Application of Pavement Management Systems for the Nicosia Turkish Municipality Road Network

Deniz Ulunay

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Approval of the Institute of Graduate Studies and Research

Assoc. Prof. Dr. Ali Hakan Ulusoy
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Assoc. Prof. Dr. Serhan Şensoy
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Asst. Prof. Dr. Mehmet M. Kunt
Supervisor

Examining Committee

1. Asst. Prof. Dr. Şevket Can Bostancı
2. Asst. Prof. Dr.Tolga Çelik
3. Asst. Prof. Dr. Mehmet M. Kunt

ABSTRACT

Pavement management systems are used throughout the world to restore and maintain a country's pavements to better serve communities. This thesis aimed to identify existing rehabilitation and management techniques and examine the work of the Nicosia Turkish Municipality as a case study. In addition, using a condition survey, this thesis explored main challenges pertaining to the Nicosia road network, propose relevant rehabilitation works, and calculate associated costs. Briefly, the main problems of the Nicosia road network were identified using QGIS. Associated rehabilitation costs for the pavements were calculated using the 2016 costbook, the most up-to-date costbook available at the commencement of this thesis. The roads were categorised, using specific color codes, according to their construction date. The results of the condition survey were analysed and relevant recommendations were made for a better pavement system. The current conditions of the pavements were discussed alongside the rehabilitation and maintenance techniques. The Pavement Condition Index for each road were calculated and the current budget for the reconstruction, rehabilitation, and maintenance of the roads were considered in view of effective rehabilitation and maintenance techniques. Graphs, charts and tables were used to illustrate the data produced in this research. It was concluded that the current budget of the Nicosia Turkish Municipality does not provide sufficient maintenance and rehabilitation. The current budget should be almost doubled in order to provide better maintenance and rehabilitation services for the community. Therefore, the living standards of the citizens will improve while both individual and public transportation will become faster and safer. Uniquely, this thesis constitutes the first research study on Nicosia road network.

Keywords: Nicosia Turkish Municipality, Nicosia, pavement, rehabilitation and management.

ÖZ

Günümüzde yol yapım çalışmaları günlük hayatı kolaylaştırmakla birlikte, ilgili birimlerin halka karşı olan sorumluluklarını yerine getirerek halka hizmet etmelerini kolaylaştırmaktadır. Düzgün ve kullanılabilir yollara sahip olan ülkelerdeki yaşam standartlarının diğerlerine kıyasla daha yüksek olduğu yadsınamaz bir gerçektir. Bu çalışma, KKTC'nin başkenti olan Lefkoşa'daki yolların durumlarını ele alarak Lefkoşa Türk Belediyesi'nin sorumluluğunda olan yolların durumunu QGIS programı vasıtası ile veri haline getirmiştir. Araştırmacı bu çalışmanın amacına hizmet edebilmesi adına Lefkoşa'daki yolların durumunu birebir ziyaret ederek kaydetmiş ve bu yolları iyileştirebilmek adına önerilerde bulunmuştur. Bu bağlamda, yollar bozukluk seviyeleri ve trafik yoğunluğuna göre sınıflandırılarak iyileştirme yönündeki çalışmalarda öncelik hakkının hangi yolda olması gerektiği konusunda sonuçlara varılmıştır. Araştırmacı bu sonuçları tablo ve grafikler halinde sunulmaya hazırlayarak daha kolay bir anlaşılırlık sunmuştur. Yapılan çalışma sonucunda, Lefkoşa Türk Belediyesi'nin mevcut mali bütçesinin yol çalışmaları için yetersiz kaldığı kanısına varılmıştır. Etkili yol çalışmaları için mali bütçenin neredeyse iki katına çıkarılması gerektiği ve böylelikle halkın daha etkili bir yol hizmetine erişebileceği sonucu çıkarılmıştır. Bununla birlikte, hem özel hem de toplu taşımacılıkta daha hızlı ve daha güvenli ulaşım sağlanacaktır. Literatürde yapılan taramada Lefkoşa bölgesine özgün bir çalışmaya rastlanmamıştır ve çalışma orjinalite bakımından özgünlüğünü korumaktadır.

Anahtar Kelimeler: Lefkoşa Türk Belediyesi, Lefkoşa, yol, yol yapım çalışmaları.

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LIST OF ABBREVIATIONS

CDV	Corrected Deduct Values
GIS	Geographical Information System
HMA	Hot Mixed Asphalt
M&R	Maintenance and Rehabilitation
NTM	Nicosia Turkish Municipality
PACER	Pavement Surface Evaluation and Rating
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PCS	Pavement Condition Survey
PMS	Pavement Management System
QGIS	Quantum Geographical Information System
TDV	Total Deduct Value
TRNC	Turkish Republic of Northern Cyprus

Chapter 1

INTRODUCTION

Paved road networks are crucial assets for both the developing and developed countries. With improving technology, countries desire to attain faster and more effective transportation than ever before. Pavement management systems allow the preservation of roads and pavements, and maintenance and rehabilitation can also contribute to road safety, comfort and economic effectiveness.

Transportation development demands interdisciplinary efforts involving engineers, researchers, traders, businessmen, and workers. These interdisciplinary efforts aiming to provide, develop, and construct pavements is known as pavement management system (Haas and Hudson, 1978). This term was coined in the 1960s to describe the activities for the maintenance and rehabilitation of roads. In order to establish an effective pavement management system (PMS), the supply of pavement needs should be organised in "sub-system of planning, designing and constructing and maintaining pavements" (Haas and Hudson, 1978).

1.1 Problem Statement

Developed countries with high quality PMSs can maintain high living standards. Without organized pavement management, the road quality and comfort would be adversely affected. PMS serves the community by providing safety, comfort and speed with the aim of improving the road Pavement Condition Index (PCI) level.

Accordingly, a comprehensive PMS should be developed to serve the community in the best manner. Maintaining and rehabilitating the pavements is as important as constructing the pavements. The distresses forming on pavements should be properly treated to improve pavement condition, which is influenced by time, traffic, and the environmental issues such as weather conditions (Haas and Hudson, 1978).

As a developing country, Cyprus is one of the rare islands in which two communities, being the Turkish Cypriots and the Greek Cypriots, live separately under two distinct governments. In this thesis, the Nicosia Turkish Municipality road network was selected as a case study in order to investigate problematic road sections. By doing so, a road analysis of the developing Northern region of the island was performed to improve the living standards of the community. The Nicosia Turkish Municipality has a very limited budget which cannot provide sufficient road maintenance systems. A comprehensive PMS is crucial to provide safety, comfort, and speed of transport for the community. The budget of a municipality depends upon the revenues and the expenditures. Taking into consideration that the revenues, including the governmental funds, of the Nicosia Turkish Municipality are much lower than the expenditures of the municipality, the budget is not efficient for PMS.

The Nicosia Turkish Municipality is the biggest municipality in North Cyprus as Nicosia is the capital city of North Cyprus with the highest population. According to the latest population count of North Cyprus, the de facto population of Nicosia was 97,293. The de facto count includes all of the people in the island during the counting process. This amount includes tourists and students as well as other visitors in the country. Table 1 below illustrates the distribution of population by cities (Devlet Planlama Örgütü, 2011).

Table 1: TRNC Population Count (Devlet Planlama Örgütü, 2011).

	DE JURE	**DISTRIBUTION (%)**	**DE FACTO**	**DISTRIBUTION (%)**
LEFKOSA	94,824	33.1	97,293	33.1
GAZİMAĞUSA	69,741	24.4	69,838	23.7
GİRNE	69,163	24.1	73,577	25.0
GÜZELYURT	30,037	10.5	30,590	10.4
İSKELE	22,492	7.9	23,098	7.8
TOTAL	286,257	100.0	294,396	100.0

Deterioration of a road can take place due to the traffic volume, climate and drainage conditions (Garber and Hoel, 2010). During the commencement of this thesis, it was common knowledge that both the road network and the pavements in the city of Nicosia were underdeveloped and not routinely maintained. Indeed, the municipality tends to address problems pertaining to pavements only when an accident occurs or citizens make serious complaints. The complaints are shared on social media, which in todays world has a considerable impact in governmental issues. The social media also influence the journalists and the newsmakers. Once a problem attracts social attention, it is shown on television and radio news and programs, local newspapers and the journals.

This could be partly explained by the small budget of the Nicosia Turkish Municipality. For instance, between 2009 to 2015, the average annual budget of the Nicosia Turkish Municipality was approximately 1,600,000 TL, which is insufficient for rehabilitating all deterioriated and problematic roads, which need to be addressed under Maintenance and Rehabilitation (M&R).

Funding is not the only challenge for pavement management and rehabilitation. Identifying adequately qualified personnel is another issue faced by relevant agencies. Therefore, it is crucial to study the current situation in Nicosia as well as existing PMS strategies to find reasonable solutions to address the current challenges faced by the Nicosia road network and pavements.

1.2 Objectives and the scope of the study

The main aim of this thesis was to develop realistic goals for managing the roads of Nicosia to improve both the performance and quality of the roads. With this aim in mind, the road network of Nicosia and pavement sections were examined by using Quantum Geographical Information System (QGIS) thoroughly in this thesis to meet the following objectives:

i. identify and evaluate the current condition of the pavements of Nicosia Turkish Municipality through a pavement condition survey.

ii. develop a system to rehabilitate/develop pavements through QGIS and calculate the necessary budget for the Maintenance and Rehabilitation (M&R) programs.

Chapter 2

LITERATURE REVIEW

2.1 Pavements

Pavements are one of the most valuable assets for both developing and developed countries as they provide a long-lasting road surface. They could be used to transfer the load of the vehicles to the sub-base, base and underlying soil. Modern flexible pavements include gravel, sand or crushed stone that are squeezed together with asphalt, asphaltic oil and tar, used as a binder. Flexible pavement techniques have sufficient flexibility to allow the surface to absorb impacts and shock at a maximal level. Rigid pavements are generally made up of concrete and mixed with fine aggregate and Portland cement. Rigid pavements are commonly reinforced with mesh and steel rod (Yoder and Witczak, 1975).

Road construction technologies mainly concentrate on two pavement types which are flexible and rigid pavements. These pavements have unique characteristics. The differences between Flexible Pavements and Rigid Pavements are summarized in Figure 1 and Table 2 (The Constructor Civil Engineering Home, 2017).

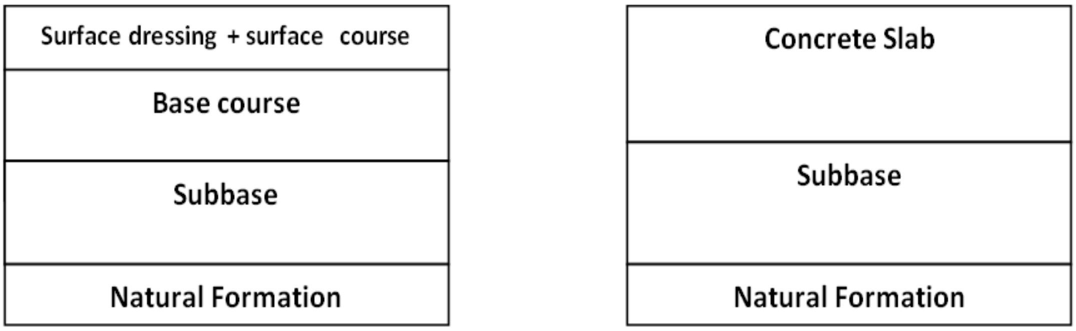


Figure 1: Pavement Types (Türkiye Mühendislik Haberleri, 2013 and Karayolları Genel Müdürlüğü, 2005)

Table 2: Flexible Pavement vs Rigid Pavement (The Constructor Civil Engineering Home, 2017)

Flexible Pavement	**Rigid Pavement**
It includes a layers of high quality materials at the surface or near surface	It consist one layer Portland cement concrete
It reveals the deformation of the sub-grade on the surface of the road	It is able to handle the localised failures, so it is not visible on the surface
Its stability depends on the aggregate interlock and friction	Its stability is provided by the pavement slab(concrete slab)
Temperature variation do not generate stress in flexible pavement	Temperature variation generate huge stress in rigid pavement
It has self curing properties due to flexible properties (i.e.: heavy wheel loads cause settlement)	It has no self curing properties due to heavier wheel loads because of its rigidity. (i.e.. settlements are permanent)

2.2 Importance of Road Maintenance

Roads contribute to countries' economic growth and bring many social benefits. For instance, access to social, employment, health and education services provided by paved roads inspire economic and social growth. Hence, roads are a crucial public asset (World Highways, 2015). Developed roads bring advantages to road users through improved access to hospitals, markets, schools and also improvenets in communal quality of lives. Having well-conditioned roads will not only provide speed of access throughout the country but also allow people to travel safely. Improved quality of roads also decrease the operating cost of a vehicle. Therefore, the community would have lower expenditure on their vehicles` services such as the tyre costs and the fuel costs. All in all, they would have access to cheaper individual and public transportation.

