إقـــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Developing a Pavement Management (PM) for Rafah City Regarding to Maintenance, Material, and Cost

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The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification

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تطوير نظام إدارة الرصفات لمدينة رفح فيما يخص (الصيانة و المواد و التكلفة)

Developing a Pavement Management System (PMS) for Rafah City Regarding to Maintenance, Material, and Cost

M. Sc. Thesis

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ **مهند صلاح محمد بريكة** لنيل درجة الماجستير في **كلية *الهندسة*** قسم الهندسة المدنية- البنى التحتية وموضوعها:

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Developing a Pavement Management System (PMS) for Rafah City Regarding to Maintenance, Material, and Cost

وبعد المناقشة العلنية التي تمت اليوم الأربعاء 29 ربيع الآخر 1436هـ، الموافق 2015/02/18م الساعة العاشرة صباحاً بمبنى طيبة، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق،،،

مساعد نائب الرئيس للبحث العلمي وللدراسات العليا

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Dedication

I would like to dedicate this thesis to my father's soul and to my mother for her unlimited support .

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Firstly, I thank Great Allah for giving me intention and patience to complete this work. Secondly, I wish to express my sincere gratitude particularly to my supervisor, **Prof. Shafik Jendia** for his patience and kind guidance throughout the period of field work and report writing. Without his attention and dedicated guidance, this report would not be successfully completed.

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Abstract

As the rest of Gaza Strip, Rafah City infrastructure facilities are suffering from being old. Among these facilities are the asphalt pavements, which were mainly constructed between 1998 and 2005. Since construction, Rafah City network was subject to lots of distresses.

Rafah network consists of 57 asphalt branches, which can be divided into 132 sections depending on the condition of each branch.

In order to keep the satisfactory pavements at their satisfactory condition, and to avoid more distresses in other streets, maintenance will be needed for these pavements. Pavement Condition Index (PCI) will be used to know what type of maintenance to be used to produce a good pavement management system by using computer software as Excel, Micro PAVER, and Arc GIS.

After calculating the PCI and identify the needed maintenance technique, one could easily calculate the cost of maintenance for each branch in the network. If maintenance of all branches started by next year, the costs would amount to $3,732,434. Meanwhile, if maintenance delayed five years, the costs would be $6,607,232 and an amount of $11,827,017 for ten years if nothing were done to the current state of the pavements assuming that no new pavements are constructed in the next ten years. In conclusion, we need to maintain the entire Rafah City network to avoid more costs in the future.

Due to the lack of funding, a priority index, for the whole network will be presented to help the decision-makers to take the right decision and make optimum use of allowable funds.

Key words:

Pavement management system, Pavement maintenance type, Pavement maintenance cost, Micro PAVER, Rafah City, Rafah City evaluation.

ملخص البحث

كجزء من قطاع غزة تعاني مدينة رفح من قدم مرافق البنية التحتية، مثل الشوارع الإسفلتية و التي أنشأ غالبها في الفترة المحصورة بين العامين ١٩٩٨ و ٢٠٠٥، و خلال الفترة الزمنية التالية نشأ الكثير من العيوب في طبقة الأسفلت في شبكة الطرق لمدينة رفح.

مدينة رفح تتكون من ٥٧ شارع أسفلت حيث تم تقسيم هذه الشوارع إلى ١٣٢ قسم و ذلك طبقا لظروف هذه الشوارع.

حتى تبقى الشوارع ذات الأسطح الجيدة في نفس حالتها و تجنب أي تشوهات جديدة يجب القيام بعمليات الصيانة، و معرفة نوع الصيانة المطلوبة نحتاج حساب معامل حالة الرصفة الذي من خلال معرفته نستطيع إنشاء نظام جيد لإدارة الرصفة، حيث تم استخدام برامج الحاسوب مثل Excel و Micro PAVER و Arc GIS.

من خلال حساب معامل حالة الرصفة تم معرفة التكلفة الحالية لعملية الصيانة لكل شوارع مدينة رفح التي قدرت بحوالي 3,732,434 $ و لكن في حالة عدم الصيانة خلال العام هذه التكلفة سوف تغير إلي 6,607,232 $ بعد خمس سنوات من التاريخ الحالي و 11,827,017 $ بعد عشر سنوات، و ذلك مع إهمال الشوارع الجديدة التي من المتوقع إنشاءها خلال العشر سنوات القادمة، و مع زيادة التكلفة بصورة كبيرة في حالة عدم الصيانة الفورية فشوارع مدينة رفح تحتاج إلي صيانة حتى يتم تجنب مزيد من التشوهات المستقبلية.

بسبب نقص التمويل، تم حساب معامل الألوية لكافة الشبكة، و تم ترتيبها حتى تساعد صناع القرار في اتخاذ القرار الأمثل حسب التمويل المتاح.

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Abbreviations

AC	Asphalt Concrete
ADT	Average Daily Traffic
AO1	Very Thin Asphalt Overlay Layer (3-5 cm)
AO2	Thick Asphalt Overlay Layer (5-7 cm)
ASTM	American Society of Testing and Materials
BB	Benkelman Beam
CF	Road Classification Factor
FWD	Falling Weight Deflectometer
GIS	Geographic Information System
HMAC	Hot Mix Asphaltic Concrete
I.F	Road Importance Factor
MF	Maintenance Cost Factor
M&R	Maintenance and Rehabilitation
PCC	Portland Cement Concrete
PCI	Pavement Condition Index
PI	Priority Index
PMS	Pavement Management Systems
RC	Reconstruction
RM	Routine Maintenance
S.F	Citizen Complaints Factor
TF	Traffic Volume Factor

Chapter One: Introduction

1.1 Background

"Pavement management systems (PMS) are used by agencies to assist in identifying cost-effective strategies for preserving the pavement network and for determining the level of funding required to meet agency goals for desired levels of service. These activities are conducted using pavement inventory and condition information stored in the pavement management database and pavement analysis models, which include pavement deterioration models, treatment rules, and cost models. An agency can use its PMS to evaluate various pavement rehabilitation, maintenance, and preservation strategies and estimate the impact of those strategies on the future condition of the pavement network for various budget levels" [1].

Rafah is a City located in the southern Gaza Strip. It is far about 8.85 km from Mediterranean Sea coast, 38 km from Gaza City, and 13 km from Khanyounis City. It is bounded from east by green line, and from west by Mediterranean Sea, and from north by Khanyounis City, and Egypt from south. Rafah has a total area of around 30500000 m² and a population of about 230000 people, as of the year 2013. The Rafah Governorate manages roads having a total length of 204.5 km. 129 km of these roads have good surface conditions [2]. Figure (1.1) shows exact location of Rafah City.

Figure (1.1): Rafah City location and borders [3]

Distresses found in the pavements of Rafah City can be assessed and evaluated by first knowing the amount and the degree of danger of such defects. Then rating them by pavement condition index (PCI) and entering the collected data to the MicroPAVER program. By developing a GIS program, this latter program will take the results from MicroPAVER and then will provide a system that shows the best decision to take with the lowest costs to maintain the pavements. The cost aspect is incredibly important considering the bad economic situation in the Gaza Strip.

The result of this study, by the pavement management system software, gives a description of each section of the Rafah pavements. It also rates these sections according to the health of the pavement, year of construction, type of materials needed for pavement maintenance, the amount of funds needed for providing maintenance and lastly the eventual future amount of funds needed if the maintenance process was to be delayed. The previous statements about the funds prove that preserving pavements in good conditions is way cheaper economically than waiting for them to wear out and then replacing them.

1.2 Problem statement

As the rest of the Gaza Strip, Rafah's pavement network is under bad conditions. That is because most Rafah's pavements were constructed between the year; 1998 and 2005. No actual maintenance took place during the following years. That worsened the situation and caused more deterioration to the Rafah pavements. If no management system for these pavements is in place soon, the pavements will end up in a much worse situation in a few years. The only solution then would be reconstructing the pavements totally. That requires a huge amount of funds. Therefor the best solution to the problem is to set in place a pavement management system instantaneously. The cost of maintaining all of Rafah's pavements will double in 5 years if nothing is done right away. If the decision makers in five years do not take measures to fix the problem, another doubling of the costs is expected after that.

There are many factors causes problem to Rafh City network:

- Increase rate of deterioration.
- Overloading of vehicles.
- Rapid traffic growth.

- Poor maintenance. (improper materials, bad habits and wrong implementation)
- Limited resources (geometry, funds, equipments, materials …etc)
- Insufficient information for decision-making.
- Inefficient current traditional management system.

1.3 Objectives

The primary objective of this research is to develop a pavement management system. Specifically, this research work is intended to achieve the following objectives:

- Establishing a suitable database for the maintenance works of Rafah City pavements.
- Using software programs like Micro PAVER with ArcGIS software to review, interpret and evaluate data for supporting decisions made.
- Developing software program to present pavements data, cost, and materials that help decision makers to select maintenance type.

1.4 Research importance

The importance of this research summarized into the following points:

- Establish database for Rafah City pavements.
- Study the priorities to maintain pavements with minimum available funds to continue with good pavement service.
- Develop useful Excel software for finding a way to decrease rate of pavement deterioration, guide to adjust work plan, and schedules to reflect changing conditions.

1.5 Methodology

To have the previous objectives, there are many necessary steps should be followed to work this research as the follows:

- Reviewing previous studies related to a pavement management system.
- Getting data from municipality of Rafah about the network and the actual system of maintenance.
- Monitoring pavements in Rafah City, to determine all distresses, and types of these distresses.
- Using the Micro PAVER software, to evaluate the pavements.
- Establishing direct integration between Micro PAVER outcomes and Arc GIS databases.

1.6 Thesis structure

Thesis includes five chapters and four appendices. A brief description of the chapters' contents is presented below:

Chapter (1): this chapter presents an introduction, which highlights the concept of research. In addition, statement of problem, aim, objectives, research contribution, methodology of research are described and study limitation.

Chapter (2): this chapter shows an introduction related to pavement management system (PMS), this chapter focuses on the part "Pavement". It also illustrates the general structure of a pavement, pavement distresses, ways of failure and methods of pavement evaluation. Also discusses pavement maintenance where maintenance aims, types, strategies, and techniques.

Chapter (3): this chapter discusses how to evaluate Rafah city pavements by using pavement condition index (PCI). Rafah city network divided to branches then to sections, then to sample units. Also discuss using of computer software's as Micro PAVER, and Arc GIS, and to enter data to these software's.

Chapter (4): this chapter shows outputs of Micro Paver and Arc GIS software's, gives results to easily deal with network information and outputs. Also calculate maintenance cost and future vision according to maintenance cost for next five and ten coming years. Also calculate priority index to all Rafah City pavement network.

Chapter (5): this chapter presents the conclusion derived from the experimental results presented in the previous chapters. This chapter also contains recommendations to fix the problem presented in this study.

Chapter Two: Literature Review

2.1 Introduction

Pavements age with time and gradually deteriorate due to environmental effects, traffic loadings, and other factors. Resources for maintaining and repairing roads can be efficiently managed so that the money is spent in the right place at the right time by knowing the current condition of the pavement network and the rate at which it deteriorates. Many local agencies have recognized the benefits of performing regular pavement condition surveys to evaluate the existing pavement conditions and to allocate maintenance and construction funds [1].

Generally, pavements are divided mainly into flexible and rigid classes. Flexible pavements contribute most percent of Rafah paved roads. Therefore, focus will be concentrated on flexible pavements analysis. Figure (2.1) shows a typical flexible pavement structure. It is comprised of several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath.

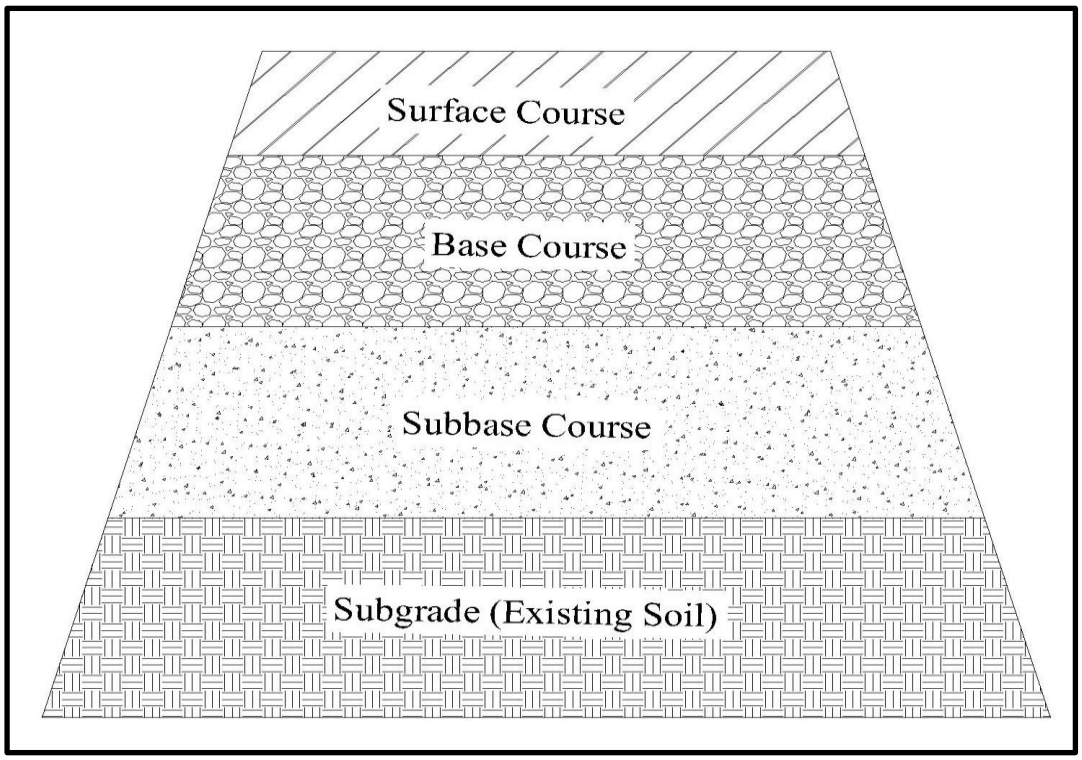


Figure (2.1): Typical flexible pavement structure.

They also support loads through bearing rather than flexural action as in rigid pavements. Figure (2.2) illustrates the distribution of load stresses in flexible

pavement. The design is such that the load transmitted to each successive layer does not exceed the layers load-bearing capacity.

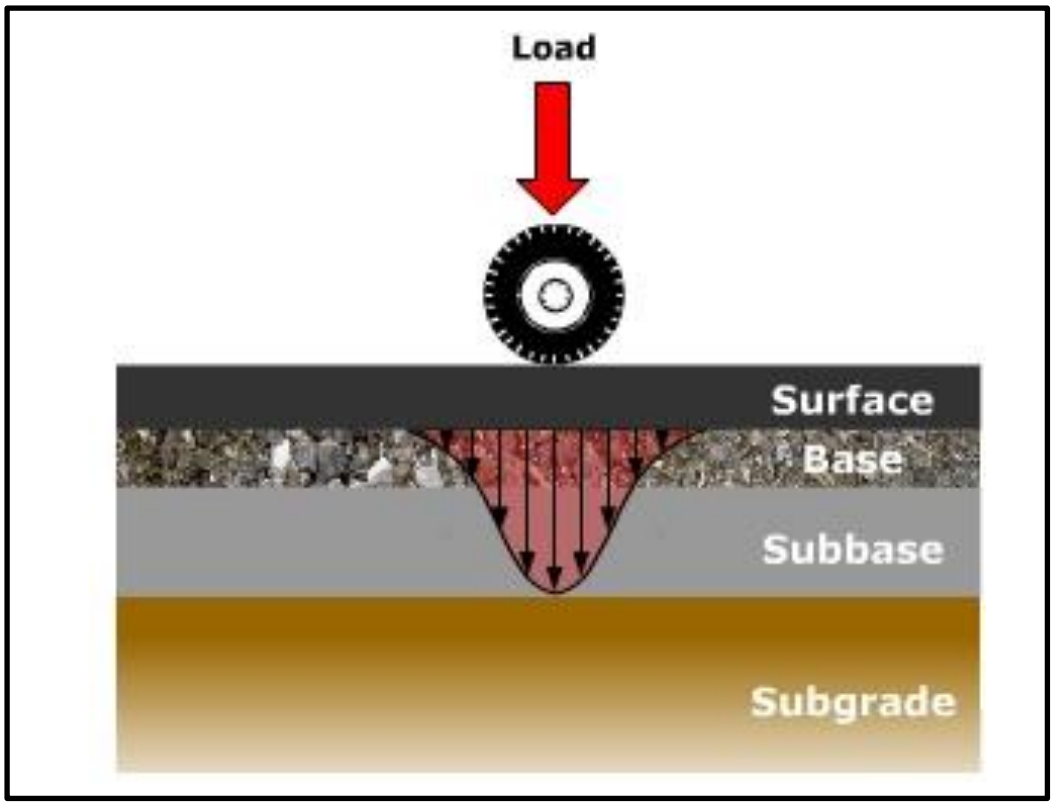


Figure (2.2): Distribution of load stresses in flexible pavements.[4]

Typical layers of a flexible pavement includes asphalt, base course, sub-base, and natural sub-grade [5,6],

1. Asphalt layer:

   It is generally comprised of a wearing and a binder course layers. It includes a mixture of various selected aggregates bounds together with asphalt cement or other bituminous binders. Its function is to prevent the penetration of surfaces water to the road base, provide smooth, well bond surface, resist the stresses and furnish a skid resistant surface.

2. Road base:

   Base course plays a very important role in the overall integrity of bituminous pavement layer. The base course is placed between the prepared sub base and the top pavement layer. Base course serves a variety of purposes depending on the construction practices and the environment. It is noted that gradation of the base course is the very important factor in success of aggregate as a base

course. Since the gradation of the aggregate can affect structural capacity, drainage, and frost susceptibility, control of gradation is a principal concern for most engineers.

3. Sub base:

   Sub base is the layer of aggregate material laid on the subgrade, on which the base course layer is located. It may be omitted when there will be only foot traffic on the pavement, but it is necessary for surfaces used by vehicles. Sub base is often the main load-bearing layer of the pavement. Its role is to spread the load evenly over the subgrade. The materials used may be either unbound granular, or cement-bound. The quality of sub base is very important for the useful life of the road. Unbound granular materials are usually crushed stone, crushed slag or concrete, or slate.

4. Subgrade:

   The ability of the subgrade (natural or improved underlying soils) to support loads transmitted from the pavement is a critical factor in pavement design. In roadway construction, the subgrade provides the foundation for the pavement. Different types of soils have different abilities to provide support. In general, a sandy soil, for example, will support greater loads without deformation than a silty clay soil.

2.2 Pavement management system

PMS is a coordinated and systematic process for carrying out all activities related to providing and maintaining pavements. The primary goal of the PMS is to predict the pavement condition and the cost associated with its maintenance and rehabilitation over a given time frame, and aid in the planning and programming of works. With a properly developed and implemented PMS, it is possible to make good, well informed, and consistent decisions on maintenance, rehabilitation or reconstruction of pavements. Pavement management systems can assist the engineer in identifying the most appropriate treatment on selected sections of the road network through the use of economic analysis, predictive models and time-series information. The pavement management can be taken up at two levels: network level and project level [7].

2.3 Pavement management overview

Pavement management is a systematic method of [8]:

1. Assessing current pavement conditions.
2. Determining maintenance and rehabilitation needs.
3. Prioritizing these needs to make the best use of anticipated funding levels. An APMS is typically a computerized software program, such as Micro PAVER, that facilitates the storage and analysis of airport pavement-related data.

2.3.1 Pavement management historical perspective

The concept of pavement management has evolved significantly since its 1970s inception. The intent of original pavement management practitioners was to develop an objective approach to do the following [8]:

1. Assess current pavement condition.
2. Predict future pavement condition.
3. Prioritize pavement rehabilitation needs over a multi-year period in an effort to optimize the use of available funding.

As standardized condition survey techniques came into place, more information regarding the cause of pavement deterioration became available. This information was then used to readily assess available repair alternatives and select the better repair strategy. This approach greatly improved the effectiveness of selected rehabilitation treatments since they were now being chosen to address the deficiencies present and prevent their recurrence.

Finally, as computerized pavement management systems became available, an even more sophisticated level of analysis became possible. With today's systems, the results of the pavement condition surveys are used not only to assess current pavement conditions but to identify pavement deterioration trends as well. This capability provides the agency with the ability to forecast future pavement conditions. As a result, agencies are able to assess the long term impacts of decisions made today on future network conditions and identify the optimal time for repair so that funding can be scheduled in advance of the forecasted need. Figure (2.3) shows how the relationship between pavement condition and pavement age.

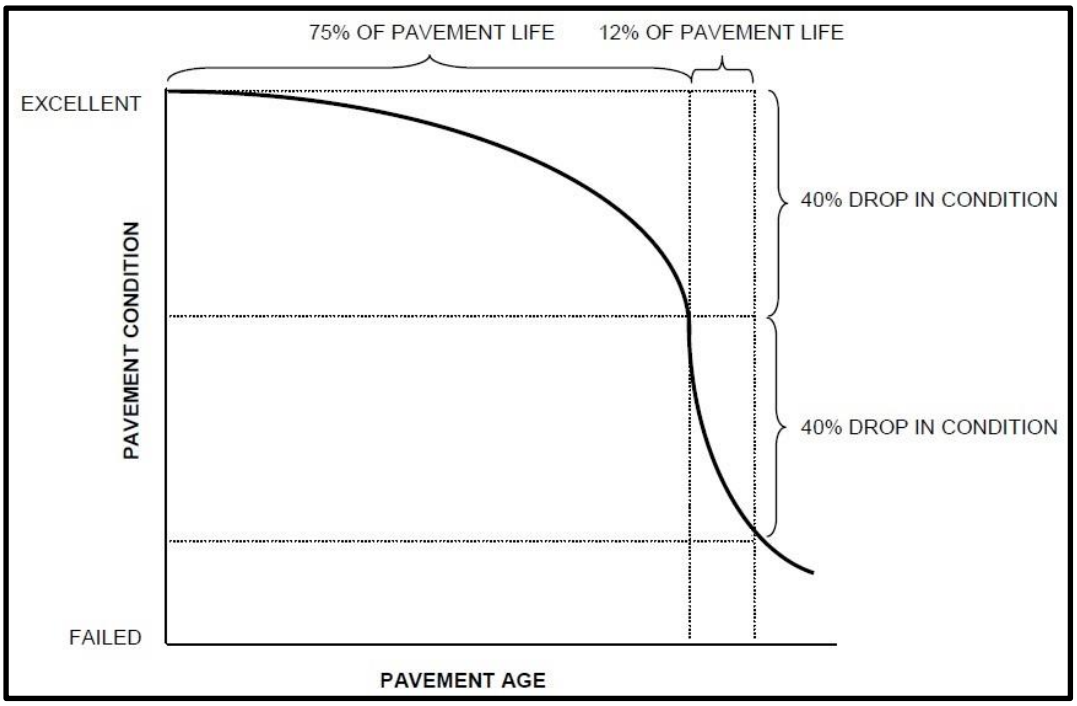


Figure (2.3): Typical pavement condition life cycle [8]

2.3.2 Levels of pavement management

Pavement management provides information for decision making at two distinct levels: network-level management and project-level management.

- Network-Level pavement management

  Network-level pavement management involves the evaluation of all pavements under an agency's jurisdiction to determine future maintenance and rehabilitation needs for the development of multi-year budget plans. The level of pavement evaluation required to perform this type of management involves visually inspecting representative samples of pavement. Based on the analysis of the network-level pavement condition data, candidate pavement areas are selected for potential maintenance and rehabilitation (M&R) projects. General unit costs are used at the network level and specific designs are not developed [8].

- Project-Level pavement management

  Once a pavement area has been identified as a candidate for repair, it is then evaluated at the project level. This level of analysis requires higher inspection sampling rates. Additional testing, such as nondestructive testing and coring, is often used during project-level analysis to provide additional knowledge about

pavement condition and distress mechanisms. Based on the results of project-level analysis, specific treatments (such as an overlay) can be selected for the candidate pavement areas and more accurate cost estimates can be developed [8].

- Network inventory

  Network inventory is used to define the physical characteristics of the pavements being managed. Typically, the collected information includes construction, maintenance, traffic, and condition data. It is important to keep two guidelines in mind when determining the extent of historical information to include in the inventory. First, the data should be accessible so that substantial time is not invested in a search of construction records. Secondly, the collected information should serve a purpose [8].

- Condition assessment

  Pavement management decisions depend on some method of pavement evaluation. The method selected to evaluate pavement condition is extremely important because it is the basis of all recommendations [8].

