in the references.

2.2 Serviceability Performance Concept

Cary and Irick (1960) provided the most widely known means for the use of the objective roughness measurements, for estimating the subjective pavement serviceability, and in developing the Present Serviceability Index (PSI) equation at the AASHO road test (Hass, Hudson, & Pedigo, 1980). The original form of this equation is:

$$PSI = 5.03+(-1.91R_1+....) + (-1.38D_1+-0.01D_2+...) \qquad (1)$$

R_1 = function of profile roughness [log $(1+\overline{SV})$]

$\overline{SV}$ = mean slope variance obtained from Road Test Profilometer.

D_1 = Function of surface rutting ($\overline{RD}^2$, where $\overline{RD}$ = mean rut depth as measured by simple rut indicator)

D_2 = function of surface deterioration (C+P), where C+P is the amount of cracking and patching in square foot per 1000 ft^2

The above PSI equation showed that for the particular variables selected, it is a best-fit equation based on all observed data used in the equation. Other variables that were candidates for inclusion in the model proved in the regression to add no significance in predicting PSI when added to the equation. Other forms of the PSI equation have been developed for other pavements and for other input variables.

Hand, Sebaaly, and Epps (1998) developed for Nevada Department of Transportation (NDOT) a network optimization system (NOS). The objective of the system was to evaluate various alternatives and to recommend the most effective rehabilitation treatment to be used on the various sections of the state highway system. The NOS consisted of several subsystems, which included performance models, life cycle cost analysis, and network optimization. NDOT developed the performance models, selected the unit cost to be used in the life cycle analysis, and identified unique segments on the entire road network.

Performance models had been developed for the rehabilitation treatments most commonly used by NDOT which included overlay and mill-overlay. The performance models were developed based on the PMS data that have been collected by NDOT for the past fifteen years.

The data used in the performance modeling were extracted from the PMS and historical databases. Traffic, climate, and performance indicators were obtained from the PMS database while the structural numbers, material types, and pavement age were taken from historical database. The models were generated through statistical analyses, which relate the PSI to age, traffic, environment, structural, and material properties. For each treatment, numerous in-service projects were selected and their corresponding PMS, structural, and environmental data were used to develop the statistical relationships.

The analyses were performed using a General Linear Model procedure (GLM) to develop a linear regression equation. NDOT has divided the state into three districts. The best overlay performance models were developed when data of districts one and two were analyzed separately while the data analysis of district three did not produce a significant model. In the case of mill-overlay, the combination of data from all three districts was the only data set that produced a significant model. Table 2-1 summarizes the selected models. The following definitions of variables apply for the selected models summarized in Table 2-1:

DPT: depth or thickness of overlay used in rehabilitation projects, located in as-built plans, inches.

ESALS: Cumulative value of Equivalent 80KN Single Axle Loads, calculated by multiplying the daily 80KN ESALS by 365 and a growth factor and adding to the previous year, beginning with year zero of a project. Daily 80KN ESALS are obtained from the D80KN field in the PMS data base, units are ESALS.

FT: The total number of freeze thaw cycles that a pavement may experience over the course of one year, obtained from the weather section of the PMS data base, cycles per year.

MILL: The depth of the asphalt concrete layer that is milled prior to overlay in inches.

PMF: Percent mineral filler used in the asphalt concrete mixtures, found in mix design section of as-built plans, percent.

TMAX: Maximum average yearly air temperature that a pavement section may experience, obtained from the weather section of the PMS data base, degree Fahrenheit.

TMIN: Minimum average yearly air temperature that a pavement section may experience, obtained from the weather section of the PMS data base, degree Fahrenheit.

SN: Structural Number (AASHTO design Guide) prior to application of any rehabilitation or maintenance technique.

WETD: The total number of wet days. Days that moisture was recorded, over the course of one year, obtained from the weather section of PMS database, days per year.

Year: Service year of the project. The year of construction is represented by year zero.

Table 2-1: Summary of Nevada Department of Transportation Performance Models

AC Overlay-District 1 Model	Number of Observations	R^2
PSI = 2.50+0.37DPT+0.60SN-0.96PMF+0.0098TMAX - 2.23e-7ESALS-.013YEAR-0.22DPT*SN+0.29DPT*PMF	182	0.80
AC Overlay-District 2 Model	Number of Observations	R^2
PSI = -0.83+0.23DPT+0.27SN+0.19PMF+0.078TMIN+ 0.0037FT-7.10e-7ESALS-0.14TEAR	154	0.87
Statewide AC Mill/Overlay	Number of Observations	R^2
PSI = -7.89+C1-0.22DPT+0.75MILL+0.12TMAX-8.4e-8ESALS+0.07WETD-0.007FT-0.16YEAR-1.3e-12ESALS^2	86	0.65

Source: Hand, Sebaaly, and Epps, 1998.

The developed models appear to fit the data well as indicated by their R^2 values and the comparison between predicted and observed pavement performance. The paper showed that large databases are needed to develop significant performance models. Such data has to be collected over a multiple-year period in order to capture the true performance of rehabilitation treatments.

Based on the paper, establishing a monitoring system for roadway network is very important. It is a powerful tool to establish roadway performance model, using pavement data obtained through the regular annual roadway survey, environmental data, traffic data, and structural data.

2.3 Performance model

Ping, Yang, He, and Dietrich (1999) estimated the average flexible pavement performance life in Florida for Maintenance (M) and Rehabilitation (R) applications. The pavement condition survey history data since 1976 from the Florida Department of Transportation (FDOT) were used for this analysis. The paper presented the development of a pavement performance modeling procedure based on the polynomial model and results of analyzing past flexible pavement performance in Florida. The average pavement performance life-cycles were evaluated for flexible pavement at the network level based on the performance curves.

The FDOT evaluated pavement condition using Pavement Condition Rating (PCR) values, which were assigned by panels of expert raters in conducting field inspections each year. These ratings were all in a zero to ten point scale.

The methods used to collect the surface distress data included windshield surveys to assess surface defect by type, and automated surveys using non-contact sensors to obtain profile information at traffic speeds to assess rutting as longitudinal profile variation. Pavement condition ratings including crack, rut, and ride ratings were reported to the nearest integer value. A reported rating of six or less was considered deficient pavement.

The point at which pavements were rated as deficient was the most important level to predict. In Florida, the pavement performance life was defined as the time period it takes the pavement to reach a deficient PCR value of 6.4.

The method applied in their paper for modeling pavement performance involved organizing the pavement network into families of pavements that perform in a similar manner for data manipulation and model development. The pavement sections were broken down by geographical region. There were total of seven districts in Florida. Then the pavement sections were divided into four subgroups within each district on the basis of system type. Four system types were classified including primary, toll, interstate, and turnpike. Since the majority of Florida maintained pavements were primary and interstate types, and the large portion of rehabilitation activities done in the past was resurfacing. Therefore, pavement performance analysis was concentrated on those two types, with resurfacing projects.

The primary data sources used in their study were Pavement Condition Survey (PCS) data and Work Program Administration (WPA) data. The methodology for developing pavement performance models consisted of fitting the selected models to the observed pavement condition data for each pavement section and subsequently establishing equations for predicting the parameters of the model using regression analysis. The regression equations were a function of pavement performance age.

In Ping, Yang, He, and Dietrich (1999), the models that were developed predicted the trend in PCR with time. These boundary conditions suggest the use of a non-linear, polynomial curve for modeling performance. A suitable function that follows this shape was:

$$PCR = a_0 + a_1X + a_2X^2 + a_3X^3 \qquad (2)$$

Where:

PCR = Pavement condition rating

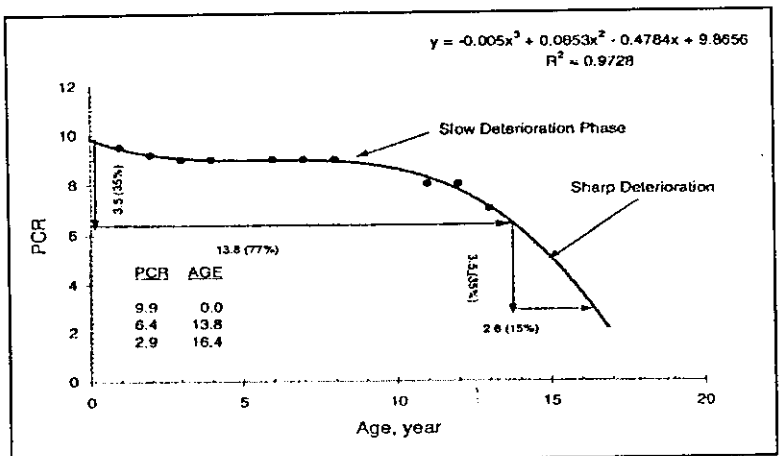
X = Pavement age in years

a_0, a_1, a_2, a_3 = Regression parameters

Figure 2-1 illustrates the typical regression curve defined by Equation (2). It gives general trend of pavement performance with time. A total of two hundred and seventy nine (279) pavement sections from the surveyed pavement network were selected for model development and curve fitting.

These curves were constrained in that they were not allowed to have a positive slope since PCR cannot increase within one life-cycle period. The performance curves developed from equation (2) were statistically significant with R^2 larger than 0.5. These curves were further classified into three groups.

Figure 2-1: Constrained Third Degree Polynomial Curve



Source: Ping, Yang, He, and Dietrich, 1999.

Group I included seventy-eight sections, which showed that pavement rehabilitation was done after the sections became deficient, when PCR value was 6.4. The performance lives of these sections were shorter than the number of years that pavements were in service and can be determined directly from regression curves.

Group II had fifty-three pavement sections, which showed that the rehabilitation was done before the sections became deficient. The performance lives of these pavement sections were obtained by projecting the regression curves to a certain point where the PCR value was 6.4 and should be longer than that shown in life cycle.

Group III with one hundred and forty-eight pavement sections. The life cycles extracted for curve development were last performance cycles. These pavement sections had not been rehabilitated since last rehabilitation and their last values of PCR were greater than 6.4. This means that performance lives of pavement sections in group III had longer values than that given in life cycle data. The developed curves were used to predict the performance lives of pavement sections.

As a further verification of the model, comparisons were made between the measured PCR data and the predicted PCR data for all of the PCR data in the analyzed database. The results showed that the residuals were normally distributed.

A study was conducted for a resurfacing project to determine how accurate the model was in predicting pavement conditions for 1994 as compared to the conditions measured in 1994 by regressing the predicted PCR against the measured PCR for one hundred and forty-seven sections. The results also showed that in general the primary system had longer average performance life than the interstate system for resurfacing, reconstruction, and new construction projects. For the three project types considered, the average performance life of resurfacing projects was the lowest among these project types. Distributions of pavement ages for two hundred and seventy-nine sections ranged from eight to seventeen years.

Silva, Vandam, Bulleit, and Ylitalo (2000) proposed pavement performance models for local government agencies in Michigan. The State of Michigan had 191,432 KM of roadway including highways, roads, and streets, of which local government agencies are responsible for 176,270 Km of these roads and streets. To best maintain this network of roads in the most cost-effective manner, these local agencies relied on a PMS called RoadSoft to assist in managing their pavement network.

The overall goal of their study was to improve pavement performance models to assist in the overall planning of maintenance and rehabilitation strategies. In this paper, various deterministic and probabilistic models were evaluated using data from two Michigan counties. It was found that the logistic growth model and Markov model provided the best combination of predictive ability and potential for applicability in Michigan counties.

Michigan counties used an objective, repeatable rating system for assessing pavement condition called Pavement Surface Evaluation and Rating (PASER), which was based on the visual condition of the pavement. The simplicity of this procedure made data collection easier but also less accurate. Nevertheless, the system has been widespread use in Wisconsin and Michigan for a number of years, and the accuracy of the data were found to be adequate for local agency applications. In the PASER system, the asphalt pavement surface was evaluated in discrete condition states rated using a scale that ranges between one, which is a state of very poor condition, and ten, which is an excellent condition in whole number increments. The method did not entail the quantification of distress, but instead the ratings were assigned on the basis of photographs of roads in various conditions presented in the PASER manual.

The method used in RoadSoft PMS to establish pavement performance curves was by plotting the change in pavement condition over time as assessed by PASER. These models were used at the network level to predict future pavement condition to assist in determining maintenance and rehabilitation requirements.

Kuo (1995) was the first to apply the logistic growth model to Michigan's pavements. Kuo's pavement model was based on an ascending distress index with different design service life values. In this formulation, the starting distress index of a reconstructed or resurfaced pavement was established as zero. The model thus passes through zero at new construction. To reflect this boundary condition in a logistic growth model, the following equation was used:

$$DI = \left[\frac{(\alpha + \beta)}{(\alpha + \beta e^{-\gamma t})} - 1 \right]$$

DI = Distress index,

α = Potential initial DI,

β = Limiting DI,

t = Age (years),

$\gamma = -(1/DSL)\ln([\{(\alpha+\beta)/(\alpha+CDP)]-1\}\ \alpha/\beta)$, which is a deterioration pattern index,

DSL = Design service life, and

CDP = Predetermined DI.

In Silva, Vandam, Bulleit, and Ylitalo (2000), the pavement condition data collected by two local agencies in Michigan based on PASER method scale was used in both the logistic growth model and the Markov probabilistic model. A plot of all the selected data showed that the data were widely scattered. Therefore, four representative segments were selected and independently analyzed to demonstrate how well each model performed on a segment-by-segment basis using local government agency pavement condition data.

To apply the logistic growth model, the parameter values had to be inverted to meet the constraints of the PASER and RoadSoft data, in which the values ranged from one to ten and the starting DI of distress free pavement was ten. To reflect this, the model passed through ten at time zero. This boundary condition was included such that:

$$\text{PASER Rating} = \alpha - \beta\left[\frac{(\alpha+\beta)}{(\beta+\alpha e^{-\gamma t})} - 1\right]$$

α = Potential initial DI (assumed to be 10 in most cases),

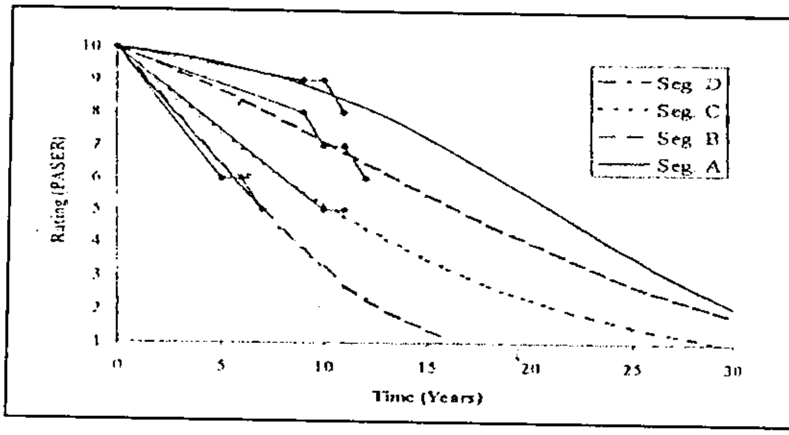
DI = Distress index,

β = Limiting DI (assumed to be 1), and

$\gamma = -(1/DSL)\ln([\{(\alpha+\beta)/(\alpha+\beta-CDP)]-1\}\ \beta/\alpha)$.

Figure 2-2 illustrates the logistic growth model fitted to four representative pavement segments with ratings starting at ten but with different deterioration rates.

Figure 2-2: Plot of Logistic Growth Model Fit to Four Pavement Segments



Source: Silva, Vandam, Bulleit, and Ylitalo, 2000.

As an alternative to deterministic models, probabilistic models are sometimes considered. The Markov transition process is one probabilistic approach that has received attention by pavement engineers and researchers. The principles of applying probabilistic models for the prediction of pavement deterioration were first discussed in the early 1970s. Since that time a considerable progress has been made in the development of probabilistic models and their application to PMS.

The major challenge facing the use of existing probabilistic models is difficulties with establishing the Transition Probability Matrices (TPMs). Most TPMs are constructed by using one of the following methods (Hass, Li, and Xie, 1997):

- Pavement performance deterioration versus age or traffic loading is modeled as a time-independent Markov process. Each element of TPM is based on individual interviews and questionnaires, reflecting the average subjective opinions of experienced engineers.

- A large number of functionally and structurally categorized pavement performance history data are observed under different initial pavement conditions.

A state vector indicates the probability of a pavement section's being in each of the given states in any given year.

The Markov model requires the development of TPMs to predict the way the pavement deteriorates with time, but first the transition matrix should be built. The Markov transition matrix expresses the probability that a group of pavements with similar characteristics will transition from one state to another. The formation of transition matrix and TPM are shown in Table 2-2a and Table 2-2b.

Table 2-2a: Transition Matrix Developed

Rating	10	9	8	7	6	5	4	3	2	1	Total
10	7	9	0	0	0	0	0	0	0	0	16
9	0	11	10	0	0	0	0	0	0	0	21
8	0	0	10	12	0	0	0	0	0	0	22
7	0	0	0	12	9	0	0	0	0	0	2
6	0	0	0	0	11	10	0	0	0	0	21
5	0	0	0	0	0	8	7	0	0	0	15
4	0	0	0	0	0	0	9	8	0	0	17
3	0	0	0	0	0	0	0	9	7	0	16
2	0	0	0	0	0	0	0	0	5	3	8
1	0	0	0	0	0	0	0	0	0	2	2
							Total No. of Sections				159

Table 2-2b: Developed Transition Probability Matrix

Rating	10	9	8	7	6	5	4	3	2	1
10	0.4373	0.5625	0	0	0	0	0	0	0	0
9	0	0.5238	0.4762	0	0	0	0	0	0	0
8	0	0	0.4545	0.5455	0	0	0	0	0	0
7	0	0	0	0.5714	0.4286	0	0	0	0	0
6	0	0	0	0	0.5238	0.4762	0	0	0	0
5	0	0	0	0	0	0.5333	0.4667	0	0	0
4	0	0	0	0	0	0	0.5294	0.4706	0	0
3	0	0	0	0	0	0	0	0.5625	0.4375	0
2	0	0	0	0	0	0	0	0	0.625	0.375
1	0	0	0	0	0	0	0	0	0	1

Source: Silva, Vandam, Bulleit, and Ylitalo, 2000.

The state vector for any duty cycle `` t `` is obtained by multiplying the initial state vector v(0) by the TPM raised to the power of t (Howard, 1971). Thus,

$$[v(1)] = [v(0)] * [TPM]$$

$$[v(2)] = [v(1)] * [TPM] = [v(0)] * [TPM]^2$$

$$[v(t)] = [p(t-1)] * [TPM] = [v(0)] * [TPM]^t$$

Where [v(t)] is the row vector and [TPM] is the square transition probability matrix.

Table 2-3 presents the Markov probability distribution for the first five years based on analysis of the data set. The probability distribution within each sate vector is the main characteristic that makes the Markov model more attractive than the deterministic models.

Table 2-3: Probability Distribution Values from Markov Model

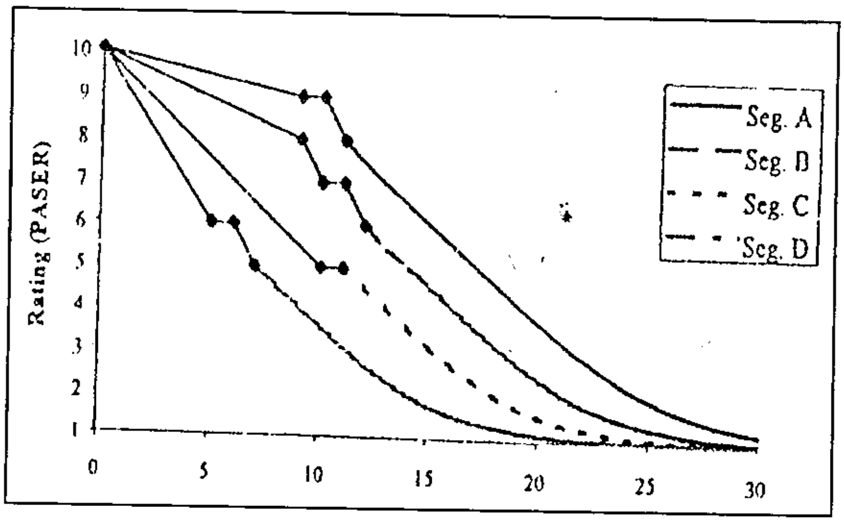
Rating	Year 1	Year 2	Year 3	Year 4	Year 5
10	0.438	0.191	0.084	0.037	0.016
9	***0.563***	***0.541***	***0.391***	0.252	0.153
8	0	0.268	0.379	***0.359***	0.283
7	0	0	0.146	0.29	***0.361***
6	0	0	0	0.063	0.157
5	0	0	0	0	0.03
4	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
1	0	0	0	0	0

Source: Silva, Vandam, Bulleit, and Ylitalo, 2000.

In Table 2-3, the state of maximum probability is the most likely deterioration path that the segments will follow. Following this procedure, the transition matrix probabilities can be estimated and the future state of the pavement at any duty cycle, t, can be predicted.

In Silva, Vandam, Bulleit, and Ylitalo (2000), the four pavement segments used to evaluate the logistic growth model were also used to analyze the performance of the Markov model, as shown in Figure 2-3. In Markov model, predicted future deterioration started at the last rating the segment received. The line for each segment represented the average state of pavement determined from a probability distribution based on the TPM established from the entire data set.

Figure 2-3: Plot of Markov Model for Four Pavement Segments



Source: Silva, Vandam, Bulleit, and Ylitalo, 2000.

A comparison between the logistic growth and Markov models was made. One pavement segment was chosen for analysis. Using the five condition ratings received by this segment, starting with a date at time zero, each model was used to predict future pavement deterioration. These predicted values were then compared with the actual ratings. The results of analyzed data showed that both models predicted similar deterioration rates, but the logistic growth model had a shorter predicted pavement performance life than the Markov model had. It also lied slightly closer to the actual rating.

In addition, the evaluation of the deterministic logistic growth model, and the Markov probability model using data from two Michigan counties, provided adequate predictive ability for estimated future pavement condition. Because of the high level acceptance of the logistic growth model in Michigan, it was planned to be implemented in RoadSoft by year 2000. The Markov model would be added at a future date as local organizations gather sufficient pavement condition data over the following years.

A thorough study of the different methodologies used for the development of performance model was carried out in order to select an approach to the development of performance prediction model for roadway network at the local level. It was obvious that the constrained polynomial performance model for flexible pavement developed by Ping, Yang, He, and Deitrich (1999) using pavement condition rating values, provides a useful tool for developing roadway performance model in Palestine. Adopting this model, which depends only on pavement age and pavement condition ratings assigned by pavement experts in conducting field inspections, will match well the available data being collected for the case study of this research.

The performance models developed for flexible pavement by Hand, Sebaaly, and Epps (1998) showed the importance of establishing a comprehensive databank through applying a periodic monitoring system for pavements in order to model pavement performance using the linear regression analysis and PSI concept. The databank should include traffic data, pavement age, material properties, and environmental conditions.

The pavement performance models for local government agencies in Michigan proposed by Silva, Vandam, Bulleit, and Ylitalo (2000), indicated the need to apply an alternative for the constrained polynomial least square deterministic model. This can be achieved by calibrating the collected data for the logistic growth model and for Markov probabilistic model, which is a realistic approach to modeling pavement deterioration.

Chapter Three

Methodology

3.1 Introduction

Road and street network represents a major area of investment in transportation. The pavement portion of this investment is quite substantial. People who are interested with the responsibility of expanding the funds allocated for these investments require an efficient set of management practices. Any type of management is concerned with information, coordination of activities, making decisions, and taking action. In order to do this in an efficient and cost effective manner, a set of guiding principles and practices should be defined and organized in a systematic way.

Pavement management is a process developed to respond to managing one of the most substantial areas of investment in transportation. It is broadly based and incorporates all the activities required to provide and maintain pavements. These include the programming of investments, design, construction, maintenance, and in-service monitoring.