In order to maintain the road quality, a well-planned program of maintenance needs to be followed to increase the benefits of road (Burningham and Stankevich, 2005). Not having effective road maintenance techniques that are applied on time will bring adverse consequences both to the society and the government. The pitfalls that can be brought up through disorganised road maintenance are listed below:

i. <u>High cost to authorities:</u> If a problem is underestimated on the road surface, an entire road section may fail. This may require re-construction, associated with high costs.

ii. <u>High cost to vehicle owners:</u> The operation of the vehicles could indirectly increase costs, whereby vehicles may need frequent repairs or consume have increased fuel consumption due to tyre wearing off.

iii. <u>Reduction of living standards:</u> Construction problems on the roads could lead to traffic congestions. Therefore, people may not be able to attend to their daily needs in a timely manner which could harm life standards. For instance, challenges with commuting to work due to road maintenance problems could bring social and economic problems for a person (Burningham and Stankevich, 2005).

Considering the importance of roads, road maintenance should be conducted on a regular basis to maintain their effectiveness. Maintenance comprises activities aiming to upkeep pavements, drainages, shoulders, road margins and other structural properties. A standard asphalt pavement serves up to 10-12 years without any application of M&R services. However, after 10-12 years, regular maintenance and rehabilitation services should be conducted to increase its lifetime allowing it to serve an approximate of 20-25 years (Haas and Hudson, 1978). Maintenance activities can be classified in 3 main headings:

i. Routine Maintenance: Overall, routine maintenance techniques include simple and cheap methods such as shoulder cleaning, grass cutting, cleaning of water channel next to the road, patching and pothole repair (Burningham and Stankevich, 2005). Crucially, it does not require advanced professional instruments and complex knowledge and experience. It can be performed with simple instruments and often requires a relatively short time. For instance, trimming grass or sweeping the rubbish extracts from the surface of the road are activities which do not require extended time and effort (Burningham and Stankevich, 2005). When routine maintenance is done by the people themselves, the governmental authorities can take further action for more professional maintenance techniques. Routine maintenance must be conducted continuously on every road depending on its structural characteristics and the traffic volume it serves. Routine maintenance is mostly small-scale and can be done using manual labour or inhouse arrangements. It can be planned at fixed intervals in a year in order to prevent the deterioration of pavements (Gram and Yojana, (n.d.)).

ii. Periodic Maintenance: Periodic maintenance is generally done at relatively long intervals, and it aims to prevent and preserve the structural reliability of the road. These maintenance operations are generally conducted in large-scale and require experienced staff and special equipments. Periodic maintenance costs a lot more than routine maintenance, and it requires one to identify, implement and plan according to the specific road problem. Periodic maintenance techniques include resurfacing, overlaying and pavement reconstruction. Overlay and resealing strategies are developed by taking the deterioration in the road condition in consideration (Burningham and Stankevich, 2005).

iii. Urgent Maintenance: Urgent maintenance involves repairing unforeseen and emergency pavement problems, such as collapses, landslides, and other obstructions (Burningham and Stankevich, 2005).

2.3 Pavement Distress Types and Causes

Pavement Condition Rating (PCR) and Pavement Condition Index (PCI) are two measures which help to determine pavement distress levels. High distress levels adversely influence the riding quality of the routes (Asghar, 2001). This section will focus on Hot Mix Asphalt (HMA), as this is the main type of asphalt used in the Nicosia road network. Notably, well designed and maintained HMA has the capability supply extended service when applied effectively. However, without proper maintenance HMA can be damaged in various ways (Lanham, 2012). The major distress types observed throughout the world are summarized in Table 3 below. A more detailed explanation of each severity type and the reasons behind these severities can be found in the Appendix A.

Table 3: Most Common Distress Types

Distress Type	Unit of Measurement	Defined Severity Level
Alligator Cracking	Meter square (m^2)	YES
Longitudinal Cracking	Meter (m)	YES
Transverse Cracking	Meter (m)	YES
Patching	Meter square (m^2)	YES
Potholes	Meter square (m^2)	YES
Rutting	Millimeters (mm)	YES

2.3.1 Alligator Cracking (Fatigue)

The name of this type of distress comes from the look of the crack. When the side cracks occur it looks like an alligator/crocodile back which gives the name of the crack type (Lanham, 2012). This distress type involes a series of interconnected cracks (Federal Highway Administration, 2009) that include longitudinal cracks and side cracks. Longitudinal cracks start forming first and then side cracks form stemming from the longitudinal crack.

2.3.2 Longitudinal Cracking & Transverse Cracking

Longitudinal cracks, which can occur anywhere within the pavement, are primarily parallel to the centreline of the road. Transverse cracks primarily occur perpendicularly to the centreline of the road, and they can be visible anywhere in the lane (Federal Highway Administration, 2009).

2.3.3 Patching

Patching occurs when an area of the pavement is replaced with new materials in order to restore the pavement in to its original condition (Lanham, 2012).

2.3.4 Potholes

A pothole is a sharp-edged hole that has a bowl-shape. It is formed as a result of a collapse on the surface of the pavement (Lanham, 2012).

2.3.5 Rutting

Rutting generally occurs at the wheel paths. The pavement surface settles down and creates surface depression which can be described as a pit on the surface of the pavement (Lanham, 2012).

2.4 Pavement Management

Pavement Management has multiple definitions. Nevertheless, it is most commonly defined as “the effective and efficient direction of activities involved in providing and sustaining pavement in an acceptable condition at the least life cycle cost” (Mc Kinney,1986: 25).

Pavement management aims to provide the best management at the lowest cost to the public. Crucially, pavement management models are not only used for roads but also for ports, airports, and any other pavements used for industrial purposes as well as drainage facilities and any construction sites with routes (OPUS, 2016). Overall, pavement management starts with developing an effective plan and design, followed by construction and maintainence, all of which should be conducted with great care and coordination (Mc Kinney,1986). The selection of a particular PMS requires careful data collection which will be detailed in the next section.

2.4.1 History of Pavement Management Systems

Pavement maintenance started to be used to maintain pre-constructed roads in usable condition considering limited governmental budgets, since effective pavement management would cost much less than rebuilding and reconstructing pavements. Indeed, prior to the use of PMSs, high sums of money, collected through taxes, were spent on road maintenance and reconstruction. PMSs were developed to ensure low cost and reliable systems to maintain pavements to ensure that taxes were used for cost effective actions.

In the late 1960s, the first PMS started in Texas and California in the United States of America (Haas and Hudson, 1978). Different systems were developed to design and manage pavements, and soon these were taken up by other states. The simplest database management programs were used to schedule road repairs and management activities. However, it was not until fourteen years later in 1973, when the first Pavement Management System entered academic literature. In the fiscal Year of 1979, the PMSs attracted great attention. Many states and governments started to use the cheaper and the quicker fix, and PMSs became accepted globally when The Federal Highway Administration of the United States of America recognized the importance of PMSs (Haas and Hudson, 1978).

PMSs have seven basic components that start with planning activities including assessing the deficiencies in the network, establishing priorities and programming and budgeting. Once an efficient program is established, the design activities can start. The traffic volume, climate and the materials to be used are a vital part of the design activities. The material to be used in PMS should be selected by taking the climate into consideration. Alternative design strategies to be applied in any case of disparity should also be in-hand. Then, the economic evaluation should be optimised for the construction, maintenance and pavement activities. Once the activities are completed the new data should be entered into the system for further research. The basic components of a PMS, adapted from Haas and Hudson (1978) is shown in Figure 2 below.

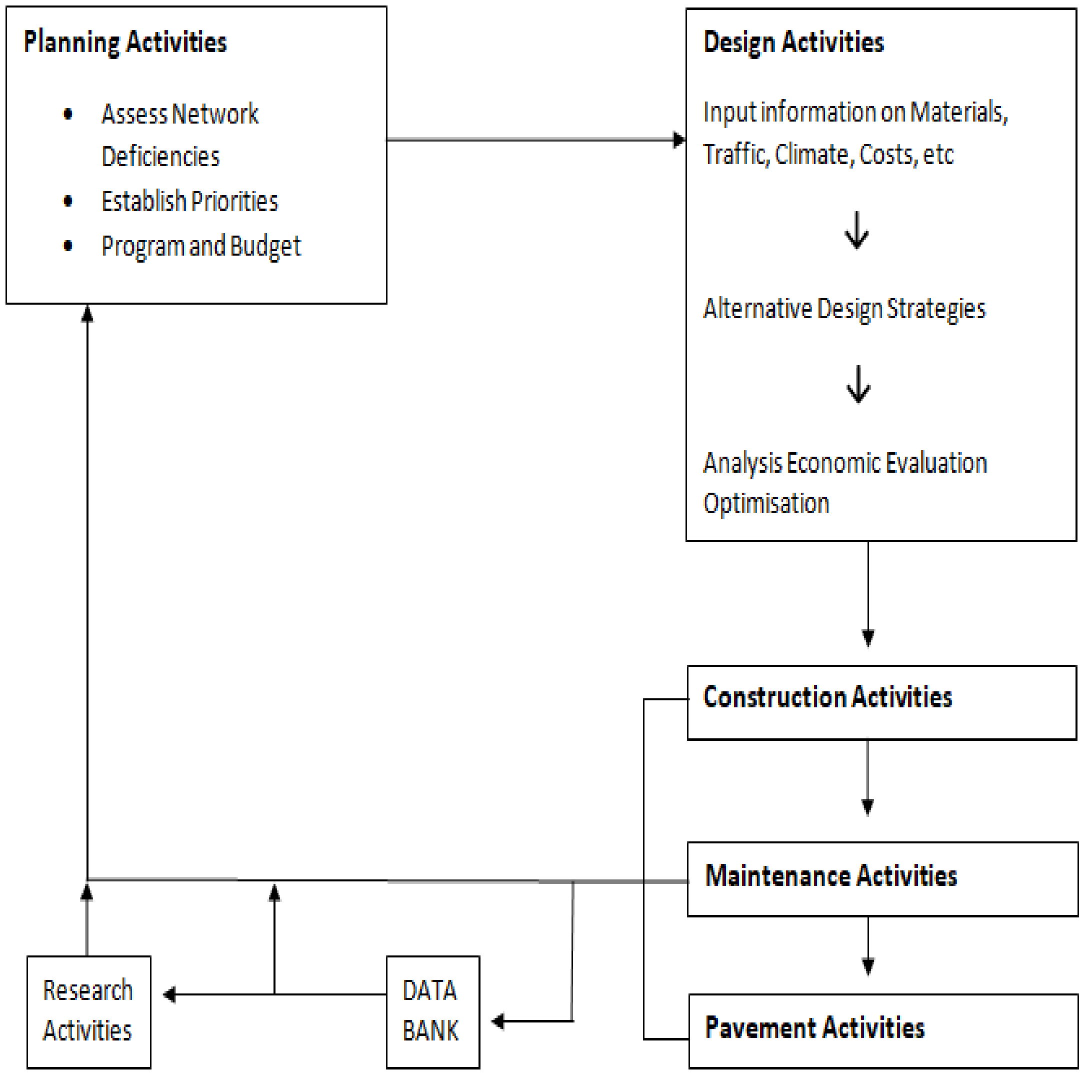


Figure 2: Basic Components of a Pavement Management System (Haas and Hudson, 1978)

2.4.2 Pavement Management Systems

Proper understanding of the basics of PMSs is essential to evaluate its uses and advantages of PMS. PMSs in general have four main aims. These are to:

i. allow making efficient decisions,
ii. provide the opportunity to get feedback on decisions made
iii. assess the feasibility of decisions,
iv. improve and develop the decisions made in order to reach more effective PMS.