- Database

  Once the network inventory and pavement condition assessment data have been collected, a database can be established to use the information. Although a manual filing system may be possible for a small network, the efficiency and cost-effectiveness of storing data on a computer makes an automated database the most practical alternative [8].

- Data analysis

  Data analysis can occur at the network- or project-level. At the network level, potential rehabilitation needs of the entire network are evaluated and prioritized for planning and scheduling budget needs over a multi-year period. The objective of network level analysis is to valuate rehabilitation needs for a future time period and prioritize project lists so that the agency makes the best use of the limited funds available for M&R. After the planning and programming decisions have been made during the network-level analysis, the information in the database can be used to supplement a project-level analysis. At the project-level, each individual project is investigated in detail to determine the appropriate rehabilitation treatment [8].

- System outputs

  Results of planning analyses are useful only if the information provided can be easily conveyed. There are a number of different methods for presenting the results of the analyses discussed in the previous sections including tables, reports, graphs and maps [8].

The Micro PAVER pavement management software, provides a direct GIS link between CAD maps and pavement management database to facilitate the development of this type of output.

2.4 Pavement distresses

External indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses are cracks, rutting, and weathering of the pavement surface [9].

Distress is defined as a condition of pavement structure that reduces serviceability or leads to a reduction in serviceability. Serviceability is defined as the ability of a pavement to provide a safe and comfortable ride to its users. Distresses may be treated with a range of repairs, each having a varying degree of success. Some of the treatments shown for the distresses will provide only a short term solution, which may be all that is needed [10].

Flexible pavement surface distresses include a wide variety of pavement defects that generally fall into the following categories [9]:

1. Alligator cracking

   Alligator cracking is a series of interconnected cracks in an asphalt layer forming a pattern, which resembles an alligator's hide or chicken wire. The cracks indicate fatigue failure of the asphalt layer generally caused by repeated traffic loadings and this distress allows water to penetrate the surfacing materials and subgrade, which furthers the damage. Alligator cracking, also called fatigue cracking.

2. Bleeding

   Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement or tars in the mix, excess application of a bituminous sealant, or low air void content, or a combination thereof. It occurs when asphalt fills the voids of the mix during

hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface.

3. Block cracking

   Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 0.3 by 0.3 m to 3 by 3 m. Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling, which results in daily stress/strain cycling. It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings, and therefore, are found only in traffic areas, that is, wheel paths.

4. Bumps, and sags

   Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including buckling or bulging of underlying Portland cement concrete (PCC) slabs in asphalt concrete (AC) overlay over PCC pavement, frost heave (ice, lens growth), and infiltration and buildup of material in a crack in combination with traffic loading. Sags are small, abrupt, downward displacements of the pavement surface.

5. Corrugation

   Corrugation, known as “wash-boarding”, is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals, usually less than 3 m (10 ft) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress usually is caused by traffic action combined with an unstable pavement surface or base.

6. Depression

   Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a "birdbath" area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning.

7. Edge cracking

   Edge cracks are parallel to and usually within 0.3 to 0.5 m of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up.

8. Reflection cracking

   This distress occurs only on asphalt surfaced pavements that have been laid over a PCC slab. It does not include reflection cracks from any other type of base, that is, cement- or lime-stabilized; these cracks are caused mainly by thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimension beneath the AC surface will help to identify these distresses.

9. Lane/Shoulder drop-off

   Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level.

10. Longitudinal and transverse cracking

    Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by poorly constructed paving lane joint, and Shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or daily temperature cycling, or both. Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. These types of cracks are not usually load-associated.

11. Patching and utility cut patching

    A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress.

12. Polished aggregate

    This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating.

13. Potholes

    Potholes are small usually less than 750 mm in diameter bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering.

14. Railroad crossing

    Railroad crossing defects are depressions or bumps around, or between tracks, or both.

15. Rutting

    A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a rainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades, usually caused by consolidated or lateral movement of the materials due to traffic load.

16. Shoving

    Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements.

17. Slippage cracking

    Slippage cracks are crescent or half-moon shaped cracks, usually transverse to the direction of travel. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs in overlaps when there is a poor bond between the surface and the next layer of the pavement structure.

18. Swell

    Swell is characterized by an upward bulge in the pavement's surface, a long, gradual wave more than 3 m long. Swelling can be accompanied by surface cracking. This distress usually is caused by frost action in the subgrade or by swelling soil.

19. Weathering and raveling

    Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, raveling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under raveling.

2.5 Pavement evaluation

In order to carry out design of final stage pavements or pavement rehabilitation, the existing pavement condition must be evaluated. Such an evaluation usually involves the assessment of the existing pavement structural adequacy, surface distress, roughness, and rutting. The design of final stage pavements may only involve the assessment of pavement structural adequacy because the first stage pavement is usually not old enough to exhibit distresses related to traffic loading and the environment [11].

Pavement evaluation techniques differ between different highway agencies. Some agencies , emphasis has been placed on carrying out structural evaluation of pavements using non-destructive deflection testing. Another consideration which should be recognized to develop and implement a Pavement Management System (PMS). The PMS database provides a wealth of information about the pavement network and individual pavement section performance. This information should not be overlooked during the pavement evaluation stage of pavement rehabilitation design [11].

The pavement evaluation systems are basically categorized into two major types: functional and structural evaluation.

2.5.1 Structural evaluation

Structural evaluation deals with the quantitative assessment of structural adequacy of the pavement for rehabilitation. It is dependent upon the engineer's ability to evaluate the structural properties of the pavement components. Structural adequacy is the primary response of pavement to transient loads and consists in deflections, stresses, strains and pavement deformation at critical points in pavement layers [12] in [13]. Structural evaluation can be divided into:

1. Destructive field tests

   This type of evaluation is done by take part of the road for examination in the laboratory as it happens in the case of (core test), and this type of evaluation is the base type in a number of countries that lack modern equipment in the evaluation, and it take time, effort and cost [14].

2. Non-destructive field tests

   Non-destructive tests can also be less labor intensive, require less time to conduct, ultimately cost less, and can be just as accurate as conventional destructive tests. Non-destructive test methods that require less time to conduct and cost less can be used to perform more tests on a given section of pavement. This increase in the number of sampling locations for a given section of pavement statistically provides a greater confidence in the measured pavement property. Most common devices are:

   - Benkelman beam (BB):

     The Benkelman beam is a deflection-measuring device developed in 1953 by A.C. Benkelman of the Bureau of Public Roads, (Figure 2.4). The work

procedure is to measure the deflection for a point beside pavement edge with 9 ton truck (axle load) and follow the following steps [15]:

1. Obtain inspection point every (20-50 m), and 150 m in long distances. Every point should be far from pavement edge a distance that depends on lane width as shown in Table (2.1):

Table (2.1): Inspection sample distance from lane edge. [15]

Lane width (m)	Distance from pavement edge (m)
2.5 m or less	0.5 m
3 m	0.6 m
3.25 m	0.8 m
3.5 m or more	1 m

2. Stopped truck load with inspection point accrue in the middle of the back tires.
3. Keep the pointed top of the device at the point and take the first reading.
4. Fix Device and moved truck 5 m, then take the second reading, (Figure 2.5).

Deflections values will be taken by the device, and values will be corrected according to load and temperature factors.

Figure (2.4): Benkelman device [16]

Figure (2.5): Use Benkelman device [16]

- The falling weight deflectometer:

  The Falling Weight Deflectometer (FWD) is a nondestructive testing device used to measure the deflection of the pavement surface due to an impact load. The impact load is generated by a falling weight that is dropped on to a buffer system that transmits a dynamic load to the pavement surface through a circular plate. The deflections of the pavement surface caused by this dynamic load are measured by a sensor located below the center of the circular plate and by other sensors that are attached to a bar and placed at various locations away from the load plate. Typically the sensors attached to the bar are placed at distances of 8, 12, 18,24, 36, and 60 inches from the center of the load plate [17].

  The FWD data can be used to estimate the elastic modulus of pavement layers using a procedure called back calculation. In back calculation, the elastic moduli for pavement layers are assumed, and the theoretical deflections are computed using a multi-layer model. The moduli of pavement layers are adjusted until the theoretical deflections match the measured deflections within a specified tolerance. The thickness of the pavement layers should be accurately known to perform back calculation. Several programs for performing back calculation are available. The stresses and strains computed using these back calculated moduli are used as inputs in mechanistic pavement design and analysis procedures. Such

procedures are used to estimate damage accumulation in the pavement caused by traffic, estimate the remaining life of the pavement, determine cost effective rehabilitation strategies, and to compute overlay thickness, Figure (2.6) shows falling weight deflectometer [17].

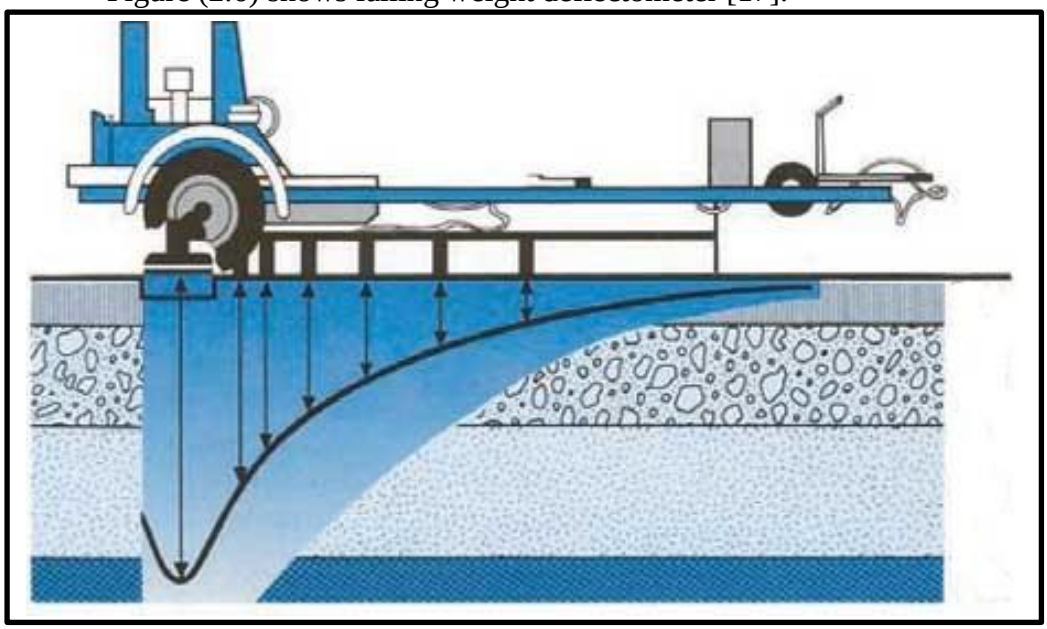


Figure (2.6): Falling weight deflectometer [17]

2.5.2 Functional evaluation

Pavement condition refers to the condition of the pavement surface in terms of its general appearance. A perfect pavement is leveled and has a continuous and unbroken surface, while a distressed pavement may be fractured, distorted, or disintegrated. In order to obtain a useful condition assessment of the pavements, unbiased and repeatable survey procedures must be used. To provide for maximum usefulness, the survey procedures must be easily understood and relatively simple to perform in the field. The most common survey technique used in the World Wide is the Pavement Condition Index (PCI) procedure developed by the US Army Corps of Engineers. The condition of the pavements is determined by a field survey of the surface operational condition of all pavements using this procedure. The PCI - a measure of the pavement's surface operational condition and ride quality on a scale of zero to 100, with 100 being excellent - has several unique qualities, which make it a useful visual surveying tool. It agrees closely with the collective judgment of experienced pavement engineers and has a high degree of repeatability [18].

2.6 Pavement maintenance

Pavement maintenance is the key to pavement preservation. An effective pavement preservation program integrates many maintenance strategies and treatments.

The selection of the right maintenance strategy at the right time is of utmost importance for an effective management of highway pavements. The appropriate maintenance strategy will be influenced by the type, severity, and extent of the pavement surface distresses and the structural and roughness condition of the pavement. Choosing the right treatment also depends on the extent or frequency that the distress occurs[10].

2.6.1 Types of pavement maintenance

1. Preventive maintenance

   Planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity). Surface treatments that are less than two inches in thickness are not considered as adding structural capacity.

   A preventive maintenance program has been shown to often be six to ten times more cost-effective than a "do nothing" strategy. Conservatively, $1.00 spent for preventive maintenance will provide the same pavement condition that costs $10-15 if rehabilitation is needed. By extending the life of a pavement until it needs rehabilitation, preventive maintenance allows the department to even out its budget for both maintenance and construction.

   Preventive maintenance treatments include: crack sealing, armor coating/chip sealing, fog sealing, broom or scrub seals, rut filling (in some cases), and thin overlays [10].

2. Corrective maintenance

   Performed after a deficiency occurs in the pavement, such as moderate to severe rutting, raveling or extensive cracking. This may also be referred to as "reactive" maintenance [10].

   The differences between preventive and corrective maintenance occur in the timing and cost. Corrective maintenance is reactive, i.e., it is done after a road is in need of repair so the cost is greater. Delays in corrective maintenance result in even larger costs since defects and their severity continue to increase.

Corrective maintenance treatments include: structural overlays (3 inches or greater), milling, patching and crack repair [10].

3. Emergency maintenance

Performed during an emergency situation, such as a blowup or severe pothole that needs repair immediately. This could also include temporary treatments that hold the surface together until a more permanent treatment can be performed [10].

Emergency maintenance is often related to safety and time, with cost not being a primary consideration. Likewise, materials that may not be acceptable for preventive or corrective maintenance may be the best choice for emergency situations, (Figure 2.7).

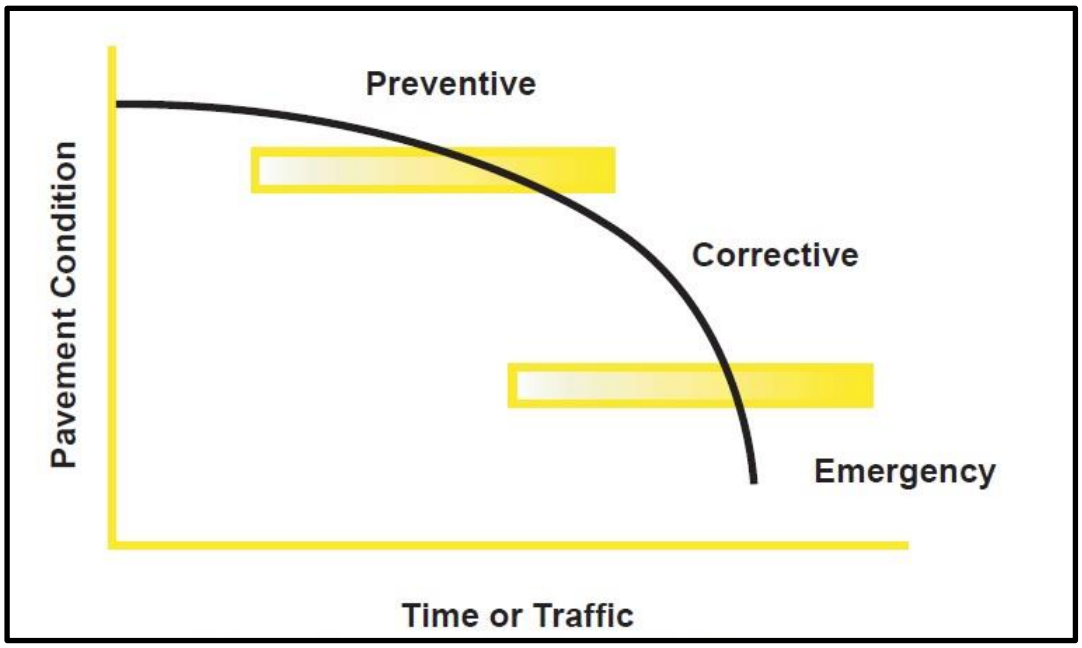


Figure (2.7): Categories of pavement maintenance [10]

2.6.2 Recommended treatment practices

There are many variables that influence the selection of the right treatment. After the treatment is selected, there are still many choices as to the proper procedures and materials to use [10].

1. Preventive maintenance

✓ Crack filling

The placement of materials into nonworking cracks to substantially reduce the intrusion of incompressible and infiltration of water, while also

reinforcing the adjacent pavement. Crack filling should be distinguished from crack sealing [10].

✓ Crack sealing

A maintenance procedure that involves placement of specialized materials into working cracks using unique configurations to reduce the intrusion of incompressible into the crack and to prevent infiltration of water into the underlying pavement layers.

Crack filling and sealing is our first line of defense in roadway maintenance. Crack sealing should be done within 2 years after an asphalt overlay. Cracks 1⁄4-inch or wider should be filled or sealed before rainfall seasons or before maintenance surface treatments, such as fog seals, scrub seals, slurry seals, chip seals, maintenance overlays, etc., are applied [10].

Crack sealing operations can be very labor intensive. A value engineering study concluded that 66 percent of the total cost for these projects was for labor, 22 percent for equipment, and 12 percent for materials. Because crack sealing takes a lot of time, workers are exposed to traffic and motorists encounter delays. Therefore, it is safer and usually more cost-effective to use a product that will last longer, even if it is more expensive [10].

✓ Seal coats

Asphalt roadway surfaces tend to deteriorate over time as the elements of nature cause the asphalt to become hard and brittle. This often occurs in the form of raveling or surface cracks. Application of a seal coat can restore the resilient properties of the asphalt surface and prevent further deterioration. Seal coats will not help the load carrying ability of a roadway.

Seal coats commonly used in roadway maintenance are fog seals, scrub seals, slurry seals, and chip seals. Seal coats should not be placed over AC mixes with a history of moisture sensitivity or stripping problems [10].

✓ Fog seal

A light application of slow setting asphalt emulsion diluted with water and without the addition of any aggregate applied to the surface of a bituminous pavement. Fog seals are used to renew aged asphalt surfaces, seal small cracks and surface voids, or adjust the quality of binder in newly applied chip seals [10].

✓ Scrub seal (Broom Seal)

Application of a polymer modified asphalt to the pavement surface followed by the broom scrubbing of the asphalt into cracks and voids, then the application of an even coat of sand or small aggregate, and a second brooming of the aggregate and asphalt mixture. This seal is then rolled with a pneumatic tire roller [10].

A scrub seal may be used effectively to fill cracks in cases of low to moderate non-working cracks, as long as the roadway profile is good [10].

✓ Slurry seal

A mixture of slow setting emulsified asphalt, well graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to improve skid resistance [10].

✓ Chip seal

A surface treatment in which the pavement is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non-load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low volume roads [10].

2. Corrective maintenance

✓ Full depth asphalt repair

Full depth asphalt repair should be considered anytime you have rutting greater than 3⁄4 ", corrugations and shoving, surface depressions, or a series of potholes [10].

The first step of full depth patching is to cut an area, 1-2 feet larger than the distressed area needing repair, by using a wheel cutter or pavement saw. Use a backhoe, milling machine, or front-end loader to remove as much of the pavement as needed, making sure the subgrade is stable. If the subgrade is unstable, remove it also. Restabilize and compact the subgrade to proper depth, using a plate packer. Clean all edges and apply a tack coat to all vertical edges and to the base, if desired. Dump hot-mix asphalt directly into the excavated area, making sure to use enough to allow for compaction. Compact the edges first, then compact from the low to the high side,

overlapping about 6-10 inches with each pass. When finished, the patch should match the existing surface [10].

- ✓ Spray injection patching

  Spray injection patching is a quick and safe method that can be used to repair alligator cracking, transverse cracking, edge breaks, depressions, rutting and potholes [10].

  Asphalt mixes basically consist of two components – the aggregate, which provides the structure for the mix, and the asphalt binder, which "glues" it all together. The spray injection pothole patcher has two separate storage tanks one for the aggregate and the other for the asphalt binder. The asphalt and aggregate are mixed as they travel under pressure through the machine's spray hose; the mix is then sprayed into the pothole, filling it. A layer of aggregate is then placed on top of the patched area [10].

- ✓ Patch using Cold-Mix asphalt

  There are numerous types of distress that may be encountered in our highways. The reason for the distress should be determined and action taken to correct the condition that caused the problem [10].

  Cold-mix asphalt is a combination of unheated aggregates, fillers, and asphaltic oils. Although gravel and/or sand are the most commonly used aggregates, asphalt millings and crushed concrete have also been used successfully. Clay is the most commonly used filler. Emulsified asphaltic oil is recommended but cutbacks can also be used [10].

- ✓ Hot mix asphalt patch

  When hot mix asphaltic concrete (HMAC) is available, this is often the material of choice for repairing ruts, corrugations, depressions or raveling. This practice is commonly referred to as skin patching or surface patching. Most skin patches are 1 to 4 inches deep depending on what distress is being remedied. Skin patches may be feathered at the ends to meet an existing grade, the grade at the ends of the patch may be milled to get a better transition, or a portion or the entire distressed pavement may be milled.

  After milling, broom the surface and apply a tack coat, waiting until the oil breaks before starting to lay the hot mix. Use enough trucks to assure material can be supplied to keep from having a cold joint in a lane. The lay

down machine speed should be consistent and the use of the vibratory screed is recommended since about 80% of the density occurs as a result of its use [10].

- ✓ Profile milling

  Profile milling may be considered as a possible treatment to restore roadway cross sections، when wheel rutting is greater than 1⁄2". This may be followed up with either a chip seal or machine patch. Milling may also be used to treat roads with excess asphalt or extreme cases of raveling [10].

3. Emergency maintenance
   - ✓ Hand patching

     The Strategic Highway Research Program looked at three methods of repairing potholes [10]:

     - ☒ The throw-and-roll method, in which the crew simply fills the pothole with patching material, then compacts the patch by driving over it.
     - ☒ The semi-permanent method, which involves squaring up the edges of the pothole with a saw or other equipment، placing the repair material, and compacting it with a small vibratory compactor. The technique is effective but very labor-intensive.
     - ☒ The spray injection method, which employs special truck or trailer mounted equipment that shoots asphalt and aggregate into the pothole. Although the spray-injection equipment is expensive، the technique is extremely fast and can be done by a crew of just one or two workers.

2.6.3 Maintenance techniques

Remedial measures for different types of distress severity are shown in Table (2.2). As an example, rutting distress requires shallow patching when its severity is medium but deep patching is required when it is high [19].

Table (2.2): Remedial measures for different types of distress severity. [19]

ID	Distress Type	Distress Severity (Density)		
		Low	Medium	High
1	Alligator Cracking	X4	X1	X2
2	Bleeding	-	X8	X8
3	Block Cracking	X4	X4	X4
4	Bumps and Sags	-	X1	X1
5	Corrugation	-	X2	X2
6	Depression	-	X2	X2
7	Edge cracking	X4	X4	X1
8	JI Reflection cracking	X4	X4	X1
9	Lane Shoulder Dropoff	-	X7	X7
10	Long & Trans Cracking	X4	X4	X1
11	Patching and Util Cut Patching	-	X1	X1
12	Polished Aggregate	-	-	-
13	Potholes	X1	X1	X2
14	Rail road Crossing	-	X1	X1
15	Rutting	-	X1	X2
16	Shoving	-	X1	X1
17	Slippage Cracking	X1	X1	X1
18	Swell	-	X2	X2
19	Weathering & Raveling	-	X5	X5

X1 = Shallow Patching X2 = Deep Patching X3 = Localized settlement layer

X4 = Sealing X5 = Overlaying X6 = Asphalt layer

X7 = Fill shoulder X8 = Spreading and rolling fine gravel aggregate

Table (2.3) shows the suggested pavement maintenance treatment according to the PCI condition evaluation of the network segments. When PCI of a segment ranges between 70 and 100 (condition is good or very satisfactory), routine maintenance including small patching and crack sealing is required while reconstruction is needed for segments of failed or serious condition.

Table (2.3): Suggested pavement maintenance treatment versus PCI ranges. [19]

PCI Range	Pavement Condition	Condition Class	Suggested Maintenance
70 – 100	Good / Satisfactory	I	Routine Maintenance (RM)
55 – 70	Fair / without effect of loads	II	Routine Maintenance (RM)
55 – 70	Fair / with effect of loads	III	Very thin Asphalt Overlay layer (AO1)
25 – 55	Poor / Very poor	IV	Doubled Asphalt Overlay layer (AO2)
0 – 25	Serious / Failed	V	Reconstruction (RC)

2.7 Summary:

Later than reviewing the preceding studies related to PMS, it's clear that PMS is set of tools or methods that can assist the decision makers in finding cost effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition.

External indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination therefore. Typical distresses are cracks, rutting, and weathering of the pavement surface.