Since 1960, all the studies pointed to broader needs in the pavement field, such as a need to qualitatively look at pavements. These studies pointed out the following:

- The need for real, continuous observations of pavements in service, and the need to record these observations in a data set.
- It was found that pavements generally do not last twenty to twenty-five years without heavy maintenance and\ or overlay.
- It was generally found that equations or mathematical models are essential to predict pavement deterioration history as a function of time, traffic, and environment.
- It was found that there is a significant variability in most pavement factors, such as materials, construction, and traffic. This variability requires that periodic updating be done of all predictions of plans.

One of the pavement management principles and practices is the performance prediction model in pavement design. The main aim of this thesis is to establish a performance model for flexible pavement at the local level in Palestine and to predict its trend in the future for rehabilitation needs in a cost-effective manner. This issue is a major objective of the related agencies' policy. To achieve this objective, the following tasks were considered:

1. Categorize the pavement sections by their classification, layers of construction, and age of roadways, which are selected for this study to build a database for the last seven years of pavement life that had received rehabilitation or reconstruction.

2. Pavement data are collected in accordance with World Bank Manual for Developing Countries, "Road Monitoring for Maintenance Management", 1990. Visual road condition survey and detail visual inspections are performed for selected rehabilitated village access roads, reconstructed arterial roads, and overlaid arterial roads.

3. Initial data verification and identification. The primary data sources used in this study were Pavement Condition Rating (PCR) data. MathCAD software was used for Markov probabilistic model and Microsoft Excel was used for calculation of logistic growth regression model, and for developing polynomial regression curves of second degree.
4. Data are analyzed by testing the data for the constrained polynomial model and the Markov probabilistic model.
5. PCR data is calibrated by applying the deterministic logistic growth model. The results of the three models are statistically compared.
6. Pavement life cycle is analyzed and compared for the models developed
7. The models' outcomes are used to support the decision making towards suitable maintenance and rehabilitation strategies.

The proposed methodology will establish the basic steps involved in the development of pavement performance model and evaluation of the standing polices, for which the interested ministries, municipalities, and institutions can adopt.

3.2 Deterministic Models

Many deterministic models forms are available for predicting pavement performance, including straight-line extrapolation, polynomial constrained least squares, and logistic growth models. A number of advantages and disadvantages must be considered when deterministic models are used. The advantages include (Silva, Vandam, Bulleit, & Ylitalo, 2000):

- A simple mathematical method to analyze performance data and to develop performance prediction models is provided.
- Development of linear, S-shaped curves, and polynomial constrained least squares performance prediction models are allowed.
- The adequacy of prediction of the performance model in relation to the actual data can be described by using the coefficient of deterministic values.
- Models can be updated or adjusted using future analysis of results and engineering judgment.

While the disadvantages (Silva, Vandam, Bulleit, & Ylitalo, 2000) are:

- The models require an accurate and abundant set of data. Any regression model is only as good as the data used to develop it.

- It is necessary to include all significant variables affecting deterioration.
- Accuracy of the performance model is affected by minor rehabilitation or maintenance activities.
- It is not completely accurate to apply deterministic models to pavement condition data, which are not continuous but rather are collected in discrete condition states.

Deterministic models are also unable to address some other concerns in pavement management applications (Hass, Li, & Xie, 1997), including:

- The uncertainties in pavement behavior under variable traffic load and environmental conditions.
- The difficulties in quantifying the factors or parameters that substantially affect pavement deterioration, and
- The errors associated with measuring pavement condition and bias from subjective evaluation of pavement condition.

Even with these limitations, it is still a common practice to use deterministic models in pavement applications primarily because of their relative simplicity, ease of use, and familiarity. In this thesis, two deterministic models are considered for application.

3.2.1 Constrained Polynomial Regression Model

In recent years, there has been an increasing use of regression analysis based on survey data in engineering sciences, empirical econometrics, statistics, physical, and biological sciences. The regression techniques are powerful tools. In pavement management they are applied to establish an equation that describes the behavior of pavement condition with time for a group of streets having similar characteristics.

The methodology for developing pavement performance polynomial regression model consists of fitting the selected model to the observed pavement condition data for each pavement section and subsequently establishing equations for predicting the parameters of the model using regression analysis. The regression equation is a function of pavement age. The variable "age" is the most significant factor for predicting Pavement Condition Rating (PCR) because it is a common factor in the estimation of both cumulative traffic loads and environmental loads over the life-cycle period. The independent variable is pavement age, while the PCR is the dependent variable.

In developing the performance prediction models, it is important to choose a function that obeys the boundary conditions for the PCR variable being predicted. For this study, the model developed should predict the trend in

PCR with time. Since this rating is defined on zero to five scale, the model adopted must obey these minimum and maximum boundaries. These boundary conditions suggest the use of a non-linear, polynomial curve for modeling performance. A suitable function that follows this shape is:

$$PCR = a_0 + a_1 t + a_2 t^2 \qquad (3)$$

Where:

PCR = Pavement condition rating

t = Pavement age in years

a_0, a_1, a_2 = Regression parameters.

The regression curve defined by equation (3) gives a general trend of pavement performance with time. These curves are constrained in that they are not allowed to have a positive slope since the PCR cannot increase within one life-cycle period.

Constrained second-degree polynomial equation calculates the least squares, which is a measure of the goodness of fit of the polynomial model. The method of least square results in a curve that minimizes the sum of squared vertical distances from the observed data points to the predicted polynomial curve. The new values of PCR are predicted by using linear regression.

3.2.2 Logistic Growth Model

Kuo (1995) was the first to apply the logistic growth model to Michigan's pavements. Kuo's pavement model was based on an ascending distress index with different design service life values. In this formulation, the starting distress index of a reconstructed or resurfaced pavement is established as zero. The model thus passes through zero at new construction.

The logistic growth model assumes that the growth rate at time t is proportional to the product of the population size at time t and the future amount of growth. As time t increases, deterioration approaches to one hundred. Regardless of the values of these parameters, the curve has an S-shape and is symmetric about its point of inflection. However, the values of these parameters collectively determine the exact shape of the curve.

The surveyed data set were carefully analyzed, and all segments containing consecutive pavement condition ratings from one year to another without showing increases in pavement condition were included. Segments that showed improved condition without new construction dates were rejected. Logistic growth model fitting was done using MS-Excel.

To apply the logistic growth model, the parameter values had to be inverted to meet the constraints of the PCR values, in which the values ranged from one to five and the starting DI of distress free pavement is five. To reflect this, the model must pass through five at time zero. This boundary condition is included such that:

$$\text{PCR Rating} = \alpha - \beta \left[\frac{(\alpha + \beta)}{(\beta + \alpha e^{-\gamma t})} - 1 \right]$$

α = Potential initial DI (assumed to be 5 in most cases),

DI = Distress index,

β = Limiting DI (assumed to be 1), and

$\gamma = -(1/DSL)\ln([\{(\alpha+\beta)/(\alpha+\beta-CDP)]-1\}\ \beta/\alpha)$.

The logistic growth model reflects the nonlinear deterioration rate of the segments. On the basis of the model's ability to reflect a none-linear deterioration rate and its previous use and acceptance for application to local agencies, it is believed that this is an appropriate deterministic model for calibrating road condition data collected for the representative road samples with the limitations considered.

3.3 Markov Probabilistic Model

Uncertainty, complexity, and dynamism have been continuing challenges to man's understanding and control of his physical environment. In the development of logical structures to describe these phenomena, the model originated by Markov stands as a major accomplishment. Where previous contributors had modeled uncertainty as a sequence of independent trials, Markov saw the advantage of introducing dependence of each trial on the result of its predecessor. While it is tempting to consider even more complex dependency of the present trial on the results of past trials, such temptation usually leads to results that are both analytically and computationally intractable (Howard, 1971).

Consequently, Markov models represent the first outpost in the domain of dependent models that is powerful both in capturing the essence of many dependent systems observed in practice and in producing the analytical and computational results necessary to gain insight into their behavior. The Markov model is a consistent application of the fundamental principles of probability and linear system theory.

The Markov model was considered as an alternative to the deterministic models because of its relatively simple implementation, capabilities of providing an accurate prediction of pavement performance, and limited effort required on the part of the user.

The Markov transition process is one probabilistic approach that has received attention by pavement engineers and researchers. The principles of applying probabilistic models for the prediction of pavement deterioration were first discussed in the early 1970s. Since that time a considerable progress has been made in the development of probabilistic models and their application to PMS.

Butt (1991) outlined several advantages of using a Markov probability decision process in pavement management:

- Future decisions on preservation actions are not fixed but depend on how the pavements actually perform.
- Actions to be taken now and in the future can be identified, and the actions to be taken in the future can be identified with a high degree of probability.
- The success or failure of pavement management decisions can be evaluated by comparing expected proportions of the roads in given condition states with actual proportions of roads observed in the field.
- Probability-based models have the potential for significant cost savings by selecting less conservative rehabilitation actions that still satisfy the prescribed performance standards.

- The probability-based Markov deterioration model ensures that modeled pavements will continue to have the classic pattern of worsening condition with age.
- Finally, Markov process is a natural tool to use in alliance with dynamic programming to produce optimal solutions.

3.3.1 The Transition Concept

A pavement begins its life in a near-perfect condition. As it is subjected to a sequence of duty cycles, the pavement condition deteriorates and the damage increases. A duty cycle for a pavement is commonly defined as one year's duration of weather and traffic. A state vector indicates the probability of a pavement section's being in each of the given states in any given year.

The Markov model requires the development of TPMs to predict the way the pavement deteriorates with time. On the basis of the assumptions stated earlier, the TPM for a process having five states are written in Table 3-1, where:

P(j) = is the probability that a segment will stay in state j during one duty cycle, and

q(j) = 1 - p(j), is the probability that the segment will transition to the next state (j + 1) during one duty cycle.

Table 3-1: Transition Probability Matrix for Process with Five States

Rating	5	4	3	2	1
5	p(1)	q(1)	0	0	0
4	0	p(2)	q(2)	0	0
3	0	0	p(3)	q(3)	0
2	0	0	0	p(4)	q(4)
1	0	0	0	0	1

The entry of one in the last row of TPM as shown in Table 3-1 indicates a reconstruction state. The pavement condition cannot transit from this state at all. This is called an absorbing state (Butt, 1991). The Markov transition matrix expresses the probability that a group of pavements with similar characteristics will transition from one state to another.

To analyze the data using the Markov model, the following assumptions were made in the study:

- Pavement condition was expressed in a finite number of states corresponding to the five ratings used for pavement condition rating system.
- The transition probabilities depend only on the present condition state.
- The transition process is stationary, that is, the probability of transition from one condition state to another is independent of time.
- Condition ratings will always remain constant or decrease with time. Increases in condition rating, because of road maintenance, are not

considered. Deterioration following maintenance was included as a new segment by replacing previous data points for that particular segment.

- The pavement condition cannot degrade by more than a single state in one year. Data showing such that were not included in the analysis.
- The TPM may be non-homogeneous, meaning that a TPM is required for each year. But in this study, TPM was assumed to be homogeneous and the same matrix is used from year to year.

3.3.2 Calculation of State Probability

On many occasions we shall want to speak of the probability that a certain state is occupied after *n* transitions without including in our notation the state in which the process was started. Such a probability is called a state probability; the probability that state *I* is occupied at time *t* will be given the symbol [v(t)] (Howard, 1971).

The state vector for any duty cycle, *t*, is obtained by multiplying the initial state vector v(0) by the TPM raised to the power of *t*. Thus,

$$[v(1)] = [v(0)] * [TPM]$$

$$[v(2)] = [v(1)] * [TPM] = [v(0)] * [TPM]^2$$

$$[v(t)] = [p(t-1)] * [TPM] = [v(0)] * [TPM]^t$$

Where [v(t)] is the row vector and [TPM] is the Transition Probability Matrix. [TPM] is a square matrix of degree five.

With this procedure, the transition matrix probabilities can be estimated and the future state of the pavement at any duty cycle, *t*, can be predicted.

After data filtering and outlier analysis, all the surveyed pavement segments, regardless of age, were categorized into one of the five condition states. The state vector at age zero is given by (1, 0, 0, 0, 0), since it is known with a probability of one that the pavement segments must lie in state one at age of zero years.

Using the PCR received by these sections, each model was used to predict future pavement deterioration. These predicted values were then compared with the actual ratings. In many cases the models were chosen for the best fit without regard to the suitability or intrinsic relevance of variables selected. It is suggested to implement these pavement deterioration models in the PMS program planned by the Palestinian related agencies to establish pavement performance prediction method.

Chapter Four

Data Collection

4.1 Introduction

Regular and reliable information on road condition is essential for managing the maintenance of a road network, both for assessing the physical and financial needs and for evaluating the effectiveness of road maintenance practices. The data collection method used for this study is intended to aid the management of road maintenance and also be used for rehabilitation. It does comprise the components that should be common to all monitoring methods and thus is intended to serve as a basic operational method. It is neither complex, nor dependent on sophisticated mechanical equipment and highly-trained individuals to carry out the work.

Management of a road network requires different information at different levels of decision-making, such as for planning, programming, design, and implementation. When, where, and how the data should be collected by an inspection system, depend very largely on the use of the data. The two principal management applications are (World Bank & OECD, 1990):

- Maintenance management, whose aim is the efficient organization, scheduling, and budget control of maintenance activities within the budget.

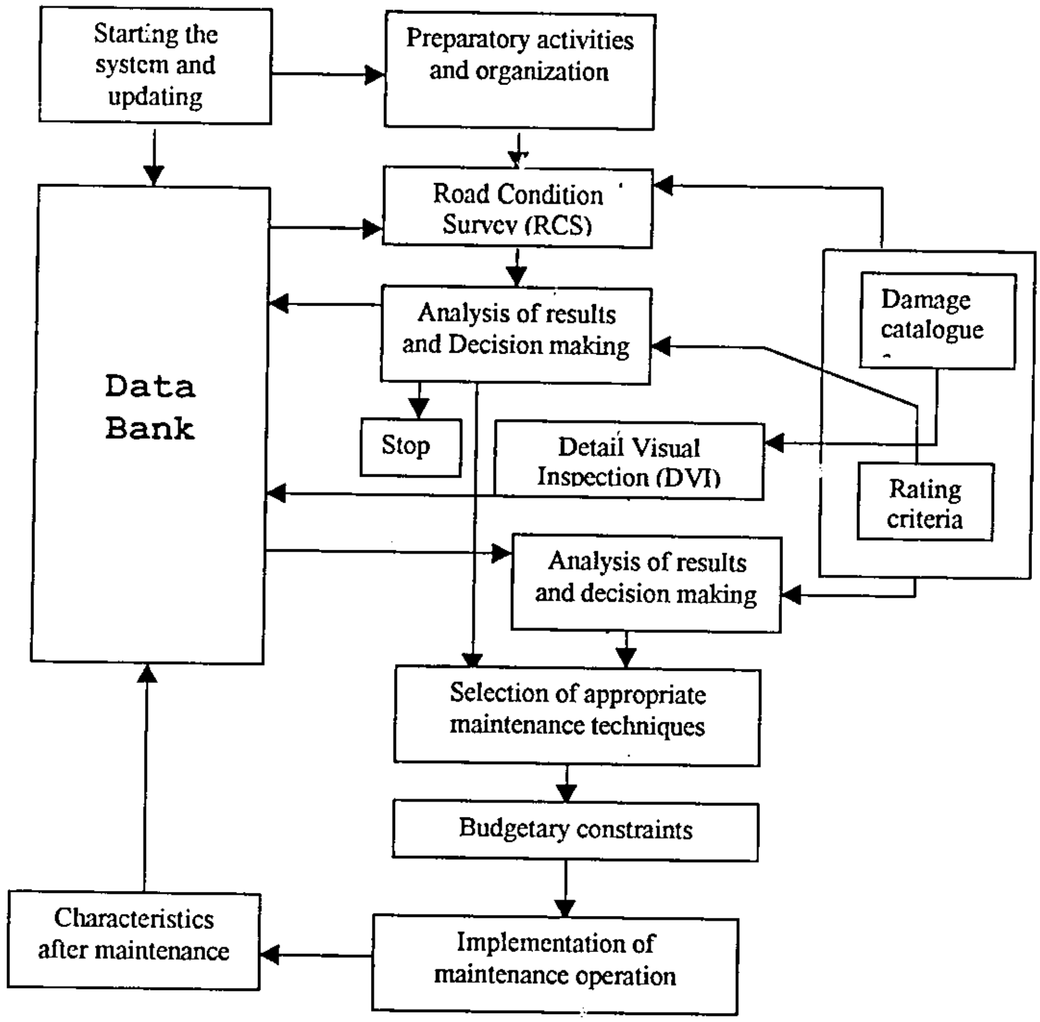
- Pavement management, which consists mainly of planning and programming procedure that minimizes the whole life cost of the road and requires information on the condition and trafficking of the pavement, in order to evaluate and schedule appropriate major maintenance or rehabilitation works, in both medium-term plans and yearly programs.

In both management processes, there are two indispensable components, information and a decision process. The information component comprises a monitoring or data collection method and a data bank for storing the information, and provides quantitative data on the state of the network. The information elements may be either simple-basic ones, or detailed and comprehensive, depending on the resources and capabilities of the road agencies.

A road monitoring method needs to be consistent with local requirements and resources. For this reason the method proposed here does not present a rigid scheme, but may be adjusted to suit local conditions and preferences.

Figure 4-1 shows the general scheme of the monitoring system. The road monitoring method presented here is intended to serve as a basic information subsystem, and is presented in two levels (World Bank & OECD, 1990):

Figure 4-1: Flow Chart of Road Monitoring System and Its Interaction with Planning and Programming Maintenance Activities.



Source: Road Monitoring for Maintenance Management, World Bank & OECD, 1990.

- The *primary level*, which provides basic information for maintenance management through a Road Condition Survey (RCS). This survey should be conducted over the entire network at an approximately annual frequency. The basic survey is primarily visual and may be supplemented by some instrumented measurements. It provides a regular assessment of road condition and needs. It could also be used as a basis to align budget allocations and to evaluate the effectiveness of maintenance practices.

- The *second level* is a Detailed Visual Inspection (DVI) of road condition, which might be done selectively for only those sections appearing to need major works. DVI is intended to identify the sections to be considered for the programming of major maintenance.

4.2 Establishing a Road Monitoring Scheme

The road monitoring system as described here is of a general nature. It allows for adjustments to the specific demands of a particular maintenance organization or subdivision of road network. The following elements are dealt with in this section:

- Functional classification of the road network.

- Road sampling method.

- Division of the road network into sections and sub-sections.

- The referencing of sections and sub-sections.

4.2.1 Functional Classification of Road Network

No doubt that the class of the road has a direct impact on the pavement distress that the road suffers from. Functional classification of road network involves grouping streets and highways into classes or systems according to the character of service they intended to provide. Generally, highways serve a dual role in a highway system:

1. Mobility: It is a characteristic describing the quantity of traffic that can be handled and the speed at which it can be transported.

2. Land Access: It is a characteristic indicating the provision of direct access to adjacent territories.

According to these dual roles, roads can be classified as following:

- ***Arterial:*** which serves major movement of high volume of traffic and at a high speed but with a limited accessibility.

- ***Collector:*** which serves intra-district traffic at moderate volumes, moderate speeds, and moderate accessibility.

- ***Local Road:*** which serves directly abutting land at low-volume, low-speed, and high accessibility.

- ***Village Access Road:*** which serves directly the villages nearby at moderate volumes, moderate speed, and high accessibility.

4.2.2 Sampling Method

The sampling method is an important aspect for a good representative data. The sampling selection method depends mainly on the type of roadway network, type of information needed, the duration of survey project, allocated funds for the survey, and the institution to conduct the survey. There are four sampling methods:

1. Systematic Random Sampling

The roadway numbers are put in a table form. In this method, the numbers are chosen in terms of their orders in a systematic period, such that one number is chosen in each period. The number of periods represents a percent of the sample size of the road network.

2. Completely Random Sampling

The sample is chosen such that each element of the road network has the same selection probability. Selecting any roadway is independent of selecting any other one. The selection is done randomly up to reach the required sample size.

3. Stratified Random Sampling

When the roadway represents some of certain classification groups, it is preferable to use the stratified method. In this method, the roadway network is divided into groups, and the percent of group sample size represents the same percent of this group population, accordingly.

4. Cluster Random Sampling

This method is used when the roadway is too large and distributed in different areas and the sampling of all the area elements is difficult. Some roadway districts are chosen to represent the roadway network randomly. All chosen district's elements are considered as the sample size.

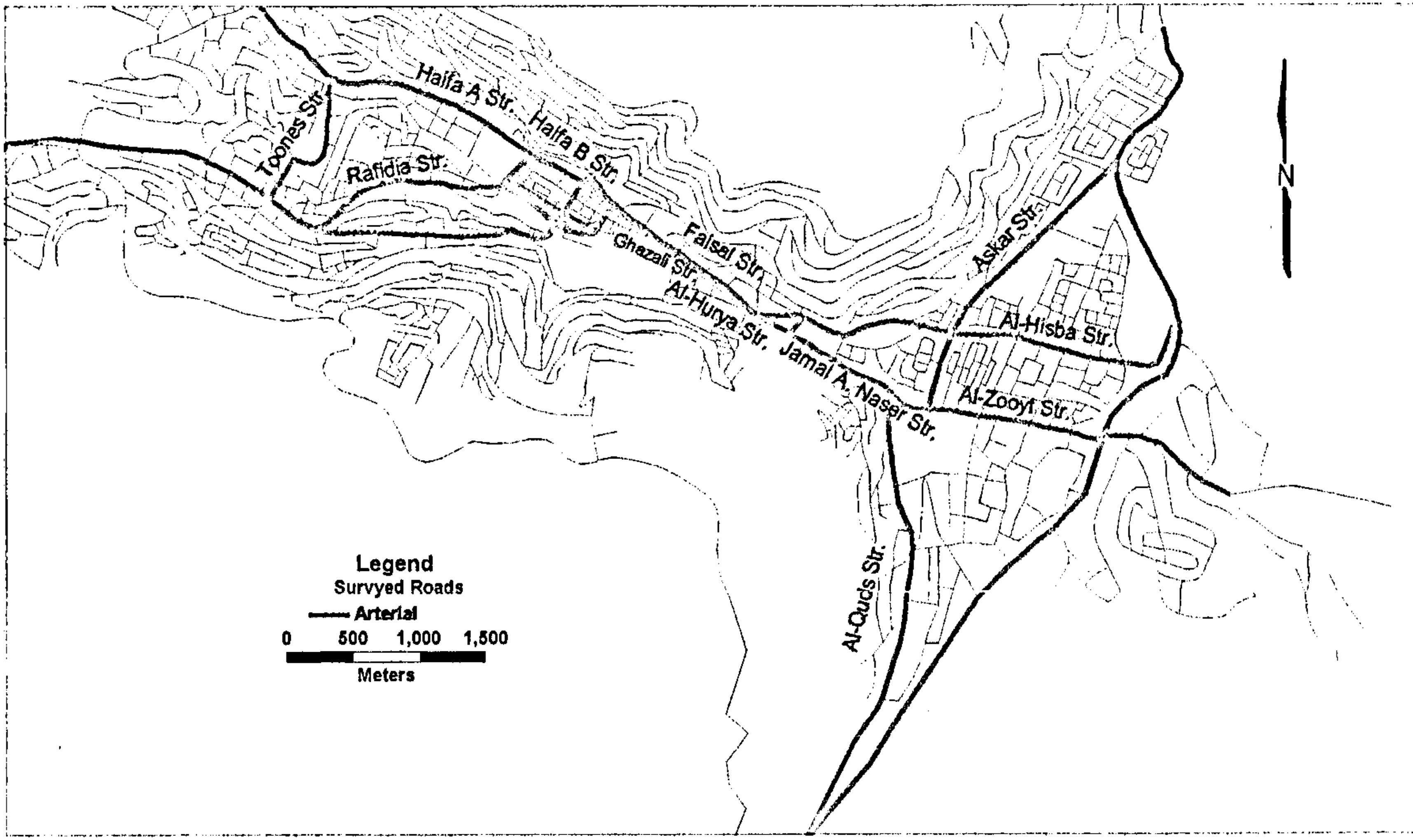
The sampling method selected to accommodate the objective of this study in modeling performance trend for roadway network is the cluster random method, since the roadway network is very large and distributed in different areas. So, Nablus Province was chosen to be the study area. Two road classifications were selected; the arterial roads and village access roads.