In order to reach these aims the following should be carefully performed:

i. systematic collection and storage of data,
ii. appropriate data analysis,
iii. appropriate data formatting,
iv. decision making in line with data,
v. regular database updates (Wildan Serving Public Agencies, 2002).

2.4.3 Data Collection

The developments in the technological devices and instruments as well as understanding of PMS resulted in standardized collection and analysis of the data (Vavrik et. al., 2013). To ensure reliability and relevance, relevant PMS data are increasingly collected through semi-automatic or automatic methods. Overall, several factors, such as the aim and financial capacity of data collectors, influence data collection methods. The variety of the data depends on the weather condition, work of the transportation department of the area, and the deterioration level of the pavement (Okine and Adarkwa, 2013).

The data used directly affect the reliability and the application of the PMS. For the PMS to be effective, the data collected should provide the agency with full details of the pavement condition and should forecast the performance rates and should have suggestions for the improvement of the area that PMS will be applied. The data collection methods can be categorized into three:

i. Traffic volume data collection
ii. Inventory data collection
iii. Condition data collection.

Traffic volume data collection includes the reporting of the traffic volume on the road where PMS is going to be applied. Inventory data collection includes the observation of the physical status of the road that are not expected to be easily altered throughout a long time interval. Condition data collection is the observation of the elements that are easily changeable throughout time. These types of data should be collected regularly to provide useful pavement evaluation.

The methods and the technical equipments for data collection for PMS should be compatible with the condition of the items. For instance, distress data are generally collected through traditional manual methods as the collection does not require a high accuracy rate and can be done at a relatively low cost. However, data collection processes which require a high accuracy rate should be collected through automated methods (Qin et. al., 2017).

2.4.4 Manual and Automated Data Collection

Manual data collection can be performed by a member of staff manually without technical equipment. In this process, the surveyor walks along pavement sections to identify the distresses types and associated severity. Observed distresses for each pavement section are recorded on a map of the area and then manually recorded in a table or database, where the surveyor can input the data directly into the database while observing the pavements.

Automated collection of data includes the use of functional vehicles including high resolution cameras and lasers that record images and videos of the pavements. There are semi-automated and fully-automated techniques that are used according to the type of the research. The semi-automated methods require employees to investigate the distress types, while fully-automated methods use a software to investigate the distress types. Transportation departments generally use automated data collection methods, as they allow relatively quick data collection. However, these methods involve a high cost and complex technology (Okine and Adarkwa, 2013). In this thesis, manual data collection techniques were used to identify the pavements and the distresses on the selected pavement sections in the Nicosia road network. Figure 3 illustrates the Flowchart of Maintenance and Rehabilitation (M&R) process for this thesis.

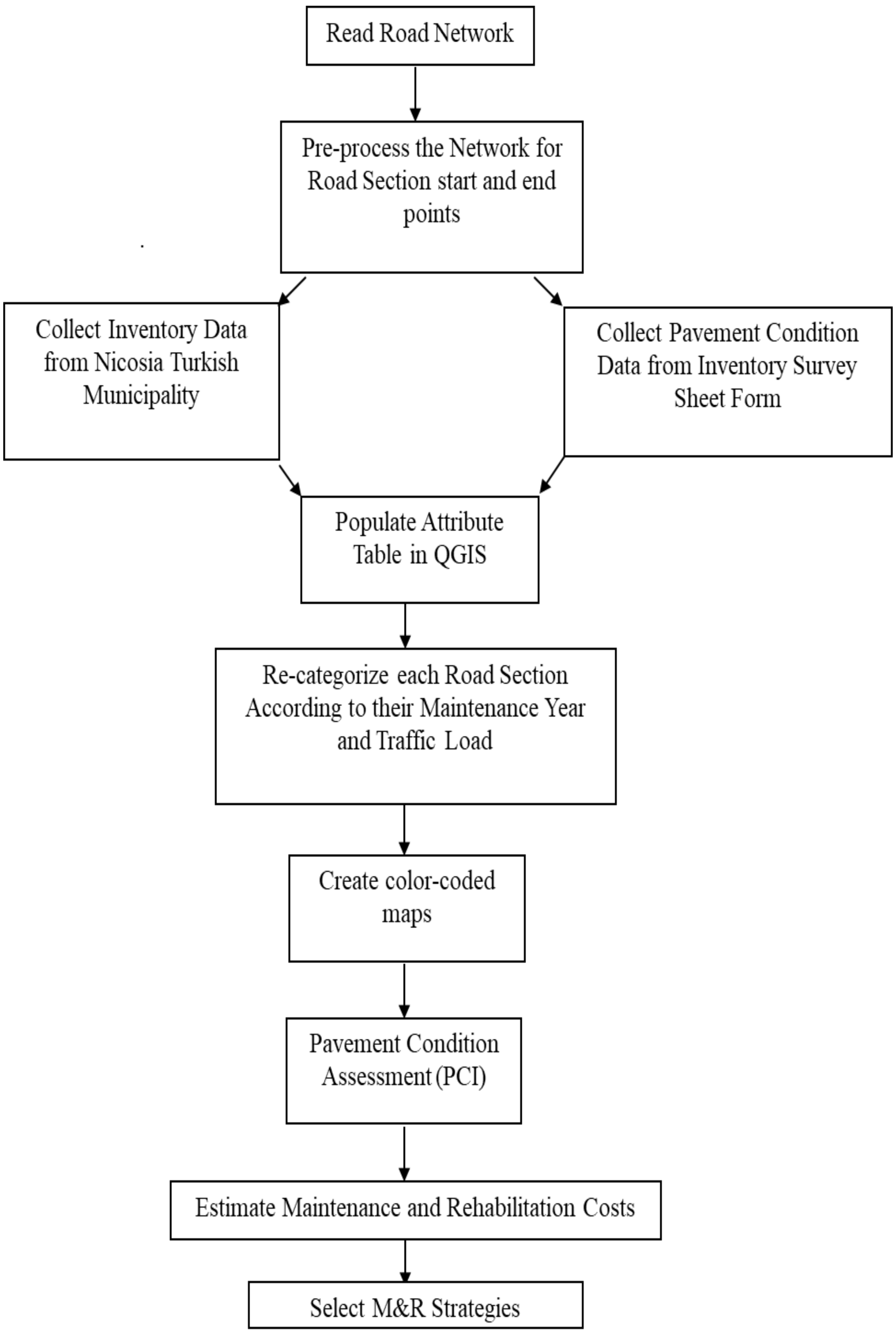


Figure 3: Flowchart of Maintenance and Rehabilitation for This Thesis

The thesis initially retrieved the GIS map from the Nicosia Turkish Municipality and defined the road network using this map. Once the network was defined, inventory data and pavement condition data were collected manually in field research. Then, a database was created to thoroughly illustrate the condition of the roads in the pavement condition assessment. After assessing pavement conditions of the roads, the cost for maintenance and rehabilitation strategies were calculated. Accordingly, appropriate M&R techniques were identified and recommended.

2.5 Role of engineer in PMS

Highway engineers use PMSs to make decisions for maintaining and preserving pavements. The PMS is selected by considering the cost, the effectiveness and the condition of the road. Four basic components are needed to form an effective PMS. These are:

i. The database formed as a result of detailed research and observation,
ii. The pavement rating system indicating the condition of the pavement,
iii. The prediction model that analyses the data to understand the deterioration date of the pavement,
iv. The ranking method to help choose the most suitable maintenance and rehabilitation program for the pavement (Wang and Qin, 2013).

After selecting the appropriate PMS model, the pavement engineer is responsible for ascertaining the suitable materials and treatments that should be used for maintenance of the pavement. These materials should be cost-effective and long lasting to provide sustainability. The materials should be selected by considering the condition of the pavement and the traffic volume. The capacity of the pavement should be increased to its maximal level while the cost of the repair should be decreased to its minimum (Wang and Qin, 2013).

2.6 Pavement Condition Survey

The infrastructure of a city consists of pavements which should function correctly for the improvement of the city. Generally, the Department of Transportation is the authority responsible for upkeeping the condition and renovation of pavements. The condition of the pavements should be observed regularly to keep them working at their maximum effectiveness. This observation of the pavements is named as Pavement Condition Monitoring (PCM). Various techniques are to maintain the best road quality according to relevant financial budget. For instance, the Michigan Department of Transportation uses high technologically equipped cars using accelerometer sensors and camera systems that monitor the condition of the road (Michigan Department of Transportation, 2013). This monitoring system enables the transportation department to detect the problems on the road surface and to intervene with the problem instantly.

The conditions of the pavements are also determined by taking four main characteristics of the pavement into consideration. These characteristics are (i) roughness of the road, (ii) distress level of the road, (iii) deflection of the pavement, (iv) safety of the pavement. The roughness of the pavement can be said to be the smoothness of the road and the distress level is considered as being the PCI level. The deflection levels which are the structural failures on the road are also taken into consideration as well as the safety of the pavement (Garber and Hoel, 2010).

The backbone of the repair and rehabilitation services is formed using condition monitoring surveys that provide relevant reports pertaining to the pavement conditions. These reports are then analysed by the pavement management employees who decide which management strategy should be used to receive maximum efficiency.

Overall, pavement condition surveys (PCS) enable engineers to ascertain the conditions of road pavements. These surveys can be performed by taking three basic steps involving data collection, rating of the condition of the pavement, and managing quality of the road (Yoder and Witczak, 1975). PCSs are considered by the departments of transportation as they provide both general and detailed information about the pavements. By doing so, the department of transportation of the city ensures the efficiency of adopted pavement strategies as well as the efficiency of their maintenance. Using the PCS, the transportation employees identify the most effective managing and rehabilitative service that would bring the most benefit. PCSs also allow the department of transportation to make comparative discussions between the pavements of the city. This would allow the decision regarding which prioritization of pavement works. Overall, survey reports allow the forecasting of the deterioration levels as well as the cost and the time to needed for the maintenance and rehabilitation of pavements. The deterioration level of the pavement directly affects the cost of rehabilitation. As discussed earlier, a new pavement may be required in cases of extreme deterioriation. Therefore, understanding the condition of the pavement to be rehabilitated allows to make a appropriate budgets for future operations (Okine and Adarkwa, 2013).

2.6.1 Pavement Condition Index (PCI)

The US Army Corps of Engineers developed a data gathering system called the Pavement Condition Index (PCI) in which the severity of the deterioration is given on a scale of 0 to 100, where 0 stands for the worst condition where 100 means that the pavement is in excellent condition (Okine and Adarkwa, 2013). The PCI allows a low-cost method for selecting appropriate management and rehabilitation technique. The acceleration rates of the cracks and potholes can be forecasted through PCI, which allows priorities for rehabilitation. Each deterioration type is assigned a value according to its type and severity. The distress levels are observed in 39 sections and the severity levels are classed into three being high, medium and low.

The type of the pavement is also important when calculating the PCI. The Asphalt Concrete pavement distresses are classified into 20 categories while the Portland Cement Concrete pavement distresses are classified in 19 different categories. The values for one pavement are all added up at the end and then subtracted from 100 to gain the PCI value. If there are more than one deterioration in one pavement, all the values are considered to calculate a mean score for the entire pavement.

Maintaining the condition of the pavement is often more cost-effective than pavement rehabilitation. The PCI rates are calculated to give a set standard for the level of distress of the pavement. If the calculated value is below the critical value, which is 55, the cost to rehabilitate the pavement increases. However, if there is sufficient funding for the maintenance and rehabilitation techniques, PCI calculations are vital to suggest the most suitable method of rehabilitation. A PCI value that is greater than the critical value will require an urgent check. If there are distresses on the pavement that would greatly affect the life of the pavement the rehabilitation will be applied (Qin et. al., 2017).