Flexible pavement surface distresses include a wide variety of pavement defects that generally fall into 19 categories.

According to distresses types and quantity, pavement condition can be evaluated and maintaining by preventive, corrective, and emergency maintenance.

Chapter Three: Rafah City Network Evaluation

3.1 Introduction

Pavement evaluation was mentioned previously in chapter 2, and in this chapter will discuss the Rafah City pavements evaluation by using PCI procedure.

Rafah City contains roads having a total length of around 204.97 km. 129.31 km of these roads are paved while 75.66 km of them remain unpaved. These roads may be classified as; main roads with the length of 38.27 km, secondary roads having a length of 42.63 and local roads with the remaining length of 48.4 km. [2]

3.2 Rafah City pavements surface type

Rafah city roads are classified into three types according to surface, (Figure 3.1)

- Asphalt roads.
  There are 57 asphalt roads in Rafah City, which be detailed in appendix A.
- Interlock roads.
  Interlock roads in Rafah are a high percentage of the internal roads. The width of interlock roads varies from 4 m to 8 m. Interlock roads have a total length of about 11 km.
- Unpaved roads.
  Unpaved roads are the roads which are neither classified as asphalt-nor interlock roads. Those roads are opened by the Rafah Municipality in different blocks of the city. The width of these unpaved roads varies from 4 m to 30 m.

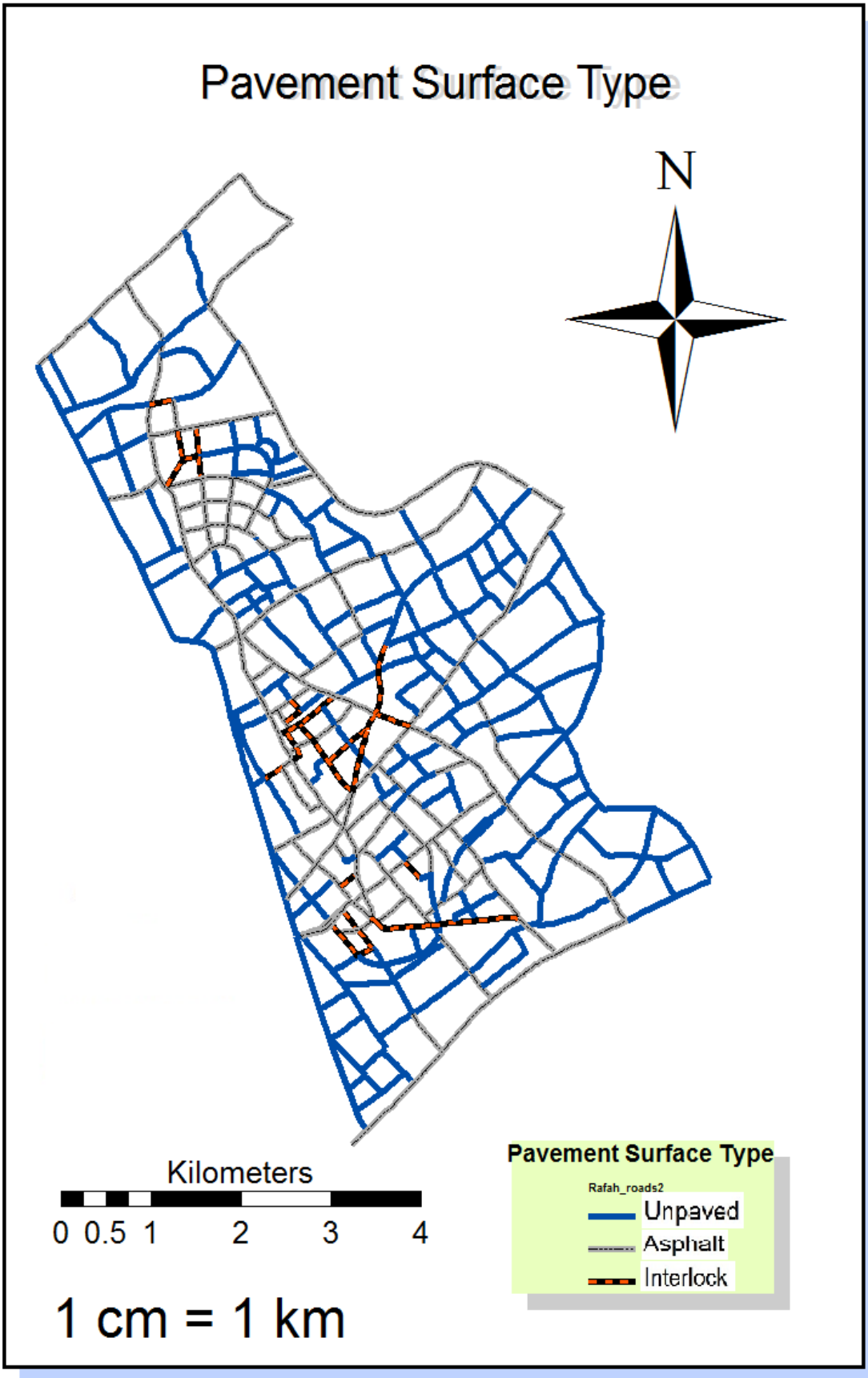


Figure (3.1): Pavement surface type for Rafah City.

3.3 Pavement condition index (PCI)

Pavement condition index (PCI) is defined as a numerical rating of the pavement condition that ranges from 0 to 100 with 0 being the worst possible condition and 100 being the best possible condition.

The Pavement Condition Index (PCI) procedure developed by the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers is widely used to assess the condition of a pavement surface. This procedure is described in ASTM Standard D 6433. In this procedure, the quantity and severity of various distresses on the roadway are recorded by performing a field survey. The ASTM standard presents guidelines for determining the severity level of a distress and how to measure the quantity of each distress. The data recorded in the field are then used to computes the PCI for the pavement, Figure (3.2) shows inputs and outputs of PCI [8,20].

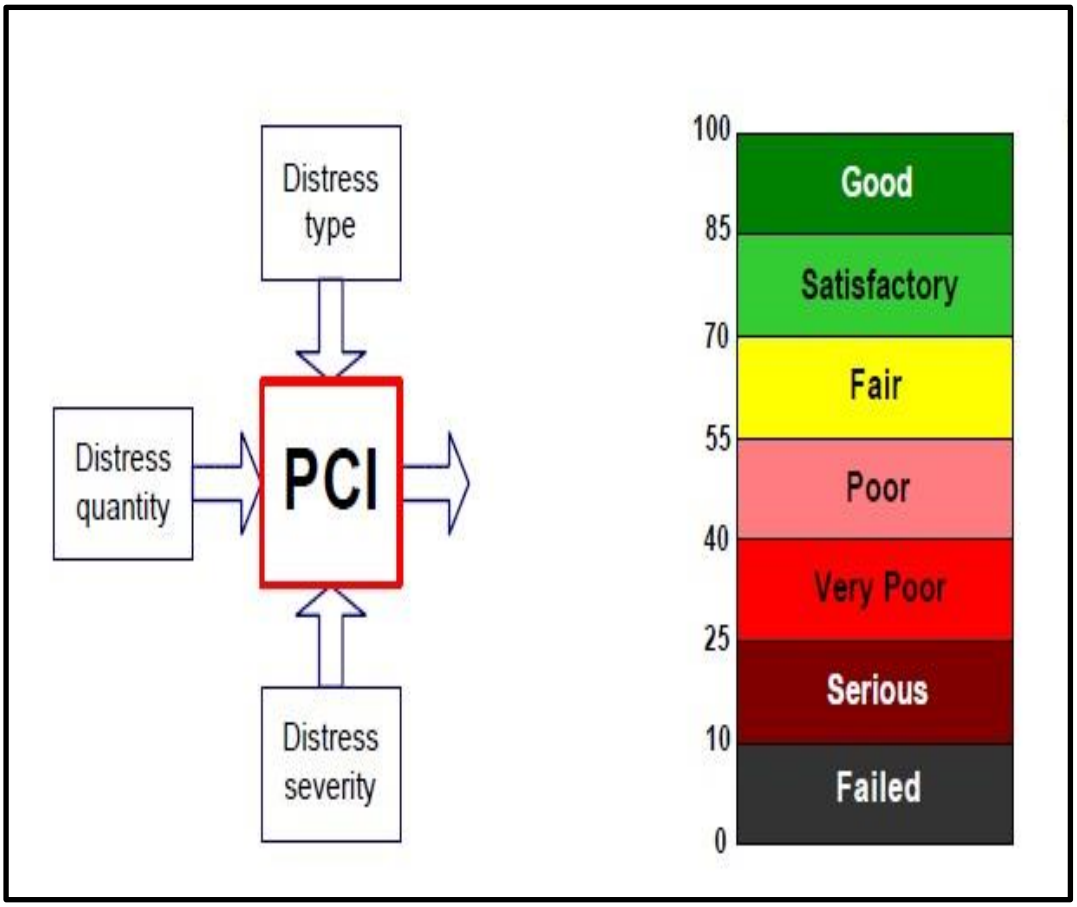


Figure (3.2): Pavement condition index (PCI), rating scale, and suggested colors [8]

3.3.1 Network division and data collection

Once the network is identified, it must be broken into smaller components to manage the inventoried pavements. Fairly specific guidelines have been established dividing

the network for use with the PAVER System. Some flexibility has been built into the procedure to accommodate unusual situations or specific agency constraints; however, it is strongly suggested that, without the guidance of someone experienced in PAVER implementations, the guidelines and recommendations for work division be followed closely [8,20].

- Network division:

1. The zone

   The decision to divide an agency's network into zones can be made at the agency's discretion. Typically zones are used to group geographic portions of a large network based on a characteristic common to the subset. Zones can be used in any way that would prove useful to the agency implementing the system. Zones have been used effectively to designate remote areas, funding sources for M&R work [20].

The first step is considering Rafah City as the case study area and as the research territory.

2. The branch:

   A branch, a mandatory component of a pavement network, is defined as any identifiable part of the pavement network which is a single entity and has a distinct function. For example, an individual street and a parking lot would each be considered a separate branch of the pavement network [20].

There are 57 asphalt branches in Rafah City. The asphalt roads are the most spread kind of roads in Rafah. Table (3.1) shows all the asphalt roads in Rafah City:

Part of Rafah is taken as an example, Figure (3.3) Omar Ibn Al-Khattab street shows an example of branch, the street connect between east and west of Rafah City, and it begins from Egyptian border to KhanYounis City border.

Table (3.1): Rafah pavement roads

Road No.	Road (branch) name	True area (m^2)	Road No.	Road (branch) name	True area (m^2)
1	Abu Baker El-Seddeq	108318	48	Road No.48	2790
2	Omar Ibn Al-Khattab	68253	49	Al-Hadad	7560
3	Taha Hussien	41740	50	Belal Ibn Rabah	7810
4	Haroon Al Rasheed	4620	51	Road No.51	7770
5	Road No.5	12950	52	Road No.52	8920
6	Othman Ibn Affan	15300	53	Keer	1440
7	Road No.7	2635	54	Ramadan Azzam	5760
8	Saddam Hussien	18060	56	Road No.56	3000
9	Al-Emam Ali	30420	61	Road No.61	10300
12	Road No.12	19980	66	Magdy Younis	7200
16	Al Rasheed	32500	67	Road No.67	4920
17	Road No.17	14000	73	Road No.73	3600
18	Road No.18	5110	75	Road No.75	29050
19	Al Matar	19540	77	Al-Shaheed	9000
20	Al-Eman	7350	80	Abu-Yousif Al-Najar	11880
21	Beer Qeshta	20820	82	Dair Yaseen	7380
23	Road No.23	4320	200	Road No.200	20188
24	Al Shaarea Al-Akheer	15480	201	Road No.201	1150
25	Al-Nos	12000	202	AlQuds School Street	525
26	Ibn Seena	21260	203	Al-Baladia Kindergarden	1680
27	Jaafer Al-Tayar	5320	204	Beer Al-Nashel	3990
28	Road No.28	2100	205	Al-Noor Mosque Street	1715
29	Al-Worood	6360	206	Al-Salheen Mosque Street	1890
31	Al-Dakhlia	5690	207	Kamal Odwan School Street	5600
32	Road No.32	7000	208	Road No.208	1398
35	Al-Quds	9000	209	Road No.209	358
36	Tareq Ibn Zyad	8760	210	Road No.210	2200
37	Heefa	8520	211	Road No.211	3240
44	Moraj	18550			

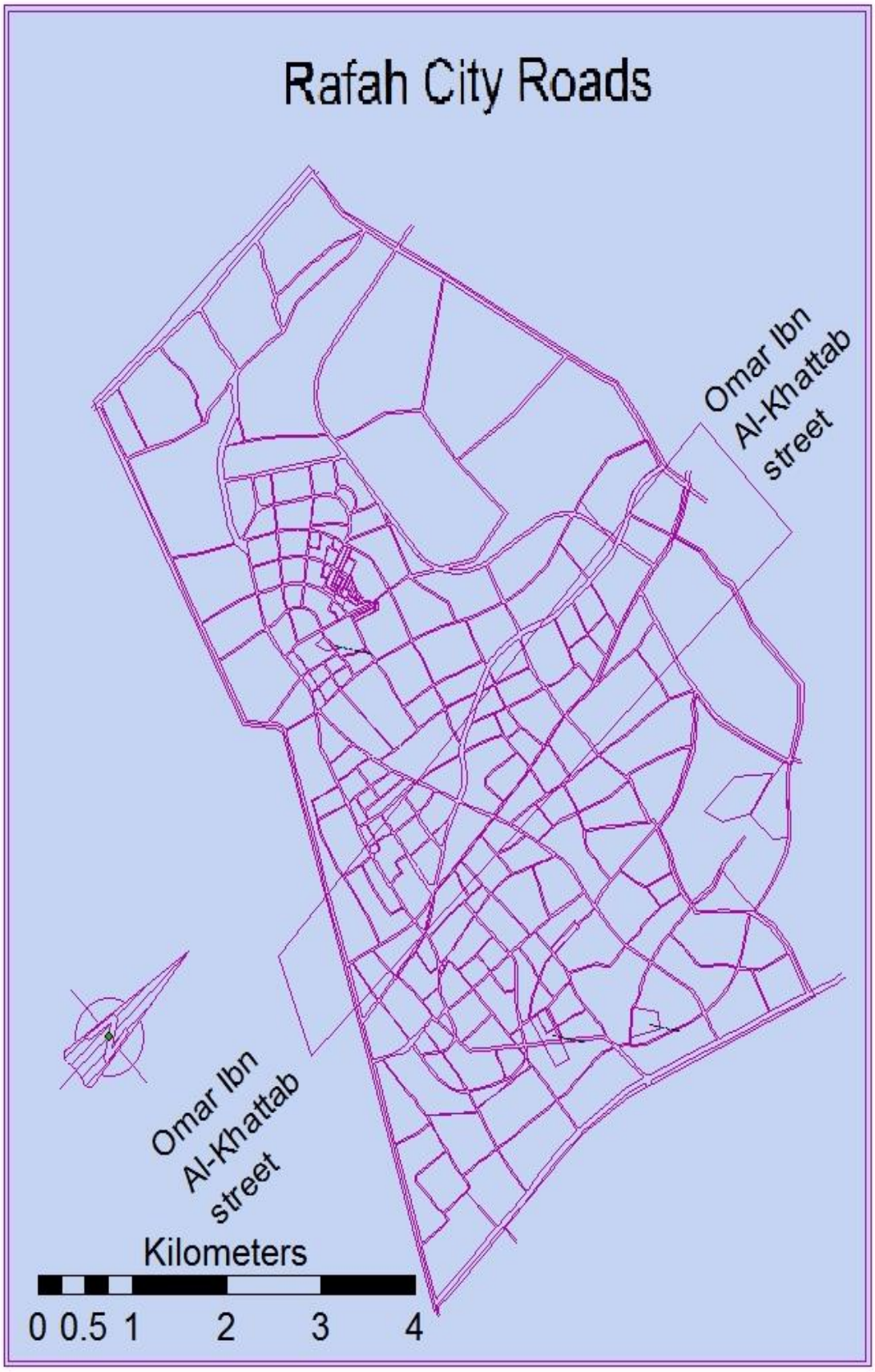


Figure (3.3): Omar Ibn Al-Khattab branch

3. The section

   Because a branch is typically a large unit of the pavement network, it does not always have consistent characteristics throughout its entire area or length. For this reason, branches are subdivided into smaller components called "sections" for management purposes. A section should be viewed as a segment of the branch which a manager would treat in a uniform way when considering issues such as the application and selection of M&R treatments. Each branch must consist of at least one section, but may consist of more if characteristics vary throughout the branch. Points to consider when dividing branches into sections are [20]:

   - ☒ Pavement structure.
   - ☒ Traffic.
   - ☒ Construction history.
   - ☒ Pavement rank.
   - ☒ Drainage facilities and shoulders.
   - ☒ Condition.

Omar Ibn Al-Khattab is a branch in Rafah City network is divided into 8 sections, each section has different sample unit number, and each section has its own data, as show in Table (3.2).

4. The sample unit

   The smallest component of the pavement network is the sample unit. A sample unit is defined as any easily identified, convenient area of pavement section which is designated only for the purpose of pavement inspection. pavement sample unit is a subdivision of a pavement section that has a standard size range (225 ± 90 m^2), for AC pavement. It is strongly recommended that, on the section identification sketches kept for each section, the size and location of sample units be shown. These sketches can be used to relocate sample units for future inspections [20].

   The minimum number of sample units (n) that must be surveyed within a given section to obtain a statistically adequate estimate (95 % confidence)

of the PCI of the section is calculated using the following formula and rounding *n* to the next highest whole number:

$$n = \frac{Ns^2}{\frac{e^2}{4}(N-1)+s^2} \qquad [9]$$

where:

e = acceptable error in estimating the section PCI; commonly, *e* = ± 5 PCI points;

s = standard deviation of the PCI from one sample unit to another within the section. When performing the initial inspection the standard deviation is assumed to be ten for AC pavements.

N = total number of sample units in the section.

Once the number of sample units to be inspected has been determined, compute the spacing interval of the units using systematic random sampling. Samples are spaced equally throughout the section with the first sample selected at random. The spacing interval (*i*) of the units to be sampled is calculated by the following formula rounded to the next lowest whole number:

$$i = \frac{N}{n} \qquad [9]$$

where:

N = total number of sample units in the section.

n = number of sample units to be inspected.

The first sample unit to be inspected is selected at random from sample units 1 through *i*.

For section 01 in Omar Ibn Al-Khattab street, its length is 530 m, and width is 13 m then area for this section is 6890 m².

Assume sample unit area = 250 m², (in range 230 ± 90 m²).

$$N = \frac{6890}{250} = 27.56 \approx 28\ sample$$

$$n = \frac{28 * 10^2}{\frac{5^2}{4}(28-1) + 10^2} \approx 10\ samle$$

$$i = \frac{28}{10} = 2.8$$

So we take the following samples in this section: 2,4,6,9,12,15,18,21,24,27.

Individually inspect each sample unit chosen. Sketch the sample unit, including orientation. Record the branch and section number and the number and type of the sample unit (random or additional). Record the sample unit size measured with the hand odometer. Conduct the distress inspection by walking over the sidewalk/shoulder of the sample unit being surveyed, measuring the quantity of each severity level of every distress type present, and recording the data. Each distress must correspond in type and severity.

Table (3.2) shows Omar Ibn Al-Khattab branch data, and Figure (3.4) shows Omar Ibn Al-Khattab branch details, Table (3.3) shows sample unit number 27 in section number 01 in Omar Ibn Al-Khattab branch.

Figures (3.5, 3.6, 3.7, 3.8) shows field distresses surveying.

Other Rafah branches are shown in Appendix A.

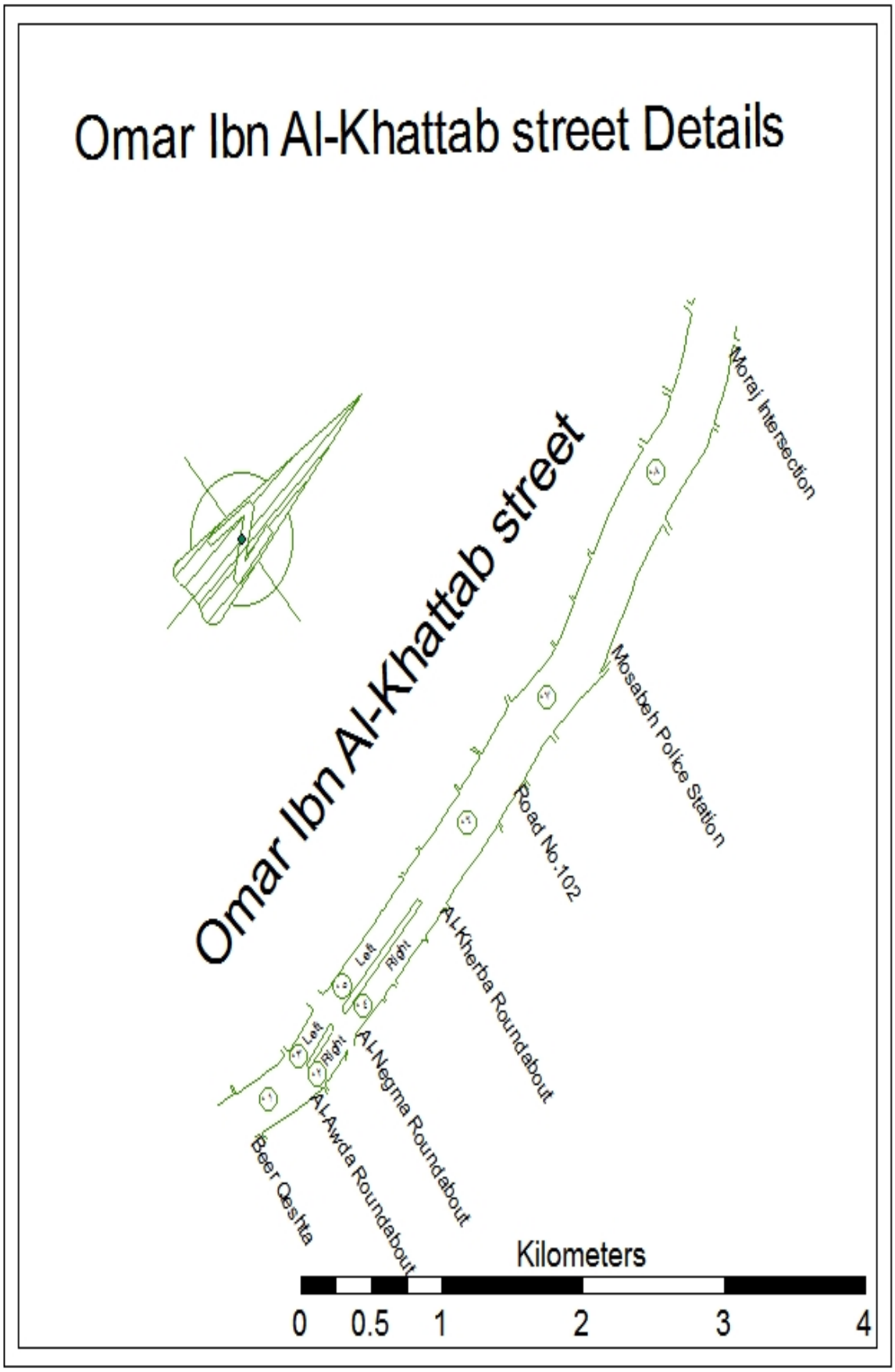
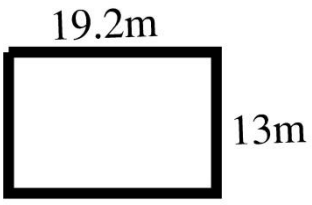


Figure (3.4): Omar Ibn Al-Khattab branch detailes.