The total length of arterial roadway network in West Bank by the end of 1997 was approximate 455.6 Km, and the total length of village access roadway was 1,371.2 Km (Palestinian Central Bureau of Statistics,1999).

In this project, representative samples of arterial and village access roads were chosen for this study. In selecting the road sample, consideration was taken into account for years in service after the last maintenance or rehabilitation action the pavement has received. Total length of resurfaced arterial was 15.7 Km. The total length of arterial roads that have received major maintenance was 17.5 Km. The total length of rehabilitated village access roads was 25.8 Km (PECDAR, 2000).

With a close look to the road network of Nablus City and Nablus Province, all streets selected for this study are shown in Figure 4-2.

Figure 4-2a: Surveyed Arterial Roads in Nablus City



4.2.3 Division into Sections and Sub-Sections

Before the road network can be divided into sections, the road classification has to be indicated on a small-scale map. The first large map can be transformed into a simplified road map.

Sub-sections should be homogeneous, as possible, in character with regard to cross-section, and pavement structure. The secticn should consist of no more than five sub-sections. The length of the sub-section should be chosen in a logical way to accommodate selected sample of roadway network for RCS. The length of the section of arterial roads was chosen as 100 m while the length of village access roads was 200 m within the limits proposed by World Bank & OECD (1990).

4.3 Road Condition Survey (RCS)

Usually, road condition survey is to be conducted over the entire road network, preferably at least annually. This survey provides a regular assessment of all maintenance needs and of the condition of the road network. The quality of decision making can be improved in the long-term by monitoring a set of representative sections for research. The sections are sampled throughout the network and selected on the basis of age, traffic, structure, and environment in order to provide long-term performance evaluation data, which could be useful for modeling road deterioration. The purposes of the RCS are:

- To assess the general condition of the road network.

- To identify those sections or sub-sections of the road network, which are in critical condition. In the later case, a Detailed Visual Inspection (DVI) is mandatory.

- To detect sever damage that requires immediate maintenance action.

Before the survey begins, its itinerary has to be prepared. The road identification details have to be completed in the top part of Figure 4-3, which is the road condition survey form. On the RCS form, three groups are identified:

1. The carriage-way to be evaluated on a five point scale;

2. The roadside components as well as obstructions to be evaluated on a three point scale;

3. Road signs and furniture to be evaluated on a three point scale.

Figure 4-3: The Road Condition Survey Form

Road condition survey (RCS)			**Road Name:**	**Road Classification:**
Date:	Weather: ° Clear ° Rainy	Carr. Way: ° Dry ° Drying ° Wet	Section No.:	Section length:
Time:			From :	To:
			Summary (Average Condition)	**Carriageway:**
				Roadside:

SUB-SECTION	**1**	**2**	**3**	**4**	**5**
Roadside					
Carriageway Rating (PCR)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Prevailing damage					

Damage Type	**Rating (PCR)**				
Roadside					
Shoulder Deformation	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Shoulder Scour	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Side Drains (Curbs)	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Obstacles or Debris	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Embankments	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Road Signs and Markings	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Average					

Remarks: ______________________________

Source: Road Monitoring for Maintenance Management, World Bank and OECD, 1990.

4.3.1 Evaluation of Carriage-Way

This parameter gives an overall evaluation of the surface characteristics by converting the user's general impression of the riding quality of the road and visual impression of the road surface into a number. By applying the conditions described in Table 4-1, the inspection will result in a value of one being excellent to five being bad for the pavement. These numbers are combined into an average indicating the condition of the carriage-way of the section, that will determine the need for detailed visual inspection.

Table 4-1: Conditions to Estimate Road Condition Survey Points

Conditions	Points
• No deformation or potholes, or • Depressions < 2mm/3m	1
Surface degraded by: • Depressions (5-15mm/3m), or • Repairs and potholes (1-5 per 100m), or • Surface not damaged, but undulations and corrugations exist.	2
• Depressions (10-20mm), or • Frequent repairs, or • Occasional potholes, or • Surface not damaged but strong undulations and corrugations exist.	3
• Serious faults, or • Frequent and deep depressions (20-35)mm at a frequency of 6-10 per 100m, or • Frequent poor repairs and potholes (6-20 per 100m)	4
• Frequent and deep depressions and potholes (>40mm; frequency 16-30 per 100m)	5

Source: Road Monitoring for Maintenance Management, World Bank and OECD , 1990.

4.3.2 Evaluation of Roadside Elements

The inspection of the side elements is important in helping to keep the carriage-way and the road structure itself in an acceptable condition. The applicable characteristics listed on the survey form, will be evaluated quantitatively on a three-point scale. Rate one for good condition, rate two for moderate, and rate three for poor one. Finally, an average number representing the whole section should be calculated.

4.3.3 Road Signs and Road Markings

All items related to road safety are included as road furniture. A three-point scale is given according to the following condition (World Bank & OECD, 1990):

- Assign one when signs are clean, not damaged;
- Assign two when dirty and have some damage;
- Assign three when very dirty, or full damage, or missed.

The RCS in this project was done by driving over the road network either at the design speed or at a low speed of fifteen kilometer per hour.

4.3.4 Interpretation of Survey Results

Results of the itineraries were grouped into tables and were used to update the data bank. The average values per section were calculated and entered on Figure 4-4, which is a road condition survey summary form. For a given section, the interpretation of survey results can lead to one of the following conclusions:

1. The section in question is in a satisfactory condition. Normal maintenance activities should continue as planned.

2. A Detailed Visual inspection is required to reveal the proper type of maintenance activity required. In general, when a rating of three or more is obtained.

3. Certain repairs must be undertaken immediately. This is especially true for sever but not extensive damage.

Figure 4-4: Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS) Asphalt Paved Roads

Designation of Road Section

Road Classification	Section No.	Identification Points (IP)			Section Length (m)	Pavement Width (m)
		I.P	Designation	Km		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To.		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		
		From		From		
		To		To		

Nablus Province/ Road Name		Page
Date:	Roadside:	

Survey Data

Carriageway	Roadside Elements & Road Signs	Notes / Remarks

4.3.5 Data Processing

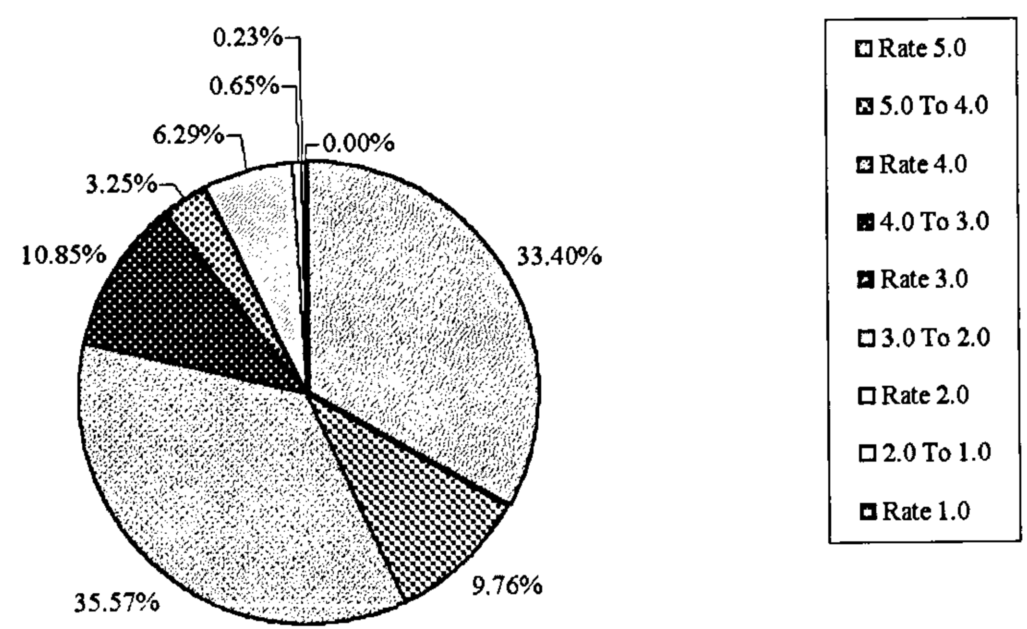
The basic three types of processing of the information contained in the data are (World Bank & OECD, 1990):

- Technical processing involving the preparation of overall analyses to facilitate work scheduling.
- Statistical processing involving the production of various specific statistics relating to one or more types of data such as histograms, correlation, and regression.
- Data aggregation.

The most common type of processing is the generation of rout diagrams, which summarize all the data based on selected pavement criteria.

Figure 4-5 is a pie chart that represents the percentage values of rating range distribution for all the surveyed sections used in this study. The results showed that the largest value of 35.57 percent for PCR value of four, followed by the value of 33.4 percent for PCR value of five, while a value of 9.76 percent is recorded for PCR range from five to four. These records showed that 33.4 percent of sections were in excellent condition and 45.33 percent were in good condition. Another considerable value of

Figure 4-5: Percentage of Total Number of Sections For Pavement Condition Rating Distribution

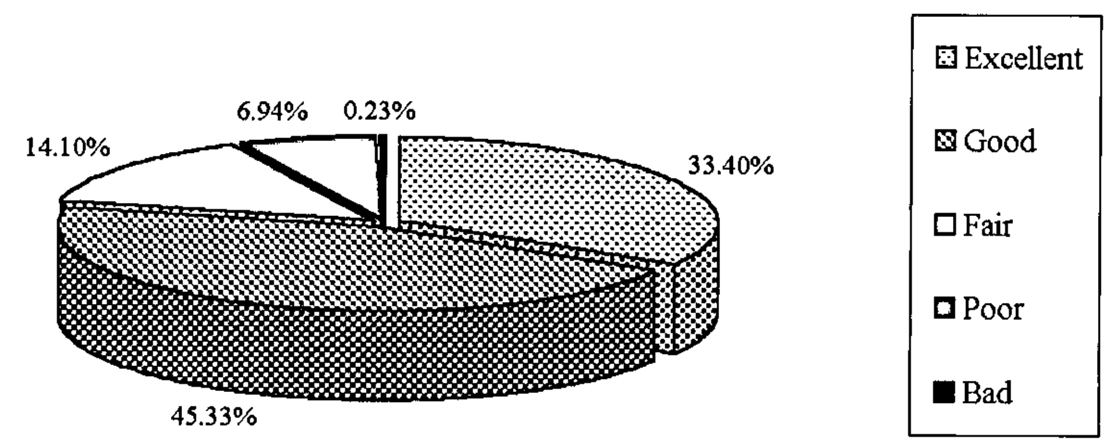


10.85 percent for PCR range from four to three, followed by the value of 6.29 percent for values from three to two and the value of 3.25 percent for PCR value of three. These records showed that 14.10 percent of sections were in fair condition. Other values of less than 0.70 % were recorded for PCR value of two and PCR range from two to one. This means that only 6.94 percent of sections were in poor condition and only 0.23 percent of sections were in bad condition.

Figure 4-6 is a pie chart that represents the percentage values of rating range distribution for all surveyed sections used in the study based on categorizing the PCR values according to their condition-state. An excellent condition-state was given for PCR value of five. Good condition-state was given for PCR range from five to four, fair condition-state was given for PCR range from four to three, poor condition-state was given for PCR range from three to two, and bad condition-state was given for PCR range from two to one.

The survey showed that 33.40 percent of pavement section were in excellent condition, only annual routine maintenance is needed. Also, 45.33 percent of pavement section were in good condition-state, annual routine maintenance and localized reconstruction of one percent is needed every five years. The survey showed that 14.10 percent of pavement sections were in fair condition-state, a localized reconstruction of ten percent and

Figure 4-6: Percentage of Rating Range Distribution for All Surveyed Sections



asphalt overlay is needed every ten years. The survey showed that 6.94 percent of pavement sections were in poor condition-state, an asphalt overlay and a localized reconstruction of more than ten percent is needed every fifteen years. Surveyed pavement sections of only 0.23 % were in bad condition-state, a major reconstruction is needed every twenty years.

Since all surveyed sections were at most seven years in service, the largest number of sections of 199 and 214 were recorded for excellent and good condition-state respectively.

Figure 4-7 represents a summary histogram for the total number of sections having PCR values from one to five for overlaid arterial roads. The survey showed that forty-two sections were in excellent condition, seventy-four sections were in good condition, nineteen sections were in fair condition, twenty-two sections were in poor condition, and none in bad condition. Since all surveyed sections were at most in service seven years, the largest percent of surveyed sections of 26.75 percent and 47.14 percent were recorded for excellent and good condition-state respectively.

Figure 4-7: Pavement Condition Rating Distribution for Overlaid Arterial Roads

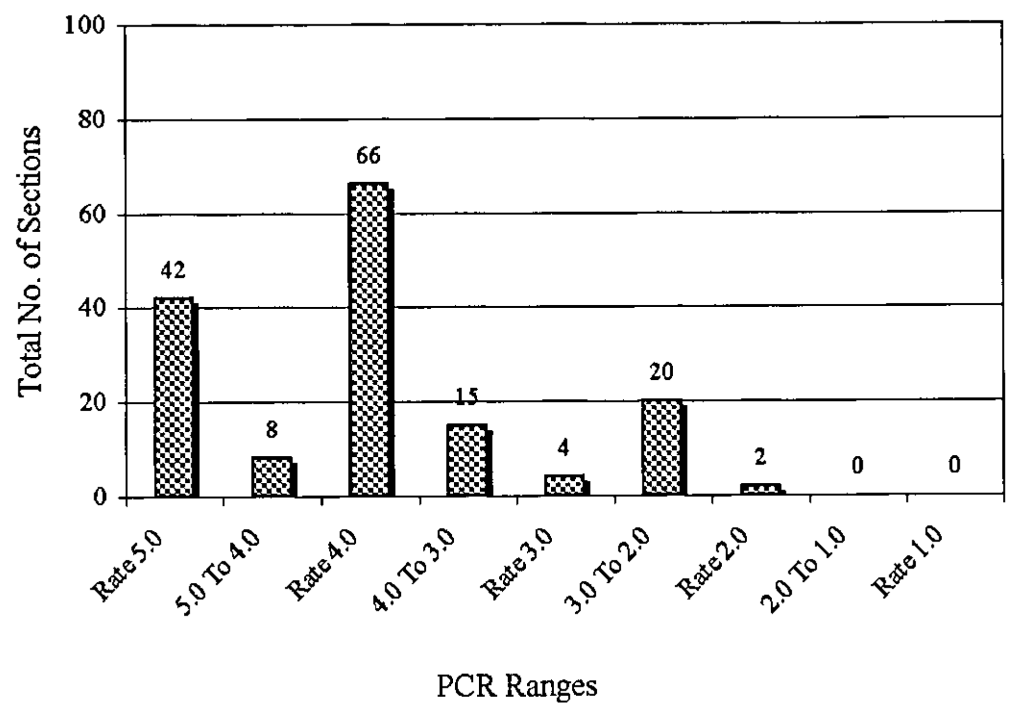
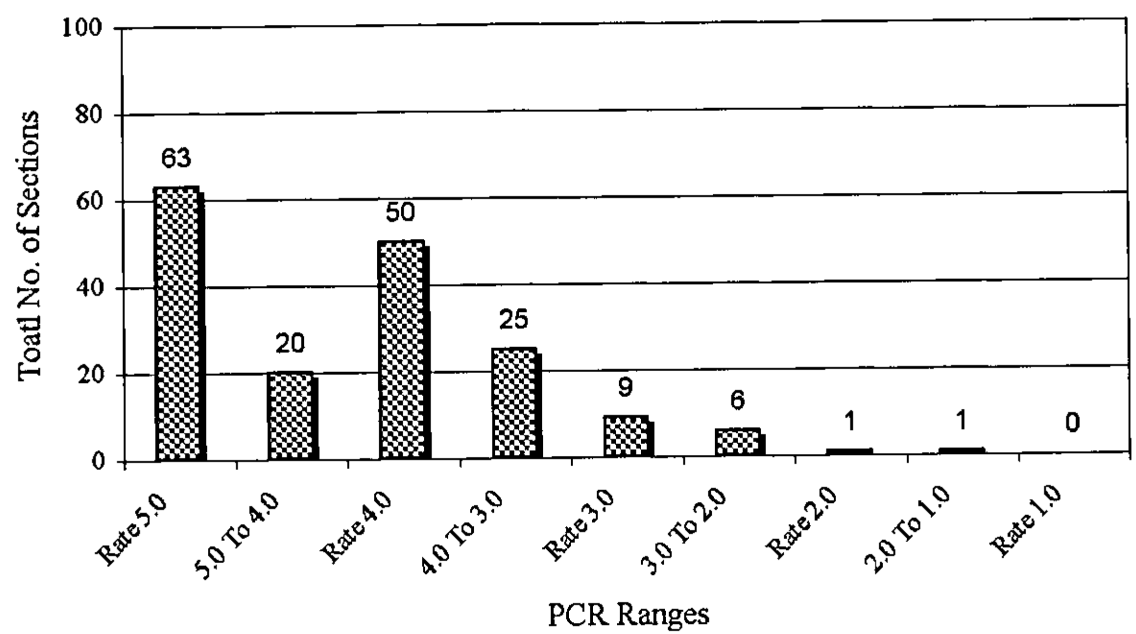


Figure 4-8 showed the summary histogram for total number of sections having PCR values from one to five for arterial roads received major maintenance. The survey showed that sixty-three sections were in excellent condition, seventy sections were in good condition, thirty-four sections were in fair condition, seven sections were in poor condition and one section in bad condition. Since all surveyed sections were at most six years in service, the largest percent of surveyed sections of 36.0 percent and 40.0 percent were recorded for excellent and good condition-state respectively.

Figure 4-9 showed the summary histogram for the total number of sections having PCR values from one to five for rehabilitated village access roads. The survey showed that fourty-nine sections were in excellent condition, sixty-five sections were in good condition, twelve sections were in fair condition, three sections were in poor condition, and none in bad condition. Since all surveyed sections were at most in service four years, the largest percent of surveyed sections of 37.98 percent and 50.39 percent were recorded for excellent and good condition-state, respectively.

Figure 4-8: Pavement Condition Rating Distribution for Sections of Major Maintained Arterial Roads



4.4 Detail Visual Inspection (DVI)

Detail visual inspection must be conducted for road sections that were identified by RCS as needing major carriage-way maintenance, having PCR value greater or equal to three (World Bank & OECD, 1990).

The purpose of the detailed visual inspection is to record the type, extent, and the severity of damage.

4.4.1 Method of Evaluating Detail Visual Inspection

Each detail visual inspection parameter is to be assessed on a five-point scale. Conditions are rated by:

1. The extent of the damage, expressed as the percentage of the surface area, and
2. The severity of the damage.

Figure 4-10 represents the form used to perform detail visual inspection. In order to keep the forms workable, only the most common types of damage for asphalt paved roads were included.

Figure 4-10: The Detailed Visual Inspection Form

Detail Visual Inspection (DVI)			**Road Name:**	**Road Classification:**
Date: / /	Weather: ° Clear	Carr. Way: ° Dry	Section No.:	Section length:
Time:		° Drying	Pavement Width:	
° RT ° LT	° Rainy	° Wet	From :	To:
			Summary (Average DVI Rating)	

SUB-SECTION		1			2			3			4			5		
Damage Type		L	M	S	L	M	S	L	M	S	L	M	S	L	M	S
Rutting	<10%	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Corrugation	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Patching	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Settlement	<10%	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Block & Traverse crack	<15%	1	2	4	1	2	4	1	2	4	1	2	4	1	2	4
	15-30%	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	>30%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
Longitudinal Cracking	<10%	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Alligator Cracking	<10%	1	4	5	1	4	5	1	4	5	1	4	5	1	4	5
	10-50%	2	5	5	2	5	5	2	5	5	2	5	5	2	5	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Potholes	<5 (N/100m)	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	5-15	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
	>15	4	5	5	4	5	5	4	5	5	4	5	5	4	5	5
Edge Distress	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Raveling	<10%	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Bleeding	<5 %	1	X	X	1	X	X	1	X	X	1	X	X	1	X	X
	5-50%	2	X	X	2	X	X	2	X	X	2	X	X	2	X	X
	>50%	3	X	X	3	X	X	3	X	X	3	X	X	3	X	X
Average PCR for subsection																

Source: Road Monitoring for Maintenance Management, World Bank and OECD , 1990.

4.5 Pavement Distresses

A good knowledge and understanding of pavement distresses and failures is an important key for pavement management engineer to be able to evaluate pavement surfaces. Clear definitions for types and levels of severity of these failures, facilitate performing condition surveys and minimize the errors resulting from personal judgment. Distresses categorizing and severity were assigned according to appendix A.

Detail visual inspection was carried out by walking the sub-sections. For each type of damage, the value to be recorded was based on the relevant matrix given in the damage catalogue (World Bank & OECD, 1990).

The average values of the sub-sections have to be combined into an arithmetic length weighted average for the complete section. The averages will be carried to Figure 4-11, which is the summary form for the detail visual inspection results used to update the data bank.

All data surveyed and its summary forms are presented in Appendix B and C.

Figure 4-11: Summary of Detail Visual Inspection Results (Average Condition Value)

Detail Visual Inspection Survey (DVI)	
Asphalt Paved Roads	Age:
Date:	Roadside: RT

Detail Visual Inspection Data

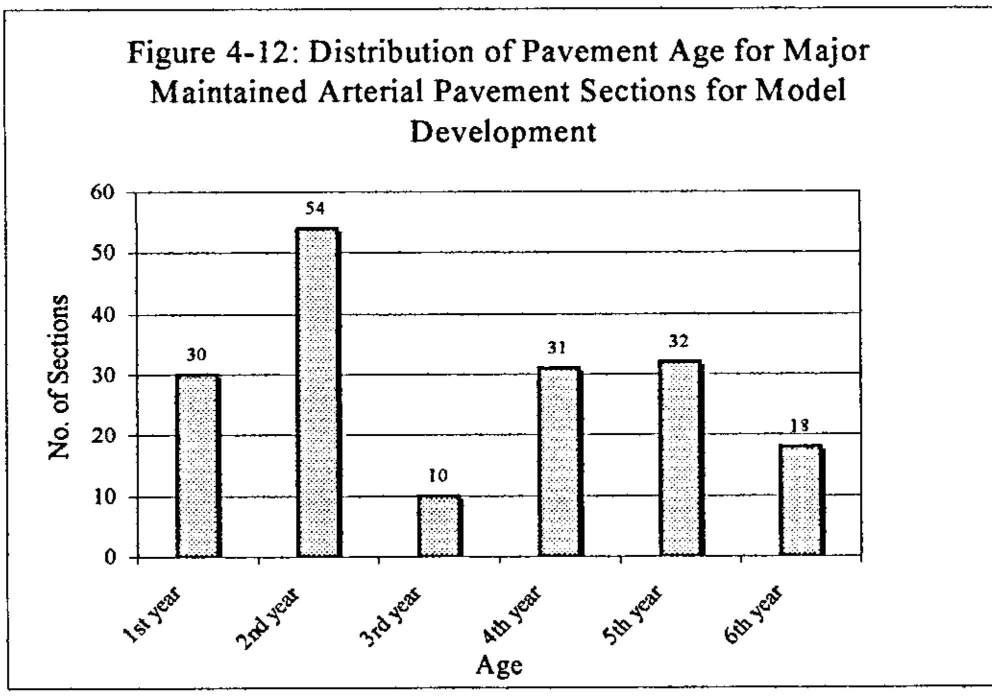
Section No.	Rutting	Corrugation	Patching	Settlement	Trav/ Block Long.Cracking	Alligator Cracking	Potholes	Edge Distress	Raveling	Average Condition Value

Nablus Province/ Road Name:		Page
Road Classification:		
Date:	Roadside: LT	

Detail Visual Inspection Data

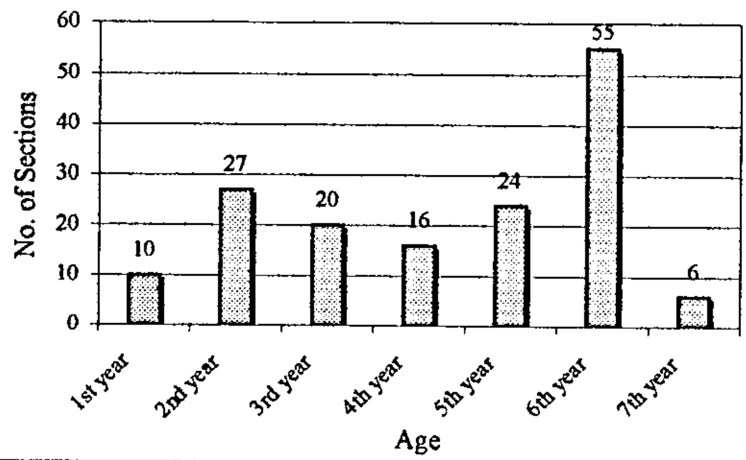
Section No.	Rutting	Corrugation	Patching	Settlement	Trav/ Block Long.Cracking	Alligator Cracking	Potholes	Edge Distress	Raveling	Average Condition Value

Distributions of pavement ages for one hundred and seventy-five reconstructed arterial sections were summarized and shown in Figure 4-12. As can be seen from this figure, the ages of sections range from one to six years, although the distribution is skewed toward first two years of pavement age.