Another technique to identify the distress level if the pavement is called Pavement Surface Evaluation and Rating (PACER). PCI, however, is a more preferable technique, since it provides a simple method for collecting data as well as a relatively cheap alternative for developing maintenance and rehabilitation systems. In this thesis, the PCI technique was used monitor the distress and severity of the roads of Nicosia.

These steps below constitute the basics for attaining the best PCI value:

i. Identify the area of the pavement,
ii. Classify environmental factors,
iii. Create a data table should,
iv. Determine the sample units of observation,
v. Use random sampling for computing data,
vi. Determine deduction values of pavements (Qin et. al., 2017).

In this thesis, the guidelines detailed above were followed, and the following steps were applied to calculate the PCI levels for each pavement:

i. The pavements were marked in 100 meter/foot increments to allow accurate application of the survey. The traffic volume for each pavement was then considered to classify the pavements according to the priority levels of rehabilitation. The thickness of each pavement according to the material used on construction were determined. The features of each pavement were recorded to figure out the distress levels.

ii. The unique features of the pavements were broken down into smaller sample units that were then given the distress type and the severity level. The densities of the sample units were also noted to identify the distress types according to the materials to be able to calculate the most accurate PCI.

iii. The sample units were analyzed to find out the deduct value (DV) by using the guideline curves.

iv. Each sample unit was used to calculate the total deduct value (TDV) . This was done by summing the distress condition values recorded at the beginning.

v. The rigidness and the flexibility of pavements were then considered to calculate the corrected deduct values (CDV) of each pavement.

vi. The PCI values were then calculated by using the formula: PCI = 100 - CDV. This was done for each sample unit.

vii. The total PCI was calculated by getting the average of the PCI levels of each sample unit.

viii. The pavement condition rating was then identified from the correlation (Department of Defense, 2004).

2.6.2 Prioritization Strategy for the Road Network

The rehabilitation work on the pavements should be done according to the extent of severity for each pavement. Each pavement sample should be tested and analyzed by experienced professionals when priorization rehabilitation work.

The pavements of the mostly used streets should always be in reasonable working condition. The transport departments generally aim to maintain the segments of streets in useable condition without reconstructing them. Therefore, the distressed pavements on the streets should be addressed promptly to prevent them from needing reconstruction (Public Works Maintenance, 2015). This type of maintenance is called proactive maintenance in which the pavements are preserved and kept in reasonable condition to prevent complete reconstruction. This method does not only save money to be spent on repairing and rehabilitation but it also enables a relatively long lifespan for the pavement. Figure 4 below describes the general life-cycle of a pavement according to its PCI level and the money to be spent on the rehabilitation of the pavement (Department of Public Works, 2017).

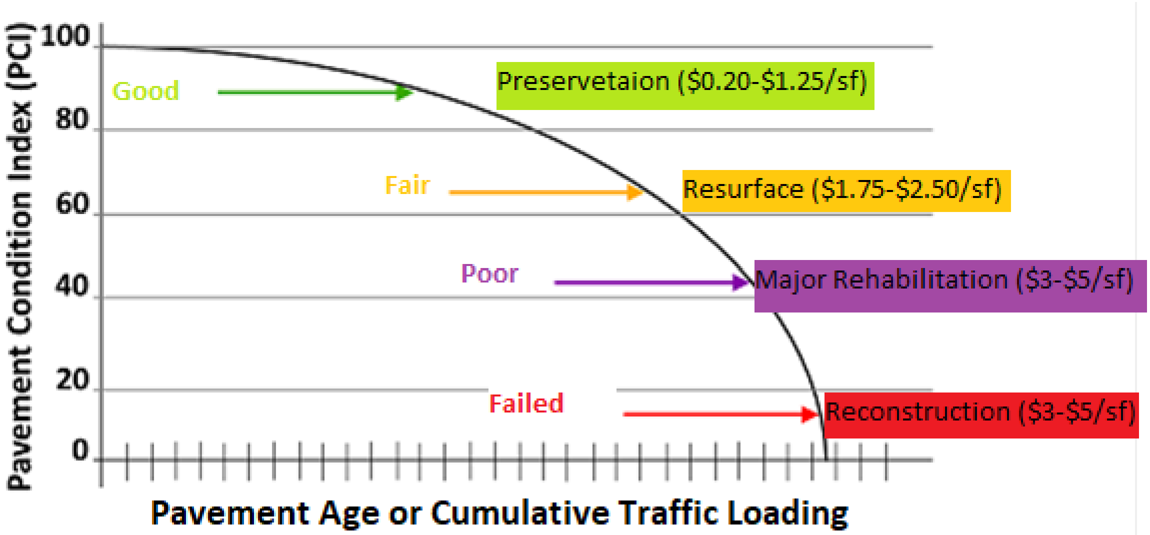


Figure 4: Pavement Condition Index vs Pavement Age (Department of Public Works, 2017)

The first couple of years of the pavement when it is in good condition, require only 0.20 USD for preservation. A standard pavement is forecasted to stand for approximately 20 years. However, when the preservation rehabilitations are not done, the rehabilitation costs get higher as the pavement gets older. The graph above indicates that the reconstruction of a standard pavement would cost 3 USD when it completely fails. If effective rehabilitation and maintenance is done on time, the lifespan of a pavement can increase by 15 years, substantially saving money which would be spent on reconstruction. Treating the pavement before it deteriorates completely is called preventative street maintenance, a process which is also known as overlaying (Public Works Maintenance, 2015).

2.6.3 Deciding on the Priority of Action

The decision of which pavement is to be attended with firstly depends on the experience of the person who conducts condition surveys. Firstly, the total cost for each segment to be rehabilitated should be calculated. The severity levels of each segment should be considered and the financial priority to improve the segment should be established. The calculations should be made for 2 years in a row to allow for the observation of cost difference for each year in which the pavement is not treated. The annual savings made if the pavement is attended urgently can then be forecasted. Experienced professionals consider all the following factors when suggesting a rehabilitative technique for the pavement:

i. The current condition of the pavement,

ii. The level pothole formation if the pavement is not attended, and

iii. The methods which can be used to improve the condition of the pavement with the minimum cost.

During the investigation of the field, these three factors above are considered and recorded as necessary. The locations of the potholes on the pavement are marked on the map as well as the rutting and all other deteriorating places in the pavement which affect riding quality. When the data are entered in the computing system, the severity of the pavement and the financial priority can be calculated. Both the cost and the need for rehabilitation are considered when identifying the priority pavement.

However, the analyses of the segments are not always as clear as described above. As each pavement has its unique conditions, the deteriorations should be considered separately for the condition of each segment. For instance, if a pavement is used daily by the majority of the population is cracked, compared with overlaying it, rebuilding would be more cost-effective, since , the overlay is likely develop distress quickly and need regular maintenance.

The engineer plays a vital role in making rehabilitation decisions. The engineer conducts the pavement thickness analysis and forecasts the traffic volume of the pavement to determine the rehabilitation strategy (Wildan Serving Public Agencies, 2002). The maintenance and rehabilitation plans aim to increase the lifespan of the pavement by improving the condition of the distresses on the pavement. The funding of the maintenance and rehabilitation should be forecasted to forecast when and how the maintenance and rehabilitation can be carried out. The maintenance and rehabilitation methods are developed by recognizing the condition of the pavements and forecasting a yearly budget for the maintenance and rehabilitation techniques. Understanding the economic context would allow the pavement engineer to suggest appropriate methods of maintenance and rehabilitation. All in all, the current budget to be provided should be known before selecting the appropriate M&R program. The construction of the roads start with the budget, and then continue with maintenance and rehabilitation which again require a consideration of budget.

2.7 Recording PCI and Other Road Network Attributes in QGIS

The QGIS program is supported by Linux, Unix, Mac OSX, Windows and Android and is therefore suitable to be used to enter the PCI values (Creative Commons Attribution, 2017). The geographical information system (GIS) data include the characteristics of the pavement data. The characteristics are entered easily into the program and can be controlled and updated regularly. Attributes such as the location, the construction year, the severity levels, the surface conditions and the general conditions of the pavements can also be recorded (Dempsey, 2018). The program stores and organizes the data and provides frequent information about the condition of the pavements enabling effective decisions regarding maintenance and rehabilitation techniques.

2.7.1 TRNC Road Maintenance

As discussed earlier, this thesis aimed to investigate the pavement condition of the Nicosia road network, the capital city of the Turkish Republic of Norther Cyprus (TRNC). The literature on maintenance techniques used in Nicosia in North Cyprus is particularly scarce. Indeed, the literature review conducted for this thesis identified no formal publications on this topic. However, the first relevant study conducted in 2007 was identified. This study applied a PMS to a neighbourhood in the city of Famagusta (Kunt, 2008). All in all, Byrar Qadir Ahmad, a student of Asst. Prof. Dr. Kunt conducted a PMS study for the EMU campus in June 2012. In his masters thesis he emphasised the importance of PMS for the university environment and evaluated 79 locations in the EMU campus. After calculating the PCI levels for each location he then proposed PMS strategies to keep the loccations in fair condition (Bryar, 2013).

Considering the scarcity of written literature, the municipality engineer in Nicosia was interviewed to identify the costs of the rehabilitation of the roads. The roads were then visited in person during field research, and the data were collected manually by sketching and marking the deteriorations on the map.

Chapter 3

METHODOLOGY

3.1 The Analysis of Data Obtained from the Nicosia Turkish Municipality

The literature review presented in Chapter 2 constituted the first piece of work undertaken in this thesis. Notably, no scholarly research papers or other written publications were identified in this literature review. Following the literature review, the map of the road network in a shape file format and other relevant data were received from the Nicosia Turkish Municipality. Moreover, face to face interviews were also conducted in order to gather more data and information from the municipality employees who currently work in the road maintenance department.

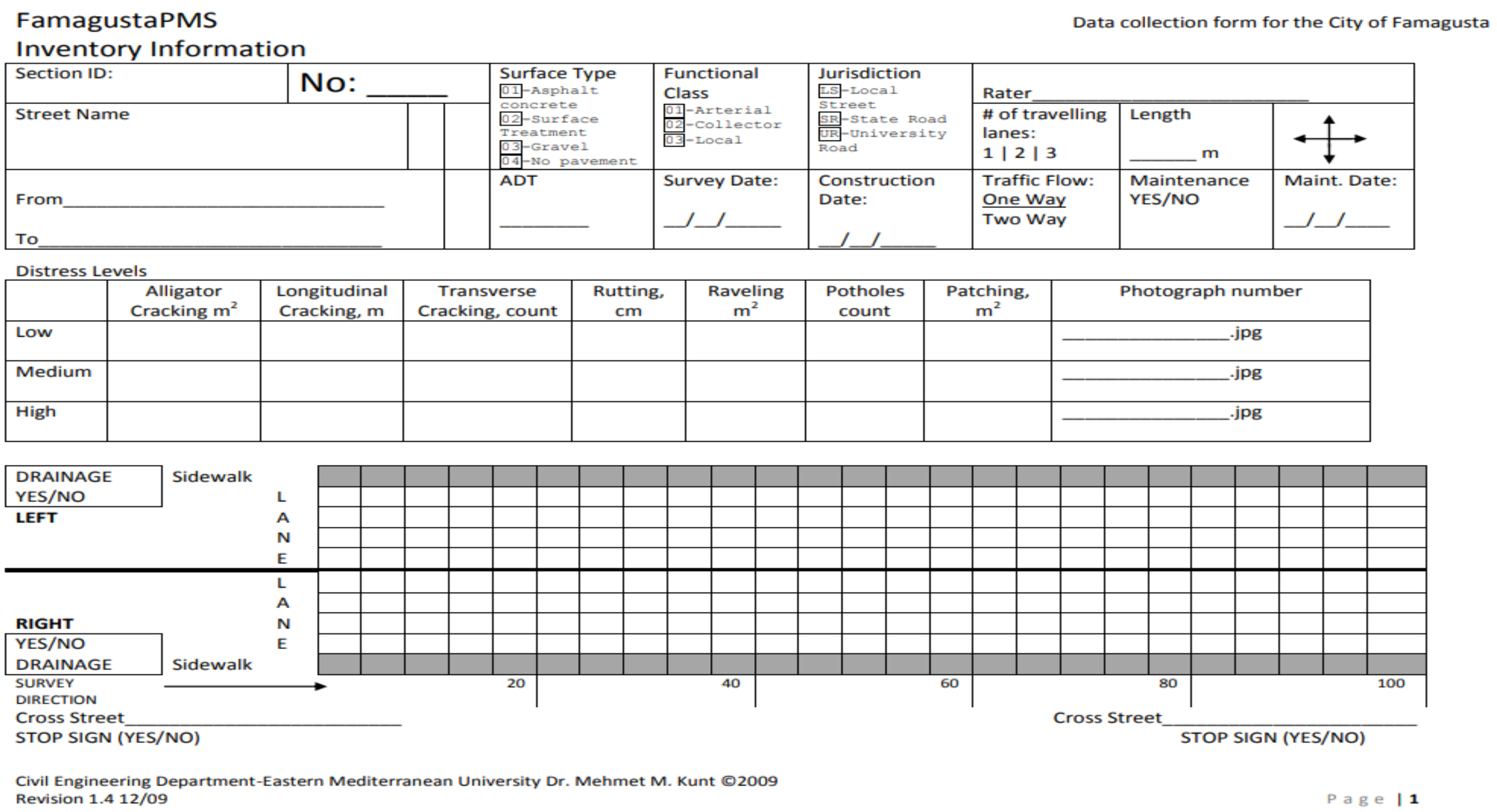
A shapefile is a a storage system for geographic and geometric data. It can show these data in various ways using the database to form tables, graphs, and figures, and it can be manipulated to represent and convert the data (Environmental Systems Research Institute, 2016). The shape file of the road network was compatible with the QGIS program and contained the name of the streets of Nicosia and the lengths of the routes. The widths of the roads were measured and marked on the road map after field research.