Table (3.2): Omar Ibn Al-Khattab branch data

Road No.	Road (branch) name	Section ID	From	To	Lane Direction (Figure 3.4)	Length	Width	True area (m^2)	Total Number of Samples	Number of inspected samples	Sample Area (m^2)	Construct year
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	530	13	6890	28	10	250	1982
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	300	6.5	1950	8	5	250	1999
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	300	6.5	1950	8	5	250	1999
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	915	8.75	8006.25	32	11	250	1998
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	915	8.75	8006.25	32	11	250	1998
		06	Al-Kherba Roundabout	Road No.102	-	875	15	13125	53	13	250	1982
		07	Road No.102	Mosabeh Police Station	-	825	15	12375	50	12	250	1982
		08	Mosabeh Police Station	Moraj Intersection	-	1100	14.5	15950	64	13	250	1982

Table (3.3): Pavement condition inspection form for Omar Ibn Al-Khattab street

Asphalt condition survey data sheet			
Branch: Omar Ibn Al-Khattab	Section: 01	Sample unit: 27	
Surveyed by: Mohanad	Date: 26/05/2014	Sample Area: 249.6 m²	

1- Aligator Cracking 2- Bleeding 3- Block Cracking 4-Bumps and Sags 5- Corrugation	6- Depression 7- Edge cracking 8- JI Reflection cracking 9- Lane Shoulder Dropoff 10- Long & Trans Cracking	11- Patching and Util Cut Patching 12- Polished Aggregate 13- Potholes 14-Railrood Crossing 15-Rutting	16- Shoving 17- Slippage Cracking 18- Swell 19- Weathering & Raveling

Distress Severity	Quantity									Total
3M	1.4	10								11.4
10L	8.2									8.2
10H	4.7	6								10.7
11M	19.2									19.2
13M	4									4
13H	4									4
15L	3.75									3.75

Figure (3.5): Omar Ibn Al-Khattab street distresses.

Figure (3.6): Moraj street distresses.

Figure (3.7): Pavement Condition inspection in Taha Hussien street.

Figure (3.8): Abu Baker El-Seddeq street distresses.

3.4 Proposed PMS software

3.4.1 Micro PAVER

Micro PAVER is a comprehensive pavement management system first developed in the early1970s by the U.S. Army Corps of Engineers to help the Department of Defense manage maintenance and rehabilitation needs of military roads. MicroPAVER is currently used by more than 600 entities including cities, counties, airports, and private consulting firms [21].

The distresses measured during the visual survey were entered into MicroPAVER software to obtain pavement condition index for all sections in a network. MicroPAVER software automatically calculates PCI for every single unit from distress data entered.

The following steps are performed to construct Micro PAVER work that constitutes the input software program in the proposed Rafah PMS.

1. Firstly change the MicroPAVER unit to metric unit system, (Figure 3.9)

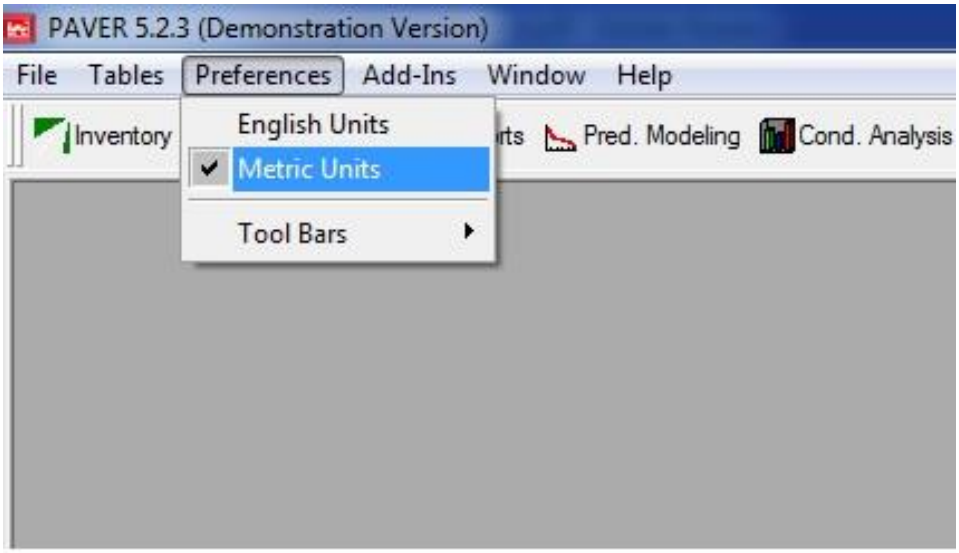


Figure (3.9): Change the MicroPaver units.

2. "Inventory Items" icon is first clicked to show Network, Branch and Section sub icons.

3. "Network" sub icon is also clicked to enter Network ID and name. For Rafah case, (Figure 3.10), the network is named " Rafah City " and its ID is set "01".

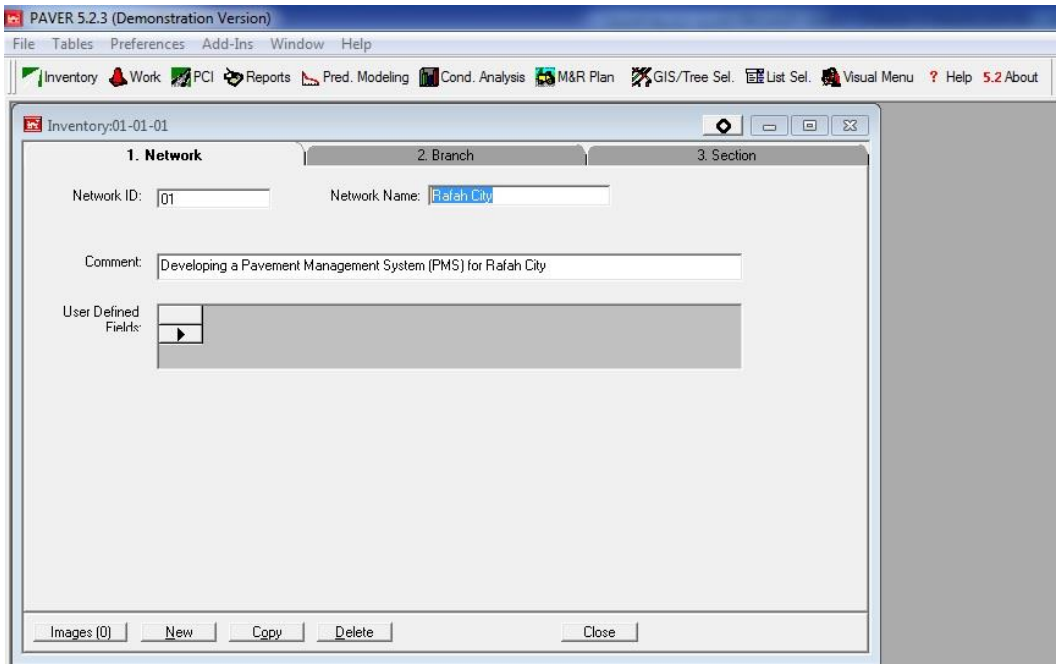


Figure (3.10): Rafah network name and ID establishment in the MicroPAVER

4. All information about Rafah streets "Branches" are entered in the MicroPAVER by clicking the "Branch" sub icon, including branch name, branch ID and the pavement use as shown in (Figure 3.11).

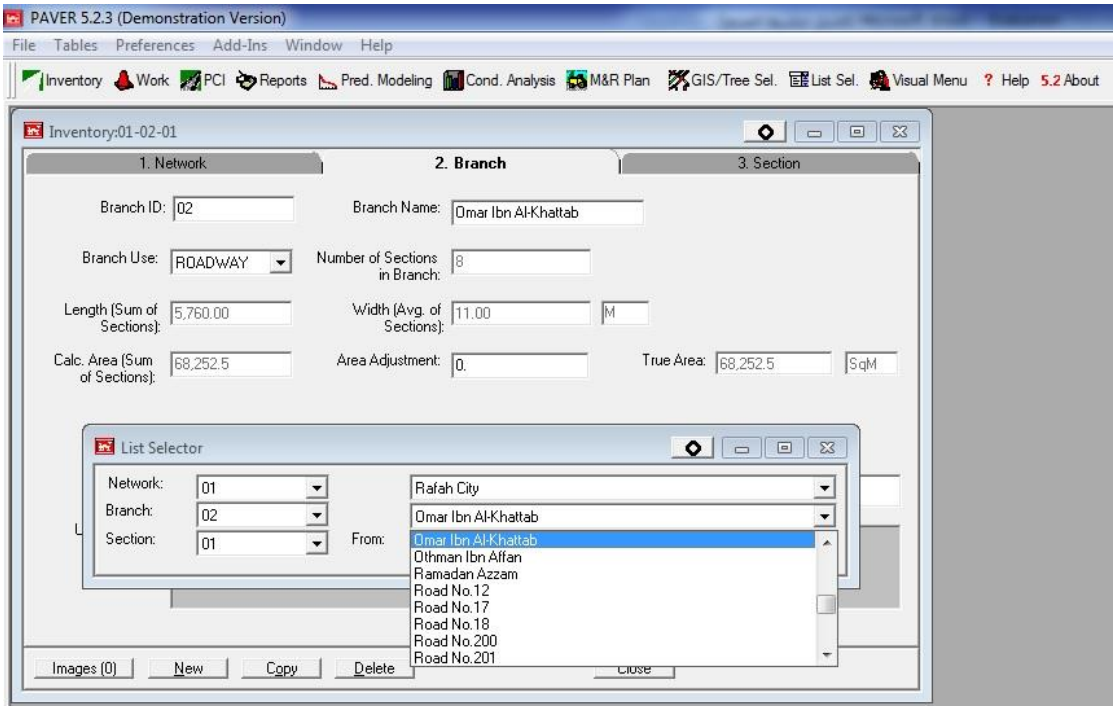


Figure (3.11): Rafah pavement branch definition in the MicroPAVER.

5. Sectioning Gaza pavement network in the Micro PAVER is then established by using the "Section" sub icon and selecting "New" button to enter the section data as shown in (Figure 3.12).

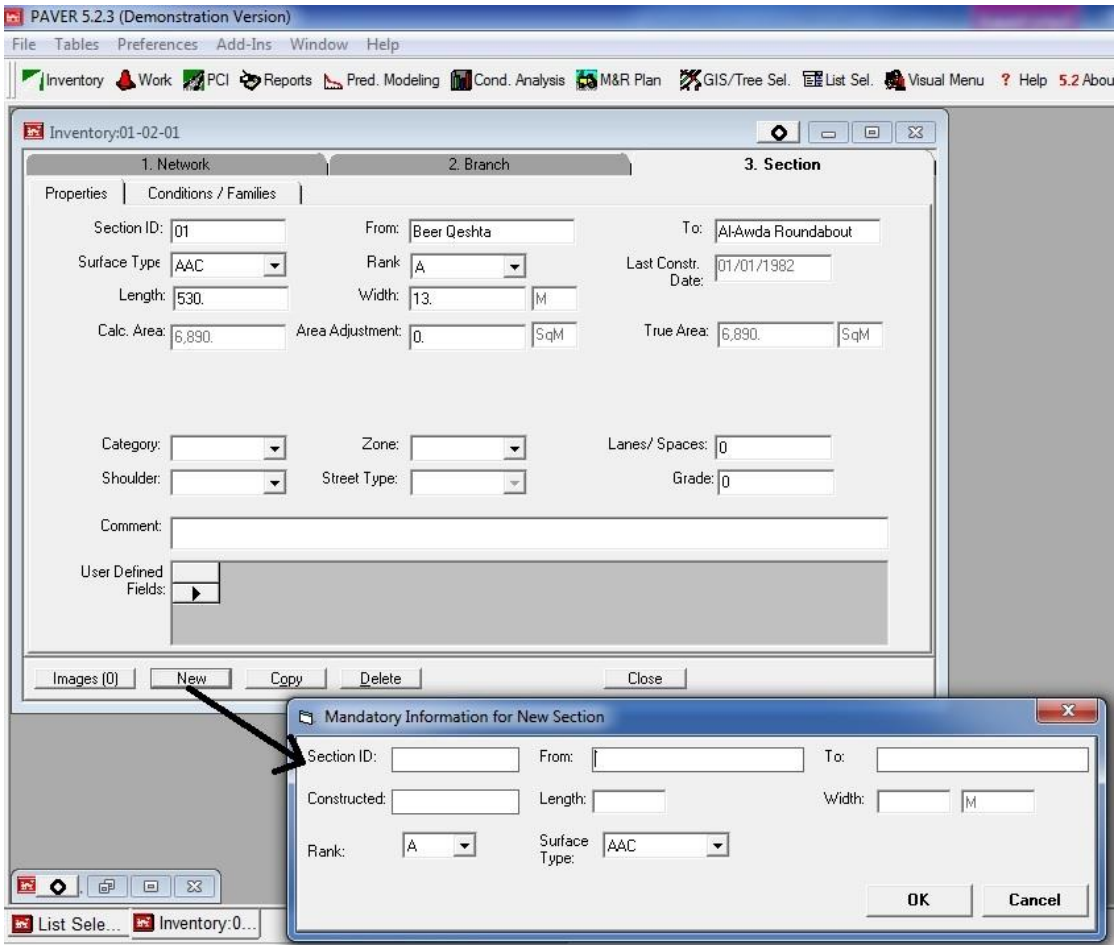


Figure (3.12): Rafah pavement section definition in the Micro PAVER.

6. After defining all the elements of Rafah network, the inspection data entry has been established by pressing "PCI" icon. Figure (3.13) illustrates the inspection data entry in the MicroPAVER for " Omar Ibn Al-Khattab Str. - Section 01-02-01", where 01 means network (Rafah), 02 means branch (Omar Ibn Al-Khattab Str.), and 01 means the section (from Beer Qeshta St., to Al-Awda roundabout).

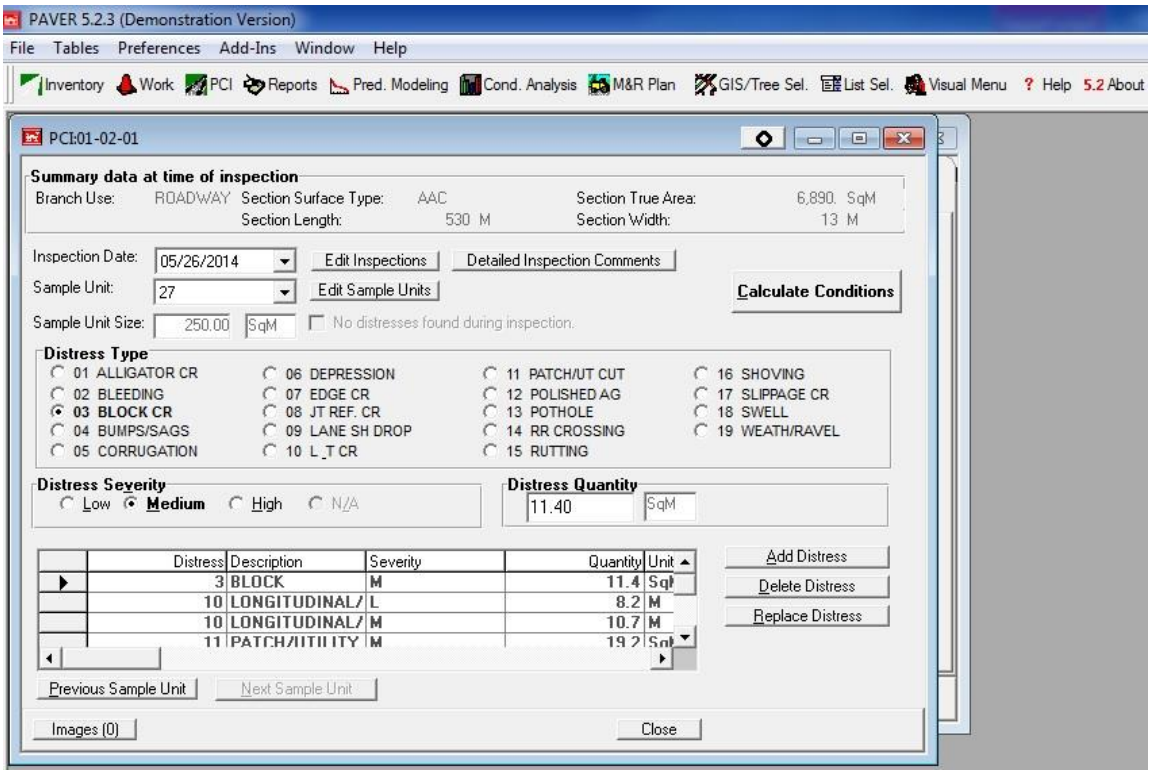


Figure (3.13): Rafah inspection data entry in the MicroPAVER.

The condition of this section (01-02-01) may be shown by pressing "Calculate Condition" button as illustrated in Figure (3.14).

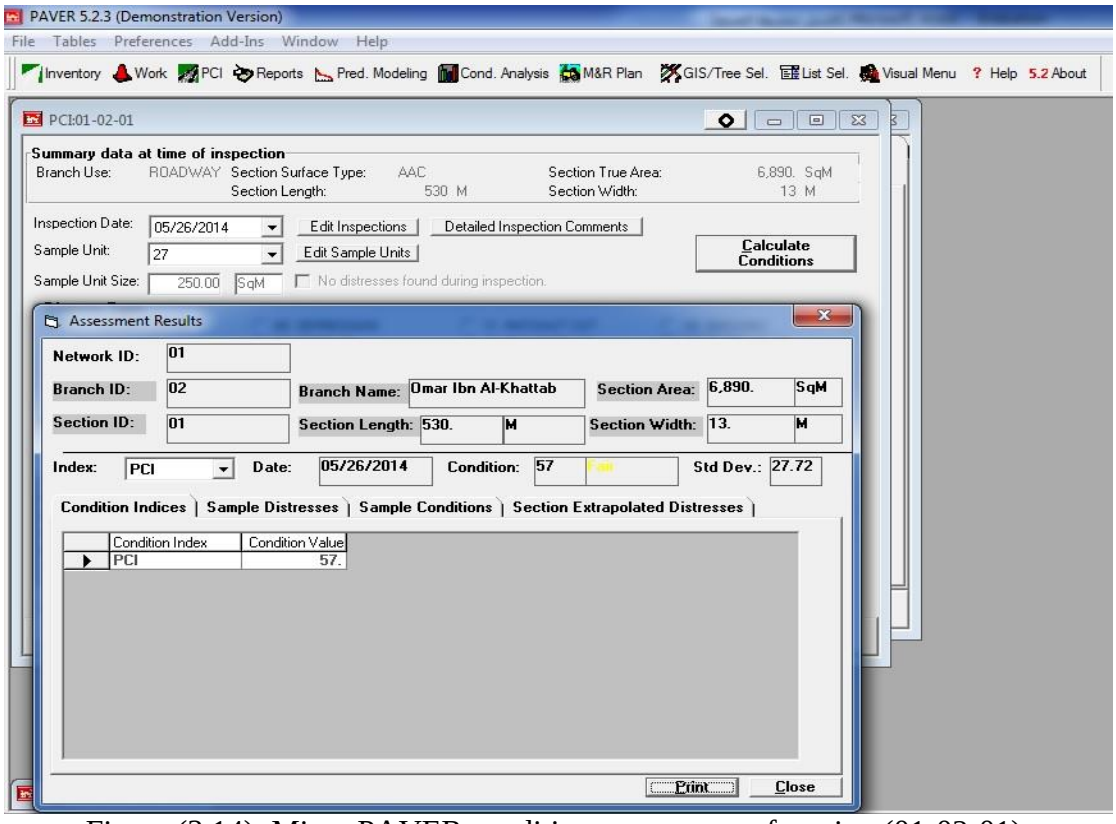


Figure (3.14): Micro PAVER condition assessment of section (01-02-01).

3.4.2 GIS software (Arc GIS 9.3)

Since geographical information systems with their spatial analysis capabilities, match the geographical nature of the road networks, they are considered to be the most appropriate tools to enhance pavement management operations, with features such as graphical display of pavement condition [22].

Nowadays, as GIS is increasingly used in public authorities, there is a growing trend toward integrating PMS data into the GIS. With the technological advances in computer hardware and software, this integration is becoming more realistic. Advantages of such integration include flexible database editing and the ability to visually display the results of database queries, statistics and charting, pavement management analyses on a map of the highway network, view network conditions through dynamic color-coding of highway sections, and access sectional data through the graphical map interface [22].

ArcGIS 9.3 will be used in this software according to the following steps.

1. Get a geo referencing Aerial photo from municipality of Rafah.
2. Create new shape file from Arc catalog named (Roads_from_south_image), defining the local coordinate system of Palestine-1923-Palestine-Grid, (Figure 3.15).

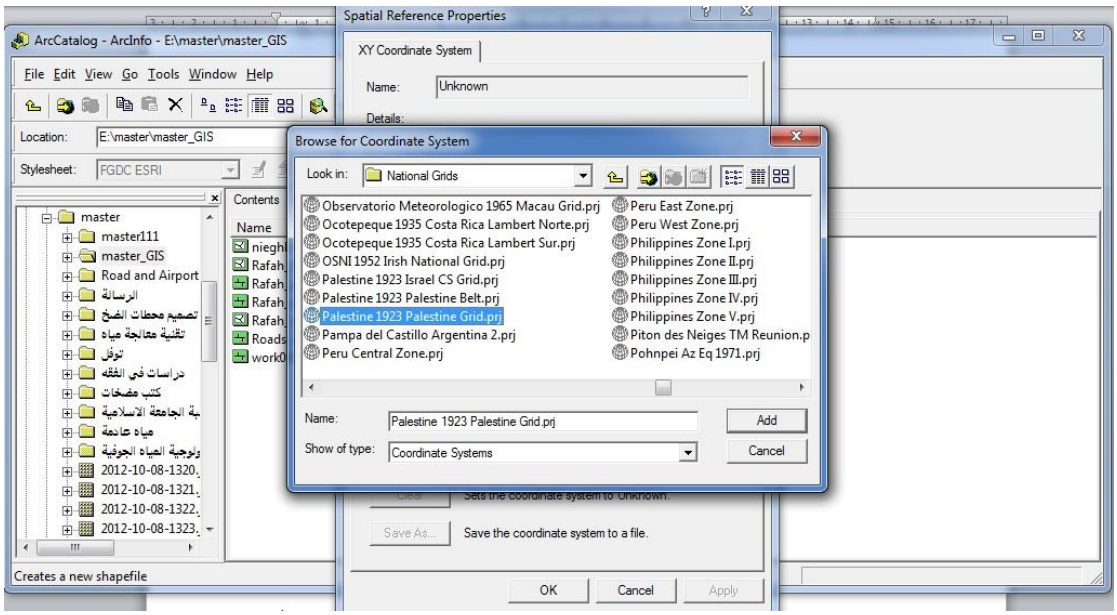


Figure (3.15): New shape file coordinate system.