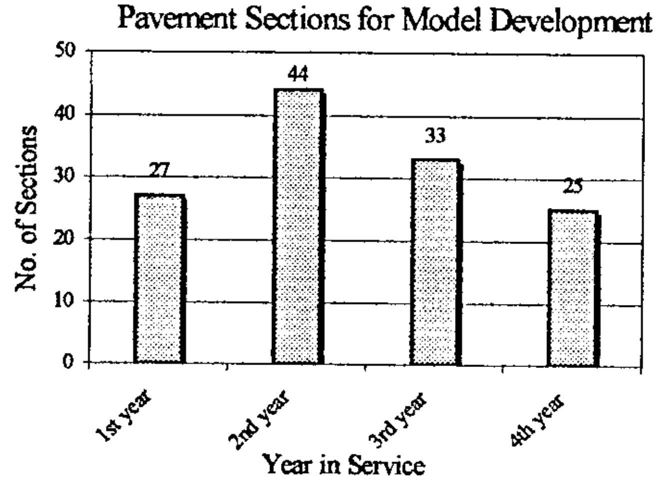
Distributions of pavement ages for one hundred and fifty-seven resurfaced arterial sections were summarized and shown in Figure 4-13. As can be seen from this figure, the ages of sections ranged from one to seven years, although the distribution is skewed toward six year of pavement age.

Figure 4-13: Distribution of Pavement Age for Overlaid Arterial Pavement Sections for Model Development



Distributions of pavement ages for one hundred and twenty-nine rehabilitated village sections were summarized and shown in Figure 4-14. As can be seen from this figure, the ages of sections ranged from one to four years only although the distribution is skewed toward first two years of pavement age.

Figure 4-14: Distribution of Pavement Age for Village Access Pavement Sections for Model Development



Chapter Five

Data Analysis and Model Formation

5.1 Introduction

Attempts have been made over the last thirty years to develop models that can accurately predict the performance of highway pavements over time. Many of the pavement performance models that exist in the literature were very simple and include only some explanatory variables. The more complex models that account for a large number of variables as well as the effects of maintenance have been found to be more realistic, but have proven to fit the data very poorly. A series of models that can provide a proper balance between realism and proper fit of in-service data are the key to effective use of modeling within the pavement management system.

There are generally three accepted measures of pavement performance: safety, structural performance, and functional performance. Functional performance has been the one most commonly modeled and the one used in this research. This is partially attributed to the fact that most network pavement management systems in use today are designed to measure the pavement's functional condition, which is a measure of the pavement's ability to serve the user over time. It is measured in terms of riding quality of the pavement surface.

One of the major functions of a design methodology is to be able to predict the performance of alternative design strategies being considered. The prediction of performance needs to cover the entire design period, so that a complete economic analysis can be conducted. Moreover, unless the pavement functional performance is predicted, the effects of varying serviceability on user costs and the effects of changing the minimum acceptable level of serviceability cannot be evaluated completely. If the design period extends beyond the initial service life of the alternative being considered, then the prediction of functional performance must also include the effects of any overlays or other major rehabilitation.

Since overlay alternatives can be a part of any design strategy, a comprehensive performance method must also be able to predict the functional performance for overlays or other types of rehabilitation as well as new design. For this reason, the overlaid arterial and rehabilitated village access roads were considered in this study to predict their performance.

5.2 Data Collection

In order to accurately predict pavement performance, an objective repeatable rating system for assessing pavement condition must be used. Many transportation departments and institutions used an assessment method, which is based on the visual condition of the pavement.

In this study the collection of data was based on the visual inspection method named the Pavement Condition Rating (PCR). In the PCR system, The asphalt pavement surface is evaluated using a scale that ranges between one and five. One indicates a poor condition, while five indicates an excellent condition. PCR values were obtained by converting RCS and DVI rating values that ranges between one being excellent and five being poor to PCR values.

Figure 5-1 is a sketch for Hisbeh Arterial Street. This figure is a plan that shows the sections surveyed. The Data are collected using RCS and DVI forms prepared for this study. Figure 5-2 and Figure 5-3 is sample forms for RCS and DVI performed for Hisbeh Arterial Street in Nablus City.

5.3 Pavement Performance Prediction Model

The objective of this study is to develop performance models for major maintenance and resurfacing treatment for urban arterial roads and rehabilitated village access roads in Nablus Province. The models were developed based on statistical analyses correlating pavement performance as indicated by PCR index with pavement age, and or design service life. For each treatment, representative in-service projects were selected and their corresponding data were used to develop pavement performance models.

Figure 5-1: Sketch for Hisbeh Arterial Street

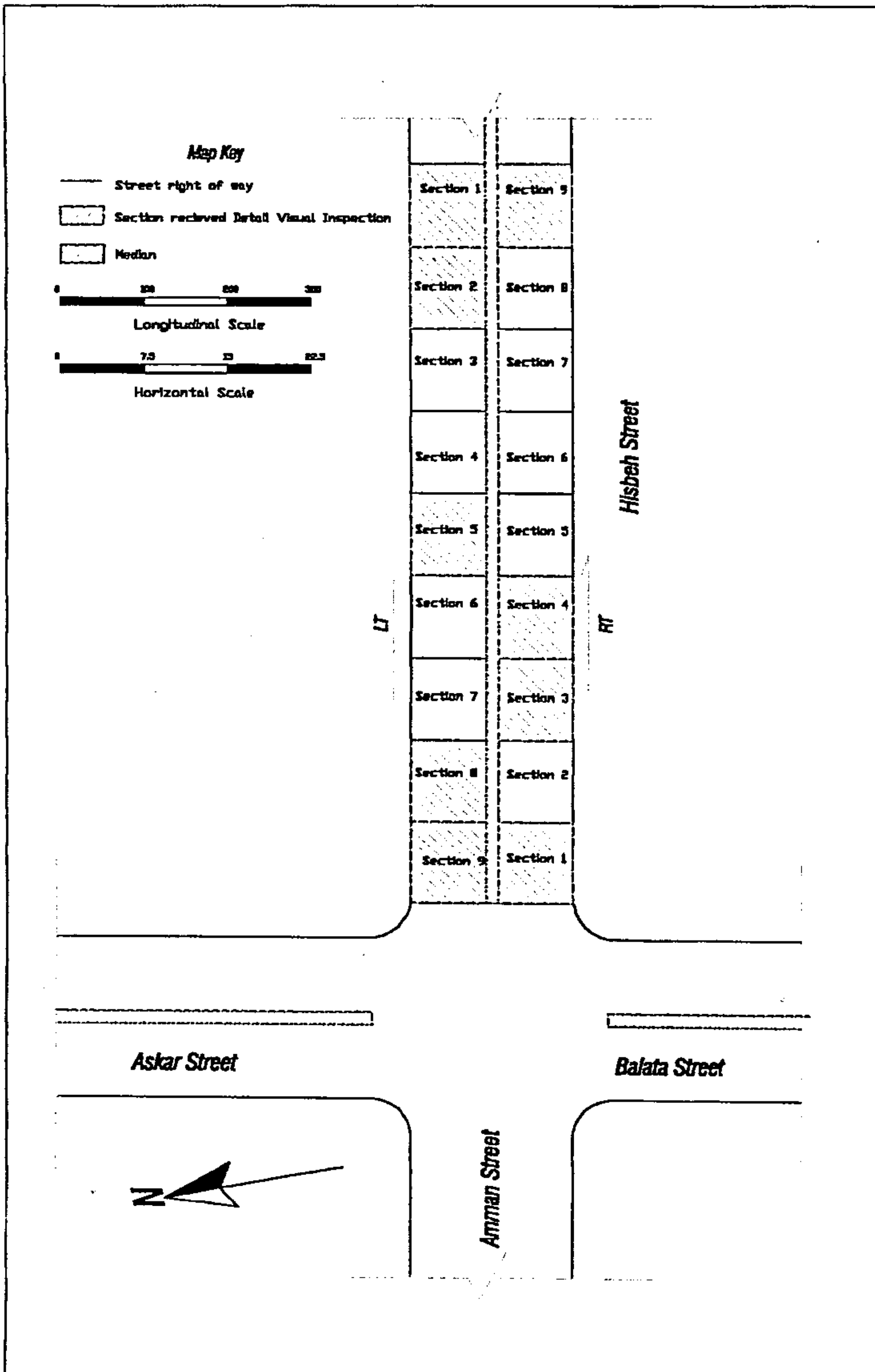


Figure 5-2: Sample for Road Condition Survey Form

Road Condition Survey (RCS)			**Road Name: Hisbeh**	**Road Classification:** Arterial
Date:	Weather: (o) Clear ° Rainy	Carr. Way: (o) Dry ° Drying ° Wet	Section No.: 3	Section length: 100m
Time: (o) RT ° LT			From : 0 + 200	To: 0 + 300
			Summary (Average Condition)	**Carriageway:** 3.0 **Road side elements:** 1.64

SUB-SECTION	**1**			**2**			**3**			**4**			**5**		
Carriageway Rating (PCR)	1	2 / 4	(3) / 5	1	2 / 4	(3) / 5	1	2 / 4	(3) / 5	1	2 / 4	(3) / 5	1	2 / 4	(3) / 5
Prevailing damage															

Damage Type	**Rating (PCR)**									
Shoulder Deformation	1	(2) / 3	(1)	2 / 3	1	(2) / 3	1	(2) / 3	1	(2) / 3
Shoulder Scour	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3
Side Drains (Curbs)	1	2 / (3)	1	2 / (3)	1	(2) / 3	1	2 / (3)	1	2 / (3)
Obstacles or Debris	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3	(1)	2 / 3
Embankments	1	2 / 3	1	2 / 3	1	2 / 3	1	2 / 3	1	2 / 3
Road Signs and Markings	1	(2) / 3	1	(2) / 3	(1)	2 / 3	1	(2) / 3	(1)	2 / 3
Average PCR per subsection	1.8		1.6		1.4		1.8		1.6	

Remarks:

Figure 5-3: Sample for Detail Visual Inspection Form

Detail Visual Inspection (DVI)			**Road Name: Hisbeh**	**Road Classification:** Arterial
Date:	Weather: (◉) Clear	Carr. Way: (◉) Dry	Section No.: 3	Section length: 100m
Time:		° Drying	Pavement Width: 9 m	
(◉) RT ° LT	° Rainy	° Wet	From : 0+200	To: 0+300
			Summary (Average DVI Rating)	

SUB-SECTION		**1**			**2**			**3**			**4**			**5**		
Damage Type		L	M	S	L	M	S	L	M	S	L	M	S	L	M	S
Rutting	<10%	1	3	5	1	3	5	1	(3)	5	1	(3)	5	1	3	5
	10-50%	(2)	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Corrugation	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Patching	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Settlement	<10%	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Block & Traverse crack	<15%	1	2	4	1	2	4	1	(2)	4	1	2	4	1	2	4
	15-30%	1	(3)	5	1	(3)	5	1	3	5	1	3	5	1	(3)	5
	>30%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
Longitudinal Cracking	<10%	1	(3)	5	1	(3)	5	1	(3)	5	1	(3)	5	1	(3)	5
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Alligator Cracking	<10%	1	4	5	1	4	5	1	4	5	1	4	5	1	4	5
	10-50%	2	5	5	2	5	5	2	5	5	2	5	5	2	5	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Potholes	<5 (N/100m)	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	5-15	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
	>15	4	5	5	4	5	5	4	5	5	4	5	5	4	5	5
Edge Distress	<10%	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
	10-50%	2	3	5	2	3	5	2	3	5	2	3	5	2	3	5
	>50%	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Raveling	<10%	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	10-50%	2	4	5	2	4	5	2	4	5	2	4	5	2	4	5
	>50%	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
Bleeding	<5 %	1	X	X	1	X	X	1	X	X	1	X	X	1	X	X
	5-50%	2	X	X	2	X	X	2	X	X	2	X	X	2	X	X
	>50%	3	X	X	3	X	X	3	X	X	3	X	X	3	X	X
Average PCR per subsection		2.67			3.0			2.67			3.0			3.0		

Remarks: ....

These models are used at the network level to predict future pavement condition to assist in determining maintenance and rehabilitation requirements. Prediction models are used for condition forecasting, budget planning, inspection scheduling, and work planning. The models are also fundamental to performing a life-cycle cost analysis to compare the economies of various maintenance and rehabilitation alternatives.

Many deterministic model forms are available for predicting pavement performance, including straight-line extrapolation, polynomial constrained least squares, and logistic growth models. Two deterministic models are applied in this study, the first is by applying directly polynomial regression model to the surveyed PCR values against their age. The second deterministic model is by applying logistic growth model to PCR data collected for arterial and village access roads. Then by applying polynomial regression analysis to the calibrated PCR values obtained from logistic growth model to develop pavement performance model. Each model was used to predict future pavement performance. The results of the models were compared and statistically analyzed.

As an alternative to deterministic models, Probabilistic Markov model was applied. The Markov transition matrix expresses the probability that a group of pavements with similar characteristics will transition from one state to another. After data filtering and outlier analysis, all the surveyed pavement sections, regardless of age were categorized into one of the five condition states, so the condition distribution of the surveyed sections for major maintained arterial, overlaid arterial, and rehabilitated village access roads were summarized. Then the transition matrices were built based on the condition distribution data. The Transition Probability Matrices (TPMs) were built by dividing each column value of the transition matrix by the sum of the same row to give the probability value for each state. The transition matrix probabilities can be estimated and the future state of the pavement at any duty cycle, ``t`` can be predicted. So Markov model require the development of TPMs to predict the way the pavement deteriorates with time. The state of the maximum probability is the most likely deterioration path that the sections will follow.

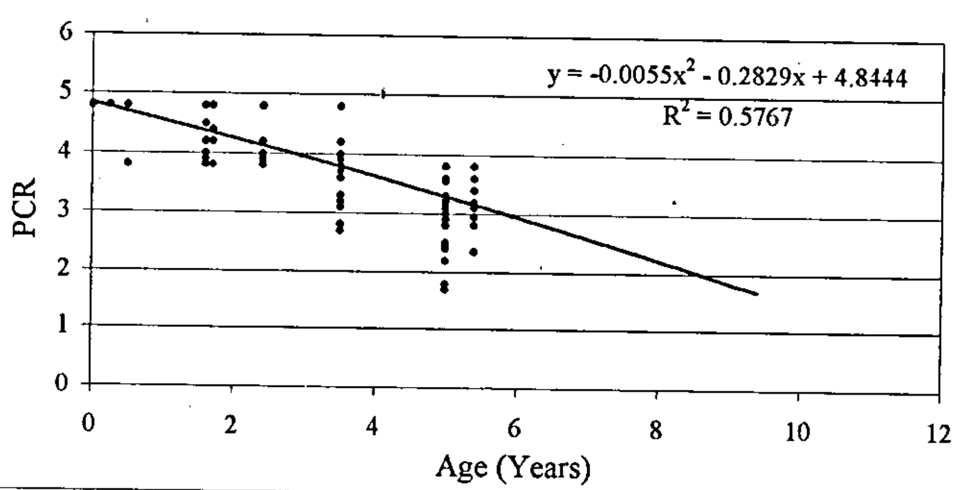
Each model developed was used to predict future pavement deterioration. The results of Markov models and deterministic models were compared and statistically analyzed.

5.3.1 Polynomial Regression Model for Major-Maintained Arterial Roads

The methodology for developing pavement performance models consists of fitting the selected models to the observed pavement condition data and subsequently establishing equations for predicting the parameters of the model using regression analysis. It is important to choose a function that obeys the boundary conditions for the PCR value being predicted besides, the performance trend should initially start out horizontally, bounded from above by a rating of five, with time the pavement condition rating decreased, and asymptotes to a minimum value. In this study the polynomial model of second degree for modeling pavement performance with pavement age was selected, since it agrees with model condition.

Figure 5-4 illustrates polynomial regression model for major maintained arterial roads. A total of one hundred and seventy five surveyed sections were selected for model development and curve fitting.

Figure 5-4: Plot of Performance Trend for Major Maintained Arterial Roads Using Polynomial Regression Model



Since all surveyed sections were at most six years in service, the trend of pavement performance in the future is obtained by projecting the regression curves to intersect the minimum acceptable condition rating value of 2.5 for major roads. The curve developed in Figure 5-4 shows that the pavement reaches minimum acceptable performance level at PCR value of 2.5 at age 7.5 years. The R^2 value for the fitted curve is 0.58, which is an acceptable value.

5.3.2 Logistic Growth Model for Major-Maintained Arterial Roads

To apply the logistic growth model, the values had to be defined to meet the PCR data, in which the values ranged from one to five and starting DI of a distress free pavement is five. This boundary condition is included such that:

$$\text{PCR Rating} = \alpha - \beta \left[\frac{(\alpha + \beta)}{(\beta + \alpha e^{-\gamma t})} - 1 \right]$$

$$\text{PCR}' = 5 - \left[\frac{(5+1)}{(1 + 5e^{-\gamma t})} - 1 \right]$$

where:

$\gamma = -(1/DSL) \ln([\{(\alpha + \beta)/(\alpha + \beta - CDP)\} - 1] \beta/\alpha)$,

DI = Distress Index

α = Potential initial DI assumed to be 5

β = Limiting DI assumed to be 1

t = Age in years

γ = Deterioration rate index

DSL = Design Service Life

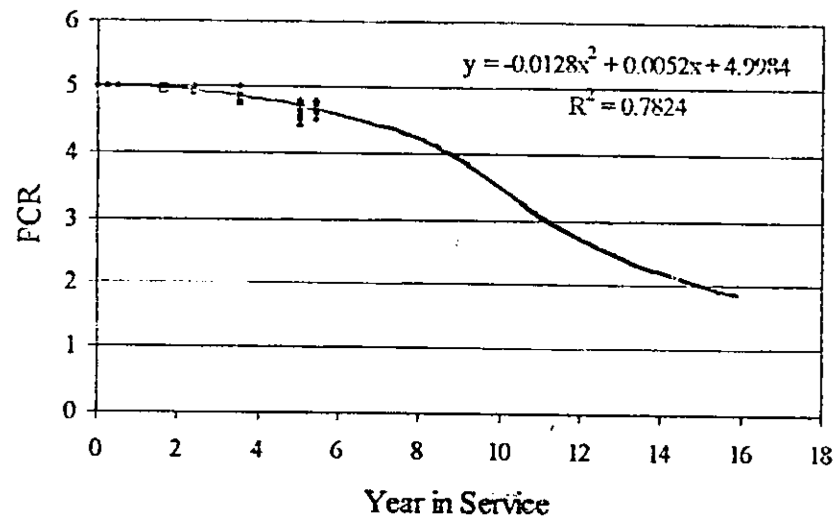
CDP = Predetermined DI

γ = -(1/20) ln ([{6/(6- CDP)}- 1] 1/5).

Figure 5-5 illustrates the logistic growth model fitted to major maintained arterial road sections. The logistic growth model reflects the nonlinear deterioration rates of the sections. The curve developed in Figure 5-5 shows that the pavement reaches minimum acceptable performance level of 2.5 at age 12.5 years for twenty years DSL. The curve developed is used to predict the performance lives of arterial roads that has received major maintenance by applying polynomial regression equation of second degree.

The R^2 value for the fitted curve is 0.78, which means that this developed curve is better fitting the calibrated data obtained by applying logistic growth model than the polynomial model obtained by fitting the surveyed raw data directly.

Figure 5-5: Plot of logistic Growth Model for major Maintained Arterial Roads



On the basis of the model's ability to reflect a nonlinear deterioration rate and its previous use and acceptance for application to local road agencies, it is believed that this is an appropriate deterministic model to apply for major maintained arterial roads.

5.3.3 Markov Model for Major-Maintained Arterial Roads

The distribution of condition data for major maintained arterial road sections and surveyed for this study is shown in Table 5-1. After data filtering, all the surveyed pavement segments were used in the development of the TPM. The formation of transition matrix and the transition probability matrix are shown in Table 5-2. The calculations required for the Markov model were conducted using MathCAD.

Table 5-1: Condition Data Distribution for Major Maintained Arterial Roads

PCR	No. of Sections
5	63
5 - 4	20
4	50
4 - 3	25
3	9
3 - 2	6
2	1
2 - 1	1
1	0
Total	175

Table 5-2a: Transition Matrix for Major Maintained Arterial Roads

Rating Value	5	4	3	2	1	Total No. of Sections
5	63	20	0	0	0	83
4	0	50	25	0	0	75
3	0	0	9	6	0	15
2	0	0	0	1	1	2
1	0	0	0	0	0	0
			Total No. of Sections			175

Table 5-2b: Transition Probability Matrix for Major Maintained Arterial Roads

Rating Value	5	4	3	2	1
5	0.759	0.241	0	0	0
4	0	0.600	0.400	0	0
3	0	0	0.600	0.400	0
2	0	0	0	0.500	0.500
1	0	0	0	0	0

Table 5-3 presents the Markov probability distribution for the first six years as calculated by MathCAD. The probability distribution within each state vector is the main characteristic that makes the Markov model more attractive than the deterministic models.

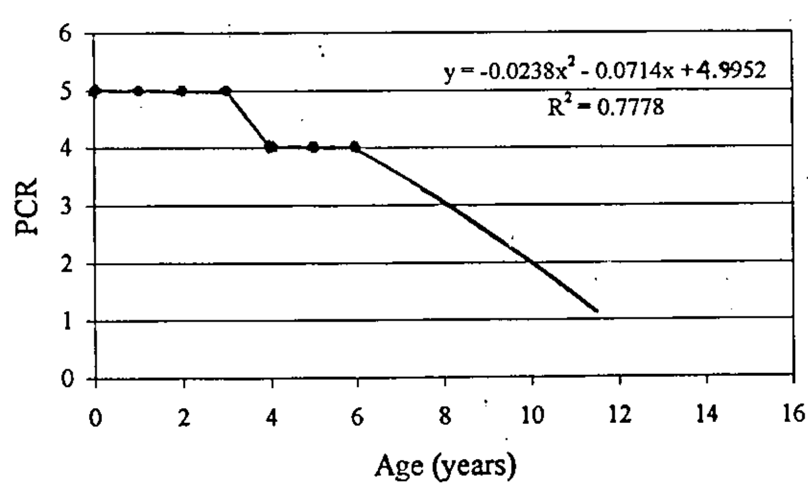
In Table 5-3 the state of maximum probability is shown in boldface italics. This path is the most likely deterioration path that the sections will follow. For example, at year four there is a probability of 0.332 for the sections to stay at PCR value five, but the highest probability value of 0.351 for that year is at PCR value four.

Figure 5-6 shows the plot of Markov model for major maintained arterial pavement sections. In Markov model, predicted future deterioration trend starts at the last rating the sections received. The line represents the average state of the pavement determined from a probability distribution based on the TPM established from the entire data set.