3.2 Pavement Condition Survey Procedures

The survey sheet was collected from Asst. Prof .Dr. Mehmet Metin Kunt in Eastern Mediterranean University Civil Engineering Department. Asst. Prof. Dr. Kunt conducted an original inventory survey sheet for his Famagusta PMS research. For his study, he used the survey sheet for displaying inventory data and provided clear viewing of the field observations. The table that includes information spaces for the name of the street , the surface type, the functional class and the jurisdiction as well as the number of travelling lanes and the traffic flow were filled in manually during field visits. The survey paper was used to mark the locations of the alligator cracks on the pavements. The road distresses were also photographed. The original form (Kunt, 2009) is shown in Figure 5. This inventory data sheet includes various information about the surface type, functional class, jurisdiction, number of lanes and the traffic flow of the road to be observed.

The roads were categorized according to associated traffic volumes. As there were no historic data on the traffic volume, field observations were undertaken for a month in December 2016 throughout the day to map the traffic volume during rush hours and regular hours. Roads were categorized using personal personal judgement by taking the approximate number of cars observed on each road (see section ID in Figure 5). Letter A indicates high traffic volume, letter B indicates intermediate traffic volume, and letter C indicates low traffic volume. A filled survey form is included in Figure 6.

The PCI levels for each road were calculated using the *a priori* table shown in Figures 7a and 7b. The table helped the easy observation and categorization of the types of the roads after the relevant calculations. The calculations were done using the help of the table and the Unified Facilities Criteria created by the Department of Defence in America in 2004. These criteria were also used as basic guidelines for evaluating the condition of the pavements.



FamagustaPMS
Inventory Information

Data collection form for the City of Famagusta

Section ID:	No: ______	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater______________		
Street Name					# of travelling lanes: 1 | 2 | 3	Length ______ m	
From______________ To______________		ADT ________	Survey Date: __/__/____	Construction Date: __/__/____	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: __/__/____

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low								______________.jpg
Medium								______________.jpg
High								______________.jpg

DRAINAGE
YES/NO
Sidewalk
LEFT
LANE
LANE
RIGHT
YES/NO
DRAINAGE
Sidewalk

SURVEY DIRECTION
20 40 60 80 100

Cross Street______________
STOP SIGN (YES/NO)

Cross Street______________
STOP SIGN (YES/NO)

Civil Engineering Department-Eastern Mediterranean University Dr. Mehmet M. Kunt ©2009
Revision 1.4 12/09

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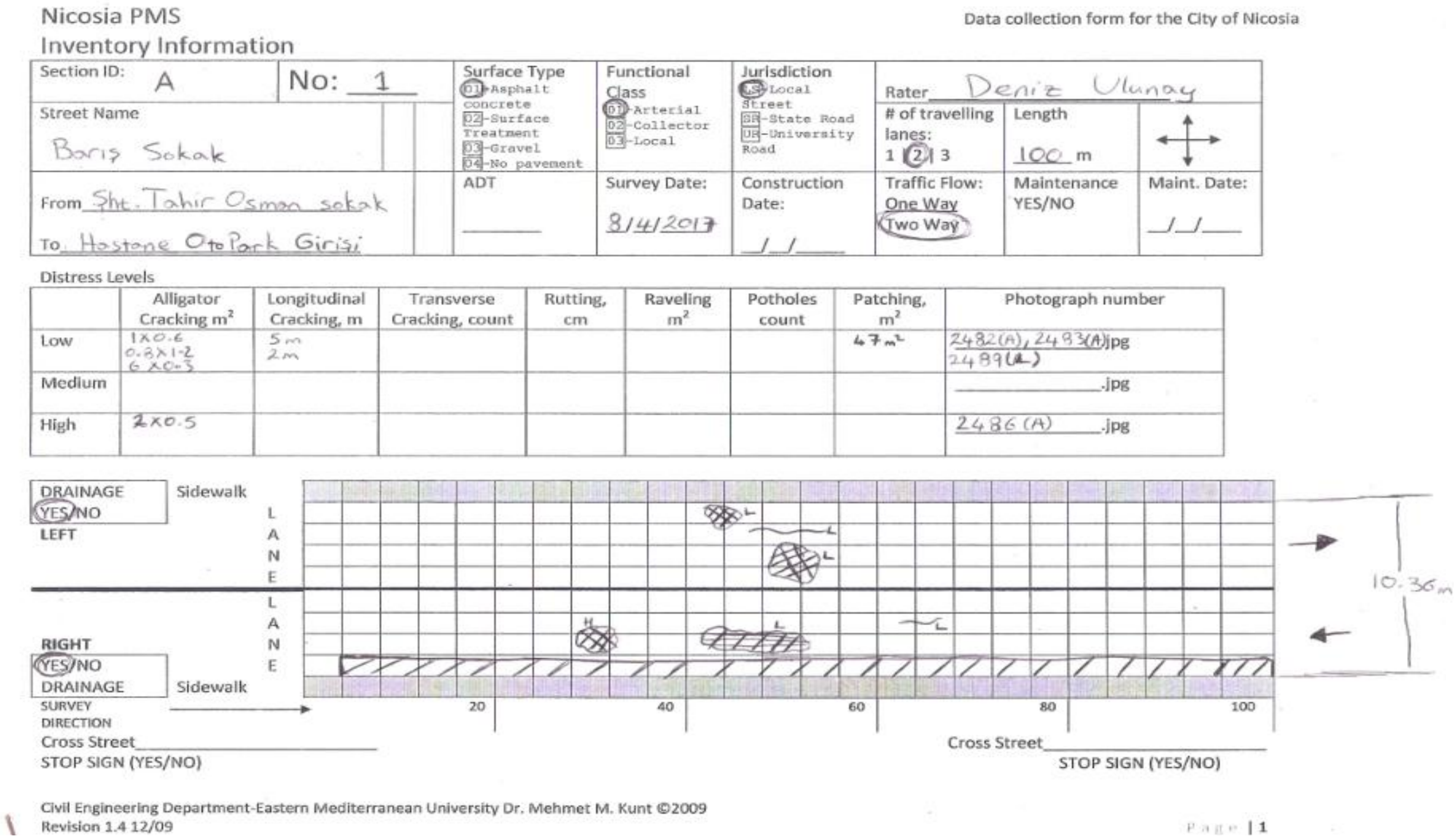
Figure 5: Inventory Survey Sheet (Kunt 2009)



Nicosia PMS

Inventory Information

Data collection form for the City of Nicosia

Section ID: A	No: 1	Surface Type: 01-Asphalt concrete, 02-Surface Treatment, 03-Gravel, 04-No pavement	Functional Class: 01-Arterial, 02-Collector, 03-Local	Jurisdiction: LS-Local Street, SR-State Road, UR-University Road	Rater Deniz Ulunay	
Street Name: Baris Sokak					# of travelling lanes: 1 2 3	Length 100 m
From Sht. Tahir Osman sokak		ADT	Survey Date: 8/4/2017	Construction Date: / /	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: / /
To Hastane Oto Park Girisi						

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low	1x0.6 0.8x1.2 6x0.3	5 m 2 m					47 m^2	2482(A), 2483(A).jpg 2489(A)
Medium								.jpg
High	2x0.5							2486 (A) .jpg

Figure 6: Filled Survey Sheet

(a)

Pavement Condition Survey Data Sheet					
Street Name			Area of Sample =		
Section ID					
Date					
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
4-Rutting,cm					
5-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L				
	M				
	H				
Distress Type	Severity	Density %	Deduct Value		
Deducted Total					
Corrected Deducted Value (CDV)					
PCI = 100 - CDV					

(b)

Pavement Condition Survey Data Sheet					
Street Name	Bariş sokak		Area of Sample = 1036 m²		
Section ID	A − 1				
Date	10/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L	3.36 m²	7 m		47m²
	M				
	H	1 m²			
Distress Type	Severity	Density %	Deduct Value		
1	L	0.32	12		
1	H	0.1	16		
2	L	0.68	4		
4	L	4.53	9		
Deducted Total			41		
Corrected Deducted Value (CDV)			22		
PCI = 100 - CDV			78 - Very Good		

Figure 7: (a) Blank and (b) Filled Pavement Condition Survey Data Sheets

3.3 Unit Prices

The prices of the different maintenance and management techniques used to maintain the deteriorated pavements on Nicosia road network were collected from the Nicosia Turkish Municipality. The average costs between 2009 to 2015 were calculated in Turkish Lira to be spent for the maintenance of per square metre of the pavement. Table 4 was formed to show the actions to be taken and the prices for each action. The VAT were excluded from the prices. The total amount of money spent for the pavements of Nicosia is explained in the analysis and results section of this paper.

Table 4: Unit Prices for Each Treatment

Name of Action	**Unit Prices for Nicosia Turkish Municipality TL/m^2 ***	**Unit Prices for Nicosia Turkish Municipality \$/m^2 ***
Do Nothing	0 TL	$ 0
Patch	20 TL	$ 6.45
Overlay(50mm)	15 TL	$ 4.83
Mill and overlay(50mm)	20 TL	$ 6.45
Reconstruction	65.4 TL	$ 21

*Average unit prices are considered for 2016 ($1=3.1TL).

3.4 Health and Safety Precautions During the Survey

A tape measure and a ruler were used to measure the lengths and the widths of the pavements that would be used in research. Therefore, for the measurement, the time of the day when the traffic volume were at its lowest was chosen. The measurements were taken both early in the morning and late at night to provide a balanced volume count. For safety reasons, condition survey was conducted on two-lane roads only. Distresses of each road section were photographed on clear days. The manually collected data was entered into an attribute table in QGIS for analysis. The next section evaluates the QGIS program and its uses.

3.5 QGIS Database Formation

The road network data that are entered into QGIS includes 3237 rows of data which contain the name of the streets, location of each road and the length of the roads. Apart from the entered data, the maintenance date for each road that have been attended before 2016 as well as the tonnage of asphalt used for the maintenance done have been calculated according to the type of road, the road width and the area of the road. These extra data were collected for the maintained roads only. Maintained roads formed a total of 1492 rows that gives a sum of approximately 6000 data points that have been processed for the purpose of this research. The data were entered manually. Figure 8 illustrates the road network of the city of Nicosia.