3. Add Arial photo of Rafah city in Arc GIS 9.3, (Figure 3.16).

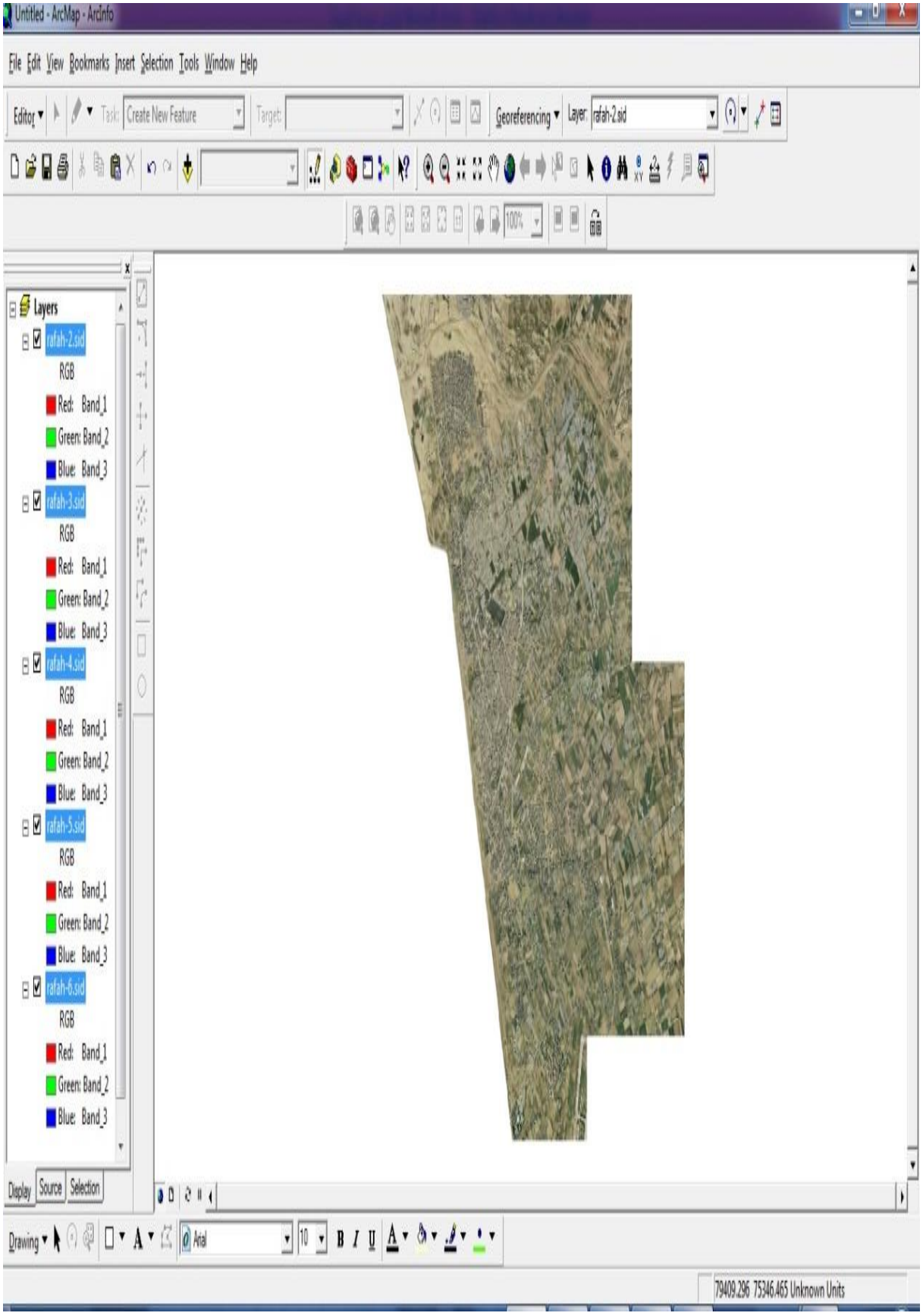


Figure (3.16): Aerial photo of Rafah City in Arc GIS

4. Start digitizing process to draw asphalt Rafah streets, by click icon "Editor", then click "Start Editing", then "sketch tool" will be active and click on it to start drawing Rafah streets, (Figure 3.17)

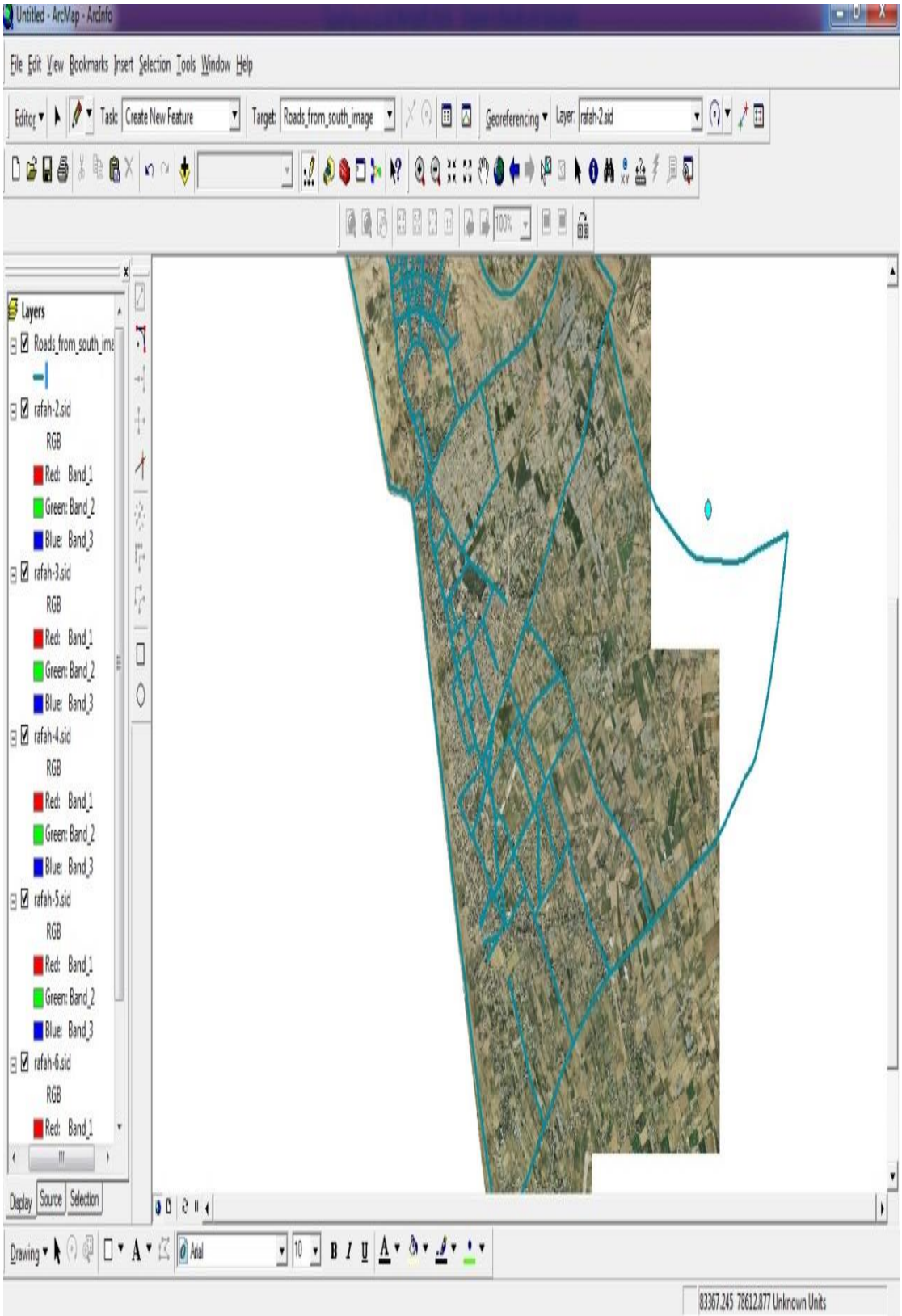
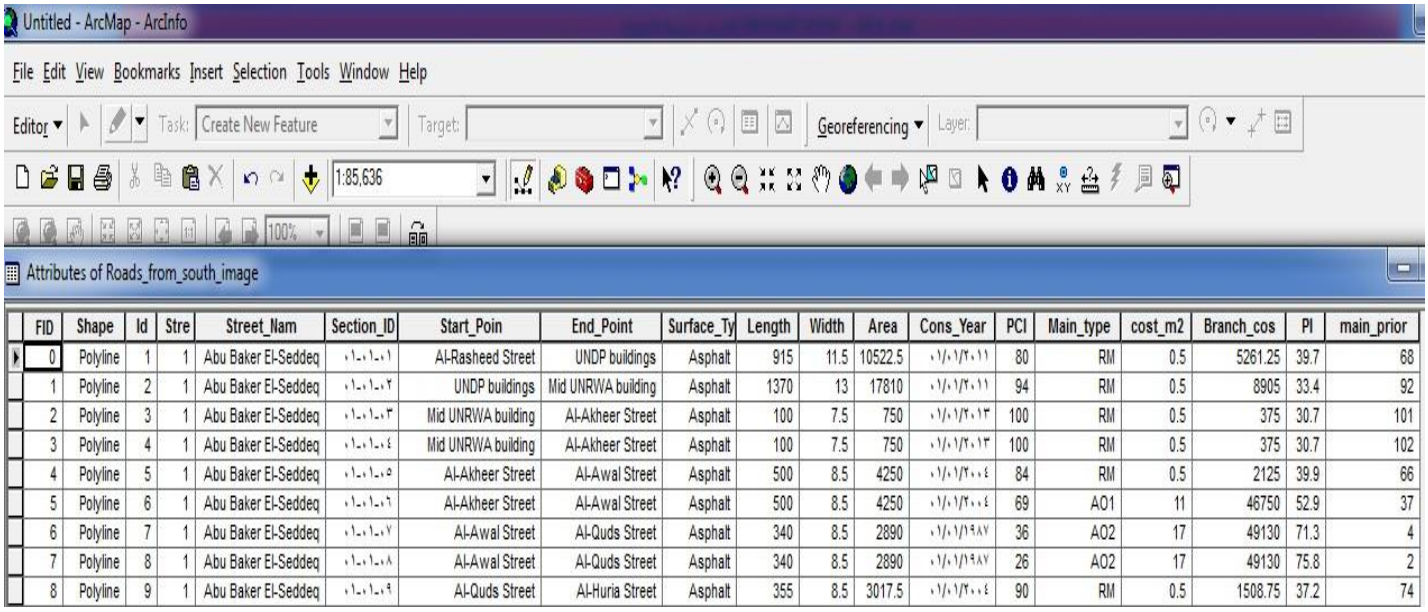


Figure (3.17): Digitizing Rafah City asphalt streets

5. Add streets information b right click on the name of shape file (Roads_from_south_image), the clicking on " open attribute table", and add all information about all streets, (Figure 3.18).



FID	Shape	Id	Stre	Street_Nam	Section_ID	Start_Poin	End_Point	Surface_Ty	Length	Width	Area	Cons_Year	PCI	Main_type	cost_m2	Branch_cos	PI	main_prior
0	Polyline	1	1	Abu Baker El-Seddeq	١-١-١	Al-Rasheed Street	UNDP buildings	Asphalt	915	11.5	10522.5	١/١/٢٠١١	80	RM	0.5	5261.25	39.7	68
1	Polyline	2	1	Abu Baker El-Seddeq	١-١-٢	UNDP buildings	Mid UNRWA building	Asphalt	1370	13	17810	١/١/٢٠١١	94	RM	0.5	8905	33.4	92
2	Polyline	3	1	Abu Baker El-Seddeq	١-١-٣	Mid UNRWA building	Al-Akheer Street	Asphalt	100	7.5	750	١/١/٢٠١٣	100	RM	0.5	375	30.7	101
3	Polyline	4	1	Abu Baker El-Seddeq	١-١-٤	Mid UNRWA building	Al-Akheer Street	Asphalt	100	7.5	750	١/١/٢٠١٣	100	RM	0.5	375	30.7	102
4	Polyline	5	1	Abu Baker El-Seddeq	١-١-٥	Al-Akheer Street	Al-Awal Street	Asphalt	500	8.5	4250	١/١/٢٠٠٤	84	RM	0.5	2125	39.9	66
5	Polyline	6	1	Abu Baker El-Seddeq	١-١-٦	Al-Akheer Street	Al-Awal Street	Asphalt	500	8.5	4250	١/١/٢٠٠٤	69	AO1	11	46750	52.9	37
6	Polyline	7	1	Abu Baker El-Seddeq	١-١-٧	Al-Awal Street	Al-Quds Street	Asphalt	340	8.5	2890	١/١/١٩٨٧	36	AO2	17	49130	71.3	4
7	Polyline	8	1	Abu Baker El-Seddeq	١-١-٨	Al-Awal Street	Al-Quds Street	Asphalt	340	8.5	2890	١/١/١٩٨٧	26	AO2	17	49130	75.8	2
8	Polyline	9	1	Abu Baker El-Seddeq	١-١-٩	Al-Quds Street	Al-Huria Street	Asphalt	355	8.5	3017.5	١/١/٢٠٠٤	90	RM	0.5	1508.75	37.2	74

Figure (3.18): Rafah network attribute table

Chapter Four: Results and Discussion

4.1 Introduction

Rafah PMS provides various outputs that can help in reducing the time needed to the maintenance activity. The outputs will also help in facilitating the decision making process since they show every section's type of recommended maintenance, costs needed for the maintenance and the priority of each maintenance.

This chapter also discusses the results acquired from the Micro PAVER and the Arc GIS soft wares. These results calculate the cost of maintenance and show the maintenance priority for each section.

4.2 Micro PAVER output

MicroPAVER gives a lot of reports and figures. The most important among these is the PCI value of each section. Those are detailed in appendix A.

4.2.1 Network definition

Figure (4.1) shows information of Rafah network and the Section 132. It also shows the area of asphalt pavements (722817.5 m²) and the pavements' average age at inspection date (13.79 years)

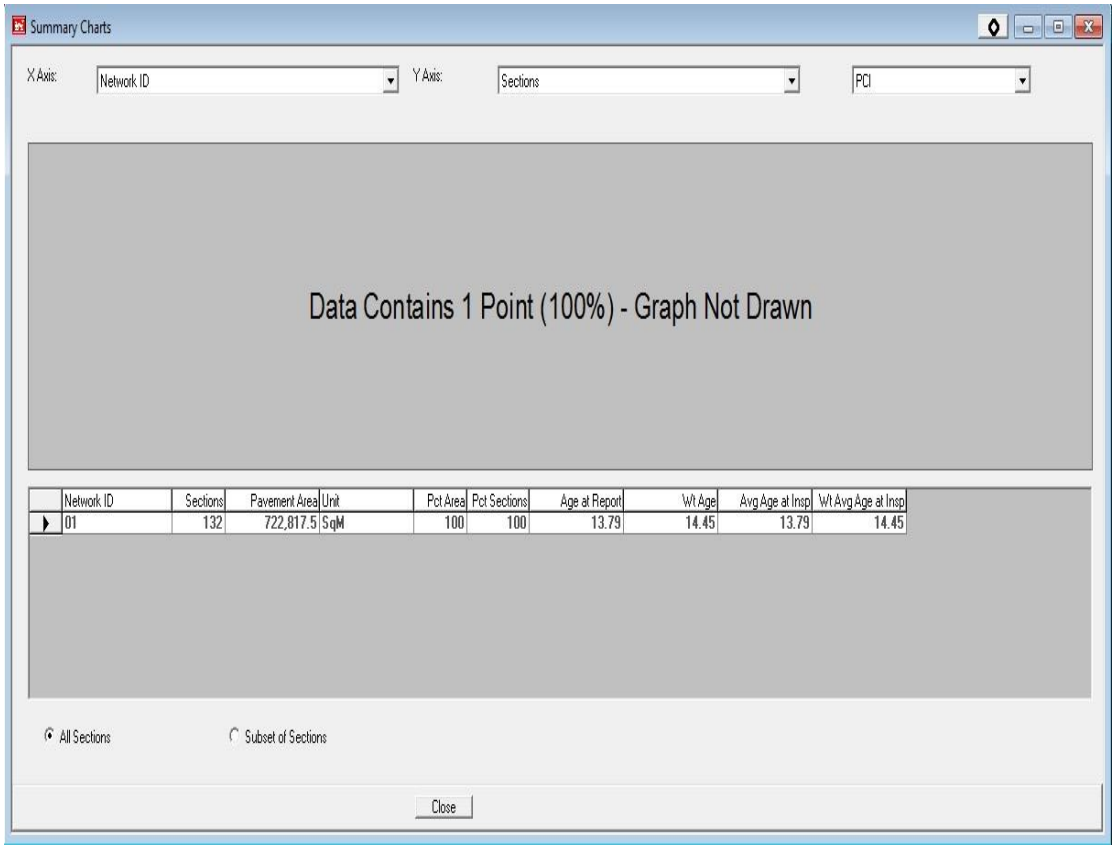


Figure (4.1): Rafah city network outlines.

4.2.2 Condition at last inspection

Rafah city has a lot of asphalt pavements, these pavements have different dates of construction and different surface conditions due to different traffic on them or other related factors. These factors make the conditions of the pavements differ. Figure (4.2) shows the conditions of all the pavements according to their PCI values, and shows areas of each condition according to the classification of PCI values.

Condition Category	Sections	Pavement Area	Unit	Pct Area	Pct Sections	Age at Report	Wt Age	Avg Condition	Wt Avg Condition	Avg Age at Insp	Wt Avg Age at Insp
Failed	1	1,850.	SqM	0	1	34.	34.	10.	10.	34.	34.
Serious	0				0						
Very Poor	5	18,660.	SqM	3	4	23.8	25.52	34.	34.44	23.8	25.52
Poor	18	95,252.5	SqM	13	14	27.78	29.37	49.06	48.81	27.78	29.37
Fair	31	161,037.5	SqM	22	23	16.65	19.13	64.23	63.27	16.65	19.13
Satisfactory	33	221,225.	SqM	31	25	11.48	11.88	77.33	77.6	11.48	11.88
Good	44	224,792.5	SqM	31	33	6.18	6.22	94.93	94.69	6.18	6.22

Figure (4.2): Condition of Rafah City pavements

4.3 Maintenance cost due to PCI value

There are four maintenance probabilities due to PCI value, and there:

- Routine maintenance.
- AO1: Very thin asphalt overlay layer (3-5 cm).
- AO2: thick asphalt overlay layer(5-7 cm).
- Reconstruction.

4.3.1 Field maintenance cost calculation

1 ton of Asphalt consist of 1 ton (aggregate and filler) and 50 kg bitumen.

1 ton (aggregate and filler) = 26 $.

50 kg bitumen = 52 $.

Workmanship and factory = 26 $.

Every square meter needs 1 kg MCO = 1.3 $/m².

Every square meter needs 1 kg RC2 = 1.3 $/m².

Notice: Asphalt density = 2.35g/cm³.

- Case 1: AO1

  Use 4 cm thickness of this case.

$$\frac{\frac{1}{\rho}}{thickness} = Number\ of\ m^2$$

$$\frac{\frac{1}{2.35}}{0.04} = 10.65\ m^2$$

  10.65 m² needs (1.3 * 10.65) RC2 = 13.85 $.

  10.65 m² needs (26 $ +52 $ +26 $) 1 ton asphalt = 104 $.

  10.65 m² needs (13.85 $ + 104 $) = 117.85 $.

  Each 1 m² of AO1 needs (117.85 / 10.65) = 11$.

- Case 2: AO2

  Use 6 cm thickness of this case.

$$\frac{\frac{1}{\rho}}{thickness} = Number\ of\ m^2$$

$$\frac{\frac{1}{2.35}}{0.06} = 7\ m^2$$

  7 m² needs (1.3 * 7) RC2 = 9.1 $.

7 m² needs (26 $ +52 $ +26 $) 1 ton asphalt = 104 $.

7 m² needs (9.1 $ + 104 $) = 113.1 $.

Each 1 m² of AO2 needs (113.1 / 7) = 16.2 $, and use 17 $

- Case 3: Reconstruction

  Use 7 cm thickness of this case.

$$\frac{\frac{1}{\rho}}{thickness} = Number\ of\ m^2$$

$$\frac{\frac{1}{2.35}}{0.07} = 6\ m^2$$

6 m² needs (1.3 * 6) RC2 = 7.8 $.

6 m² needs (26 $ +52 $ +26 $) 1 ton asphalt = 104 $.

6 m² needs (7.8 $ + 104 $) = 111.8 $.

Each 1 m² of AO2 needs (111.8 / 6) = 18.7 $, and use 19 $

Each m² needs 8 $ for removing existing layer and cover shortage in base course layer.

So each m² in reconstruction case needs 19$ + 8$ = 27$.

Table (4.1) shows every technique cost according to previous cases.

Table (4.1): Maintenance techniques costs

PCI Range	Pavement Condition	Cost (m²)	Suggested Maintenance
70 – 100	Good / Satisfactory	0.5	Routine Maintenance (RM)
55 – 70	Fair / without effect of loads	0.5	Routine Maintenance (RM)
55 – 70	Fair / with effect of loads	11	Very thin Asphalt Overlay layer (AO1)
25 – 55	Poor / Very poor	17	Doubled Asphalt Overlay layer (AO2)
0 – 25	Serious / Failed	27	Reconstruction (RC)

Appendix B shows every section maintenance cost.

4.3.2 Omar Ibn Al-Khattab branch maintenance cost

Omar Ibn Al-Khattab branch divided into 8 sections each section has different PCI, then different maintenance type, and that reflect required cost to each section, (Table 4.2).

Table (4.2): Omar Ibn Al-Khattab branch maintenance cost

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	530	13	6890	AO1	11	75790
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	300	6.5	1950	RM	0.5	975
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	300	6.5	1950	RM	0.5	975
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	915	8.75	8006.25	RM	0.5	4003.125
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	915	8.75	8006.25	RM	0.5	4003.125
		06	Al-Kherba Roundabout	Road No.102	-	875	15	13125	AO1	11	144375
		07	Road No.102	Mosabeh Police Station	-	825	15	12375	AO1	11	136125
		08	Mosabeh Police Station	Moraj Intersection	-	1100	14.5	15950	RM	0.5	7975

4.4 Maintenance Priority

There are many factors that affect the priority of maintenance. Using these factors, one could calculate the PI index. If the PI index is large, then the section needs maintenance instantly [2].

Rafah maintenance book 2014 [2] calculate PI by multiply each factors (Fi) by its weight (wi), then sum all values which gives PI, each factor has its weight as shown in Table (4.3).

$$PI = Fi * wi$$

Rafah maintenance book does not deal directly with PCI values, but it classifies pavements according to their conditions using a procedure similar to the PCI procedure. Rafah maintenance book rates the pavement's condition from 0 to 100 with 0 being the worst possible condition and 100 being the best possible condition.

Table (4.3) Priorities factors and factors weights[2].

Factor	Weight
Rafah Evaluation (0 – 100) = PCI	0.45
Road Classification	0.13
Traffic Volume	0.12
Maintenance cost	0.1
Road Importance	0.1
Citizen Complaints	0.1

After PI index calculation all sections will be descending arrange to give the decision maker real view of all sections, and to easy deal with any budget come to Rafah municipality.

4.4.1 PI factors [2]

- PCI

  It is already calculated

- Road Classification (CF)

  100 for main roads, 75 for secondary roads, and 50 for local roads.

- Traffic Volume (TF)

$$TF = \frac{ADT}{Max\ ADT} * 100$$

Where:

ADT = Average Daily Traffic.

Max ADT = Maximum Average Daily Traffic.

- Maintenance cost (MF)

$$MF = \frac{Real\ maintenance\ Cost}{Max\ maintenanc\ cost} * 100$$

Real cost is calculated previously in this chapter, and assume AO2 for max maintenance cost.

- Road Importance (I.F)

  100 for main roads, 75 for secondary roads, and 50 for local roads.

- Citizen Complaints (S.F)

  100 for much, 65 moderat, 35 little, 0 no compliants

$$PI = \big((100 - PCI) * 0.45\big) + (CF * 0.13) + (TF * 0.12) + (MF * 0.1) + (IF * 0.1) + (SF * 0.1)$$

4.4.2 PI Example

The following example is to show how to calculate PI for Omar Ibn Al-Khattab branch, section 01, (01-02-01).

Table (4.4) shows the data needed to calculate PI index for Omar Ibn Al-Khattab branch.

Table (4.4): PI example inputs for Omar Ibn Al-Khattab branch

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	PCI	ADT	Max ADT	Real Maintenance Cost ($)	Max Maintenance Cost ($)
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	57	5000	6000	75790	117130
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	90	5000	6000	975	33150
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	92	5000	6000	975	33150
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	88	5000	6000	4003.125	136106.25
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	93	5000	6000	4003.125	136106.25
		06	Al-Kherba Roundabout	Road No.102	-	61	4000	6000	144375	223125
		07	Road No.102	Mosabeh Police Station	-	61	4000	6000	136125	210375
		08	Mosabeh Police Station	Moraj Intersection	-	73	4000	6000	7975	271150
Where CF = 100 (main road), I.F = 100 (main road).										

Section (01-02-01)) start from Beer Qeshta street and end at Al-Awda Roundabout,

- PCI
  57 %.
- Road Classification (CF)
  100 because it main road.
- Traffic Volume (TF)

$$TF = \frac{5000}{6000} * 100 = 83.33$$

- Maintenance cost (MF)

$$MF = \frac{75790}{117130} * 100 = 64.7$$

- Road Importance (I.F)
  100 because it main roads.
- Citizen Complaints (S.F)
  35

$$PI = \big((100 - 57) * 0.45\big) + (100 * 0.13) + (83.33 * 0.12) + (64.7 * 0.1) + (100 * 0.1) + (35 * 0.1) = 62.32$$

After PI index calculation for all Omar Ibn Al-Khattab all sections will be descending arrange.

Table (4.5) shows PI sections for Omar Ibn Al-Khattab Branch and arrange them descending.

Appendix C shows every section maintenance priority.

Table (4.5): Omar Ibn Al-Khattab Branch maintenance priority.

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	PI	Priority
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	62.32	1
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	41.29	6
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	40.39	7
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	42.19	5
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	39.94	8
		06	Al-Kherba Roundabout	Road No.102	-	58.52	2
		07	Road No.102	Mosabeh Police Station	-	58.52	3
		08	Mosabeh Police Station	Moraj Intersection	-	46.94	4

4.5 Future vision

Pavement conditions will get much better in the future if maintenance on these road is to be performed instantaneously. Although, if the municipality of Rafah does not take action, then the Rafah network pavements will end up in very bad conditions. The duration of each situation is shown in Table (4.6)

Table (4.6): Performance of pavement condition variables [23]

Part	PCI	Pavement Condition	Suggested Maintenance	Period Age (years)
First	70 – 100	Good / Satisfactory	Routine Maintenance (RM)	6
Second	55 – 70	Fair / without effect of loads	Routine Maintenance (RM)	5
Third	55 – 70	Fair / with effect of loads	Very thin Asphalt Overlay layer (AO1)	4
Fourth	25 – 55	Poor / Very poor	Doubled Asphalt Overlay layer (AO2)	3
Fifth	0 – 25	Serious / Failed	Reconstruction (RC)	2

According to previous table PCI change by time if nothing is doing, so the technique of maintenance will be changed, then the maintenance cost will be changed also, Omar Ibn Al-Khattab branch taken as example shown in Table (4.7).