Table 5-3: Probability Distribution Values from Markov Model for Major Maintained Arterial Roads

Rating Value	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
5	***0.752***	***0.576***	***0.437***	0.3317	0.2518	0.1911
4	0.241	0.344	0.3683	***0.351***	***0.314***	***0.270***
3	0	0.0803	0.163	0.2204	0.249	0.254
2	0	0	0.0321	0.0813	0.1288	0.164
1	0	0	0	0.161	0.0407	0.0644

Figure 5-6: Plot of Markov Model for Major Maintained Arterial Roads



The model shows that PCR value is maintained at five for the first four years and then drop to value of 4.0 and maintain this value at age seven, which is not as predicted to be after seven years in service. It is obvious that a constant rate of deterioration is nonexistent, and the variability inherent in pavement performance is addressed.

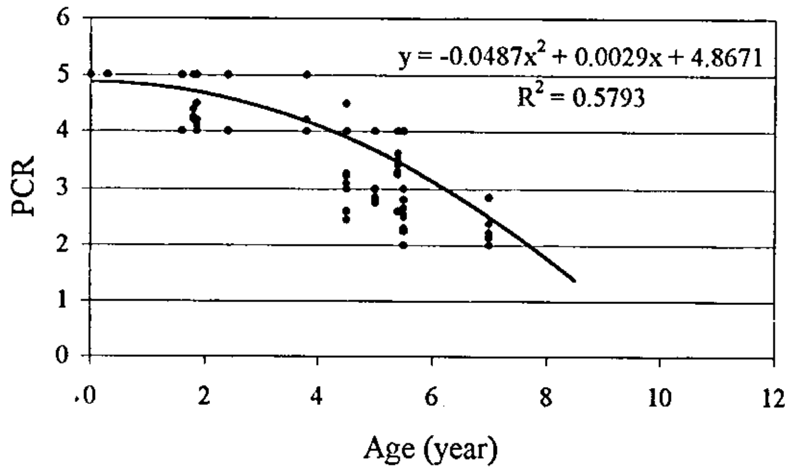
Figure 5-6 shows that the R^2 of the curve developed is 0.78. The prediction of performance trend of pavement sections shows that the pavement reaches minimum accepted performance level of 2.5 at age nine years, which is unacceptable value for twenty years pavement DSL.

5.3.4 Polynomial Regression Model for Overlay Arterial Roads

The performance trend seems initially to start out horizontally, bounded from above by a rating of five, with time the pavement condition rating decreased, and asymptotes to a minimum value of zero. The best curve that fits the surveyed pavement condition data and meets the boundary condition is the polynomial regression model of second degree.

Figure 5-7 illustrates polynomial regression model for overlay arterial roads. A total of one hundred and fifty seven surveyed sections were selected for model development and curve fitting.

Figure 5-7: Performance Trend For Overlaid Arterial Roads using Ploynomial Regression Model

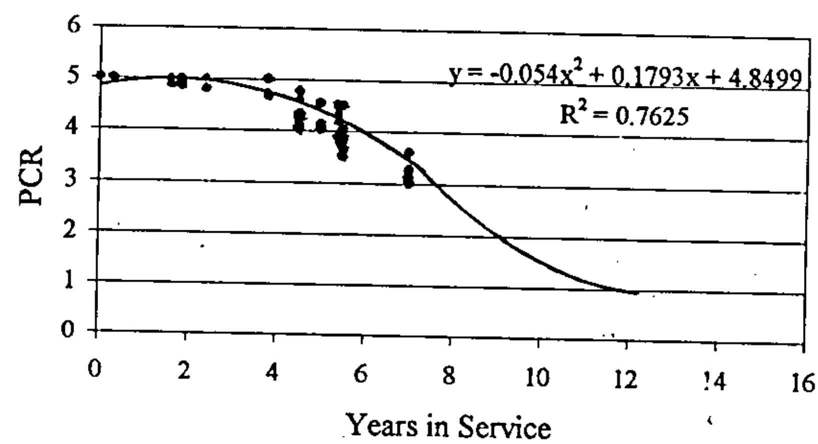


Since all surveyed sections were at most seven years in service, the trend of pavement performance in the future is obtained by projecting the regression curve to intersect the minimum acceptable performance value of 2.5. The curve developed in Figure 5-7 shows that the pavement reaches PCR value of 2.5 at age seven years. The curve developed is used to predict the performance lives of overlay arterial roads. The R^2 value for the fitted curve is 0.58, which is an acceptable value.

5.3.5 Logistic Growth Model for Overlay Arterial Roads

The logistic growth model reflects the nonlinear deterioration rates of the sections. Figure 5-8 illustrates the logistic growth model fitted to overlay arterial road sections. The curve developed in Figure 5-8 shows that the pavement reaches minimum accepted performance level of 2.5 at age 8.0 years for ten years DSL.

Figure 5-8: Plot of Logistic Growth Model for Overlaid Arterial Roads



The curve developed is used to predict the performance lives of overlay arterial roads by applying polynomial regression equation of second degree. The R^2 value for the fitted curve is 0.76, which means that this developed curve is better fitting the calibrated data obtained by applying logistic growth model than that of the polynomial model. On the basis of the model's ability to reflect a nonlinear deterioration rate, this is an appropriate deterministic model to apply for overlaid arterial roads.

5.3.6 Markov Model for Overlay Arterial Roads

The distribution of condition data for overlay arterial road sections being surveyed in this study is shown in Table 5-4.

Table 5-4: Condition Data Distribution for Overlay Arterial Roads

PCR	No. of Sections
5	42
5 - 4	8
4	66
4 - 3	15
3	4
3 - 2	20
2	2
2 - 1	0
1	0
Total	157

After data filtering, all the surveyed pavement segments were used in the development of the TPM. The formation of transition matrix and the transition probability matrix are shown in Table 5-5. The Calculations required for the Markov model were conducted using MathCAD.

Table 5-5a: Transition Matrix for Overlay Arterial Roads

Rating value	5	4	3	2	1	Total No. of Sections
5	42	8	0	0	0	50
4	0	66	15	0	0	81
3	0	0	4	20	0	24
2	0	0	0	2	0	2
1	0	0	0	0	0	0
			Total No. of Sections			157

Table 5-5b: Transition Probability Matrix for Overlay Arterial Roads

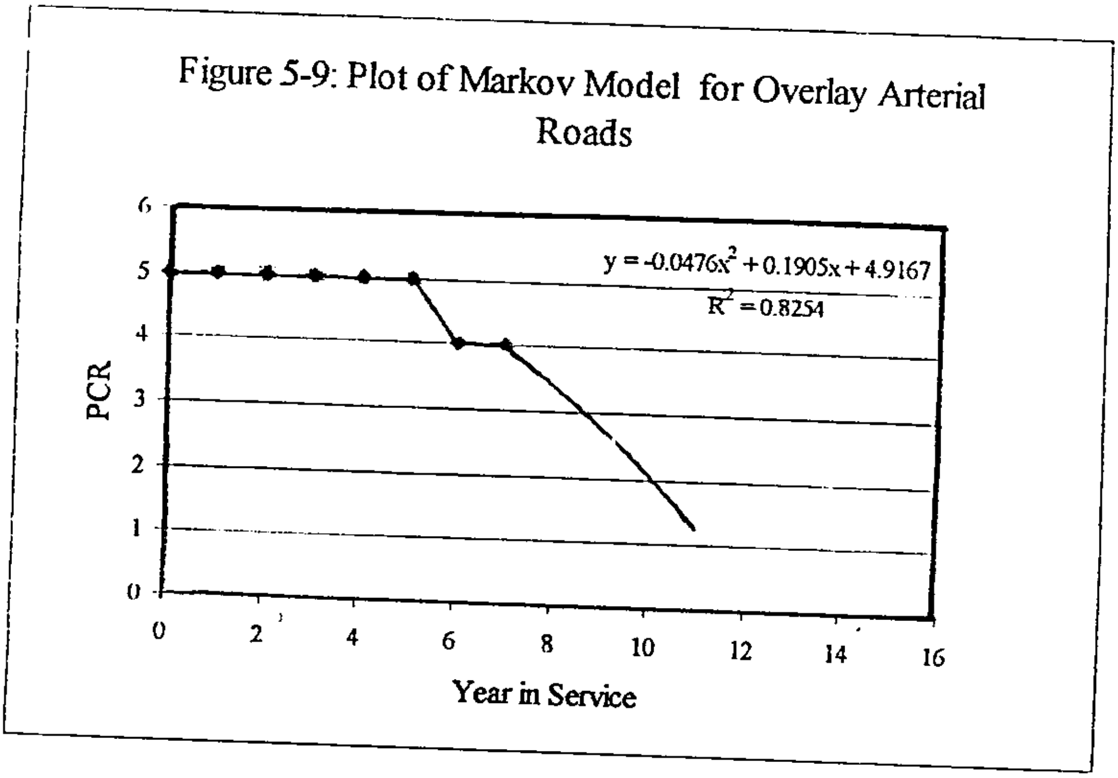
Rating Value	5	4	3	2	1
5	0.840	0.160	0	0	0
4	0	0.8148	0.1852	0	0
3	0	0	0.1667	0.8333	0
2	0	0	0	1.0	0
1	0	0	0	0	0

Table 5-6 presents the Markov probability distribution for the first seven years. The probability distribution within each state vector is the main characteristic that makes the Markov model more attractive than the deterministic models.

In Table 5-6 the state of maximum probability is shown in boldface italics. This path is the most likely deterioration path that the sections will follow. For example, at year three the highest probability is of 0.593 for the sections to stay at PCR value five, but the probability value of 0.329 for that year is at PCR value four. Figure 5-9 shows the plot of Markov model for overlay arterial pavement sections. In Markov model, predicted future deterioration trend starts at the last rating the sections received. The line represents the average state of the pavement determined from a probability distribution based on the TPM established from the entire data set. It is not reasonable that the PCR value will stay at rate five for the first five years and then drop to rate four for the next two years.

Table 5-6: Probability Distribution Values from Markov Model for Overlay Arterial Roads

Rating	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
5	***0.840***	***0.706***	***0.593***	***0.498***	***0.4183***	0.3514	0.295
4	0.160	0.265	0.3289	0.3629	0.3754	***0.3728***	***0.360***
3	0	0.0296	0.0540	0.0699	0.0790	0.0827	0.0828
2	0	0	0.0247	0.0697	0.1279	0.1937	0.2626
1	0	0	0	0	0	0	0



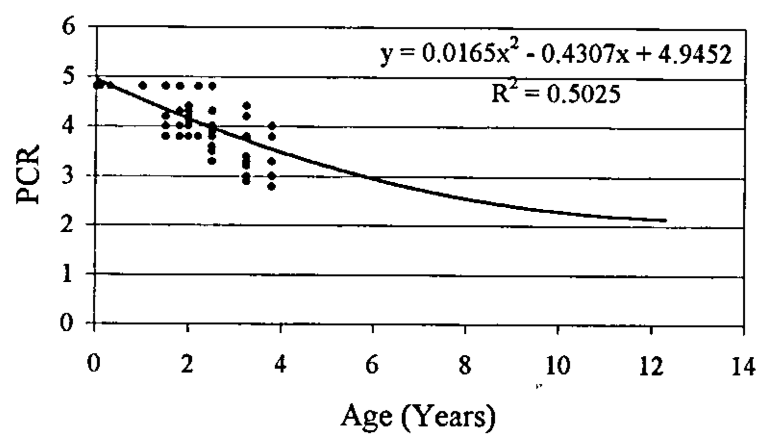
The R^2 value of the developed curve shown in Figure 5-9 is 0.83. The prediction of performance trend of pavement sections shows that the pavement reaches minimum accepted performance level of 2.5 at age nine years, which is around pavement design service life of ten years.

5.3.7 Polynomial Regression Model for Village Access Roads

A total of one hundred and twenty nine surveyed sections were selected for model development and curve fitting. Figure 5-10 illustrates polynomial regression model developed for village access roads.

The performance trend does not seem to start out horizontally. As pavement ages with time the pavement condition rating decreased, and asymptotes to a minimum value of zero. The slope of the curve at first years of pavement life is large compared to its slope at older age. This case contradicts the concept of pavement performance behavior. Thus this model will not be used in models evaluation.

Figure 5-10: Performance Trend for Village Access Road Using Polynomial Regression Model

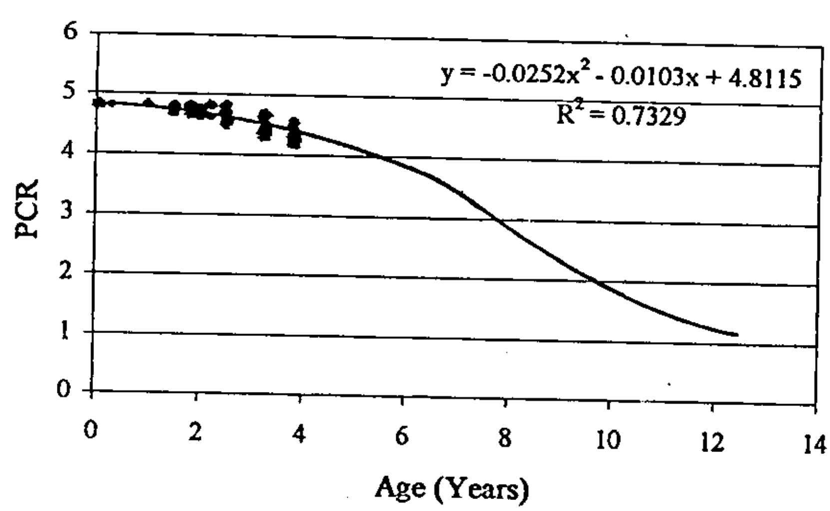


Since all surveyed sections were at most four years in service, the trend of pavement performance in the future is obtained by projecting the regression curves to intersect the minimum acceptable performance value of two for minor roads. The curve developed in Figure 5-10 shows that the pavement will not reach minimum acceptable performance value of two, even the R^2 value for the fitted curve is 0.50.

5.3.8 Logistic Growth Model for Village Access Roads

Figure 5-11 illustrates the logistic growth model fitted to village access road sections. The logistic growth model reflects the nonlinear deterioration rates of the sections. The curve developed in Figure 5-11 shows that the pavement reaches minimum accepted performance level of two at age 9.8 years for ten years DSL.

Figure 5-11: Plot of Performance Trend for Village Access Roads Using Logistic Growth Model



The curve developed is used to predict the performance lives of village access roads by applying polynomial regression equation of second degree. The R^2 value for the fitted curve is 0.73. This means that this developed curve is better fitting the calibrated data obtained by applying logistic growth model. It also matches boundary conditions, and agrees with natural pavement performance behavior than that of polynomial model obtained by fitting the surveyed raw data directly.

On the basis of the model's ability to reflect a nonlinear deterioration rate, it is believed that this is an appropriate deterministic model to apply for village access roads.

5.3.9 Markov Model for Village Access Roads

The distribution of condition data for village access road sections being surveyed in this study is shown in Table 5-7. After data filtering, all the surveyed pavement segments were used in the development of the TPM. The formation of transition matrix and the transition probability matrix are shown in Table 5-8.

Table 5-7: Condition Data Distribution for Village Access Roads

PCR	No. of Sections
5	49
5 - 4	17
4	48
4 - 3	10
3	2
3 - 2	3
2	0
2 - 1	0
1	0
Total	129

Table 5-8a: Transition Matrix for Village Access Roads

Rating Value	5	4	3	2	1	Total No. of Sections
5	49	17	0	0	0	66
4	0	48	10	0	0	58
3	0	0	3	2	0	5
2	0	0	0	0	0	0
1	0	0	0	0	0	0
			Total No. of Sections			129

Table 5-8b: Transition Probability Matrix for Village Access Roads

Rating Value	5	4	3	2	1
5	0.742	0.258	0	0	0
4	0	0.828	0.172	0	0
3	0	0	0.400	0.600	0
2	0	0	0	0	0
1	0	0	0	0	0

Table 5-9 presents the Markov probability distribution for the first four years. The probability distribution within each state vector is the main characteristic that makes the Markov model more attractive than the deterministic models.

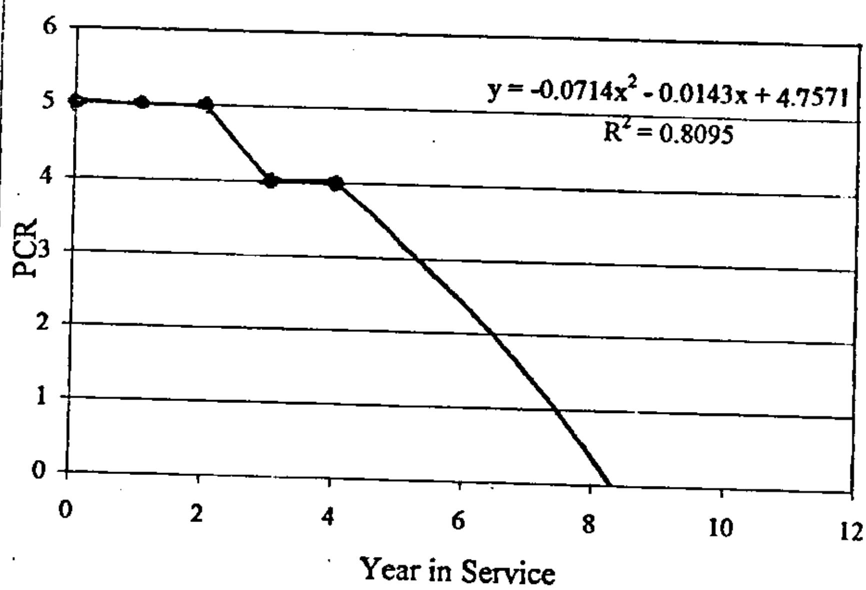
In Table 5-9 the state of maximum probability is shown in boldface italics. This path is the most likely deterioration path that the sections will follow. For example, at year three there is a probability of 0.41 for the sections to stay at PCR value five, but the highest probability value of 0.478 for that year is at PCR value four. Figure 5-12 shows the plot of Markov model for village access roads. In Markov model, predicted future deterioration trend starts at the last rating the sections received. The line represents the average state of the pavement determined from a probability distribution based on the TPM established from the entire data set.

Table 5-9: Probability Distribution Values from Markov Model for Village Access Roads

Rating	Year 1	Year 2	Year 3	Year 4
5	***0.742***	***0.5506***	0.409	0.3035
4	0.258	0.4051	***0.4775***	***0.5009***
3	0	0.0444	0.0874	0.1171
2	0	0	0.0266	0.052
1	0	0	0	0

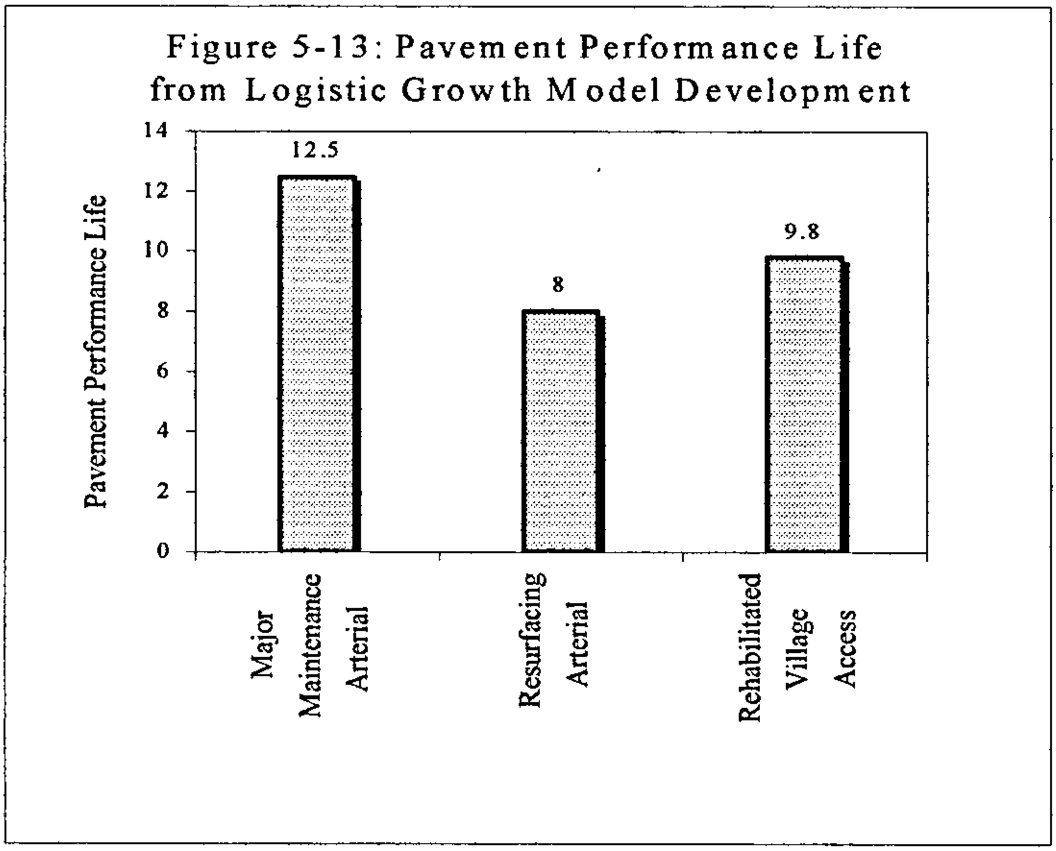
The curve of the predicted performance trend applying polynomial regression equation based on Markov results shows an R^2 value of 0.81, which is a good value. The curve reaches minimum accepted performance value of two at age seven years.

Figure 5-12: Plot of Markov Model for Village Access Roads



Based on the of ability of logistic growth models developed for reconstructed, overlaid arterial, and rehabilitated village access roads in reflecting the nonlinear deterioration rate of pavement performance. Also, the models' R^2 values and their previous use and acceptance for application to local agencies, it is believed that the logistic growth model is an appropriate deterministic model to apply for Palestinian local agencies.

The results of pavement life estimates for the selected pavement sections of major maintained arterial, resurfacing arterial, and rehabilitated village access roads are illustrated in Figure 5-13.



In general, the major maintained arterial has longer performance life than the arterial resurfacing and village access roads. Nevertheless, it should be emphasized that the traffic loads and volumes may be totally different for them. For the three project types considered in this study, the life of resurfacing arterial is the lowest among these project types.

Chapter Six

Conclusions and Recommendations

6.1 Introduction

This study aimed to establish performance model for flexible pavement in Palestine. Among the reviewed pavement performance models, it was found that the application of logistic growth model provided adequate predictive ability for estimating future pavement condition and fitted the pavement condition data. In this study, the functional pavement performance measure in terms of Pavement Condition Rating (PCR) index was used. The data were collected by visual road survey for representative arterial and village access roads in Nablus Province.

6.2 Models Results

Based on model application and comparisons of models results, the logistic growth deterministic models fitted the calibrated PCR data with respect to their regression fitting values. The curves developed for the major maintained arterial, overlaid arterial, and rehabilitated village access studied road sections were in agreement with the natural behavior of pavement performance and more realistic than the results of Markov model.

In Markov model, the pavement of major maintained arterial roads reaches the minimum acceptable performance level at age of nine years. This means that the pavement must have a major maintenance action at earlier age than it is expected or designed for. The developed logistic growth curve shows that the pavement must have a major rehabilitation action at age 12.5 years, which is closer to the designer expectation of twenty years, although the R^2 value for both models was 0.78.

The model developed by applying logistic growth equation for the overlaid arterial road sections compared to Markov probabilistic model was more realistic, even the R^2 value for Markov model was slightly larger than that of logistic model. This means that the pavement must have a major rehabilitation action around the age that is expected or designed for.

The model developed by applying logistic growth equation for the rehabilitated village access road sections compared to Markov probabilistic model was more realistic. Since in Markov model the pavement reaches the minimum acceptable performance level at age of 6.5 years. This means that the pavement must have a major rehabilitation action at earlier age than it is expected or designed for. The developed logistic growth curve shows that the pavement must have a major rehabilitation action at age 9.8 years, which was closer to the designer expectation. The R^2 value of logistic growth model is also larger than that of Markov model.