Figure 8: Adding Vectors in QGIS

Imported data that creates the attribute table in Figure 9 are shown below:

i. Maintenance date that is obtained from Nicosia Turkish Municipality
ii. Tonnage of the asphalt that is used for the rehabilitation of the asphalt pavement
iii. Type of road according to their construction date. Coding system is used in order to differentiate the road types.
    a. Code 1: oldest road that is constructed between 1993 and 2002
    b. Code 2: intermediate-aged roads constructed between 2003 and 2012
    c. Code 3: newest road that is constructed 2013 and 2016,
iv. Road width
v. Road area, which can also be obtained from QGIS.

After adding the data into the QGIS system, a completed attribute table was obtained. The Figure 9 shows attribute table. In the figure the SHAPE_leng column shows the total length of road sections, while tip_1 column illustrates the road type codes according to their age.

YOLORTAHATTI :: Features total: 3237, filtered: 3237, selected: 0

	ADINUMARAS	ACIKLAMALA	TIP	SHAPE_Leng	Main. date	Tonnage	tip_1	Road Width	Road Area
1	BOLU SOKAK	K.KAYMAKLI	3	95.91680705510	2003-2005-2009...	192-108-387-36...	3	7	671.417649
2	ÞHT. ÖNAY MEH...	GÖÇMENKÖY	3	52.85822743780	2000-2015	210-67	3	6.1	322.435187
3	ÞHT. ECVET YUS...	KIZILAY	3	96.34580620170	2002-2003-2007...	414-575-1211-4...	3	13.41	1291.99726
4	LEYLAK SOKAK	K.KAYMAKLI	3	51.34876697580	2014	46	3	6.1	313.227478
5	BEDREDDÝN DEM...	YENÝÞEHÝR	3	91.22846771280	1993-2002-2003...	811-1030-110-2...	3	12.2	1112.98730
6	BEDREDDÝN DEM...	YENÝÞEHÝR	3	72.18355933930	1993-2002-2003...	811-1030-110-2...	3	12.2	880.639423
7	ÞHT. HÜSEYÝN B...	KIZILAY	3	50.81447357400	2014	195	3	6.1	309.968288
8	BOLU SOKAK	K.KAYMAKLI	3	62.42869631000	2003-2005-2009...	192-108-387-36...	3	7	437.000874
9	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	50.73000590760	1997-2003-2005...	277-372-2432-7...	3	12.8	649.344075
10	BEDREDDÝN DEM...	YENÝÞEHÝR	3	94.60697355380	1993-2002-2003...	811-1030-110-2...	3	12.2	1154.20507
11	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	77.43957481270	1997-2003-2005...	277-372-2432-7...	3	12.8	991.226557
12	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	72.50175640450	1997-2003-2005...	277-372-2432-7...	3	12.8	928.022481

Figure 9: Attribute Table

As discussed earlier, road categories were also displayed visually using color coding:

i. Red for the oldest roads (constructed 1993-2002)

ii. Blue for the intermediate-aged roads (constructed 2003-2012)

iii. Green for the newest roads (constructed 2013-2016).

Finally, Nicosia Turkish Municipality road network was classified and colored according to pavement age which can be seen in Figure 10.

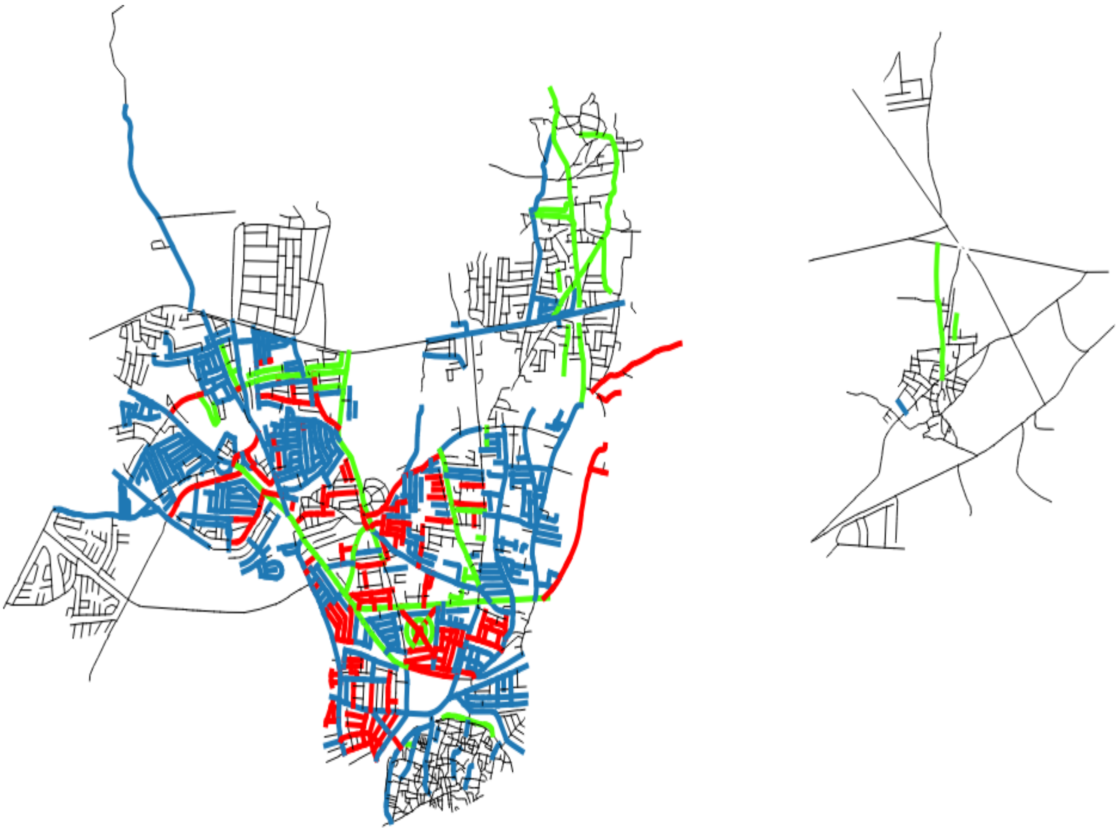


Figure 10: Categorized Road Network

The pavement information could be observed when the colored routes were selected on the QGIS program as depicted in Figure 11.

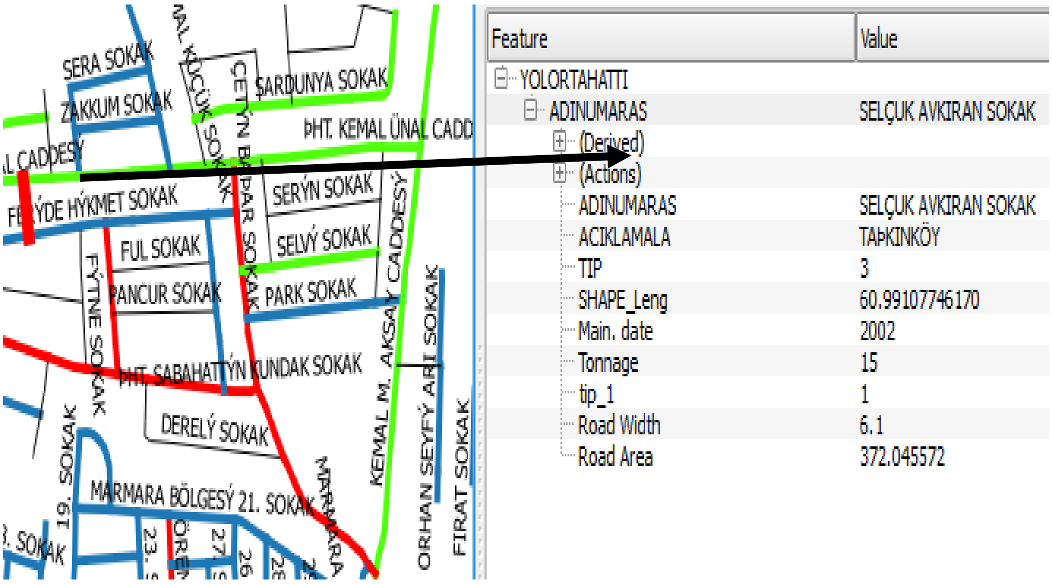


Figure 11: Road Information

From the table in Figure 11 the following information can be obtained:

- Name of street
- Region of the pavement
- Length of the pavement
- Maintenance date (only for the colored)
- Tonnage that is used for maintenance and rehabilitation (only for the colored)
- Types of road (ex: 1 , 2 or 3) (only for the colored)
- Road with(only for the colored)
- Road area (only for the colored)

The roads have been selected according to their traffic volume/level and they have been categories. Only the RED sections are selected and categorised according to their traffic level.

Category A (High traffic volume) :

1. Sht. Gazeteci Hasan Tahsin Caddesi (Ortakoy)
2. Baris Caddesi (Gocmenkoy)
3. Gazeteci Abdi Ipekci Caddesi
4. Sht. Kamil Balkan Sokak

Category B (intermediate traffic volume) :

1. Ortakoy 5. Sokak
2. Ortakoy 1. Sokak
3. Sht.Cumhur yuzlu Sokak
4. Sht. Zeki Alp Soley Sokak
5. Sht Ahmet Dervis Sokak
6. Cetin Basar Sokak
7. Sht. Sabahaddin Kundak Sokak
8. Sht.Orgun M, Hulusi Sokak
9. Istiklal Sokak
10. Cengiz Han Sokak

Category C (Low traffic volume) :

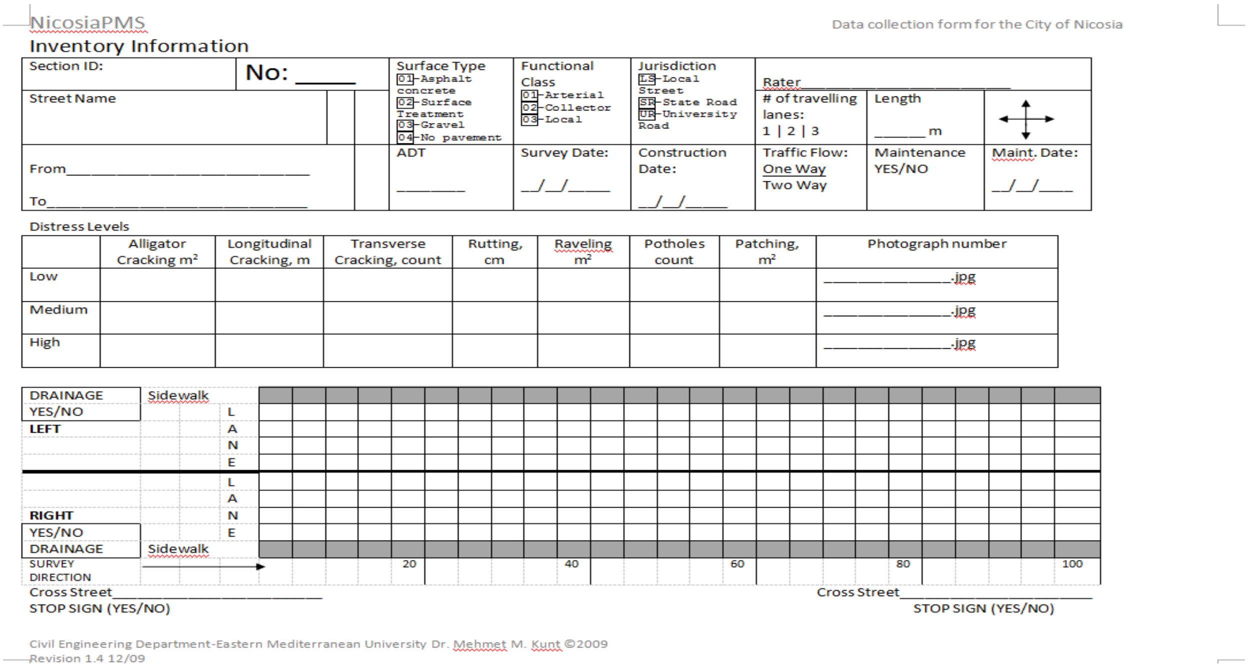
1. Laden Sokak
2. Sht, Ahmet Abdullah Sokak
3. Sht. Mehmet Ali Kirma Sokak
4. Sht Ali Camsoken Sokak
5. Sogut Sokak
6. Gelincik Sokak
7. Yayla Sokak
8. Yusuf Aziz Sokak
9. Sadik Cebbar Sokak

10. Eti Sokak
11. Tuna Sokak
12. Aka Gunduz Sokak
13. Mete Sokak
14. Sht. Ferruh Cambaz Sokak
15. Sht. Ahmet Beyaz Sokak
16. Huseyin Kucuk Sokak
17. Sht. Sener Enver Sokak

The literature was reviewed before the selection of the roads. It was concluded that a random selection of the roads would give the best results for this research. Therefore, the roads were first classified into three categories according to traffic load. Next, a random selection from each road category was made to provide an unbiased representation of the road network.