The magnitude of the maintenance cost for every section in Omar Ibn Al-Khattab branch is 374,221 $ (Table 4.7). If the municipality of Rafah does not take an action it will be cost 583,036 $ for after 5 years, and 1,109,717 $ for after 10 years. The same previous method is used to calculate the costs of maintenance for all Rafah branches. These costs are given in the Table (4.8) below as follows: If maintenance is to be performed right now, in 5 years or in 10 years.

Table (4.7): Expected maintenance type and cost after 5 and 10 Years for Omar Ibn Al-Khattab branch

						Current state			After 5 Years			After 10 Years		
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	PCI	Maintenance type	Maintenance Cost ($)	PCI	Maintenance type	Maintenance Cost ($)	PCI	Maintenance type	Maintenance Cost ($)
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	57	AO1	75790	35	AO2	117130	15	RC	186030
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	90	RM	975	70	RM	975	55	AO1	21450
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	92	RM	975	70	RM	975	55	AO1	21450
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	88	RM	4003	70	RM	4003	55	AO1	88068.75
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	93	RM	4003	70	RM	4003	55	AO1	88068.75
		06	Al-Kherba Roundabout	Road No.102	-	61	AO1	144375	55	AO1	144375	35	AO2	223125
		07	Road No.102	Mosabeh Police Station	-	61	AO1	136125	55	AO1	136125	35	AO2	210375
		08	Mosabeh Police Station	Moraj Intersection	-	73	RM	7975	55	AO1	175450	35	AO2	271150
							Total	374221			583036			1109717

Appendix D shows if nothing is doing for 5 and 10 years.

Table (4.8): Rafah network maintenance cost

Current maintenance cost	Maintenance cost after 5 years	Maintenance cost after 10 years
3,732,434	6,607,232	11,827,017

4.6 Arc GIS output

Arc GIS maps will make understanding of Rafah city pavements is easy to deal by decision makers and the can take accurate information about accurate place. Colored map will be produced by Arc GIS maps.

4.6.1 PCI map

Colored map produced by Arc GIS software that make easy to deal with Rafah city pavement network, Figure (4.3) divided PCI values according to pavement surface condition, and that let the decision makers deals directly with any condition they need to maintain.

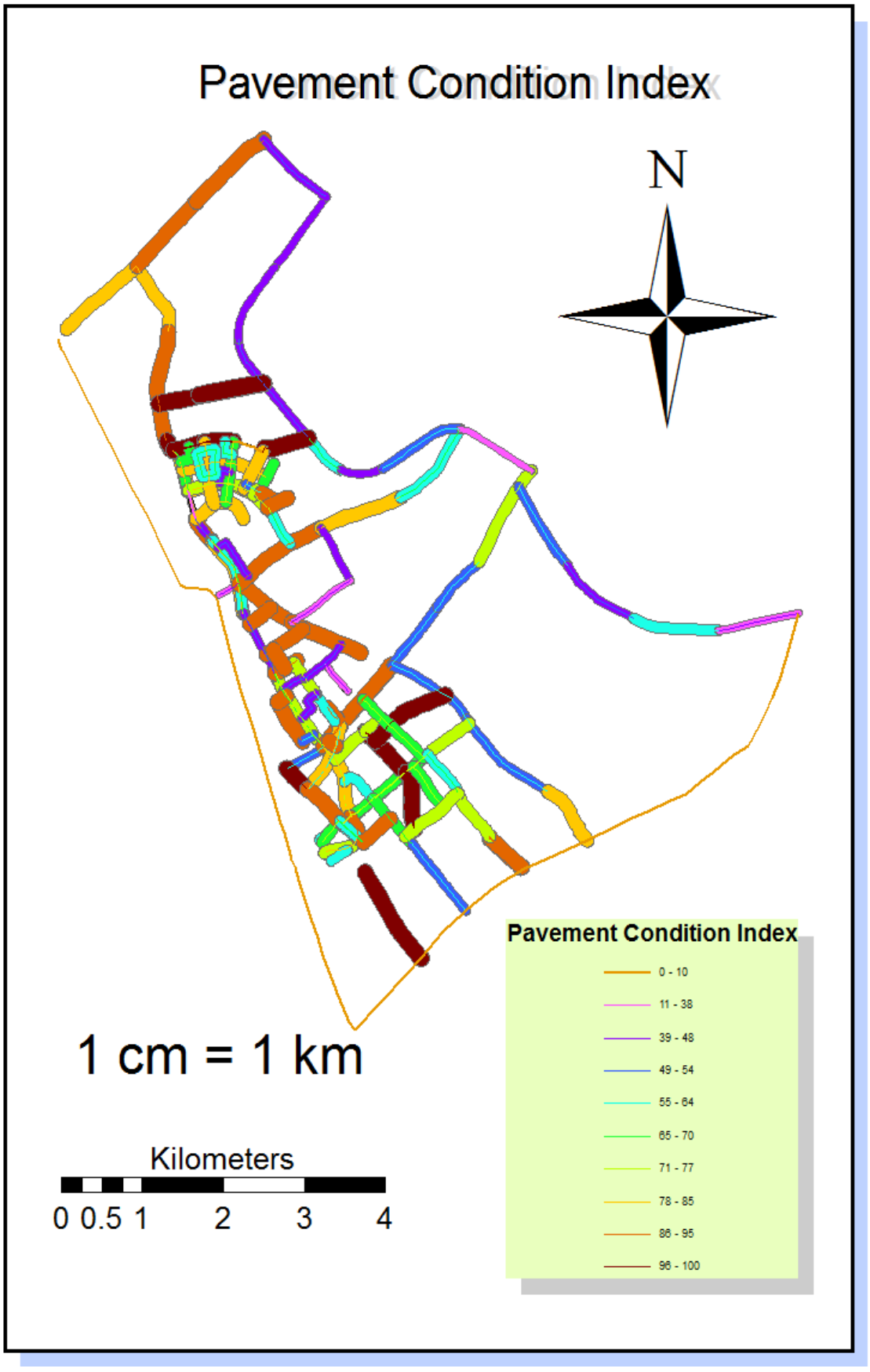


Figure (4.3): PCI values by Arc GIS software

4.6.2 Maintenance technique

Represent technique of maintenance will be used to every branch, Figure (4.4) shows the four types of offered maintenance techniques, and these results helps decision makers to take the optimum decision when they have only a specific type of materials which used to a specific type of maintenance teqniques.

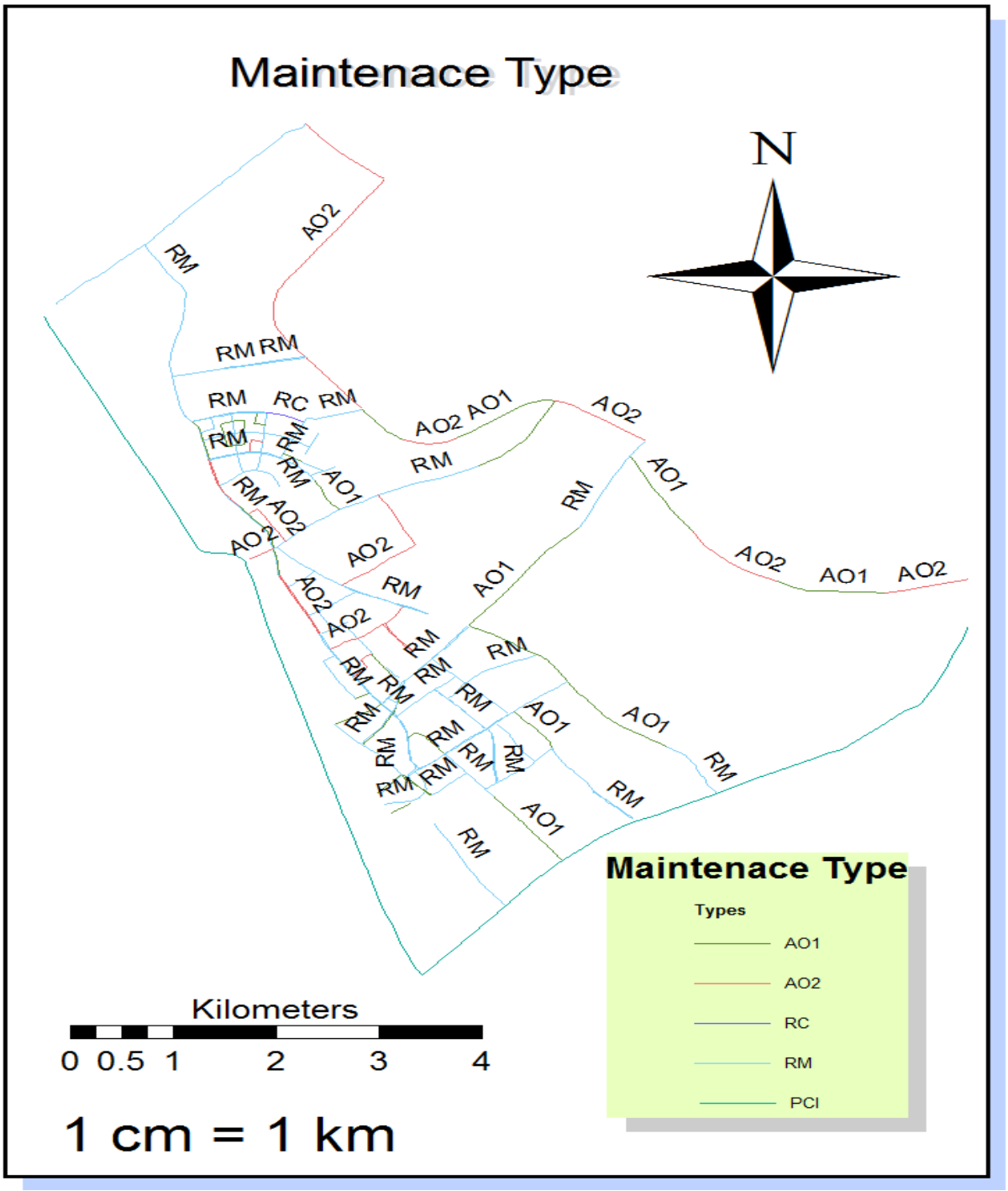


Figure (4.4): Maintenance technique for Rafah City branches

4.6.3 Priority for Maintenance

Arrange all Rafah city branches and show which section have more priority than others, Figure (4.5) shows all branches priorities that will be used when the decision makers have not funds to all branches.

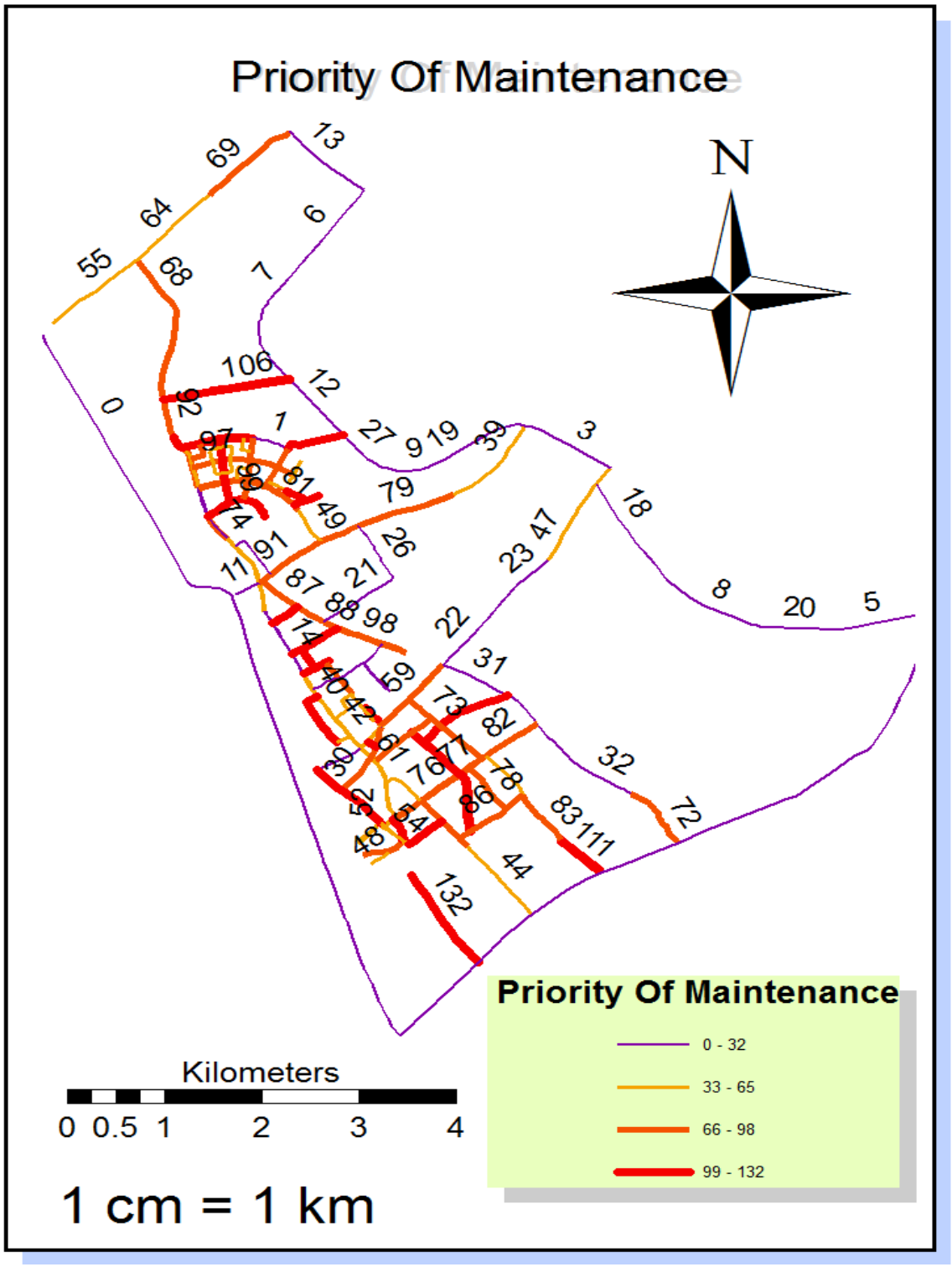


Figure (4.5): Maintenance priority for Rafah City branches

Chapter Five: Conclusion and Recommendations

5.1 Conclusion

- In this work, 132 sections of 57 branch was selected from the roads of Rafah city and all these sections are distresses due to different causes like weathering, ageing, traffic load, and also the bad maintenance, etc.
- Implement the Micro PAVER pavement management system, and perform a network level pavement condition survey of the City's roadway pavements.
- By using Micro PAVER software, 132 Rafah City section divided to 1 failed section, 5 very poor sections, 18 poor sections, 31 fair sections, 33 satisfactory sections, 44 good sections.
- Using Arc GIS tools for enhancing the management process of Rafah pavement network.
- Costs will increase in five years if nothing is done now, and another more increase of the costs is expected in ten years if no maintenance is performed. If maintenance is to be started next year, it would cost 3,732,434$. Otherwise it would cost 6,607,232$ if maintenance is to be started first in 5 years. That means that the cost of maintenance would increase by 177% in 5 years compared to the cost of maintenance next year. If one is to wait 10 years before performing maintenance, then it would cost 11,827,017$; This means that the maintenance cost would increase by 317% compared to the cost of maintenance if it would take place next year.
- Each section of the Rafah City pavement branches has a maintenance priority according to the section's surface condition.

5.2 Recommendation

- There is a great need of long-term commitment of officials, pavement managers, public and road users towards the conservation and protection of the Rafah city pavement assets.
- Adapting comprehensive maintenance programs based on the integrated, developed system would direct maintenance activities to sections with high deterioration rates rather than a random selection of streets.
- Perform regular pavement condition inspections, an effort to capitalize on this PCI inspection effort and better track the condition of its pavements, it is

strongly recommended that the City continue to perform PCI surveys on a three year cycle. Doing so will enable the City to:

1. Better track the deterioration of its pavements,
2. Develop pavement deterioration trends to better predict future pavement conditions, and
3. Assess the effectiveness of its pavement maintenance, preservation, and Major M&R activities.

- Customize Micro PAVER, due to the fact that this was a first time pavement management system implementation for Rafah City, the Micro PAVER system tables were used. Moving forward, it is recommended that these systems tables be modified – as needed – to reflect the performance of the City's pavements as well as the costs incurred by the City for different M&R activities.
- Expand existing preventive maintenance program, it is recommended that the City expand its preventive maintenance program to all asphalt-surfaced pavements that are in adequate condition and that are exhibiting pavement distresses that benefit from preventive maintenance.
- Applying the PI concept criterion to setup maintenance priorities, maintenance cost, and pavement management programs.

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Appendixes

Appendix A

PCI values for Rafah city branches

Table (A-1): PCI values for Rafah city branches.

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
1	Abu Baker El-Seddeq	01	Al-Rasheed Street	UNDP buildings	-	915	11.5	10522.5	12	250	2011	80
		02	UNDP buildings	Mid UNRWA building	-	1370	13	17810	13	250	2011	94
		03	Mid UNRWA building	Al-Akheer Street	Right	100	7.5	750	3	250	2013	100
		04	Mid UNRWA building	Al-Akheer Street	Left	100	7.5	750	3	250	2013	100
		05	Al-Akheer Street	Al-Awal Street	Right	500	8.5	4250	9	250	2004	84
		06	Al-Akheer Street	Al-Awal Street	Left	500	8.5	4250	9	250	2004	69
		07	Al-Awal Street	Al-Quds Street	Right	340	8.5	2890	6	250	1987	36
		08	Al-Awal Street	Al-Quds Street	Left	340	8.5	2890	6	250	1987	26
		09	Al-Quds Street	Al-Huria Street	Right	355	8.5	3017.5	7	250	2004	90
		10	Al-Quds Street	Al-Huria Street	Left	355	8.5	3017.5	7	250	1987	52
		11	Al-Huria Street	Zoroub Roundabout	Right	650	9	5850	10	250	2004	82
		12	Al-Huria Street	Zoroub Roundabout	Left	650	9	5850	10	250	2004	66
		13	Zoroub Roundabout	Zoroub Pharmacy	Right	340	6	2040	6	250	2004	80
		14	Zoroub Roundabout	Zoroub Pharmacy	Left	340	6	2040	6	250	2004	67
		15	Zoroub Pharmacy	Khawla School	Right	820	6	4920	6	250	1974	46
		16	Zoroub Pharmacy	Khawla School	Left	820	6	4920	6	250	1974	49
		17	Khawla School	Al-Awda Roundabout	Right	1050	6.5	6825	10	250	2004	70

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
1	Abu Baker El-Seddeq	18	Khawla School	Al-Awda Roundabout	Left	1050	6.5	6825	10	250	2004	74
		19	Al-Awda Roundabout	Al-Jawzat Roundabout	Right	1050	9	9450	11	250	2002	75
		20	Al-Awda Roundabout	Al-Jawzat Roundabout	Left	1050	9	9450	11	250	2002	85
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	530	13	6890	10	250	1982	57
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	300	6.5	1950	5	250	1999	90
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	300	6.5	1950	5	250	1999	92
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	915	8.75	8006.25	11	250	1998	88
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	915	8.75	8006.25	11	250	1998	93
		06	Al-Kherba Roundabout	Road No.102	-	875	15	13125	13	250	1982	61
		07	Road No.102	Mosabeh Police Station	-	825	15	12375	12	250	1982	61
		08	Mosabeh Police Station	Moraj Intersection	-	1100	14.5	15950	13	250	1982	73

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Number of samples	Sample Area (m^2)	Construct year	PCI
3	Taha Hussien	01	Zoroub Roundabout	Jaafer Al-Tayar Street	-	780	9	7020	10	250	1998	90
		02	Jaafer Al-Tayar	Othman Ibn Affan Street	Right	920	8	7360	11	250	2005	90
		03	Jaafer Al-Tayar	Othman Ibn Affan Street	Left	920	8	7360	11	250	2005	95
		04	Al-Kherba Roundabout	Al-Nahal Nieghborhood	-	1100	7	7700	11	250	2004	59
		05	Al-Nahal Nieghborhood	Dar Al-Fadela School	-	1350	6	8100	11	250	2003	59
		06	Dar Al-Fadela School	Salah Eldeen Street	-	700	6	4200	9	250	2003	83
4	Haroon Al Rasheed	01	Beer Qeshta	Ibn Timia Mosque	Right	330	7	2310	11	250	1999	67
		02	Beer Qeshta	Ibn Timia Mosque	Left	330	7	2310	11	250	1999	71
5	Road No.5	01	Road No.17	Al Shaarea Al-Akheer Street	-	1300	7	9100	11	250	1982	52
		03	Al Shaarea Al-Akheer Street	Moraj Street	-	550	7	3850	8	250	1982	66
6	Othman Ibn Affan	01	Beer Qeshta Street	Al-Negma Roundabout	Right	850	9	7650	11	250	2004	58
		02	Beer Qeshta Street	Al-Negma Roundabout	Left	850	9	7650	11	250	2004	81

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
7	Road No.7	01	130 m West Al-Nos Street	190 m East Al-Nos Street	-	310	8.5	2635	7	250	2004	70
8	Saddam Hussien	01	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Right	1050	6.5	6825	10	250	2005	72
		02	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Left	1050	6.5	6825	10	250	2005	72
		03	Abu-Yousif Al-Najar Street	Taha Hussien Street	-	630	7	4410	9	250	1999	73
9	Al-Emam Ali	01	Eygpt Border	Zoroub Roundabout	-	300	7	2100	6	250	1997	40
		02	Zoroub Roundabout	Road No.23	-	1100	12	13200	12	250	1997	92
		03	Road No.23	Al-Hashash Intersection	-	1100	7	7700	11	250	1997	85
		04	Al-Hashash Intersection	Moraj Street	-	1060	7	7420	11	250	1997	67
12	Road No.12	01	Al-Dakhlia Street	Saddam Hussien Street	Right	700	6.5	4550	9	250	2013	100
		02	Al-Dakhlia Street	Saddam Hussien Street	Left	700	6.5	4550	9	250	2013	100
		03	Saddam Hussien Street	Dair Yaseen Street	Right	680	8	5440	11	250	2014	100

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Number of samples	Sample Area (m^2)	Construct year	PCI
12	Road No.12	04	Saddam Hussien Street	Dair Yaseen Street	Left	680	8	5440	11	250	2014	100
16	Al Rasheed	01	Al-Ezba	Abu Baker El-Seddeq Street	-	1100	10	11000	12	250	2012	84
		02	Abu Baker El-Seddeq Street	Middle Al Rasheed Street	-	1100	10	11000	12	250	2012	91
		03	Middle Al Al Rasheed Street	End of Rafah	-	1050	10	10500	12	250	2012	94
17	Road No.17	01	Road No.32	Mid Road No.17	-	1000	7	7000	10	250	1982	47
		02	Mid Road No.17	Road No.5	-	1000	7	7000	10	250	1982	47
18	Road No.18	01	Haroon Al Rasheed Street	Al-Maslakh	-	470	7	3290	7	250	1999	78
		02	Al-Maslakh	Saddam Hussien Street	-	260	7	1820	5	250	2002	88
19	Al Matar	01	Abu Baker El-Seddeq Street	Saddam Hussien Street	-	460	9	4140	9	250	2000	64
		02	Saddam Hussien Street	Orooba Street	-	700	12	8400	11	250	2001	70
		03	Orooba Street	Salah Eldeen Street	-	1000	7	7000	10	250	2005	60

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
20	Al-Eman	01	Eastern Cemetery	Salah Eldeen Street	-	1050	7	7350	10	250	2013	100
21	Beer Qeshta	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	330	9	2970	7	250	2013	100
		02	Othman Ibn Affan Street	Haroon Al Rasheed Street	-	560	9	5040	9	250	2013	95
		03	Haroon Al Rasheed Street	Road No.67	Right	370	6.5	2405	6	250	2004	67
		04	Haroon Al Rasheed Street	Road No.67	Left	370	6.5	2405	6	250	2004	67
		05	Orooba Street	Salah Eldeen Street	Right	500	8	4000	8	250	2005	91
		06	Orooba Street	Salah Eldeen Street	Left	500	8	4000	8	250	2005	93
23	Road No.23	01	Jaafer Al-Tayar Street	Al-Emam Ali Street	-	720	6	4320	9	250	1992	47
24	Al Shaarea Al-Akheer	01	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Right	330	7.5	2475	6	250	2012	100
		02	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Left	330	7.5	2475	6	250	2012	100
		03	Tareq Ibn Zyad Street	Heefa Street	Right	350	6	2100	6	250	2014	100
		04	Tareq Ibn Zyad Street	Heefa Street	Left	350	6	2100	6	250	2014	100