It is obvious from the comparison of results that the logistic growth model is the most suitable model to apply for the road types being studied at the local level in Palestine.

6.3 Conclusions

The development of a modeling procedure for evaluating the flexible pavement performance for major maintained arterial, overlaid arterial, and rehabilitated village access roads is described in this study. The pavement performance model presented in this study provides local transportation and pavement agencies a useful tool for pavement maintenance and rehabilitation applications.

Two deterministic models, polynomial regression model of second degree and the logistic growth model and Markov probabilistic model were evaluated using data collected for representative road rehabilitation projects executed in Nablus Province.

The most appropriate model was the logistic growth model. The surveyed data were calibrated by applying logistic growth model, then polynomial regression analysis was used for predicting pavement performance. The developed models relate the PCR index to pavement age. The recommended model fits the data relatively well as indicated by their regression fitting values.

Performance life cycles of flexible pavement were evaluated for major maintained and overlaid arterial urban streets and for rehabilitated village access roads. Based on the development of performance models, the following conclusions can be drawn:

- In general, the urban arterial for major maintenance has longer performance life than the urban arterial for resurfacing and village access roads for rehabilitation because of their structural design.
- It is imperative that end users have a thorough understanding of the limitations associated with using regression models of the type presented. Specifically, predictor variable inputs must be constrained to the limits of the in-service data from which models are developed.
- The regression fitting value alone is not a good indicator of the model's ability to predict actual pavement performance. The final implementation of performance models must still include a great deal of engineering interpretation and judgement.

6.4 Recommendations

Historically, research performed at various levels of pavement management system has shown that deterministic models have tendency to overpredict actual pavement performance. It is believed that the probabilistic model does not necessarily underpredict pavement performance; it has a more accurate representation of the pattern a pavement may follow based on previous ratings the pavement received since its last new construction or rehabilitation date.

The following recommendations are suggested:

- Large data-bases are needed in order to develop more significant performance models. The term "large" means that the data must be collected over several years period related to pavement design service life in order to capture the true performance of rehabilitation treatments. This emphasizes the need to establish a road monitoring system in Palestine.
- More variables should be used in developing pavement performance models, such as axle loads, weather factors, and structural number.
- The presented performance models are based specifically on surveyed data that were collected for this study. However, the concepts and methods employed could be applied to any data set.
- It is recommended to use the Markov model at a future date as local agencies gather more pavement condition data over the next five years,

since the behavior of pavements is intuitively not deterministic, but probabilistic. This characteristic makes Markov probabilistic models attractive for pavement applications, so as to be able to explain the variability or non-linearity of pavement condition data.

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APPENDICES

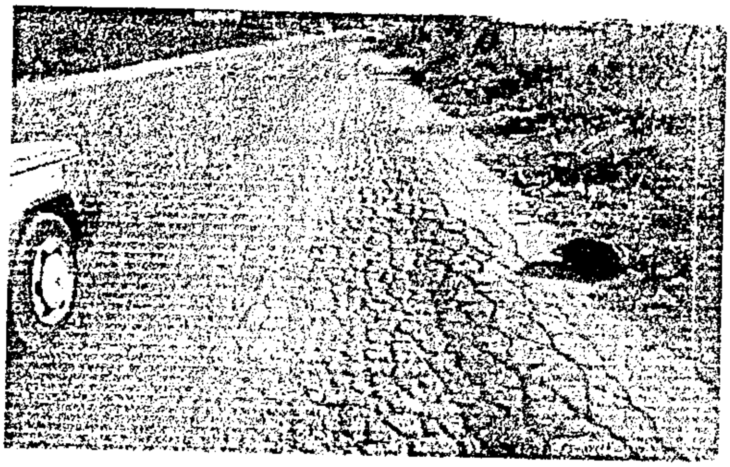
Surface Deformation

1. Rutting

It is a longitudinal vertical surface depression in the wheel path. It is caused by the consolidation of lateral movement of any or all pavement layers under traffic loads. Figure 1 illustrates the rutting in asphalt pavement.

Severity levels are not applicable. However, severity level can be identified in relation to inches of rut depth (Donnelly, 1987).

Figure 1: Rutting and Settlement Deformation Picture in Asphalt Pavement.

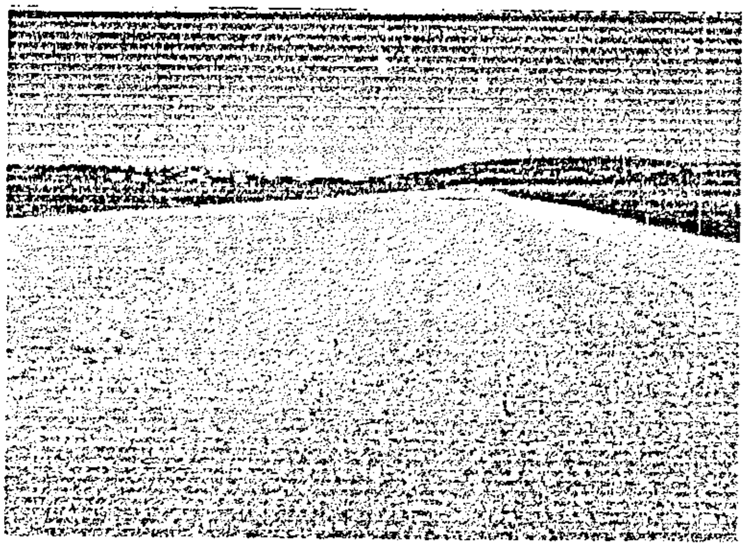


2. Corrugation

It is a series of traverse ripples occurring at regular intervals along the pavement. It is caused due to unstable bituminous mixture or poor base quality. Figure 2 illustrates the corrugation in asphalt pavement.

The severity level is not applicable but according to their effect on riding comfort, vehicle control, and speed reduction (Donnelly, 1987).

Figure 2: Corrugation Deformation Picture in Asphalt Pavement.



3. **Settlement**

It is a dip in the longitudinal profile of the pavement surface. It is considered as distress only when it causes a noticeable effect upon riding quality. It may be caused by traffic heavier than that designed for the pavement, by settlement of the lower pavement layers, or by construction methods. Figure 1 illustrates the settlement in asphalt pavement.

The severity is based upon the effect of the settlement upon vehicle control when traveling along the road (Donnelly, 1987).

4. Shoving

It is a longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement. Usually occurred in asphalt layers that lack stability, which is caused by too high asphalt content, too high a proportion of fine aggregate, or too round aggregate. Figure 3 illustrates the shoving in asphalt pavement.

The severity level can be identified by the relative effect of shoving on ride quality (Donnelly, 1987).

Figure 3: Shoving and Potholes Deformation Picture in Asphalt Pavement.

Patching and Potholes

1. Patching

It is a portion of pavement surface that has been removed and replaced. Figure 4 illustrates the patching in asphalt pavement.

The severity level is considered low when the patch is in very good condition or has low severity distress of any type. The severity is moderate when it has moderate severity distress of any type. The severity is high when it has high severity distress of any type (Donnelly, 1987).

Figure 4: Patch Deterioration Picture in Asphalt Pavement.

2. Potholes

It is a bowel-shaped holes of various sizes in the pavement surface. They are caused by weakness in the pavement resulting from too little asphalt, too many fines, too few fines, or poor drainage. Figure 3 illustrates the potholes in asphalt pavement.

The severity level is measured relating to the depth of the pothole and area occupied (Donnelly, 1987).

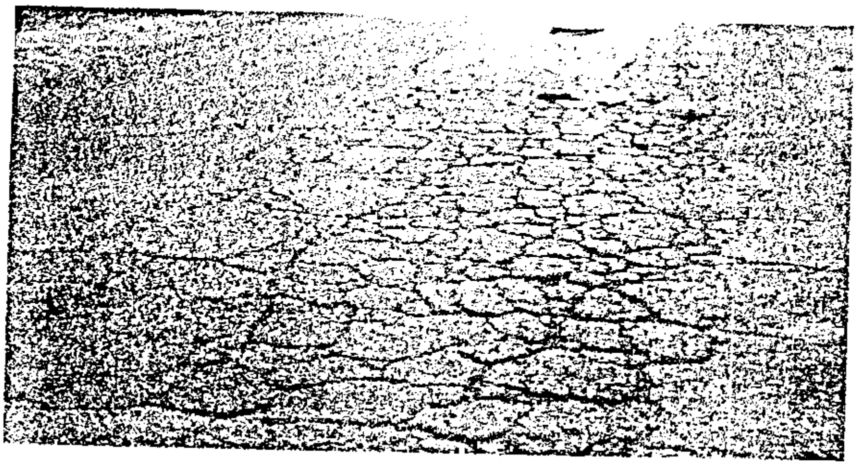
Cracking

1. Alligator Cracking

It is a series of interconnected cracks with many-sided, sharped-angle pieces, usually less than one foot on longest side with alligator pattern. It may occur due to repeated traffic loading or excessive deflection of surface over unstable subgrade or lower courses of the pavement. Figure 5 illustrates the alligator cracking in asphalt pavement.

The severity level is considered low when the cracks not spalled, moderate severity level when they are lightly spalled but can be sealed, and high severity level when pieces more severely spalled at edges and loosened until the pieces rock under traffic (Donnelly, 1987).

Figure 5: Alligator Cracking Picture in Asphalt Pavement.

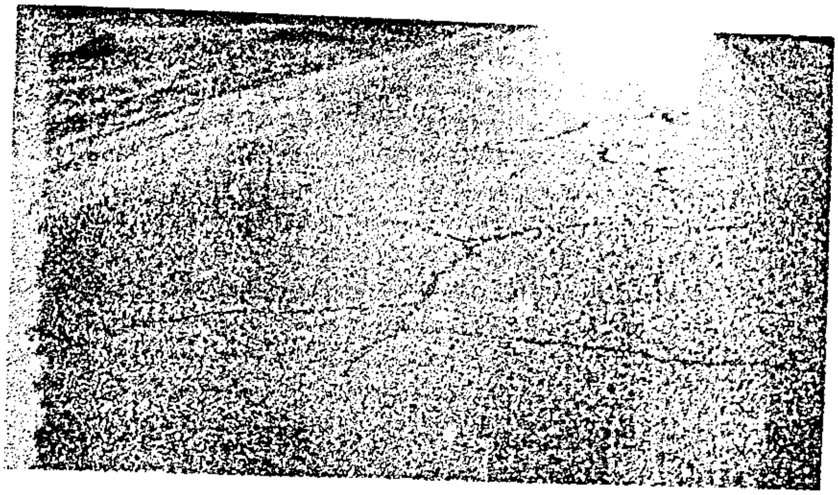


2. Block Cracking

It is a rectangular pieces of asphalt surface ranging in size from approximately one square foot to 100 square foot. The occurrence of block cracking is usually related to thermal shrinkage of asphalt binder. Figure 6 illustrates the block cracking in asphalt pavement.

The severity level is considered low when blocks are defined by unspalled cracks with a mean width of ¼ inch or less, moderate severity level when they are moderately spalled with mean-width crack greater than ¼ inch, and high severity level when cracks are severely spalled (Donnelly, 1987).

Figure 6: Block Cracking Picture in Asphalt Pavement.

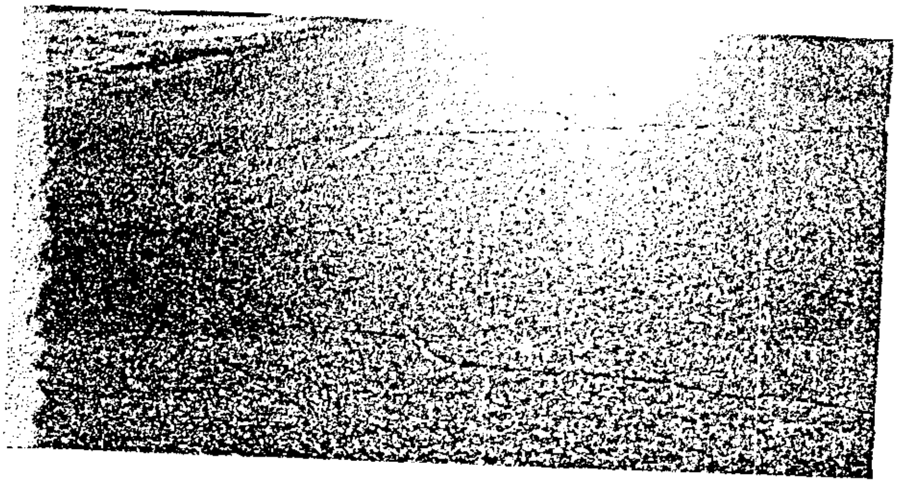


3. Transverse Cracking

It is cracks relatively perpendicular to pavement centerline. The causes are the as block cracks. Figure 7 illustrates the traverse cracking in asphalt pavement.

The severity level is considered low when no spalling cracks with a mean width of ¼ inch or less. Moderate severity level when they are moderately severe spalling with mean-width crack greater than ¼ inch. The severity level is high when cracks are severely spalled or high severity random cracking crack near the traverse crack (Donnelly, 1987).

Figure 7: Traverse Cracking Picture in Asphalt Pavement.

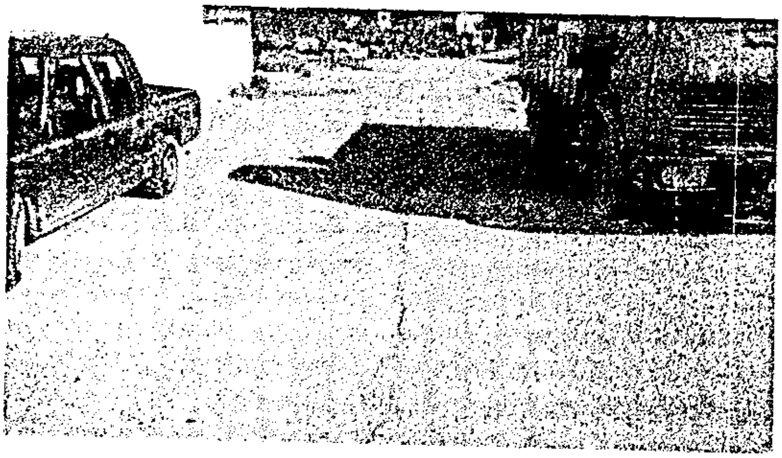


4. Longitudinal Cracking

It is cracks relatively parallel to pavement centerline. Figure 8 illustrates the longitudinal cracking in asphalt pavement.

The severity level is considered low, moderate, and high according to the same standard considered for the traverse cracking (Donnelly, 1987).

Figure 8: Longitudinal Cracking Picture in Asphalt Pavement.

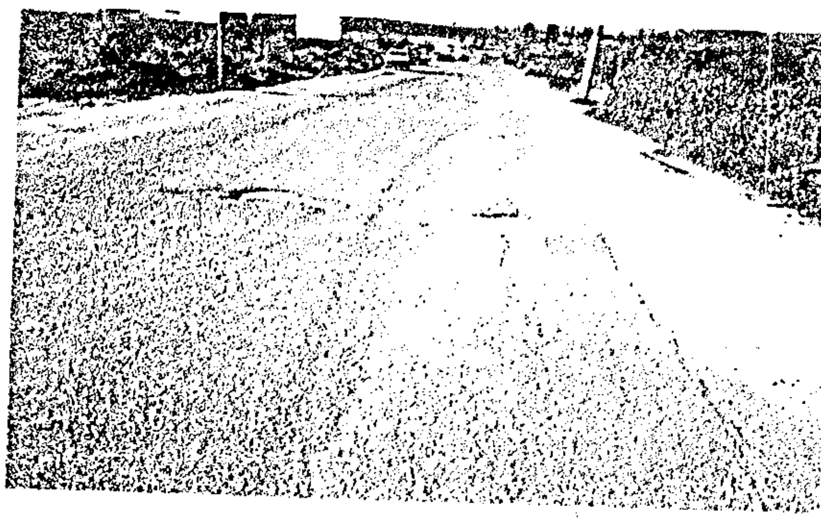


5. Edge Cracking

It is a crescent-shaped crack or fairly continuos cracks, parallel to, and usually within one to two feet of the outer edge of pavement. It occurs when paved shoulders do not exist. Figure 9 illustrates the edge cracking in asphalt pavement.

The severity level is considered low when no breakup or raveling, moderate when cracks with some breakup or raveling, and high when cracks with considerable breakup or raveling along edge (Donnelly, 1987).

Figure 9: Edge Cracking Picture in Asphalt Pavement



Surface Defects

1. Raveling

It is the process of wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. It may occur as a result of poor mixture quality, segregation, or insufficient compaction. The severity is considered low when the wearing of the aggregate has started but has not progressed significantly, it is moderate when the aggregate and/ or binder has worn away and the surface texture is becoming rough and pitted. It is high when the aggregate and/ or binder has worn away and the surface texture is becoming very rough and pitted. Figure 4-10 illustrates the raveling defect in asphalt pavement (Donnelly, 1987).

Figure 4-10: Raveling Picture in Asphalt Pavement.

1. Bleeding

It is a film of bituminous material on pavement surface, which creates a shiny, glass-like, reflective surface that may be tracky to the touch. Bleeding is caused by excess amount of bituminous binder in the mixture and/ or low air void content.

The severity level is considered low when coloring of pavement surface is visible. It is moderate when distinctive appearance with excess asphalt already free. It is high when free asphalt gives pavement surface a wet look (Donnelly, 1987).

Appendix B

Road Condition Survey Summary Data

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/ Road Name: Hisbeh | Page 1
Date: Sep. 2000 | Roadside: RT

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
Major Maintained Arterial Road	1	From	0	From	100	9	2.6	2.0	
		To	10	To					
	2	From	10	From	100	9	2.0	2.33	
		To	20	To					
	3	From	20	From	100	9	2.87	1.64	
		To	30	To					
	4	From	30	From	100	5	2.9	2.0	
		To	40	To					
	5	From	40	From	100	9	2.0	1.75	
		To	50	To					
	6	From	50	From	100	9	2.0	1.75	
		To	60	To					
	7	From	60	From	100	9	2.0	2.0	
		To	70	To					
	8	From	70	From	100	9	2.0	1.75	
		To	80	To					
	9	From	80	From	100	9	2.4	2.0	
		To	90	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Condition Survey (RCS)
alt Paved Roads

Nablus Province/ Road Name: Hisbeh | Page 2
Date: | Roadside: LT

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	3.45	2.0	
		To	10	To					
	2	From	10	From	100	9	3.0	1.75	
		To	20	To					
	3	From	20	From	100	9	2.0	1.5	
		To	30	To					
	4	From	30	From	100	9	2.0	2.0	
		To	40	To					
	5	From	40	From	100	9	2.68	1.75	
		To	50	To					
	6	From	50	From	100	9	2.0	2.0	
		To	60	To					
	7	From	60	From	100	9	2.0	2.0	
		To	70	To					
	8	From	70	From	100	9	2.2	1.75	
		To	80	To					
	9	From	80	From	100	9	2.7	1.5	
		To	90	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Haifa A		Page 3
Date:	Roadside: RT	

Road Classification	Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	12	2.0	2.25	
		To	10	To					
	2	From	10	From	100	12	2.9	2.25	
		To	20	To					
	3	From	20	From	100	12	2.0	1.75	
		To	30	To					
	4	From	30	From	100	12	3.6	1.75	
		To	40	To					
	5	From	40	From	100	12	2.58	2.5	
		To	50	To					
	6	From	50	From	100	12	2.0	2.5	
		To	60	To					
	7	From	60	From	100	12	3.0	3	
		To	70	To					
	8	From	70	From	100	12	2.25	3	
		To	80	To					
	9	From	80	From	100	12	2.6	2.25	
		To	90	To					
	10	From	90	From	100	12	2.0	2.5	
		To	100	To					
	11	From	100	From	100	12	4.1	2.5	
		To	110	To					
	12	From	110	From	100	12	2.0	2.5	
		To	120	To					
	13	From	120	From	100	12	2.0	2.25	
		To	130	To					
	14	From	130	From	100	12	3.0	2.5	
		To	140	To					
	15	From	140	From	100	12	3.33	3.0	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Haifa A		Page 4
Date: Sep. 2000	Roadside: RT	

Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100		2.5	2.5	
	To	160	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/ Road Name: Haifa A		Page 5
Date: Sep. 2000	Roadside: LT	

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	12	2.7	2.25	
		To	10	To					
	2	From	10	From	100	12	3.0	1.75	
		To	20	To					
	3	From	20	From	100	12	3.4	1.75	
		To	30	To					
	4	From	30	From	100	12	2.2	1.75	
		To	40	To					
	5	From	40	From	100	12	2.6	1.75	
		To	50	To					
	6	From	50	From	100	12	2.6	1.75	
		To	60	To					
	7	From	60	From	100	12	3.1	2.0	
		To	70	To					
	8	From	70	From	100	12	2.8	2.25	
		To	80	To					
	9	From	80	From	100	12	2.5	2.0	
		To	90	To					
	10	From	90	From	100	12	2.2	2.25	
		To	100	To					
	11	From	100	From	100	12	3.0	2.5	
		To	110	To					
	12	From	110	From	100	12	2.7	2.5	
		To	120	To					
	13	From	120	From	100	12	2.6	2.5	
		To	130	To					
	14	From	130	From	100	12	3.0	2.25	
		To	140	To					
	15	From	140	From	100	12	3.30	2.5	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
halt Paved Roads

Nablus Province/ Road Name: Haifa A		Page 6
Date: Sep. 2000	Roadside: LT	

	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	16	From	150	From	100	12	4	2.75	
		To	160	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/ Road Name: Al -Hurya		Page
Date: Sep. 2000	Roadside: 1st Lane	7

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
		Designation of Road Section: Identification Points (IP)					Survey Data		
	1	From	0	From	100	12	2.0	1.25	
		To	10	To					
	2	From	10	From	100	12	1.0	1.25	
		To	20	To					
	3	From	20	From	100	12	1.0	1.0	
		To	30	To					
	4	From	30	From	100	12	1.0	1.0	
		To	40	To					
	5	From	40	From	100	12	1.0	1.0	
		To	50	To					
	6	From	50	From	100	12	1.0	1.25	
		To	60	To					
	7	From	60	From	100	12	1.0	1.5	
		To	70	To					
	8	From	70	From	100	12	1.0	1.25	
		To	80	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

l Condition Survey (RCS)
ıalt Paved Roads

Nablus Province/ Road Name: Al -Hurya		Page
Date: Sep. 2000	Roadside: 2st Lane	8

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	Designation of Road Section: Identification Points (IP)					Survey Data		
1	From	0	From	100	12	1.0	1.25	
	To	10	To					
2	From	10	From	100	12	1.0	1.25	
	To	20	To					
3	From	20	From	100	12	1.0	1.0	
	To	30	To					
4	From	30	From	100	12	1.0	1.0	
	To	40	To					
5	From	40	From	100	12	1.0	1.0	
	To	50	To					
6	From	50	From	100	12	1.0	1.25	
	To	60	To					
7	From	60	From	100	12	1.0	1.5	
	To	70	To					
8	From	70	From	100	12	1.0	1.25	
	To	80	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

ɩoad Condition Survey (RCS)
ɩsphalt Paved Roads

Nablus Province/ Road Name: Howara | Page 9
Date: Sep. 2000 | Roadside: RT

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	7	1.0	1.0	
		To	10	To					
	2	From	10	From	100	7	2.0	1.8	
		To	20	To					
	3	From	20	From	100	7	1.0	1.4	
		To	30	To					
	4	From	30	From	100	7	2.0	1.0	
		To	40	To					
	5	From	40	From	100	7	1.0	1.2	
		To	50	To					
	6	From	50	From	100	7	2.0	1.0	
		To	60	To					
	7	From	60	From	100	7	2.0	1.0	
		To	70	To					
	8	From	70	From	100	7	1.0	1.4	
		To	80	To					
	9	From	80	From	100	7	2.0	1.4	
		To	90	To					
	10	From	90	From	100	7	1.8	1.2	
		To	100	To					
	11	From	100	From	100	7	2.0	1.4	
		To	110	To					
	12	From	110	From	100	7	1.0	1.6	
		To	120	To					
	13	From	120	From	100	7	2.0	1.8	
		To	130	To					
	14	From	130	From	100	7	1.0	2.0	
		To	140	To					
	15	From	140	From	100	7	1.0	2.0	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