3.6 PCI calculations

The underlined streets in the previous section were selected randomly in order to improve representation of road sections from each category to increase the accuracy and to get aggregating data of results from the different parts of the city. By doing so, this thesis study did not focus on one particular area of the city but rather on the entire road network. The selection of wide range of routes allowed the identification of the pitfalls of the municipality and pavement condition index in selected areas. The selected roads were used to fill in the survey form shown in Figure 12.


NicosiaPMS

Data collection form for the City of Nicosia

Inventory Information

Section ID:	No: ______	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater		
Street Name					# of travelling lanes: 1 | 2 | 3	Length ______ m	
From______ To______		ADT ______	Survey Date: __/__/____	Construction Date: __/__/____	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: __/__/____

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low								______.jpg
Medium								______.jpg
High								______.jpg

DRAINAGE YES/NO LEFT — Sidewalk — LANE

LANE — RIGHT YES/NO DRAINAGE — Sidewalk

SURVEY DIRECTION — 20 — 40 — 60 — 80 — 100

Cross Street______ STOP SIGN (YES/NO)

Cross Street______ STOP SIGN (YES/NO)

Civil Engineering Department-Eastern Mediterranean University Dr. Mehmet M. Kunt ©2009

Revision 1.4 12/09

Figure 12: Inventory Survey Sheet (Kunt, 2009)

Figure 12 shown above was used in to evaluate the road sections have been selected for the purpose of this study. With this aim, the roads were visited and the measurements of the cracks on the roads were taken. This was done at early mornings and late nights when the traffic jam is at its lowest to ensure safety. The pictures of the roads were taken and each was crossed on the map to show the cracks according to the level of the traffic jam.

A table was composed in order to calculate the pavement condition index (PCI) of the roads. The severity of the cracks were then analyzed by taking the level of the traffic jam into consideration. The severity and types of the cracks were categorized. The severity was investigated in three main sections (low, medium, and high), while the types were categorized into four classes (alligator, longitudinal and transverse cracking, rutting, and patching). According to the area of each sample, the density of the crack were obtained. The deduced values were read from the graphs given in

Unified Facilities Criteria (UFC, 2004). With the help of this table, the properties of each road were used to perform the calculations for rehabilitation and maintenance procedures. The sample table can be seen in Table 5.

Table 5: PCS Data Sheet

Pavement Condition Survey Data Sheet					
Street Name			Area of Sample (m^2) =		
Section ID					
Date					
Distress Types					
1-Alligator Cracking, m^2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m^2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking, m	Rutting, cm	Patching, m2
Total Severity	L				
	M				
	H				
Distress Type	Severity	Density %	Deduct Value		
Deducted Total					
Corrected Deducted Value (CDV)					
PCI = 100 - CDV					

The data sheet in Table 5 was created to illustrate the condition of each road separately for accurate analysis. The sheet was filled by entering the name of the street and the date the road was visited. The area that was investigated for the research was measured. The L, M, and H was decided according to the condition of distress type and more detailed explanation of the classification of severity can be found Appendix A. The graphs were used to read the deducted values and the CDV was read from the CDV graph. The PCI levels were finally calculated and entered in the table. The table then provided basic information for the recommendation of M&R strategies for each road.

Chapter 4

ANALYSIS AND RESULTS

4.1 Analysis of Condition Survey Data for Nicosia Road Network

The coloring was done according to the data received from the Nicosia Turkish Municipality. The data included the M&R dates for each road. All the roads that were maintained since 1993 were colored on QGIS to allow a visible view of the roads attended during field observation. With the coloring technique, the rehabilitated roads could be observed and the red colored ones were identified and classified according to their traffic volumes. The colors of the roads were assigned according to their recent maintenance calendar years. The black colored roads represent roads not attended by the Nicosia Turkish Municipality since 1993. An image taken from the QGIS data is shown in Figure 13 for a more detailed observation.

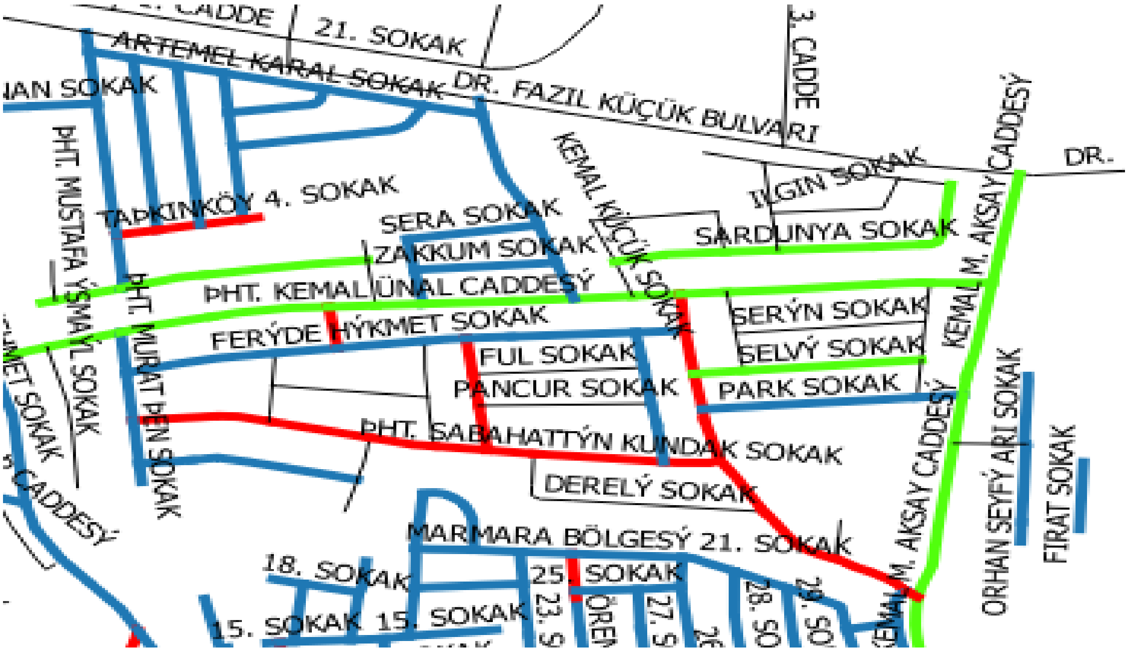


Figure 13: Roads of the City of Nicosia Color-Coded by Category

The total length of the roads taken into consideration for the purpose of this thesis was 316,057 meters. 139,387 metres that constitutes 44.1% of these roads were color-coded in QGIS for this particular research. The color-coded roads were analyzed by creating charts and graphs. The charts provided a detailed information of the color-coded roads according to their age group. The colored road charts were produced both by percentage and total length. Figure 14 shows the pie chart indicating the percentage of the color-coded roads by both total areas and lengths.

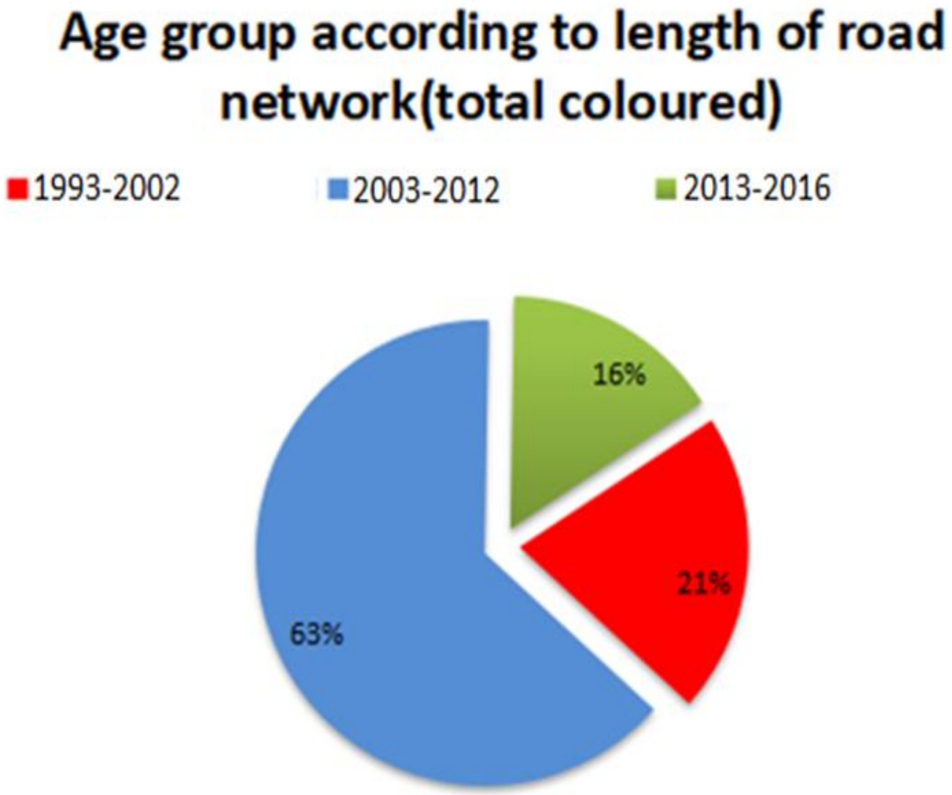


Figure 14: Color Distribution According to the Length of Road Network

Of the color-coded roads of Nicosia, 63% belonged to the blue category which are at intermediate age, while 21% and 16% were oldest and newest roads, respectively. The colors were also calculated according to areas and a pie chart was formed to illustrate the percentage of the areas of each year category (See Figure 15).

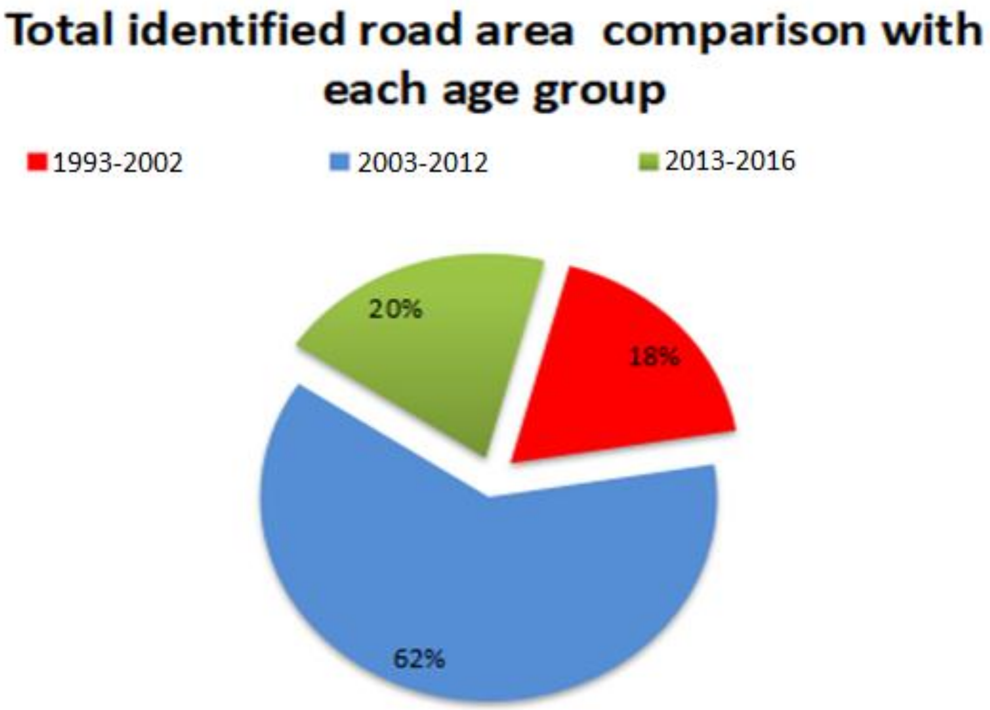


Figure 15: Total Colored Area Comparison by Road Color

Figure 15 represents the total area of the roads according to their age-group distribution by the M&R calendar. From the pie chart above, it can be clearly seen that the highest area, which constitutes 62% of roads, belong to the blue category which are the roads maintained between 2003 and 2012 while the red category of the oldest roads maintained between 1993-2002 form the lowest total area by 18%. This difference between the lengths and areas can be explained by the width of the road. The newly built and maintained green category roads that have been attended after 2013 were generally constructed wider than the older roads. Therefore, even though the length of the old roads seem to be more than those of the new ones, when it comes to the area calculations, the new roads have a larger area than the old roads. The distribution of the colors of roads are shown in a Table 6. The colored oldest roads form 9% of the total length of all roads of Nicosia while the blue colored roads that are the intermediate ones form 28% and the newest ones form 7% of all roads of Nicosia.