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
24	Al Shaarea Al-Akheer	05	Heefa Street	Kanada Well	-	370	5	1850	5	250	1980	10
		06	Kanada Well	Moraj Street	-	560	8	4480	9	250	2012	100
25	Al-Nos	01	Abu Baker El-Seddeq Street	Road No.7	-	1000	12	12000	12	250	2005	82
26	Ibn Seena	01	Abu Baker El-Seddeq Street	Emirati hospital	Right	710	9	6390	10	250	2004	81
		02	Abu Baker El-Seddeq Street	Emirati hospital	Left	710	9	6390	10	250	2004	74
		03	Emirati hospital	End Badr Camp	-	450	12	5400	10	250	2003	74
		04	End Badr Camp	Al-Emam Ali Street	-	440	7	3080	7	250	1998	65
27	Jaafer Al-Tayar	01	Taha Hussien Street	Road No.23 Street	-	760	7	5320	9	250	1992	42
28	Road No.28	01	Abu Baker El-Seddeq Street	Al-Salam Mosque	-	300	7	2100	6	250	2004	94
29	Al-Worood	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	530	12	6360	10	250	2004	88

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
31	Al-Dakhlia	01	Abu Baker El-Seddeq Street	Road No.12	-	510	9	4590	9	250	2004	76
		02	Road No.12	Al-Shaheed Street	-	220	5	1100	9	250	2004	75
32	Road No.32	01	Al-Rasheed Street	Road No.17	-	1000	7	7000	10	250	1982	53
35	Al-Quds	01	Abu Baker El-Seddeq Street	Al-Huria Street	-	750	12	9000	11	250	2005	83
36	Tareq Ibn Zyad	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	730	12	8760	11	250	2004	79
37	Heefa	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	710	12	8520	11	250	2003	72
44	Moraj	01	Road No.5	Road No.11	-	550	7	3850	8	250	1982	48
		02	Road No.11	Al-Emam Ali Street	-	1100	7	7700	11	250	1982	59
		03	Al-Emam Ali Street	Omar Ibn Al-Khattab Street	-	1000	7	7000	10	250	1982	38
48	Road No.48	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	310	9	2790	7	250	1998	89

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
49	Al-Hadad	01	Road No.52	Othman Ibn Affan Street	Right	420	9	3780	8	250	1998	30
		02	Road No.52	Othman Ibn Affan Street	Left	420	9	3780	8	250	1998	43
50	Belal Ibn Rabah	01	Al-Negma Roundabout	Mid Al-Negma Garden	Right	180	8	1440	5	250	2010	91
		02	Al-Negma Roundabout	Road No.73	Left	460	7	3220	7	250	1997	63
		03	Road No.73	Road No.28	Left	450	7	3150	7	250	1997	74
51	Road No.51	01	Keer Street	Akka Street	-	560	12	6720	10	250	2012	95
		02	Akka Street	Abu Baker El-Seddeq Street	-	150	7	1050	3	250	1987	62
52	Road No.52	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	280	7	1960	6	250	1987	53
		02	Belal Ibn Rabah Street	Taha Hussien Street	-	580	12	6960	10	250	1987	50
53	Keer	01	Abu Baker El-Seddeq Street	Road No.51	-	120	12	1440	5	250	2012	93
54	Ramadan Azzam	01	Ibn Seena Street	Al Shaarea Al-Akheer Street	-	480	12	5760	10	250	2005	80

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
56	Road No.56	01	Al-Worood Street	Road No.28	-	250	12	3000	7	250	2004	93
61	Road No.61	01	Road No.12	Taha Hussien Street	-	1030	10	10300	12	250	2013	100
66	Magdy Younis	01	Saddam Hussien Street	Dair Yaseen Street	-	600	12	7200	11	250	1997	72
67	Road No.67	01	Al Matar Street	Beer Qeshta Street	-	410	12	4920	9	250	2004	91
73	Road No.73	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	400	9	3600	8	250	1978	54
75	Road No.75	01	Omar Ibn Al-Khattab Street	1 km far	-	1050	7	7350	11	250	1982	60
		02	1 km far	2 km far	-	1050	7	7350	11	250	1982	50
		03	2 km far	3 km far	-	1050	7	7350	11	250	1982	64
		04	3 km far	Salah Eldeen Street	-	1000	7	7000	11	250	1982	45
77	Al-Shaheed	01	Omar Ibn Al-Khattab Street	Saddam Hussien Street	-	1000	9	9000	11	250	2005	71

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
80	Abu-Yousif Al-Najar	01	Saddam Hussien Street	Dair Yaseen Street	-	600	7	4200	9	250	2000	65
		02	Dair Yaseen Street	Orooba Street	-	640	12	7680	11	250	2005	74
82	Dair Yaseen	01	Abu-Yousif Al-Najar Street	Al Matar Street	-	820	9	7380	11	250	1997	77
200	Road No.200	01	Abu Baker El-Seddeq Street	End of one Side	-	475	9.5	4512.5	9	250	2013	100
		02	End of one Side	Road No.5	Right	825	9.5	7837.5	11	250	2014	100
		03	End of one Side	Road No.5	Left	825	9.5	7837.5	11	250	2014	100
201	Road No.201	01	Al-Eman Mosque	Al Kafrawi Street	-	230	5	1150	4	250	2003	64
202	AlQuds School Street	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	75	7	525	2	250	1999	92
203	Al-Baladia Kindergarden	01	Al Shaarea Al-Akheer Street	Heefa Street	-	240	7	1680	5	250	2005	68

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m²)	Number of samples	Sample Area (m²)	Construct year	PCI
204	Beer Al-Nashel	01	Al-Emam Ali Street	Abu Baker El-Seddeq Street	-	570	7	3990	8	250	2004	54
205	Al-Noor Mosque Street	01	Heefa Street	Ibn Seena Street	-	245	7	1715	5	250	2005	51
206	Al-Salheen Mosque Street	01	Abu Baker El-Seddeq Street	Al Shaarea Al-Akheer Street	-	270	7	1890	6	250	2005	70
207	Kamal Odwan School Street	01	Al-Salheen Mosque	Kamal Odwan School	-	800	7	5600	10	250	2004	67
208	Road No.208	01	Ramadan Azzam Street	Emarati Hospital	-	215	6.5	1397.5	5	250	2005	59
209	Road No.209	01	Road No.208	Ibn Seena Street	-	55	6.5	357.5	1	250	2005	76
210	Road No.210	01	Road No.208	Road No.211	-	220	10	2200	6	250	2005	92

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Number of samples	Sample Area (m^2)	Construct year	PCI
211	Road No.211	01	Ibn Seena Street	270 m far from Ibn Seena Street	-	270	12	3240	7	250	2005	93

Appendix B

Maintenance type, and cost to all branches

Table (B-1): Maintenance type, and cost to all branches

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
1	Abu Baker El-Seddeq	01	Al-Rasheed Street	UNDP buildings	-	915	11.5	10522.5	RM	0.5	5261.25
		02	UNDP buildings	Mid UNRWA building	-	1370	13	17810	RM	0.5	8905
		03	Mid UNRWA building	Al-Akheer Street	Right	100	7.5	750	RM	0.5	375
		04	Mid UNRWA building	Al-Akheer Street	Left	100	7.5	750	RM	0.5	375
		05	Al-Akheer Street	Al-Awal Street	Right	500	8.5	4250	RM	0.5	2125
		06	Al-Akheer Street	Al-Awal Street	Left	500	8.5	4250	AO1	11	46750
		07	Al-Awal Street	Al-Quds Street	Right	340	8.5	2890	AO2	17	49130
		08	Al-Awal Street	Al-Quds Street	Left	340	8.5	2890	AO2	17	49130
		09	Al-Quds Street	Al-Huria Street	Right	355	8.5	3017.5	RM	0.7	2112.25
		10	Al-Quds Street	Al-Huria Street	Left	355	8.5	3017.5	AO2	17	51297.5
		11	Al-Huria Street	Zoroub Roundabout	Right	650	9	5850	RM	0.5	2925
		12	Al-Huria Street	Zoroub Roundabout	Left	650	9	5850	AO1	11	64350
		13	Zoroub Roundabout	Zoroub Pharmacy	Right	340	6	2040	RM	0.5	1020
		14	Zoroub Roundabout	Zoroub Pharmacy	Left	340	6	2040	AO1	11	22440
		15	Zoroub Pharmacy	Khawla School	Right	820	6	4920	AO2	17	83640
		16	Zoroub Pharmacy	Khawla School	Left	820	6	4920	AO2	17	83640
		17	Khawla School	Al-Awda Roundabout	Right	1050	6.5	6825	RM	0.5	3412.5
		18	Khawla School	Al-Awda Roundabout	Left	1050	6.5	6825	RM	0.5	3412.5

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
1	Abu Baker El-Seddeq	19	Al-Awda Roundabout	Al-Jawzat Roundabout	Right	1050	9	9450	RM	0.5	4725
		20	Al-Awda Roundabout	Al-Jawzat Roundabout	Left	1050	9	9450	RM	0.5	4725
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	530	13	6890	AO1	11	75790
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	300	6.5	1950	RM	0.5	975
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	300	6.5	1950	RM	0.5	975
		04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	915	8.75	8006.25	RM	0.5	4003.125
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	915	8.75	8006.25	RM	0.5	4003.125
		06	Al-Kherba Roundabout	Road No.102	-	875	15	13125	AO1	11	144375
		07	Road No.102	Mosabeh Police Station	-	825	15	12375	AO1	11	136125
		08	Mosabeh Police Station	Moraj Intersection	-	1100	14.5	15950	RM	0.5	7975
3	Taha Hussien	01	Zoroub Roundabout	Jaafer Al-Tayar Street	-	780	9	7020	RM	0.5	3510
		02	Jaafer Al-Tayar	Othman Ibn Affan Street	Right	920	8	7360	RM	0.5	3680

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
3	Taha Hussien	03	Jaafer Al-Tayar	Othman Ibn Affan Street	Left	920	8	7360	RM	0.5	3680
		04	Al-Kherba Roundabout	Al-Nahal Nieghborhood	-	1100	7	7700	AO1	11	84700
		05	Al-Nahal Nieghborhood	Dar Al-Fadela School	-	1350	6	8100	AO1	11	89100
		06	Dar Al-Fadela School	Salah Eldeen Street	-	700	6	4200	RM	0.5	2100
4	Haroon Al Rasheed	01	Beer Qeshta	Ibn Timia Mosque	Right	330	7	2310	AO1	11	25410
		02	Beer Qeshta	Ibn Timia Mosque	Left	330	7	2310	RM	0.5	1155
5	Road No.5	01	Road No.17	Al Shaarea Al-Akheer Street	-	1300	7	9100	AO2	17	154700
		03	Al Shaarea Al-Akheer Street	Moraj Street	-	550	7	3850	AO1	11	42350
6	Othman Ibn Affan	01	Beer Qeshta Street	Al-Negma Roundabout	Right	850	9	7650	AO1	11	84150
		02	Beer Qeshta Street	Al-Negma Roundabout	Left	850	9	7650	RM	0.5	3825
7	Road No.7	01	130 m West Al-Nos Street	190 m East Al-Nos Street	-	310	8.5	2635	RM	0.5	1317.5

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
8	Saddam Hussien	01	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Right	1050	6.5	6825	RM	0.5	3412.5
		02	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Left	1050	6.5	6825	RM	0.5	3412.5
		03	Abu-Yousif Al-Najar Street	Taha Hussien Street	-	630	7	4410	RM	0.5	2205
9	Al-Emam Ali	01	Eygpt Border	Zoroub Roundabout	-	300	7	2100	AO2	17	35700
		02	Zoroub Roundabout	Road No.23	-	1100	12	13200	RM	0.5	6600
		03	Road No.23	Al-Hashash Intersection	-	1100	7	7700	RM	0.5	3850
		04	Al-Hashash Intersection	Moraj Street	-	1060	7	7420	AO1	11	81620
12	Road No.12	01	Al-Dakhlia Street	Saddam Hussien Street	Right	700	6.5	4550	RM	0.5	2275
		02	Al-Dakhlia Street	Saddam Hussien Street	Left	700	6.5	4550	RM	0.5	2275
		03	Saddam Hussien Street	Dair Yaseen Street	Right	680	8	5440	RM	0.5	2720
		04	Saddam Hussien Street	Dair Yaseen Street	Left	680	8	5440	RM	0.5	2720
16	Al Rasheed	01	Al-Ezba	Abu Baker El-Seddeq Street	-	1100	10	11000	RM	0.5	5500

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
16	Al Rasheed	02	Abu Baker El-Seddeq Street	Middle Al Rasheed Street	-	1100	10	11000	RM	0.5	5500
		03	Middle Al Al Rasheed Street	End of Rafah	-	1050	10	10500	RM	0.5	5250
17	Road No.17	01	Road No.32	Mid Road No.17	-	1000	7	7000	AO2	17	119000
		02	Mid Road No.17	Road No.5	-	1000	7	7000	AO2	17	119000
18	Road No.18	01	Haroon Al Rasheed Street	Al-Maslakh	-	470	7	3290	RM	0.7	2303
		02	Al-Maslakh	Saddam Hussien Street	-	260	7	1820	RM	0.7	1274
19	Al Matar	01	Abu Baker El-Seddeq Street	Saddam Hussien Street	-	460	9	4140	AO1	11	45540
		02	Saddam Hussien Street	Orooba Street	-	700	12	8400	RM	0.5	4200
		03	Orooba Street	Salah Eldeen Street	-	1000	7	7000	AO1	11	77000
20	Al-Eman	01	Eastern Cemetery	Salah Eldeen Street	-	1050	7	7350	RM	0.5	3675
21	Beer Qeshta	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	330	9	2970	RM	0.5	1485
		02	Othman Ibn Affan Street	Haroon Al Rasheed Street	-	560	9	5040	RM	0.5	2520

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
21	Beer Qeshta	03	Haroon Al Rasheed Street	Road No.67	Right	370	6.5	2405	AO1	11	26455
		04	Haroon Al Rasheed Street	Road No.67	Left	370	6.5	2405	AO1	11	26455
		05	Orooba Street	Salah Eldeen Street	Right	500	8	4000	RM	0.5	2000
		06	Orooba Street	Salah Eldeen Street	Left	500	8	4000	RM	0.5	2000
23	Road No.23	01	Jaafer Al-Tayar Street	Al-Emam Ali Street	-	720	6	4320	AO2	17	73440
24	Al Shaarea Al-Akheer	01	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Right	330	7.5	2475	RM	0.5	1237.5
		02	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Left	330	7.5	2475	RM	0.5	1237.5
		03	Tareq Ibn Zyad Street	Heefa Street	Right	350	6	2100	RM	0.5	1050
		04	Tareq Ibn Zyad Street	Heefa Street	Left	350	6	2100	RM	0.5	1050
		05	Heefa Street	Kanada Well	-	370	5	1850	RC	27	49950
		06	Kanada Well	Moraj Street	-	560	8	4480	RM	0.5	2240
25	Al-Nos	01	Abu Baker El-Seddeq Street	Road No.7	-	1000	12	12000	RM	0.5	6000
26	Ibn Seena	01	Abu Baker El-Seddeq St.	Emirati hospital	Right	710	9	6390	RM	0.5	3195

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
26	Ibn Seena	02	Abu Baker El-Seddeq Street	Emirati hospital	Left	710	9	6390	RM	0.5	3195
		03	Emirati hospital	End Badr Camp	-	450	12	5400	RM	0.5	2700
		04	End Badr Camp	Al-Emam Ali Street	-	440	7	3080	AO1	11	33880
27	Jaafer Al-Tayar	01	Taha Hussien Street	Road No.23 Street	-	760	7	5320	AO2	17	90440
28	Road No.28	01	Abu Baker El-Seddeq Street	Al-Salam Mosque	-	300	7	2100	RM	0.5	1050
29	Al-Worood	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	530	12	6360	RM	0.5	3180
31	Al-Dakhlia	01	Abu Baker El-Seddeq Street	Road No.12	-	510	9	4590	RM	0.5	2295
		02	Road No.12	Al-Shaheed Street	-	220	5	1100	RM	0.5	550
32	Road No.32	01	Al-Rasheed Street	Road No.17	-	1000	7	7000	AO2	17	119000
35	Al-Quds	01	Abu Baker El-Seddeq Street	Al-Huria Street	-	750	12	9000	RM	0.5	4500
36	Tareq Ibn Zyad	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	730	12	8760	RM	0.5	4380

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
37	Heefa	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	710	12	8520	RM	0.5	4260
44	Moraj	01	Road No.5	Road No.11	-	550	7	3850	AO2	17	65450
		02	Road No.11	Al-Emam Ali Street	-	1100	7	7700	AO1	11	84700
		03	Al-Emam Ali Street	Omar Ibn Al-Khattab Street	-	1000	7	7000	AO2	17	119000
48	Road No.48	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	310	9	2790	RM	0.5	1395
49	Al-Hadad	01	Road No.52	Othman Ibn Affan Street	Right	420	9	3780	AO2	17	64260
		02	Road No.52	Othman Ibn Affan Street	Left	420	9	3780	AO2	17	64260
50	Belal Ibn Rabah	01	Al-Negma Roundabout	Mid Al-Negma Garden	Right	180	8	1440	RM	0.5	720
		02	Al-Negma Roundabout	Road No.73	Left	460	7	3220	AO1	11	35420
		03	Road No.73	Road No.28	Left	450	7	3150	RM	0.5	1575
51	Road No.51	01	Keer Street	Akka Street	-	560	12	6720	RM	0.5	3360

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
51	Road No.51	02	Akka Street	Abu Baker El-Seddeq Street	-	150	7	1050	AO1	11	11550
52	Road No.52	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	280	7	1960	AO2	17	33320
		02	Belal Ibn Rabah Street	Taha Hussien Street	-	580	12	6960	AO2	17	118320
53	Keer	01	Abu Baker El-Seddeq Street	Road No.51	-	120	12	1440	RM	0.5	720
54	Ramadan Azzam	01	Ibn Seena Street	Al Shaarea Al-Akheer Street	-	480	12	5760	RM	0.5	2880
56	Road No.56	01	Al-Worood Street	Road No.28	-	250	12	3000	RM	0.5	1500
61	Road No.61	01	Road No.12	Taha Hussien Street	-	1030	10	10300	RM	0.5	5150
66	Magdy Younis	01	Saddam Hussien Street	Dair Yaseen Street	-	600	12	7200	RM	0.5	3600
67	Road No.67	01	Al Matar Street	Beer Qeshta Street	-	410	12	4920	RM	0.5	2460
73	Road No.73	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	400	9	3600	AO2	17	61200

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
75	Road No.75	01	Omar Ibn Al-Khattab Street	1 km far	-	1050	7	7350	AO1	11	80850
		02	1 km far	2 km far	-	1050	7	7350	AO2	17	124950
		03	2 km far	3 km far	-	1050	7	7350	AO1	11	80850
		04	3 km far	Salah Eldeen Street	-	1000	7	7000	AO2	17	119000
77	Al-Shaheed	01	Omar Ibn Al-Khattab Street	Saddam Hussien Street	-	1000	9	9000	RM	0.5	4500
80	Abu-Yousif Al-Najar	01	Saddam Hussien Street	Dair Yaseen Street	-	600	7	4200	AO1	11	46200
		02	Dair Yaseen Street	Orooba Street	-	640	12	7680	RM	0.5	3840
82	Dair Yaseen	01	Abu-Yousif Al-Najar Street	Al Matar Street	-	820	9	7380	RM	0.5	3690
200	Road No.200	01	Abu Baker El-Seddeq Street	End of one Side	-	475	9.5	4512.5	RM	0.5	2256.25
		02	End of one Side	Road No.5	Right	825	9.5	7837.5	RM	0.5	3918.75
		03	End of one Side	Road No.5	Left	825	9.5	7837.5	RM	0.5	3918.75
201	Road No.201	01	Al-Eman Mosque	Al Kafrawi Street	-	230	5	1150	AO1	11	12650

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
202	AlQuds School Street	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	75	7	525	RM	0.5	262.5
203	Al-Baladia Kindergarden	01	Al Shaarea Al-Akheer Street	Heefa Street	-	240	7	1680	AO1	11	18480
204	Beer Al-Nashel	01	Al-Emam Ali Street	Abu Baker El-Seddeq Street	-	570	7	3990	AO2	17	67830
205	Al-Noor Mosque Street	01	Heefa Street	Ibn Seena Street	-	245	7	1715	AO2	17	29155
206	Al-Salheen Mosque Street	01	Abu Baker El-Seddeq Street	Al Shaarea Al-Akheer Street	-	270	7	1890	RM	0.5	945
207	Kamal Odwan School Street	01	Al-Salheen Mosque	Kamal Odwan School	-	800	7	5600	AO1	11	61600
208	Road No.208	01	Ramadan Azzam Street	Emarati Hospital	-	215	6.5	1397.5	AO1	11	15372.5
209	Road No.209	01	Road No.208	Ibn Seena Street	-	55	6.5	357.5	RM	0.5	178.75

Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	True area (m^2)	Maintenance type	Cost ($/m2)	Maintenance Cost ($)
210	Road No.210	01	Road No.208	Road No.211	-	220	10	2200	RM	0.5	1100
211	Road No.211	01	Ibn Seena Street	270 m far from Ibn Seena Street	-	270	12	3240	RM	0.5	1620
									Total Cost ($)		3732434.25

Appendix C

PI for all Rafah city branches

Table (C-1): PI for all Rafah city branches

Road No.	section ID	From	To	Direction	P.I	Priority
24	01-24-05	Heefa Street	Kanada Well	-	80.98	1
1	01-01-08	Al-Awal Street	Al-Quds Street	Left	75.8	2
44	01-44-03	Al-Emam Ali Street	Omar Ibn Al-Khattab Street	-	72.97	3
1	01-01-07	Al-Awal Street	Al-Quds Street	Right	71.3	4
75	01-75-04	3 km far	Salah Eldeen Street	-	71.25	5
17	01-17-01	Road No.32	Mid Road No.17	-	70.35	6
17	01-17-02	Mid Road No.17	Road No.5	-	70.35	7
75	01-75-02	1 km far	2 km far	-	69	8
44	01-44-01	Road No.5	Road No.11	-	68.47	9
1	01-01-15	Zoroub Pharmacy	Khawla School	Right	66.8	10
9	01-09-01	Eygpt Border	Zoroub Roundabout	-	66.75	11
5	01-05-01	Road No.17	Al Shaarea Al-Akheer Street	-	66.67	12
32	01-32-01	Al-Rasheed Street	Road No.17	-	66.22	13
1	01-01-16	Zoroub Pharmacy	Khawla School	Left	65.45	14
1	01-01-10	Al-Quds Street	Al-Huria Street	Left	64.1	15
49	01-49-01	Road No.52	Othman Ibn Affan Street	Right	63.7	16
2	01-02-01	Beer Qeshta	Al-Awda Roundabout	-	62.32	17
75	01-75-01	Omar Ibn Al-Khattab Street	1 km far	-	60.97	18
44	01-44-02	Road No.11	Al-Emam Ali Street	-	59.99	19
75	01-75-03	2 km far	3 km far	-	59.17	20
27	01-27-01	Taha Hussien Street	Road No.23 Street	-	59.1	21
2	01-02-06	Al-Kherba Roundabout	Road No.102	-	58.52	22
2	01-02-07	Road No.102	Mosabeh Police Station	-	58.52	23
49	01-49-02	Road No.52	Othman Ibn Affan Street	Left	57.85	24
52	01-52-02	Belal Ibn Rabah Street	Taha Hussien Street	-	57.1	25
22	01-22-01	Jaafer Al-Tayar Street	Al-Emam Ali Street	-	56.85	26
5	01-05-02	Al Shaarea Al-Akheer Street	Moraj Street	-	56.84	27
52	01-52-01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	55.75	28
204	01-204-01	Al-Emam Ali Street	Abu Baker El-Seddeq Street	-	55.7	29
6	01-06-01	Beer Qeshta Street	Al-Negma Roundabout	Right	55.12	30
3	01-03-04	Al-Kherba Roundabout	Al-Nahal Nieghborhood	-	54.67	31
3	01-03-05	Al-Nahal Nieghborhood	Dar Al-Fadela School	-	54.67	32
1	01-01-12	Al-Huria Street	Zoroub Roundabout	Left	54.27	33
73	01-73-01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	54.27	34
205	01-205-01	Heefa Street	Ibn Seena Street	-	54.25	35
1	01-01-14	Zoroub Roundabout	Zoroub Pharmacy	Left	53.82	36
1	01-01-06	Al-Akheer Street	Al-Awal Street	Left	52.92	37