ɩ Condition Survey (RCS)
ɩalt Paved Roads

Nablus Province/ Road Name: Howara | Page 10
Date: Sep. 2000 | Roadside: RT

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100	12	1.8	1.6	
	To	160	To					
17	From	160	From	100	12	1.0	1.4	
	To	170	To					
18	From	170	From	100	12	2.0	1.2	
	To	180	To					
19	From	180	From	100	12	1.0	1.6	
	To	190	To					
20	From	190	From	100	12	1.0	1.0	
	To	200	To					
21	From	200	From	100	12	1.0	1.6	
	To	210	To					
22	From	210	From	100	12	2.0	1.2	
	To	220	To					
23	From	220	From	100	12	1.6	1.8	
	To	230	To					
24	From	230	From	100	12	1.0	1.2	
	To	240	To					
25	From	240	From	100	12	1.0	1.2	
	To	250	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Howara | Page 11
Date: Sep. 2000 | Roadside: LT

Road Classification	Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	12	1.6	1.2	
		To	10	To					
	2	From	10	From	100	12	1.0	1.2	
		To	20	To					
	3	From	20	From	100	12	2.0	1.8	
		To	30	To					
	4	From	30	From	100	12	1.0	1.2	
		To	40	To					
	5	From	40	From	100	12	1.0	1.6	
		To	50	To					
	6	From	50	From	100	12	1.0	1.0	
		To	60	To					
	7	From	60	From	100	12	1.3	1.6	
		To	70	To					
	8	From	70	From	100	12	1.0	1.2	
		To	80	To					
	9	From	80	From	100	12	1.0	1.4	
		To	90	To					
	10	From	90	From	100	12	2.0	1.6	
		To	100	To					
	11	From	100	From	100	7	1.0	2.0	
		To	110	To					
	12	From	110	From	100	7	1.0	2.0	
		To	120	To					
	13	From	120	From	100	7	1.8	1.8	
		To	130	To					
	14	From	130	From	100	7	2.0	1.6	
		To	140	To					
	15	From	140	From	100	7	1.0	1.4	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Howara | Page 12
Date: Sep. 2000 | Roadside: LT

Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100	7	2.0	1.2	
	To	160	To					
17	From	160	From	100	7	1.0	1.4	
	To	170	To					
18	From	170	From	100	7	1.0	1.4	
	To	180	To					
19	From	180	From	100	7	2.0	1.0	
	To	190	To					
20	From	190	From	100	7	2.0	1.0	
	To	200	To					
21	From	200	From	100	7	2.0	1.2	
	To	210	To					
22	From	210	From	100	7	2.0	1.0	
	To	220	To					
23	From	220	From	100	7	1.8	1.4	
	To	230	To					
24	From	230	From	100	7	1.9	1.8	
	To	240	To					
25	From	240	From	100	7	2.0	1.0	
	To	250	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Al- Qudus		Page 13
Date: Sep. 2000	Roadside: RT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From / To	0 / 10	From / To	100	9	1.9	1.5	
	2	From / To	10 / 20	From / To	100	9	2.7	1.75	
	3	From / To	20 / 30	From / To	100	9	2.5	1.5	
	4	From / To	30 / 40	From / To	100	9	1.8	1.75	
	5	From / To	40 / 50	From / To	100	9	2.0	1.25	
	6	From / To	50 / 60	From / To	100	9	2.0	1.25	
	7	From / To	60 / 70	From / To	100	9	2.0	1.5	
	8	From / To	70 / 80	From / To	100	9	1.0	1.25	
	9	From / To	80 / 90	From / To	100	9	2.0	1.25	
	10	From / To	90 / 100	From / To	100	9	1.0	1.25	
	11	From / To	100 / 110	From / To	100	9	2.0	1.5	
	12	From / To	110 / 120	From / To	100	9	2.0	1.5	
	13	From / To	120 / 130	From / To	100	9	2.0	1.25	
	14	From / To	130 / 140	From / To	100	9	1.6	1.25	
	15	From / To	140 / 150	From / To	100	9	2.2	1.5	

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Al- Qudus		Page 14
Date: Sep. 2000	Roadside: RT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	16	From / To	150 / 160	From / To	100	9	2.6	1.5	
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					
		From / To		From / To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Al- Qudus		Page 15
Date: Sep. 2000	Roadside: LT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	2.1	1.5	
		To	10	To					
	2	From	10	From	100	9	1.8	1.25	
		To	20	To					
	3	From	20	From	100	9	2.0	1.5	
		To	30	To					
	4	From	30	From	100	9	1.0	1.5	
		To	40	To					
	5	From	40	From	100	9	2.0	1.5	
		To	50	To					
	6	From	50	From	100	9	1.0	1.25	
		To	60	To					
	7	From	60	From	100	9	2.0	1.5	
		To	70	To					
	8	From	70	From	100	9	1.0	1.75	
		To	80	To					
	9	From	80	From	100	9	1.0	1.5	
		To	90	To					
	10	From	90	From	100	9	2.0	1.75	
		To	100	To					
	11	From	100	From	100	9	1.8	1.0	
		To	110	To					
	12	From	110	From	100	9	1.6	1.0	
		To	120	To					
	13	From	120	From	100	9	2.0	1.0	
		To	130	To					
	14	From	130	From	100	9	3.1	1.5	
		To	140	To					
	15	From	140	From	100	9	3.0	1.5	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
halt Paved Roads

Nablus Province/ Road Name: Zuyoot		Page 16
Date: Sep. 2000	Roadside: RT	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	9	1.0	1.25	
	To	10	To					
2	From	10	From	100	9	1.0	1.0	
	To	20	To					
3	From	20	From	100	9	1.0	1.0	
	To	30	To					
4	From	30	From	100	9	1.0	1.0	
	To	40	To					
5	From	40	From	100	9	1.0	1.25	
	To	50	To					
6	From	50	From	100	9	1.0	1.25	
	To	60	To					
7	From	60	From	100	9	1.0	1.5	
	To	70	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Zuyoot		Page 17
Date: Sep. 2000	Roadside: LT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	1.0	1.5	
		To	10	To					
	2	From	10	From	100	9	1.0	1.5	
		To	20	To					
	3	From	20	From	100	9	1.0	1.25	
		To	30	To					
	4	From	30	From	100	9	1.0	1.25	
		To	40	To					
	5	From	40	From	100	9	1.0	1.0	
		To	50	To					
	6	From	50	From	100	9	1.0	1.0	
		To	60	To					
	7	From	60	From	100	9	1.0	1.5	
		To	70	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Condition Survey (RCS)
alt Paved Roads

Nablus Province/ Road Name: Kendy		Page 18
Date: Sep. 2000	Roadside:	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	9	2.0	1.0	
	To	10	To					
2	From	10	From	100	9	1.0	1.0	
	To	20	To					
3	From	20	From	100	9	1.4	1.0	
	To	30	To					
4	From	30	From	100	9	1.6	1.0	
	To	40	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/ Road Name: Zawata		Page
Date: Sep. 2000	Roadside: RT	19

Designation of Road Section / **Survey Data**

Road Classification	Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	1.8	2.0	
		To	10	To					
	2	From	10	From	100	9	2.0	1.75	
		To	20	To					
	3	From	20	From	100	9	1.0	1.5	
		To	30	To					
	4	From	30	From	100	9	1.0	1.25	
		To	40	To					
	5	From	40	From	100	9	1.8	1.25	
		To	50	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
alt Paved Roads

Nablus Province/ Road Name: Zawata		Page
Date: Sep. 2000	Roadside: LT	20

Designation of Road Section / **Survey Data**

Section No.	IP	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	9	2.0	1.75	
	To	10	To					
2	From	10	From	100	9	1.6	1.5	
	To	20	To					
3	From	20	From	100	9	2.0	1.5	
	To	30	To					
4	From	30	From	100	9	1.0	1.25	
	To	40	To					
5	From	40	From	100	9	1.9	1.75	
	To	50	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS) sphalt Paved Roads	Nablus Province/ Road Name: Rafidia		Page
	Date: Sep. 2000	Roadside: RT	21

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	1[illegible]	2.5	1.5	
		To	10	To					
	2	From	10	From	100	12	2.0	1.75	
		To	20	To					
	3	From	20	From	100	12	2.0	1.25	
		To	30	To					
	4	From	30	From	100	12	2.0	2.0	
		To	40	To					
	5	From	40	From	100	12	2.0	1.75	
		To	50	To					
	6	From	50	From	100	12	2.0	2.0	
		To	60	To					
	7	From	60	From	100	12	2.0	2.0	
		To	70	To					
	8	From	70	From	100	12	2.75	1.75	
		To	80	To					
	9	From	80	From	100	12	2.6	1.8	
		To	90	To					
	10	From	90	From	100	12	2.0	1.5	
		To	100	To					
	11	From	100	From	100	12	2.0	1.5	
		To	110	To					
	12	From	110	From	100	12	2.0	1.75	
		To	120	To					
	13	From	120	From	100	12	2.6	2.0	
		To	130	To					
	14	From	130	From	100	12	2.5	2.0	
		To	140	To					
	15	From	140	From	100	12	2.0	1.5	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

l Condition Survey (RCS) alt Paved Roads	Nablus Province/ Road Name: Rafidia		Page
	Date: Sep. 2000	Roadside: RT	22

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100	12	2.0	1.75	
	To	160	To					
17	From	160	From	100	12	2.0	1.5	
	To	170	To					
18	From	170	From	100	12	2.0	1.75	
	To	180	To					
19	From	180	From	100	12	2.0	1.5	
	To	190	To					
20	From	190	From	100	12	2.75	1.75	
	To	200	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Rafidia | Page 23
Date: Sep. 2000 | Roadside: LT

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From / To	0 / 10	From / To	100	12	3.4	1.75	
	2	From / To	10 / 20	From / To	100	12	2.0	2.0	
	3	From / To	20 / 30	From / To	100	12	2.0	1.8	
	4	From / To	30 / 40	From / To	100	12	2.0	1.75	
	5	From / To	40 / 50	From / To	100	12	2.0	1.75	
	6	From / To	50 / 60	From / To	100	12	2.0	2.2	
	7	From / To	60 / 70	From / To	100	12	2.0	2.25	
	8	From / To	70 / 80	From / To	100	12	2.55	1.75	
	9	From / To	80 / 90	From / To	100	12	2.4	1.75	
	10	From / To	90 / 100	From / To	100	12	2.0	1.75	
	11	From / To	100 / 110	From / To	100	12	2.0	2.0	
	12	From / To	110 / 120	From / To	100	12	2.75	1.75	
	13	From / To	120 / 130	From / To	100	12	2.6	1.75	
	14	From / To	130 / 140	From / To	100	12	2.0	1.5	
	15	From / To	140 / 150	From / To	100	12	2.0	2.0	

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/ Road Name: Rafidia | Page 24
Date: Sep. 2000 | Roadside: LT

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From / To	150 / 160	From / To	100	12	2.0	2.0	
17	From / To	160 / 170	From / To	100	12	2.5	1.75	
18	From / To	170 / 180	From / To	100	12	2.0	1.5	
19	From / To	180 / 190	From / To	100	12	2.0	1.75	
20	From / To	190 / 200	From / To	100	12	2.7	1.75	
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					
	From / To		From / To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Jamal Abed-Naser		Page 25
Date: Sep. 2000	Roadside: RT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	2.0	1.6	
		To	10	To					
	2	From	10	From	100	9	1.8	1.6	
		To	20	To					
	3	From	20	From	100	9	2.0	1.8	
		To	30	To					
	4	From	30	From	100	9	2.0	1.6	
		To	40	To					
	5	From	40	From	100	9	2.0	2.0	
		To	50	To					
	6	From	50	From	100	9	2.0	2.0	
		To	60	To					
	7	From	60	From	100	9	2.0	1.75	
		To	70	To					
	8	From	70	From	100	9	2.0	1.75	
		To	80	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Jamal Abed-Naser		Page 26
Date: Sep. 2000	Roadside: LT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	2.0	1.75	
		To	10	To					
	2	From	10	From	100	9	2.0	1.75	
		To	20	To					
	3	From	20	From	100	9	2.0	2.0	
		To	30	To					
	4	From	30	From	100	9	2.0	2.0	
		To	40	To					
	5	From	40	From	100	9	2.0	1.25	
		To	50	To					
	6	From	50	From	100	9	2.0	1.75	
		To	60	To					
	7	From	60	From	100	9	1.0	1.75	
		To	70	To					
	8	From	70	From	100	9	2.0	1.75	
		To	80	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Askar		Page 27
Date: Sep. 2000	Roadside: RT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	3.45	1.5	
		To	10	To					
	2	From	10	From	100	9	3.35	1.75	
		To	20	To					
	3	From	20	From	100	9	3.5	2.0	
		To	30	To					
	4	From	30	From	100	9	4.0	1.75	
		To	40	To					
	5	From	40	From	100	9	3.7	1.75	
		To	50	To					
	6	From	50	From	100	9	3.75	2.0	
		To	60	To					
	7	From	60	From	100	9	3.0	2.0	
		To	70	To					
	8	From	70	From	100	9	3.2	2.25	
		To	80	To					
	9	From	80	From	100	9	2.0	1.75	
		To	90	To					
	10	From	90	From	100	9	2.0	1.75	
		To	100	To					
	11	From	100	From	100	9	2.0	1.75	
		To	110	To					
	12	From	110	From	100	9	2.0	1.75	
		To	120	To					
	13	From	120	From	100	9	2.0	2.0	
		To	130	To					
	14	From	130	From	100	9	2.0	1.75	
		To	140	To					
	15	From	140	From	100	9	3.15	2 0	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Askar		Page 28
Date: Sep. 2000	Roadside: RT	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100	9	3.85	2.0	
	To	160	To					
17	From	160	From	100	9	4.0	2.0	
	To	170	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Askar | Page 29
Date: Sep. 2000 | Roadside: LT

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	3.77	2.25	
		To	10	To					
	2	From	10	From	100	9	3.88	2.0	
		To	20	To					
	3	From	20	From	100	9	3.62	2.0	
		To	30	To					
	4	From	30	From	100	9	2.0	2.25	
		To	40	To					
	5	From	40	From	100	9	2.0	2.25	
		To	50	To					
	6	From	50	From	100	9	3.25	2.25	
		To	60	To					
	7	From	60	From	100	9	3.2	2.25	
		To	70	To					
	8	From	70	From	100	9	3.0	2.0	
		To	80	To					
	9	From	80	From	100	9	3.2	2.0	
		To	90	To					
	10	From	90	From	100	9	3.15	2.5	
		To	100	To					
	11	From	100	From	100	9	2.0	2.25	
		To	110	To					
	12	From	110	From	100	9	2.0	2.25	
		To	120	To					
	13	From	120	From	100	9	3.0	2.25	
		To	130	To					
	14	From	130	From	100	9	3.35	2.0	
		To	140	To					
	15	From	140	From	100	9	3.5	2.0	
		To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

l Condition Survey (RCS)
ialt Paved Roads

Nablus Province/Road Name: Askar | Page 30
Date: Sep. 2000 | Roadside: LT

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
16	From	150	From	100	9	2.0	1.75	
	To	160	To					
17	From	160	From	100	9	2.0	1.5	
	To	170	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Haifa B | Page 31
Date: Sep. 2000 | Roadside: RT

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	3.0	2.0	
		To	10	To					
	2	From	10	From	100	9	2.77	1.75	
		To	20	To					
	3	From	20	From	100	9	2.0	1.5	
		To	30	To					
	4	From	30	From	100	9	2.0	1.25	
		To	40	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Condition Survey (RCS)
halt Paved Roads

Nablus Province/Road Name: Haifa B | Page 32
Date: Sep. 2000 | Roadside: LT

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	9	2.0	1.5	
	To	10	To					
2	From	10	From	100	9	2.9	2.0	
	To	20	To					
3	From	20	From	100	[illegible]	2.75	2.0	
	To	30	To					
4	From	30	From	100	9	3.55	1.75	
	To	40	To					
5	From	40	From	100	9	3.4	1.5	
	To	50	To					
6	From	50	From	100	9	1.5	1.5	
	To	60	To					
7	From	60	From	100	9	2.0	1.75	
	To	70	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Toones | Date: Sep. 2000 | Roadside: RT | Page 33

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	7	2.0	1.5	
		To	10	To					
	2	From	10	From	100	7	1.0	2.0	
		To	20	To					
	3	From	20	From	100	7	1.0	2.25	
		To	30	To					
	4	From	30	From	100	7	1.0	2.0	
		To	40	To					
	5	From	40	From	100	7	1.0	2.0	
		To	50	To					
	6	From	50	From	100	7	1.0	2.0	
		To	60	To					
	7	From	60	From	100	7	1.0	2.0	
		To	70	To					
	8	From	70	From	100	7	1.0	2.0	
		To	80	To					
	9	From	80	From	100	7	1.0	2.0	
		To	90	To					
	10	From	90	From	100	7	1.0	1.25	
		To	100	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
alt Paved Roads

Nablus Province/Road Name: Toones | Date: Sep. 2000 | Roadside: LT | Page 34

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	7	2.0	1.75	
	To	10	To					
2	From	10	From	100	7	1.0	2.0	
	To	20	To					
3	From	20	From	100	7	1.0	2.0	
	To	30	To					
4	From	30	From	100	7	1.0	2.0	
	To	40	To					
5	From	40	From	100	7	1.0	2.25	
	To	50	To					
6	From	50	From	100	7	1.0	2.0	
	To	60	To					
7	From	60	From	100	7	1.0	1.75	
	To	70	To					
8	From	70	From	100	7	1.0	2.25	
	To	80	To					
9	From	80	From	100	7	2.0	2.0	
	To	90	To					
10	From	90	From	100	7	2.0	1.25	
	To	100	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Al-Gazali | Date: Sep. 2000 | Roadside: | Page 35

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	9	1.0	1.25	
		To	10	To					
	2	From	10	From	100	9	1.0	1.25	
		To	20	To					
	3	From	20	From	100	9	1.0	1.25	
		To	30	To					
	4	From	30	From	100	9	1.0	1.5	
		To	40	To					
	5	From	40	From	100	9	1.75	1.5	
		To	50	To					
	6	From	50	From	100	9	1.8	1.5	
		To	60	To					
	7	From	60	From	100	9	1.0	1.25	
		To	70	To					
	8	From	70	From	100	9	1.6	1.0	
		To	80	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Road Condition Survey (RCS)
Asphalt Paved Roads

Nablus Province/Road Name: Factory | Date: Sep. 2000 | Roadside: RT | Page 36

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	7	1.0	1.25	
		To	10	To					
	2	From	10	From	100	7	1.0	1.5	
		To	20	To					
	3	From	20	From	100	7	1.0	1.5	
		To	30	To					
	4	From	30	From	100	7	1.0	1.75	
		To	40	To					
	5	From	40	From	100	7	1.0	1.25	
		To	50	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Factory		Page 37
Date: Sep. 2000	Roadside: LT	

Designation of Road Section							Survey Data		
Classification	Section No.	Identification Points (IP) I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	100	7	1.0	1.25	
		To	10	To					
	2	From	10	From	100	7	1.0	1.75	
		To	20	To					
	3	From	20	From	100	7	1.0	1.5	
		To	30	To					
	4	From	30	From	100	7	1.0	1.5	
		To	40	To					
	5	From	40	From	100	7	1.0	1.25	
		To	50	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

l Condition Survey (RCS)
alt Paved Roads

Nablus Province/Road Name: Fisal		Page 38
Date: Sep. 2000	Roadside: RT lane	

Designation of Road Section						Survey Data		
Section No.	Identification Points (IP) I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	100	12	1.0	1.25	
	To	10	To					
2	From	10	From	100	12	1.0	1.25	
	To	20	To					
3	From	20	From	100	12	2.0	1.25	
	To	30	To					
4	From	30	From	100	12	2.0	1.75	
	To	40	To					
5	From	40	From	100	12	1.0	2.0	
	To	50	To					
6	From	50	From	100	12	1.9	1.5	
	To	60	To					
7	From	60	From	100	12	1.5	1.75	
	To	70	To					
8	From	70	From	100	12	2.0	1.25	
	To	80	To					
9	From	80	From	100	12	1.0	1.25	
	To	90	To					
10	From	90	From	100	12	2.0	1.5	
	To	100	To					
11	From	100	From	100	12	2.0	1.0	
	To	110	To					
12	From	110	From	100	12	2.0	1.0	
	To	120	To					
13	From	120	From	100	12	1.8	1.0	
	To	130	To					
14	From	130	From	100	12	1.0	1.25	
	To	140	To					
15	From	140	From	100	12	2.0	1.25	
	To	150	To					

Summary of Road Condition Survey Results (Average Condition Value)

:oad Condition Survey (RCS)
ısphalt Paved Roads

Nablus Province/Road Name: Qablan		Page 39
Date: Sep. 2000	Roadside: RT & LT	

Road Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	200	5	2.0	2.2	
		To	20	To					
	2	From	20	From	200	5	1.7	2.2	
		To	40	To					
	3	From	40	From	200	5	2.0	2.6	
		To	60	To					
	4	From	60	From	200	5	2.0	2.0	
		To	80	To					
	5	From	80	From	200	5	1.5	2.0	
		To	100	To					
	6	From	100	From	200	5	2.0	1.8	
		To	120	To					
	7	From	120	From	200	5	1.7	1.8	
		To	140	To					
	8	From	140	From	200	5	1.4	2.2	
		To	160	To					
	9	From	160	From	200	5	1.8	2.2	
		To	180	To					
	10	From	180	From	200	5	2.0	2.0	
		To	200	To					
	11	From	200	From	200	5	2.0	2.5	
		To	220	To					
	12	From	220	From	200	5	1.6	2.8	
		To	240	To					
	13	From	240	From	100	5	1.8	2.8	
		To	250	To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

ı Condition Survey (RCS)
ıalt Paved Roads

Nablus Province/Road Name: Beita		Page 40
Date: Sep. 2000	Roadside: RT &LT	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	5	2.0	1.25	
	To	20	To					
2	From	20	From	200	5	1.6	1.25	
	To	40	To					
3	From	40	From	200	5	2.0	1.0	
	To	60	To					
4	From	60	From	200	5	1.4	1.75	
	To	80	To					
5	From	80	From	200	5	2.0	1.5	
	To	100	To					
6	From	100	From	200	5	2.0	1.5	
	To	120	To					
7	From	120	From	200	5	2.8	1.5	
	To	140	To					
8	From	140	From	200	5	3.3	1.5	
	To	160	To					
9	From	160	From	200	5	2.4	1.25	
	To	180	To					
10	From	180	From	200	5	3.2	2.0	
	To	200	To					
11	From	200	From	200	5	2.6	2.25	
	To	220	To					
12	From	220	From	200	5	2.0	2.25	
	To	240	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Sabastia Beit-Omreen		Page 41
Date: Sep. 2000	Roadside: RT &LT	

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	200	5	2.1	1.8	
		To	20	To					
	2	From	20	From	200	5	2.0	2.5	
		To	40	To					
	3	From	40	From	200	5	1.0	2.2	
		To	60	To					
	4	From	60	From	200	5	1.0	2.0	
		To	80	To					
	5	From	80	From	200	5	2.4	2.2	
		To	100	To					
	6	From	100	From	200	5	2.0	1.8	
		To	120	To					
	7	From	120	From	200	5	2.0	2.0	
		To	140	To					
	8	From	140	From	200	5	2.0	2.4	
		To	160	To					
	9	From	160	From	200	5	1.6	2.6	
		To	180	To					
	10	From	180	From	200	5	2.0	2.4	
		To	200	To					
	11	From	200	From	200	5	1.8	2.2	
		To	220	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Condition Survey (RCS)
alt Paved Roads

Nablus Province/Road Name: Bazaria		Page 42
Date: Sep. 2000	Roadside: RT &LT	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	5	1.0	2.2	
	To	20	To					
2	From	20	From	200	5	1.0	2.6	
	To	40	To					
3	From	40	From	200	5	1.0	2.2	
	To	60	To					
4	From	60	From	200	5	1.0	2.6	
	To	80	To					
5	From	80	From	200	5	2.0	2.8	
	To	100	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

.oad Condition Survey (RCS)
.sphalt Paved Roads

Nablus Province/Road Name: Till - Sarah | Date: Sep. 2000 | Roadside: RT & LT | Page 43

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	200	5	2.0	2.2	
		To	20	To					
	2	From	20	From	200	5	1.8	2.4	
		To	40	To					
	3	From	40	From	200	5	3.0	2.6	
		To	60	To					
	4	From	60	From	200	5	2.0	2.0	
		To	80	To					
	5	From	80	From	200	5	2.0	1.8	
		To	100	To					
	6	From	100	From	200	5	3.0	2.0	
		To	120	To					
	7	From	120	From	200	5	2.0	2.2	
		To	140	To					
	8	From	140	From	200	5	2.0	1.8	
		To	160	To					
	9	From	160	From	200	5	2.5	2.2	
		To	180	To					
	10	From	180	From	200	5	3.2	2.0	
		To	200	To					
	11	From	200	From	200	5	2.0	2.6	
		To	220	To					
	12	From	220	From	200	5	2.0	2.4	
		To	240	To					
	13	From	240	From	100	5	2.0	2.0	
		To	250	To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
ıalt Paved Roads

Nablus Province/Road Name: Nablus - Till | Date: Sep. 2000 | Roadside: RT & LT | Page 44

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	6	1.0	1.8	
	To	20	To					
2	From	20	From	200	6	1.0	2.2	
	To	40	To					
3	From	40	From	200	6	1.0	2.2	
	To	60	To					
4	From	60	From	200	6	1.0	2.0	
	To	80	To					
5	From	80	From	200	6	1.0	1.8	
	To	100	To					
6	From	100	From	200	6	2.0	1.6	
	To	120	To					
7	From	120	From	200	6	1.0	2.4	
	To	140	To					
8	From	140	From	200	6	1.0	2.2	
	To	160	To					
9	From	160	From	200	6	2.0	2.4	
	To	180	To					
10	From	180	From	200	6	1.0	1.6	
	To	200	To					
11	From	200	From	200	6	1.0	2.0	
	To	220	To					
12	From	220	From	200	6	2.0	2.2	
	To	240	To					
13	From	240	From	200	6	1.0	1.8	
	To	260	To					
14	From	260	From	200	6	1.0	2.0	
	To	280	To					
15	From	280	From	200	6	2.0	2.2	
	To	300	To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Nablus - Till | Date: Sep. 2000 | Roadside: RT & LT | Page 45

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	16	From	300	From	200	6	1.0	1.8	
		To	320	To					
	17	From	320	From	200	6	2.0	1.4	
		To	340	To					
	18	From	340	From	200	6	2.0	1.6	
		To	360	To					
	19	From	360	From	200	6	1.5	2.2	
		To	380	To					
	20	From	380	From	100	6	1.8	2.2	
		To	390	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

Condition Survey (RCS)
alt Paved Roads

Nablus Province/Road Name: Yasid - Farah | Date: Sep. 2000 | Roadside: RT & LT | Page 46

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	5	2.0	1.8	
	To	20	To					
2	From	20	From	200	5	2.0	1.8	
	To	40	To					
3	From	40	From	200	5	2.0	2.2	
	To	60	To					
4	From	60	From	200	5	2.0	2.0	
	To	80	To					
5	From	80	From	200	5	1.5	2.0	
	To	100	To					
6	From	100	From	200	5	2.0	1.8	
	To	120	To					
7	From	120	From	200	5	2.3	2.2	
	To	140	To					
8	From	140	From	200	5	2.5	2.6	
	To	160	To					
9	From	160	From	200	5	1.0	1.8	
	To	180	To					
10	From	180	From	200	5	2.0	2.2	
	To	200	To					
11	From	200	From	200	5	1.0	2.0	
	To	220	To					
12	From	220	From	200	5	2.0	2.4	
	To	240	To					
13	From	240	From	200	5	2.0	2.6	
	To	260	To					
14	From	260	From	200	5	2.1	2.0	
	To	280	To					
15	From	280	From	200	5	1.0	2.0	
	To	300	To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Yased Farah		Page 47
Date: Sep. 2000	Roadside: RT & LT	

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	16	From	300	From	200	5	2.0	2.6	
		To	320	To					
	17	From	320	From	200	5	2.0	1.6	
		To	340	To					
	18	From	340	From	200	5	2.0	2.0	
		To	360	To					
	19	From	360	From	200	5	1.9	2.4	
		To	380	To					
	20	From	380	From	200	5	2.2	2.6	
		To	400	To					
	21	From	400	From	200	5	2.0	2.0	
		To	420	To					
	22	From	420	From	200	5	2.0	2.0	
		To	440	To					
	23	From	440	From	200	5	1.0	2.2	
		To	460	To					
	24	From	460	From	200	5	1.8	2.6	
		To	480	To					
	25	From	480	From	200	5	2.0	2.0	
		To	500	To					
	26	From	500	From	200	5	2.0	2.4	
		To	520	To					
	27	From	520	From	200	5	2.0	2.4	
		To	540	To					
	28	From	540	From	100	5	2.0	2.0	
		To	550	To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

d Condition Survey (RCS)
ıalt Paved Roads

Nablus Province/Road Name: Beit-Dajan A		Page 48
Date: Sep. 2000	Roadside: RT & LT	

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	5	1.0	1.5	
	To	20	To					
2	From	20	From	200	5	1.0	1.6	
	To	40	To					
3	From	40	From	200	5	1.0	1.2	
	To	60	To					
4	From	60	From	200	5	1.0	1.4	
	To	80	To					
5	From	80	From	200	5	1.0	2.0	
	To	100	To					
6	From	100	From	200	5	1.0	1.8	
	To	120	To					
7	From	120	From	200	5	1.0	1.8	
	To	140	To					
8	From	140	From	200		1.0	1.6	
	To	160	To					
9	From	160	From	200	5	1.0	2.0	
	To	180	To					
10	From	180	From	200	5	1.0	1.2	
	To	200	To					
11	From	200	From	200	5	1.0	1.4	
	To	220	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Summary of Road Condition Survey Results (Average Condition Value)

oad Condition Survey (RCS)
sphalt Paved Roads

Nablus Province/Road Name: Beit-Dajan B | Page 49
Date: Sep. 2000 | Roadside: RT & LT

Classification	Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
	1	From	0	From	200	5	1.0	1.0	
		To	20	To					
	2	From	20	From	200	5	1.0	1.2	
		To	40	To					
	3	From	40	From	200	5	1.0	1.2	
		To	60	To					
	4	From	60	From	200	5	1.0	1.0	
		To	80	To					
	5	From	80	From	200	5	1.0	1.2	
		To	100	To					
	6	From	100	From	200	5	1.0	1.0	
		To	120	To					
	7	From	120	From	200	5	1.0	1.4	
		To	140	To					
	8	From	140	From	200	5	1.0	1.6	
		To	160	To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					
		From		From					
		To		To					

Summary of Road Condition Survey Results (Average Condition Value)

l Condition Survey (RCS)
ıalt Paved Roads

Nablus Province/Road Name: Beit Eyba | Page 50
Date: Sep. 2000 | Roadside: RT & LT

Section No.	I.P	Designation	Km	Section Length (m)	Pavement Width (m)	Carriageway	Roadside Elements & Road Signs	Notes / Remarks
1	From	0	From	200	5	1.0	1.8	
	To	20	To					
2	From	20	From	200	5	1.0	1.6	
	To	40	To					
3	From	40	From	200	5	1.0	1.2	
	To	60	To					
4	From	60	From	200	5	1.0	1.0	
	To	80	To					
5	From	80	From	200	5	1.0	1.0	
	To	100	To					
6	From	100	From	200	5	1.0	1.2	
	To	120	To					
7	From	120	From	200	5	1.0	1.4	
	To	140	To					
8	From	140	From	200	5	1.0	1.6	
	To	160	To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					
	From		From					
	To		To					

Appendix C

Detail Visual Inspection Summary Data

Summary of Detail Visual Inspection Results (Average Condition Value)

etail Visual Inspection Survey (DVI)	
sphalt Paved Roads	
ate: Sep.2000	Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
••	••	3.0	••	2.33	••	••	••	2.5	2.60
2.67	••	••	••	2.89	••	••	••	••	2.87
3.0	••	3.0	••	3.0	••	••	••	••	3.00
••	••	2.5	••	2.56	••	••	2.0	1.0	2.40

Nablus Province\Road Name: Hisbeh		Page 51
Road Classification: Major Maintained Arterial		
Date: Sep.2000	Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	••	••	••	3.0	3.67	4.0	••	••	3.0	3.45
2	3.0	••	3.0	••	3.0	••	••	••	••	3.00
5	••	••	3.0	4.0	1.4	5.0	5.0	••	3.0	2.68
8	••	••	••	••	2.0	2.0	••	3.0	1.8	2.2
9	••	••	3.0	••	3.0	••	••	3.0	2.4	2.7

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)	
ialt Paved Roads	
Sep.2000	Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
••	••	••	••	3.3	••	••	••	1.75	2.90
••	••	••	••	3.2	••	••	••	4.0	3.60
••	1.0	••	2.33	1.89	3.6	3.0	••	••	2.60
••	••	••	••	2.57	3.0	••	••	3.2	3.00
••	••	2.0	••	1.0	2.5	••	3.0	2.4	2.25
.0	••	2.5	2.5	2.67	4.0	3.0	••	2.67	2.60
•	••	3.75	••	4.4	••	••	••	4.0	4.10
•	••	3.0	3.2	3.0	3.5	2.0	3.0	2.0	3.00
•	3.0	3.0	3.5	2.5	4.0	••	••	3.0	3.33
•	••	3.0	2.0	3.0	3.33	••	••	2.0	2.50

Nablus Province\Road Name: Haifa A		Page 52
Road Classification: Major Maintained Arterial		
Date: Sep.2000	Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	••	1.67	2.6	2.0	3.3	3.5	3.0	••	2.5	2.70
2	••	2.25	2.6	2.33	3.8	4.4	2.8	••	2.0	3.00
3	••	••	2.67	1.0	3.33	5.0	1.67	••	3.0	3.40
4	••	••	2.5	1.0	2.0	3.4	••	1.5	2.33	2.20
5	••	••	3.0	1.0	2.2	3.6	••	••	2.4	2.60
6	••	••	3.5	2.0	1.5	4.5	••	••	1.67	2.60
7	••	••	3.0	3.0	2.5	4.0	3.0	3.5	••	3.10
8	••	••	2.75	2.5	2.0	3.5	••	2.5	••	2.80
9	••	••	2.5	2.5	2.5	2.0	••	••	••	2.50
10	••	2.0	••	1.5	1.0	2.25	3.0	••	••	2.20
11	••	3.0	3.0	3.0	3.13	••	2.5	••	3.0	3.00
12	••	••	••	2.0	2.0	4.0	••	••	3.0	2.70
13	••	••	2.33	2.4	2.0	3.4	2.0	••	2.0	2.60
14	••	••	3.4	2.5	••	4.0	••	••	2.8	3.00
15	••	••	2.33	2.5	••	4.2	4.0	••	••	3.30
16	••	3.5	••	4.25	3.5	4.8	••	••	3.8	4.00

Summary of Detail Visual Inspection Results (Average Condition Value)

etail Visual Inspection Survey (DVI)	
sphalt Paved Roads	
ate: Sep.2000	Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1.33	**	**	**	2.0	**	**	2.0	**	1.80
1.33	**	**	**	2.0	**	**	2.0	**	1.80
1.5	**	**	**	2.0	**	**	**	**	1.60

Nablus Province\Road Name: Howara		Page 53
Road Classification: Major Maintained Arterial		
Date: Sep.2000	Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	1.5	**	**	2.0	**	**	**	**	**	1.60
7	1.2	**	**	**	2.0	**	**	1.0	**	1.30
13	1.33	**	**	**	2.0	**	**	2.0	**	1.80
23	1.33	**	**	**	2.0	**	**	2.0	**	1.80
24	1.5	**	**	**	2.0	**	**	3.0	**	1.90

Summary of Detail Visual Inspection Results (Average Condition Value)

l Visual Inspection Survey (DVI)	
alt Paved Roads	
Sep.2000	Roadside: RT

Detail Visual Inspection Data

	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	2.67	1.0	1.67	**	**	**	**	1.90
**	**	3.0	2.0	2.5	**	**	**	**	2.70
**	**	3.0	2.0	2.5	**	**	**	**	2.50
**	**	1.67	1.0	2.33	**	**	**	**	1.80
**	**	2.0	1.0	1.6	**	**	**	**	1.60
.5	**	3.0	1.67	3.0	**	**	**	**	2.2
.5	**	**	**	2.0	3.0	**	**	**	2.60

Nablus Province\Road Name: Al -Qudus		Page 54
Road Classification: Major Maintained Arterial		
Date: Sep.2000	Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	2.33	**	**	2.0	2.0	**	**	1.0	**	2.10
2	**	**	1.67	1.0	2.33	**	**	**	**	1.80
11	**	**	1.67	1.0	2.33	**	**	**	**	1.80
12	**	**	2.0	1.0	1.6	**	**	**	**	1.60
14	**	**	3.0	3.25	3.0	**	3.0	**	**	3.10
15	**	**	3.0	3.0	3.0	**	3.0	**	**	3.0

Summary of Detail Visual Inspection Results (Average Condition Value)

Detail Visual Inspection Survey (DVI)
Asphalt Paved Roads
Date: Sep.2000 | Roadside: RT

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
	**	1.0	1.0	**	2.0	1.5	**	**	**	1.40
	**	**	3.0	1.0	**	4.0	**	**	1.5	1.66

Nablus Province\Road Name: Kendy
Road Classification: Major Maintained Arterial
Date: Sep.2000 | Roadside:

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Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

l Visual Inspection Survey (DVI)
alt Paved Roads
Sep.2000 | Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
.33	**	**	**	1.33	**	**	2.33	**	1.80
.75	**	**	1.0	1.25	**	**	2.25	**	1.82

Nablus Province\Road Name: Zawata
Road Classification: Major Maintained Arterial
Date: Sep.2000 | Roadside: LT

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Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
2	2.0	**	**	1.0	1.0	**	**	2.0	**	1.60
5	3.0	3.0	**	1.5	1.33	**	**	1.67	**	1.93

Summary of Detail Visual Inspection Results (Average Condition Value)

etail Visual Inspection Survey (DVI)
sphalt Paved Roads
ate: Sep.2000 | Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	3.0	3.0	2.44	**	**	1.0	**	2.50
**	**	**	3.0	2.63	**	**	3.0	**	2.75
**	**	3.0	3.0	2.3	**	**	3.0	**	2.60
**	**	3.0	3.0	2.2	**	**	3.0	**	2.60
**	**	3.0	1.5	2.33	**	**	3.0	**	2.50
**	*	2.67	3.0	2.0	2.8	4.0	2.67	2.33	2.75

Nablus Province\Road Name: Rafidia
Road Classification: Overlaid Arterial
Date: Sep.2000 | Roadside: LT
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Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	**	**	2.5	3.0	3.0	4.2	5.0	**	**	3.40
8	**	**	**	2.33	2.5	**	**	**	**	2.55
9	**	**	**	2.0	2.33	**	**	**	**	2.40
12	**	**	3.0	3.0	2.4	**	**	3.0	**	2.75
13	**	**	3.0	3.0	2.2	**	**	**	**	2.60
17	**	**	3.0	2.0	2.5	**	**	**	**	2.50
20	**	**	3.0	2.0	2.6	**	**	2.0	**	2.70

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)
alt Paved Roads
Sep.2000 | Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	2.0	**	1.67	**	3.0	**	1.0	2.50

Nablus Province\Road Name: Jamal Abed-Naser
Road Classification: Overlaid Arterial
Date: Sep.2000 | Roadside: LT
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Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

)etail Visual Inspection Survey (DVI)
ısphalt Paved Roads
)ate: Sep.2000 | Roadside: RT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
••	••	4.0	3.0	2.0	4.6	1.0	3.0	3.33	3.45
••	••	••	3.67	1.67	4.2	••	3.0	••	3.35
••	••	3.0	3.25	3.5	4.0	••	4.0	••	3.50
••	••	3.0	4.0	3.2	5.0	••	5.0	••	4.00
••	••	4.0	3.0	2.6	4.8	••	••	••	3.70
••	••	4.0	3.33	3.33	4.33	••	4.0	••	3.75
••	••	3.5	2.0	2.67	4.0	••	3.0	••	3.00
••	••	••	2.0	4.0	4.0	••	3.0	••	3.20
••	••	••	••	1.75	4.0	••	••	4.0	3.15
••	••	3.0	4.0	4.5	4.33	••	••	3.5	3.85
••	••	4.0	3.2	4.0	4.8	••	••	••	4.00

Nablus Province\Road Name: Askar Street	Page 59
Road Classification: Overlaid Arterial	
Date: Sep.2000 / Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugaion	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
1	••	••	••	3.25	3.0	5.0	••	3.0	••	3.77
2	••	••	••	4.0	3.0	4.33	3.5	4.0	••	3.88
3	••	••	3.67	••	3.4	4.33	••	••	3.33	3.62
6	••	••	3.0	3.0	4.0	4.0	••	3.0	2.0	3.25
7	••	••	3.0	1.75	3.0	4.4	••	••	••	3.20
8	••	••	3.0	3.0	4.0	••	••	••	2.0	3.00
9	••	••	3.0	3.25	3.0	••	5.0	4.0	••	3.20
10	••	••	3.0	3.0	3.0	5.0	3.0	••	3.0	3.15
13	••	••	4.33	2.0	1.0	4.0	••	••	••	3.00
14	••	••	••	3.0	3.5	5.0	5.0	3.5	••	3.35
15.	••	••	3.0	••	4.0	4.0	•	3.0	••	3.50

Summary of Detail Visual Inspection Results (Average Condition Value)

ıl Visual Inspection Survey (DVI)
alt Paved Roads
Sep.2000 | Roadside: RT

Detril Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
••	••	••	2.33	3.6	3.5	••	3.0	2.25	3.00
••	••	••	2.33	3.0	3.4	••	••	2.33	2.77

Nablus Province\Road Name: Haifa B Street	Page 60
Road Classification: Overlaid Arterial	
Date: Sep.2000 / Roadside: LT	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
2	••	••	3.0	3.0	3.0	2.67	••	••	••	2.90
3	••	••	3.0	3.0	2.33	2.0	••	3.0	••	2.75
4	••	••	3.6	3.4	3.0	4.0	••	••	••	3.55
5	••	••	3.25	2.75	3.5	••	4.33	••	••	3.40
6	••	••	1.0	••	1.67	••	••	••	••	1.50

Summary of Detail Visual Inspection Results (Average Condition Value)

)etail Visual Inspection Survey (DVI)	
;sphalt Paved Roads	
)ate: Sep.2000	Roadside: One Direction

Nablus Province\Road Name: Al-Gazali Street		Page 61
Road Classification: Overlaid Arterial		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	2.0	1.0	2.0	**	**	**	**	1.75
**	3.0	2.33	**	1.0	**	**	**	4.0	1.80
**	**	1.0	1.0	2.0	2.0	**	**	**	1.60

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)	
ıalt Paved Roads	
: Sep.2000	Roadside: RT Lane

Nablus Province\Road Name: Fisal Street		Page 62
Road Classification: Overlaid Arterial		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	3.0	2.0	1.5	1.67	2.75	**	**	1.67	1.90
**	**	**	1.0	1.0	2.5	**	**	**	1.50
**	2.0	**	**	2.0	3.0	**	**	1.33	1.8

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

etail Visual Inspection Survey (DVI)	
sphalt Paved Roads	Age: 2 Years
ate: Sep.2000	Roadside: RT & LT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	3.0	1.0	1.33	**	**	2.5	**	1.75
**	**	1.0	3.0	**	**	**	1.0	**	1.50
**	**	1.0	3.0	1.0	**	**	2.0	**	1.75
**	**	**	**	1.75	1.0	**	1.0	**	1.40
**	**	3.0	1.0	1.5	**	**	2.0	**	1.80
**	**	3.0	2.0	1.0	1.0	**	**	**	1.60
**	**	1.0	1.0	2.0	**	**	**	2.0	1.80

Nablus Province\Road Name: Qablan Road		Page 63
Road Classification: Rehabilitated Village Access Road		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)	
alt Paved Roads	Age: 3.25 Years
: Sep.2000	Roadside: RT & LT

Detail Visual Inspection Data

utting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	1.0	1.0	1.75	**	**	2.33	**	1.60
**	**	**	**	1.75	1.0	**	1.0	**	1.40
**	**	**	2.33	2.75	**	**	3.0	**	2.80
**	**	**	3.0	2.0	4.0	5.0	3.67	**	3.30
**	**	**	3.0	2.25	1.0	3.0	2.5	**	2.40
**	**	**	**	3.0	3.0	5.0	3.75	**	3.20
**	**	**	**	2.2	**	**	3.0	**	2.60

Nablus Province\Road Name: Beita		Page 64
Road Classification: Rehabilitated Village Access Road		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

etail Visual Inspection Survey (DVI)	
sphalt Paved Roads	Age: 1.5 Years
ate: Sep.2000	Roadside: RT & LT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	3.0	1.0	1.0	**	**	3.0	2.0	2.10
**	**	3.0	2.5	1.5	**	**	3.0	**	2.40
**	**	1.0	1.0	1.6	**	**	1.0	2.0	1.60
**	**	2.0	1.0	2.0	**	**	1.5	**	1.80

Nablus Province\Road Name: Sabastia Beit-Omreen		Page 65
Road Classification: Rehabilitated Village Access Road		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)	
ialt Paved Roads	Age: 3.8 Years
: Sep.2000	Roadside: RT & LT

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	**	1.0	1.67	3.0	**	3.0	1.0	1.80
**	**	4.33	3.0	5.0	1.0	**	2.4	2.0	3.00
**	**	3.0	3.0	2.0	3.5	**	**	2.8	3.00
**	**	2.6	5.0	3.0	2.6	**	1.67	2.33	2.50
**	**	5.0	3.67	2.0	4.0	**	3.0	2.0	3.20

Nablus Province\Road Name: Till - Sarah		Page 66
Road Classification: Rehabilitated Village Access Road		
Date: Sep.2000	Roadside:	

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

)etail Visual Inspection Survey (DVI)	
ısphalt Paved Roads	Age: 1.8 Years
׀ate: Sep.2000	Roadside: RT & LT

Nablus Province\Road Name: Nablus -Till	Page 67
Road Classification: Rehabilitated Village Access Road	
Date: Sep.2000 / Roadside:	

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	3.0	1.0	**	**	**	1.0	**	1.50
**	**	2.0	1.0	**	**	**	2.0	2.0	1.80

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value

Summary of Detail Visual Inspection Results (Average Condition Value)

il Visual Inspection Survey (DVI)	
ıalt Paved Roads	Age: 2.5 Years
: Sep.2000	Roadside: RT & LT

Nablus Province\Road Name: Yasid - Farah	Page 68
Road Classification: Rehabilitated Village Access Road	
Date: Sep.2000 / Roadside:	

Detail Visual Inspection Data

Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value
**	**	3.0	1.0	**	**	**	1.0	**	1.50
**	**	3.0	2.0	2.0	**	**	3.0	**	2.30
**	**	3.0	2.0	2.5	**	**	3.0	**	2.50
**	**	**	1.0	2.5	**	**	2.67	**	2.10
**	**	**	1.0	1.25	4.0	**	2.33	**	1.90
**	**	3.0	1.0	2.25	**	**	3.0	**	2.20
**	**	2.0	1.0	**	**	**	2.0	**	1.80

Detail Visual Inspection Data

Section No.	Rutting	Corrugation	Patching	Settlement	Trav\Block Long.Cracking	Alligator Cracking	Pot Holes	Edge Distress	Raveling	Average Condition Value