Road No.	section ID	From	To	Direction	P.I	Priority
4	01-04-01	Beer Qeshta	Ibn Timia Mosque	Right	51.07	38
9	01-09-04	Al-Hashash Intersection	Moraj Street	-	51.07	39
1	01-01-17	Khawla School	Al-Awda Roundabout	Right	50.29	40
7	01-07-01	130 m West Al-Nos Street	190 m East Al-Nos Street	-	48.87	41
1	01-01-18	Khawla School	Al-Awda Roundabout	Left	48.49	42
50	01-50-02	Al-Negma Roundabout	Road No.73	Left	48.41	43
19	01-19-03	Orooba Street	Salah Eldeen Street	-	47.47	44
208	01-208-01	Ramadan Azzam Street	Emarati Hospital	-	47.12	45
19	01-19-01	Abu Baker El-Seddeq Street	Saddam Hussien Street	-	47	46
2	01-02-08	Mosabeh Police Station	Moraj Intersection	-	46.94	47
201	01-201-01	Al-Eman Mosque	Al Kafrawi Street	-	46.9	48
26	01-26-04	End Badr Camp	Al-Emam Ali Street	-	46.82	49
51	01-51-02	Akka Street	Abu Baker El-Seddeq Street	-	46.57	50
80	01-80-01	Saddam Hussien Street	Dair Yaseen Street	-	46.22	51
1	01-01-19	Al-Awda Roundabout	Al-Jawzat Roundabout	Right	46.04	52
21	01-21-03	Haroon Al Rasheed Street	Road No.67	Right	45.32	53
21	01-21-04	Haroon Al Rasheed Street	Road No.67	Left	45.32	54
16	01-16-01	Al-Ezba	Abu Baker El-Seddeq Street	-	43.99	55
207	01-207-01	Al-Salheen Mosque	Kamal Odwan School	-	43.52	56
4	01-04-02	Beer Qeshta	Ibn Timia Mosque	Left	43.09	57
203	01-203-01	Al Shaarea Al-Akheer Street	Heefa Street	-	43.07	58
2	01-02-04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	42.19	59
1	01-01-13	Zoroub Roundabout	Zoroub Pharmacy	Right	41.79	60
1	01-01-20	Al-Awda Roundabout	Al-Jawzat Roundabout	Left	41.54	61
2	01-02-02	Al-Awda Roundabout	Al-Negma Roundabout	Right	41.29	62
1	01-01-11	Al-Huria Street	Zoroub Roundabout	Right	40.89	63
16	01-16-02	Abu Baker El-Seddeq Street	Middle Al Rasheed Street	-	40.84	64
2	01-02-03	Al-Awda Roundabout	Al-Negma Roundabout	Left	40.39	65
1	01-01-05	Al-Akheer Street	Al-Awal Street	Right	39.99	66
2	01-02-05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	39.94	67
1	01-01-01	Al-Rasheed Street	UNDP buildings	-	39.79	68
16	01-16-03	Middle Al Al Rasheed Street	End of Rafah	-	39.49	69
6	01-06-02	Beer Qeshta Street	Al-Negma Roundabout	Left	38.59	70
19	01-19-02	Saddam Hussien Street	Orooba Street	-	38.13	71
3	01-03-06	Dar Al-Fadela School	Salah Eldeen Street	-	37.69	72
77	01-77-01	Omar Ibn Al-Khattab Street	Saddam Hussien Street	-	37.34	73

Road No.	section ID	From	To	Direction	P.I	Priority
1	01-01-09	Al-Quds Street	Al-Huria Street	Right	37.29	74
50	01-50-03	Road No.73	Road No.28	Left	37.28	75
8	01-08-01	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Right	36.89	76
8	01-08-02	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Left	36.89	77
66	01-66-01	Saddam Hussien Street	Dair Yaseen Street	-	36.89	78
9	01-09-03	Road No.23	Al-Hashash Intersection	-	36.79	79
26	01-26-02	Abu Baker El-Seddeq Street	Emirati hospital	Left	36.59	80
26	01-26-03	Emirati hospital	End Badr Camp	-	36.59	81
8	01-08-03	Abu-Yousif Al-Najar Street	Taha Hussien Street	-	36.44	82
80	01-80-02	Dair Yaseen Street	Orooba Street	-	35.99	83
206	01-206-01	Abu Baker El-Seddeq Street	Al Shaarea Al-Akheer Street	-	35.99	84
37	01-37-01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	35.89	85
82	01-82-01	Abu-Yousif Al-Najar Street	Al Matar Street	-	35.64	86
3	01-03-01	Zoroub Roundabout	Jaafer Al-Tayar Street	-	34.54	87
3	01-03-02	Jaafer Al-Tayar	Othman Ibn Affan Street	Right	34.54	88
31	01-31-01	Road No.12	Al-Shaheed Street	-	34.54	89
31	01-31-01	Abu Baker El-Seddeq Street	Road No.12	-	34.09	90
9	01-09-02	Zoroub Roundabout	Road No.23	-	33.64	91
1	01-01-02	UNDP buildings	Mid UNRWA building	-	33.49	92
26	01-26-01	Abu Baker El-Seddeq Street	Emirati hospital	Right	33.44	93
18	01-18-01	Haroon Al Rasheed Street	Al-Maslakh	-	33.31	94
209	01-209-01	Road No.208	Ibn Seena Street	-	33.29	95
25	01-25-01	Abu Baker El-Seddeq Street	Road No.7	-	32.99	96
36	01-36-01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	32.74	97
3	01-03-03	Jaafer Al-Tayar	Othman Ibn Affan Street	Left	32.29	98
54	01-54-01	Ibn Seena Street	Al Shaarea Al-Akheer Street	-	32.29	99
35	01-35-01	Abu Baker El-Seddeq Street	Al-Huria Street	-	30.94	100
1	01-01-03	Mid UNRWA building	Al-Akheer Street	Right	30.79	101
1	01-01-04	Mid UNRWA building	Al-Akheer Street	Left	30.79	102
50	01-50-01	Al-Negma Roundabout	Mid Al-Negma Garden	Right	29.63	103
29	01-29-01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	29.09	104

Road No.	section ID	From	To	Direction	P.I	Priority
200	01-200-01	Abu Baker El-Seddeq Street	End of one Side	-	29.04	105
200	01-200-02	End of one Side	Road No.5	Right	29.04	106
200	01-200-03	End of one Side	Road No.5	Left	29.04	107
48	01-48-01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	28.82	108
18	01-18-02	Al-Maslakh	Saddam Hussien Street	-	28.81	109
202	01-202-01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	28.49	110
21	01-21-05	Orooba Street	Salah Eldeen Street	Right	28.34	111
53	01-53-01	Abu Baker El-Seddeq Street	Road No.51	-	28.04	112
67	01-67-01	Al Matar Street	Beer Qeshta Street	-	27.74	113
21	01-21-06	Orooba Street	Salah Eldeen Street	Left	27.44	114
56	01-56-01	Al-Worood Street	Road No.28	-	26.84	115
21	01-21-02	Othman Ibn Affan Street	Haroon Al Rasheed Street	-	26.54	116
28	01-28-01	Abu Baker El-Seddeq Street	Al-Salam Mosque	-	26.39	117
210	01-210-01	Road No.208	Road No.211	-	26.09	118
211	01-211-01	Ibn Seena Street	270 m far from Ibn Seena Street	-	25.64	119
51	01-51-01	Keer Street	Akka Street	-	25.54	120
24	01-24-01	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Right	24.89	121
24	01-24-02	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Left	24.89	122
24	01-24-03	Tareq Ibn Zyad Street	Heefa Street	Right	24.89	123
24	01-24-04	Tareq Ibn Zyad Street	Heefa Street	Left	24.89	124
24	01-24-06	Kanada Well	Moraj Street	-	24.89	125
12	01-12-01	Al-Dakhlia Street	Saddam Hussien Street	Right	24.29	126
12	01-12-02	Al-Dakhlia Street	Saddam Hussien Street	Left	24.29	127
12	01-12-03	Saddam Hussien Street	Dair Yaseen Street	Right	24.29	128
12	01-12-04	Saddam Hussien Street	Dair Yaseen Street	Left	24.29	129
21	01-21-01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	24.29	130
61	01-61-01	Road No.12	Taha Hussien Street	-	23.69	131
20	01-20-01	Eastern Cemetery	Salah Eldeen Street	-	23.29	132

Appendix D

Expected maintenance type and cost after 5 and 10 Years

Table (D-1): Expected maintenance type and cost after 5 and 10 Years

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
1	Abu Baker El-Seddeq	01	Al-Rasheed Street	UNDP buildings	-	915	11.5	RM	5261.25	AO1	115747.5
		02	UNDP buildings	Mid UNRWA building	-	1370	13	RM	8905	AO1	195910
		03	Mid UNRWA building	Al-Akheer Street	Right	100	7.5	RM	375	AO1	8250
		04	Mid UNRWA building	Al-Akheer Street	Left	100	7.5	RM	375	AO1	8250
		05	Al-Akheer Street	Al-Awal Street	Right	500	8.5	RM	2125	AO1	46750
		06	Al-Akheer Street	Al-Awal Street	Left	500	8.5	AO1	46750	AO2	72250
		07	Al-Awal Street	Al-Quds Street	Right	340	8.5	RC	78030	RC	78030
		08	Al-Awal Street	Al-Quds Street	Left	340	8.5	RC	78030	RC	78030
		09	Al-Quds Street	Al-Huria Street	Right	355	8.5	RM	2112.25	AO1	33192.5
		10	Al-Quds Street	Al-Huria Street	Left	355	8.5	RC	81472.5	RC	81472.5
		11	Al-Huria Street	Zoroub Roundabout	Right	650	9	RM	2925	AO1	64350
		12	Al-Huria Street	Zoroub Roundabout	Left	650	9	AO1	64350	AO2	99450

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
1	Abu Baker El-Seddeq	13	Zoroub Roundabout	Zoroub Pharmacy	Right	340	6	RM	1020	AO1	22440
		14	Zoroub Roundabout	Zoroub Pharmacy	Left	340	6	AO1	22440	AO2	34680
		15	Zoroub Pharmacy	Khawla School	Right	820	6	RC	132840	RC	132840
		16	Zoroub Pharmacy	Khawla School	Left	820	6	RC	132840	RC	132840
		17	Khawla School	Al-Awda Roundabout	Right	1050	6.5	AO1	75075	AO2	116025
		18	Khawla School	Al-Awda Roundabout	Left	1050	6.5	AO1	75075	AO2	116025
		19	Al-Awda Roundabout	Al-Jawzat Roundabout	Right	1050	9	AO1	103950	AO2	160650
		20	Al-Awda Roundabout	Al-Jawzat Roundabout	Left	1050	9	RM	4725	AO1	103950
2	Omar Ibn Al-Khattab	01	Beer Qeshta	Al-Awda Roundabout	-	530	13	AO2	117130	RC	186030
		02	Al-Awda Roundabout	Al-Negma Roundabout	Right	300	6.5	RM	975	AO1	21450
		03	Al-Awda Roundabout	Al-Negma Roundabout	Left	300	6.5	RM	975	AO1	21450

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
2	Omar Ibn Al-Khattab	04	Al-Negma Roundabout	Al-Kherba Roundabout	Right	915	8.75	RM	4003.125	AO1	88068.75
		05	Al-Negma Roundabout	Al-Kherba Roundabout	Left	915	8.75	RM	4003.125	AO1	88068.75
		06	Al-Kherba Roundabout	Road No.102	-	875	15	AO1	144375	AO2	223125
		07	Road No.102	Mosabeh Police Station	-	825	15	AO1	136125	AO2	210375
		08	Mosabeh Police Station	Moraj Intersection	-	1100	14.5	AO1	175450	AO2	271150
3	Taha Hussien	01	Zoroub Roundabout	Jaafer Al-Tayar Street	-	780	9	RM	3510	AO1	77220
		02	Jaafer Al-Tayar	Othman Ibn Affan Street	Right	920	8	RM	3680	AO1	80960
		03	Jaafer Al-Tayar	Othman Ibn Affan Street	Left	920	8	RM	3680	AO1	80960
		04	Al-Kherba Roundabout	Al-Nahal Nieghborhood	-	1100	7	AO2	130900	RC	207900
		05	Al-Nahal Nieghborhood	Dar Al-Fadela School	-	1350	6	AO2	137700	RC	218700
		06	Dar Al-Fadela School	Salah Eldeen Street	-	700	6	RM	2100	AO1	46200

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
4	Haroon Al Rasheed	01	Beer Qeshta	Ibn Timia Mosque	Right	330	7	AO1	25410	AO2	39270
		02	Beer Qeshta	Ibn Timia Mosque	Left	330	7	AO1	25410	AO2	39270
5	Road No.5	01	Road No.17	Al Shaarea Al-Akheer Street	-	1300	7	RC	245700	RC	245700
		03	Al Shaarea Al-Akheer Street	Moraj Street	-	550	7	AO1	42350	AO2	65450
6	Othman Ibn Affan	01	Beer Qeshta Street	Al-Negma Roundabout	Right	850	9	AO2	130050	RC	206550
		02	Beer Qeshta Street	Al-Negma Roundabout	Left	850	9	RM	3825	AO1	84150
7	Road No.7	01	130 m West Al-Nos Street	190 m East Al-Nos Street	-	310	8.5	AO1	28985	AO2	44795
8	Saddam Hussien	01	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Right	1050	6.5	AO1	75075	AO2	116025
		02	Al-Jawzat Roundabout	Abu-Yousif Al-Najar Street	Left	1050	6.5	AO1	75075	AO2	116025
		03	Abu-Yousif Al-Najar Street	Taha Hussien Street	-	630	7	AO1	48510	AO2	74970

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
9	Al-Emam Ali	01	Eygpt Border	Zoroub Roundabout	-	300	7	RC	56700	RC	56700
		02	Zoroub Roundabout	Road No.23	-	1100	12	RM	6600	AO1	145200
		03	Road No.23	Al-Hashash Intersection	-	1100	7	RM	3850	AO1	84700
		04	Al-Hashash Intersection	Moraj Street	-	1060	7	AO1	81620	AO2	126140
12	Road No.12	01	Al-Dakhlia Street	Saddam Hussien Street	Right	700	6.5	RM	2275	AO1	50050
		02	Al-Dakhlia Street	Saddam Hussien Street	Left	700	6.5	RM	2275	AO1	50050
		03	Saddam Hussien Street	Dair Yaseen Street	Right	680	8	RM	2720	AO1	59840
		04	Saddam Hussien Street	Dair Yaseen Street	Left	680	8	RM	2720	AO1	59840
16	Al Rasheed	01	Al-Ezba	Abu Baker El-Seddeq Street	-	1100	10	RM	5500	AO1	121000
		02	Abu Baker El-Seddeq Street	Middle Al Rasheed Street	-	1100	10	RM	5500	AO1	121000
		03	Middle Al Al Rasheed Street	End of Rafah	-	1050	10	RM	5250	AO1	115500

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
17	Road No.17	01	Road No.32	Mid Road No.17	-	1000	7	RC	189000	RC	189000
		02	Mid Road No.17	Road No.5	-	1000	7	RC	189000	RC	189000
18	Road No.18	01	Haroon Al Rasheed Street	Al-Maslakh	-	470	7	AO1	36190	AO2	55930
		02	Al-Maslakh	Saddam Hussien Street	-	260	7	RM	1274	AO1	20020
19	Al Matar	01	Abu Baker El-Seddeq Street	Saddam Hussien Street	-	460	9	AO1	45540	AO2	70380
		02	Saddam Hussien Street	Orooba Street	-	700	12	AO1	92400	AO2	142800
		03	Orooba Street	Salah Eldeen Street	-	1000	7	AO1	77000	AO2	119000
20	Al-Eman	01	Eastern Cemetery	Salah Eldeen Street	-	1050	7	RM	3675	AO1	80850
21	Beer Qeshta	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	330	9	RM	1485	AO1	32670
		02	Othman Ibn Affan Street	Haroon Al Rasheed Street	-	560	9	RM	2520	AO1	55440

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
21	Beer Qeshta	03	Haroon Al Rasheed Street	Road No.67	Right	370	6.5	AO1	26455	AO2	40885
		04	Haroon Al Rasheed Street	Road No.67	Left	370	6.5	AO1	26455	AO2	40885
		05	Orooba Street	Salah Eldeen Street	Right	500	8	RM	2000	AO1	44000
		06	Orooba Street	Salah Eldeen Street	Left	500	8	RM	2000	AO1	44000
23	Road No.23	01	Jaafer Al-Tayar Street	Al-Emam Ali Street	-	720	6	RC	116640	RC	116640
24	Al Shaarea Al-Akheer	01	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Right	330	7.5	RM	1237.5	AO1	27225
		02	Abu Baker El-Seddeq Street	Tareq Ibn Zyad Street	Left	330	7.5	RM	1237.5	AO1	27225
		03	Tareq Ibn Zyad Street	Heefa Street	Right	350	6	RM	1050	AO1	23100
		04	Tareq Ibn Zyad Street	Heefa Street	Left	350	6	RM	1050	AO1	23100
		05	Heefa Street	Kanada Well	-	370	5	RC	49950	RC	49950
		06	Kanada Well	Moraj Street	-	560	8	RM	2240	AO1	49280
25	Al-Nos	01	Abu Baker El-Seddeq Street	Road No.7	-	1000	12	RM	6000	AO1	132000

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
26	Ibn Seena	01	Abu Baker El-Seddeq Street	Emirati hospital	Right	710	9	RM	3195	AO1	70290
		02	Abu Baker El-Seddeq Street	Emirati hospital	Left	710	9	AO1	70290	AO2	108630
		03	Emirati hospital	End Badr Camp	-	450	12	AO1	59400	AO2	91800
		04	End Badr Camp	Al-Emam Ali Street	-	440	7	AO1	33880	AO2	52360
27	Jaafer Al-Tayar	01	Taha Hussien Street	Road No.23 Street	-	760	7	RC	143640	RC	143640
28	Road No.28	01	Abu Baker El-Seddeq Street	Al-Salam Mosque	-	300	7	RM	1050	AO1	23100
29	Al-Worood	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	530	12	RM	3180	AO1	69960
31	Al-Dakhlia	01	Abu Baker El-Seddeq Street	Road No.12	-	510	9	AO1	50490	AO2	78030
		02	Road No.12	Al-Shaheed Street	-	220	5	AO1	12100	AO2	18700

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
32	Road No.32	01	Al-Rasheed Street	Road No.17	-	1000	7	RC	189000	RC	189000
35	Al-Quds	01	Abu Baker El-Seddeq Street	Al-Huria Street	-	750	12	RM	4500	AO1	99000
36	Tareq Ibn Zyad	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	730	12	AO1	96360	AO2	148920
37	Heefa	01	Al-Quds Street	Al Shaarea Al-Akheer Street	-	710	12	AO1	93720	AO2	144840
44	Moraj	01	Road No.5	Road No.11	-	550	7	RC	103950	RC	103950
		02	Road No.11	Al-Emam Ali Street	-	1100	7	AO2	130900	RC	207900
		03	Al-Emam Ali Street	Omar Ibn Al-Khattab Street	-	1000	7	RC	189000	RC	189000
48	Road No.48	01	Abu Baker El-Seddeq Street	Taha Hussien Street	-	310	9	RM	1395	AO1	30690

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
49	Al-Hadad	01	Road No.52	Othman Ibn Affan St.	Right	420	9	RC	102060	RC	102060
		02	Road No.52	Othman Ibn Affan Street	Left	420	9	RC	102060	RC	102060
50	Belal Ibn Rabah	01	Al-Negma Roundabout	Mid Al-Negma Garden	Right	180	8	RM	720	AO1	15840
		02	Al-Negma Roundabout	Road No.73	Left	460	7	AO1	35420	AO2	54740
		03	Road No.73	Road No.28	Left	450	7	AO1	34650	AO2	53550
51	Road No.51	01	Keer Street	Akka Street	-	560	12	RM	3360	AO1	73920
		02	Akka Street	Abu Baker El-Seddeq Street	-	150	7	AO1	11550	AO2	17850
52	Road No.52	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	280	7	RC	52920	RC	52920
		02	Belal Ibn Rabah Street	Taha Hussien Street	-	580	12	RC	187920	RC	187920
53	Keer	01	Abu Baker El-Seddeq Street	Road No.51	-	120	12	RM	720	AO1	15840

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
54	Ramadan Azzam	01	Ibn Seena Street	Al Shaarea Al-Akheer Street	-	480	12	RM	2880	AO1	63360
56	Road No.56	01	Al-Worood Street	Road No.28	-	250	12	RM	1500	AO1	33000
61	Road No.61	01	Road No.12	Taha Hussien Street	-	1030	10	RM	5150	AO1	113300
66	Magdy Younis	01	Saddam Hussien Street	Dair Yaseen Street	-	600	12	AO1	79200	AO2	122400
67	Road No.67	01	Al Matar Street	Beer Qeshta Street	-	410	12	RM	2460	AO1	54120
73	Road No.73	01	Abu Baker El-Seddeq Street	Belal Ibn Rabah Street	-	400	9	RC	97200	RC	97200
75	Road No.75	01	Omar Ibn Al-Khattab Street	1 km far	-	1050	7	AO1	80850	AO2	124950
		02	1 km far	2 km far	-	1050	7	RC	198450	RC	198450
		03	2 km far	3 km far	-	1050	7	AO1	80850	AO2	124950
		04	3 km far	Salah Eldeen Street	-	1000	7	RC	189000	RC	189000

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
77	Al-Shaheed	01	Omar Ibn Al-Khattab Street	Saddam Hussien Street	-	1000	9	AO1	99000	AO2	153000
80	Abu-Yousif Al-Najar	01	Saddam Hussien Street	Dair Yaseen Street	-	600	7	AO1	46200	AO2	71400
		02	Dair Yaseen Street	Orooba Street	-	640	12	AO1	84480	AO2	130560
82	Dair Yaseen	01	Abu-Yousif Al-Najar Street	Al Matar Street	-	820	9	AO1	81180	AO2	125460
200	Road No.200	01	Abu Baker El-Seddeq Street	End of one Side	-	475	9.5	RM	2256.25	AO1	49637.5
		02	End of one Side	Road No.5	Right	825	9.5	RM	3918.75	AO1	86212.5
		03	End of one Side	Road No.5	Left	825	9.5	RM	3918.75	AO1	86212.5
201	Road No.201	01	Al-Eman Mosque	Al Kafrawi Street	-	230	5	AO1	12650	AO2	19550
202	AlQuds School Street	01	Omar Ibn Al-Khattab Street	Othman Ibn Affan Street	-	75	7	RM	262.5	AO1	5775

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
203	Al-Baladia Kinderg arden	01	Al Shaarea Al-Akheer Street	Heefa Street	-	240	7	AO1	18480	AO2	28560
204	Beer Al-Nashel	01	Al-Emam Ali Street	Abu Baker El-Seddeq Street	-	570	7	RC	107730	RC	107730
205	Al-Noor Mosque Street	01	Heefa Street	Ibn Seena Street	-	245	7	RC	46305	RC	46305
206	Al-Salheen Mosque Street	01	Abu Baker El-Seddeq Street	Al Shaarea Al-Akheer Street	-	270	7	AO1	20790	AO2	32130
207	Kamal Odwan School Street	01	Al-Salheen Mosque	Kamal Odwan School	-	800	7	AO1	61600	AO2	95200

								After 5 Years		After 10 Years	
Road No.	Road (branch) name	Section ID	From	To	Lane Direction	Length	Width	Maintenance type	Maintenance Cost ($)	Maintenance type	Maintenance Cost ($)
208	Road No.208	01	Ramadan Azzam Street	Emarati Hospital	-	215	6.5	AO2	23757.5	RC	37732.5
209	Road No.209	01	Road No.208	Ibn Seena Street	-	55	6.5	AO1	3932.5	AO2	6077.5
210	Road No.210	01	Road No.208	Road No.211	-	220	10	RM	1100	AO1	24200
211	Road No.211	01	Ibn Seena Street	270 m far from Ibn Seena Street	-	270	12	RM	1620	AO1	35640
								Total	6607232.5		11827017.5