Table 6: Proportion of Maintenance Categories

Proportion of the color coded road	**Percentage**
Red vs. Grand Total Length	9%
Blue vs. Grand Total Length	28%
Green vs. Grand Total Length	7%

There were a substantially large number of previously-repaired roads in Nicosia, and surveying and analyzing of all these roads would need more than a year, a period which falls beyond the length of this thesis. Considering time restriction, a random selection of 16 red colored were visited and analyzed in order to calculate the PCI levels to estimate the general condition of the oldest roads. Even though the oldest roads were taken into consideration, some of them, surprisingly, had an excellent PCI level while some had fair PCI levels. Table 7 below shows the total area of the selected 16 roads and their average PCI level.

Table 7: Average PCI

Number of Sample Road Sections	**Total Area (m^2)**	**Average PCI**
16	10536	74.2

The total area of the 16 roads was 10536 m^2 and the average PCI of the roads is 74.2, which falls to the "very good" rating of PCI. The very good rating shows that the road can be maintained in reasonable condition with simple routine maintenance services. The PCI rating levels will be later explained in this section. The PCI levels of the randomly selected roads are entered in a table. The randomly selected roads were also categorized according to their traffic volume. Letter A stands for the highest traffic volume while letter B is for intermediate traffic and letter C is for low traffic volumes on the roads. The details of categorization was previously discussed in the methodology section.

The roads were visited and the distresses were marked on the map of the roads. The distress types were entered into the table to analyze the most common distress types and forecast rehabilitation techniques for the type and the severity of the distress types. The table formed is shown in table 8 on the next page.

Table 8: Condition of the selected roads

No	Name of the street	Section ID	Most common Severity	PCI level	Average PCI	PCI condition	Treatment Band
1	Barış Sokak	A1	Patching	78	**54.25**	Very Good	Preventive Maintenance
2	Şht. Kamil Balkan Sokak	A2	Alligator crack	65		Good	Structural Improvement
3	Şht. Gazeteci Hasan Tahsin cad.	A3	Alligator crack	41		Fair	Base Rehabilitation
4	Şht. Gazeteci Hasan Tahsin cad.	A4	Alligator crack	33		Poor	Base Rehabilitation
5	Ortaköy 1.Sokak	B1	Longitudinal & Transverse Cracking	66	**81.33**	Good	Structural Improvement
6	Sht. Sabahaddin Kundak Sokak	B2	Patching	82		Good	Preventive Maintenance
7	Çetin Başar Sokak	B3	Patching	60		Good	Base Rehabilitation
8	Cengiz Han Sokak	B4	Longitudinal & Transverse Cracking	96		Excellent	Do Nothing
9	Şht. Cumhur Yüzlü Sokak	B5	Patching	95		Excellent	Do Nothing
10	Ortaköy 5.Sokak	B6	Patching	89		Excellent	Routine Maintenance
11	Laden Sokak	C1	Longitudinal & Transverse Cracking	70	**80.41**	Very Good	Structural Improvement
12	Söğüt Sokak	C2	Alligator crack	48		Fair	Base Rehabilitation
13	Şht. Ali Çamsöken Sokak	C3	Longitudinal & Transverse Cracking	96		Excellent	Do Nothing
14	Şht. Ahmet Beyaz Sokak	C4	Patching	87		Excellent	Routine Maintenance
15	Hüseyin Küçük Sokak	C5	Longitudinal & Transverse Cracking	92.5		Excellent	Routine Maintenance
16	Şht. Şener Enver Sokak	C6	Patching	89		Excellent	Routine Maintenance

From Table 8, it can be understood that the category B roads had the highest PCI levels with the patching cracks. This was an unexpected result as the category B included the intermediate traffic volume roads and Category C included the roads with the lowest traffic volume. Therefore, category C roads were expected to have the highest PCI level as they were not used as much as Category A and Category B roads. However, Category C roads had an average PCI value of 80.41 which falls into the `Very Good` band on the PCI Scale. The PCI of Category A roads had the lowest average PCI level of 54.25 which belongs to the `Fair` band of the PCI scale. This result was an expected one as Category A has the highest traffic volume associated with the highest use.

Figure 16 shows the PCI band that is used internationally to rate the average PCI levels of the roads is as follows.

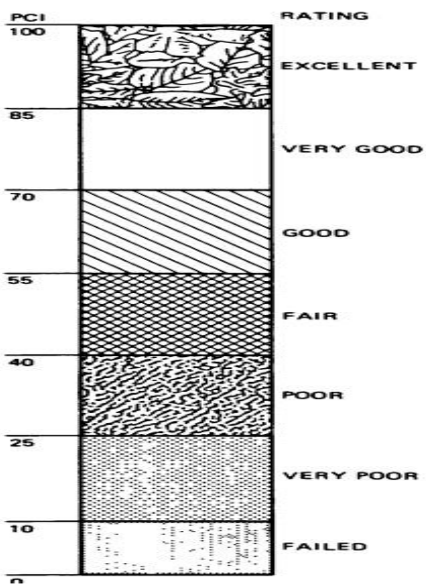


Figure 16: PCI Levels (United States Department of Defense, 2004)

Severity types included patching, alligator cracks, and longitudinal and transverse cracks. On Category A roads, the most common type of severity was alligator cracking while in Category B patching and longitudinal and transverse cracking were common. In Category C roads, all three types of severity was common. Even though all severity types were commonly observed in Category C, this category had a high PCI level and most of the roads belonging to Category C were in excellent condition.

The maintenance techniques recommended for each type of road was inserted into the Table 8. Only 3 roads out of 16 were not suggested with any treatment techniques as their PCI rating was between 93 and 100. These roads were Cengiz Han Sokak, Şht. Cumhur Yüzlü Sokak and Şht. Ali Çamsöken Sokak that had PCI levels of 96, 95 and 93 respectively. The roads with a PCI level between 86 and 92 were recommended for routine maintenance while roads with a PCI level of 72 and 85 were suggested to be applied with preventive maintenance. Only the Barış Sokak road had a PCI of 78 that required preventive maintenance. Çetin Başar Sokak in Category B and Söğüt Sokak in Category C had PCI levels of 60 and 48, respectively. These roads required base rehabilitation where a full depth reconstruction is needed for their rehabilitation. It can be summarized from Table 8 that Category C roads do not require as high rehabilitation techniques as Category A roads. The treatments of the roads undoubtedly need a financial budget. The budget issue will be discussed in detail later on in this chapter. Table 9 shows the severity types observed in the 16 sample roads. The most common severity type was patching with the highest percentage of 44% while alligator cracking was the least common severity type (25%).

Table 9: Number of Distressed Pavement Sections

	Number of distressed pavement sections		
	Alligator crack	Patching	Longitudinal & Transverse Cracking
No of Occurrences	4	7	5
Percentages of Severities	25%	44%	31%
Cost of Repair	65.4 TL/m^2	20 TL/m^2	15-20 TL/m^2

The approximate cost of repair for rehabilitation treatment for each severity type were forecasted. The most difficult repair technique is the application for alligator cracking while the easiest rehabilitation application is for longitudinal and transverse cracking. The repairing of alligator cracking costs approximately 4.36 times more than overlaying the whole road. The most common causes for different types of cracks that can be seen on the pavements are as follows:

i. Alligator cracks: High loading, poor structural base, poor construction.

ii. Longitudinal cracking & Transverse Cracking: Poor construction joints, reflective crack from base, asphalt layer shrinkage.

iii. Patching: Incorrect repairing of the deformed part, excavation of road due to applying new pipeline or electric lines.

iv. Pothole: Poor quality surface mixture, weak point in the base or subgrade, continued deformation of other distress types (Asphalt Institute, 2017).

The details of cost management are further analyzed in the next section. Table 10 was used to suggest rehabilitation techniques according to the PCI levels of each road (Rice, 2016).

Table 10: Rehabilitation Strategies (Rice, 2016)

Treatment Band	**PCI**	**Description**
Do Nothing	93-100	Excellent Condition - no maintenance needed
Routine Maintenance	86-92	Good Condition - Crack sealing or minor repair can be done locally
Preventive Maintenance	72-85	Fair Condition - Surface sealing, crack sealing or full depth patch may be needed
Structural Improvement	61-71	Deficient Condition - Pavement surface needs to be strengthen according to the traffic level. Can be repaired by overlay with or without milling
Base Rehabilitation	0-60	Poor Condition - Improvement of base is necessary. Reconstruction can be a typical repair technique

According to the sample roads, a condition index was formed. A table was created to show the general conditions of all roads regardless of their category. The percentages were calculated by taking the PCI levels of all roads. Table 11 illustrates the general percentage of roads according to their PCI ratings.

Table 11: PCI Distribution of 16 Sample Roads

PCI rating	**General Percentage**
Excellent	44%
Very Good	13%
Good	25%
Fair	13%
Poor	6%
Very Poor	0%
Failed	0%

44% of the sample roads were in excellent condition while 6% were in poor condition according to their PCI ratings. These percentages, however, do not show the factual distribution of all roads of North Cyprus as only 16 random roads were considered. The sampling was limited as the municipality did not have a currently working group on maintenance. Therefore, the roads had to be visited personally. The investigation of the roads is a time-consuming activity as all the data are entered manually. An automated system could be useful for this type of research. Considering the importance of this limited research, the municipality should form a database and track the M&R activities from an automated system.

4.2 Maintenance Budget and the Cost-comparison for Alternative Rehabilitation Techniques

The annual budget used for Maintenance and Rehabilitation of all roads by the Nicosia Turkish Municipality is calculated to be approximately 1,600,000 TL ($820,000 according to average exchange rate between 2009-2015). From the data received from the Nicosia Turkish Municipality Table 12 was formed to lay out the budget spent by the municipality since 2009 for the maintenance and rehabilitation applications.

Table 12: Annual Budget of the NTM for M&R

Year	Budget Spent(TL)	Budget Spent (USD)*
2009	1,333,000	860,000
2010	1,875,000	1,250,000
2011	2,731,629	1,606,470
2014	1,100,000	500,000
2015	960,000	325,423
Average	1,599,925.80	
Budget	≈ 1,600,000	820,000

*Average yearly exchange rate used for Turkish Lira to Dollar conversion.

In 2011, 2,731,629 TL was spent for M&S applications, the highest amount spent between the years of 2009 and 2015. The average budget was calculated by considering the amount spent in 2009, 2010, 2011, 2014 and 2015. This is because in 2012 and 2013 there were management problems faced by the municipality and the amount spent in those two years have the probability of not reflecting the actual costs. The average budget for each year was 1,600,000 TL. This budget was used for all types of rehabilitation and maintenance techniques as well as new road constructions. The budget is influenced by the currency rates. Even though the expenditure stays approximately the same the dollar-based amount seems to be reduced as the currency rates are on incline. The Nicosia Turkish Municipality did not consider the discount rate on Turkish Lira while estimating the annual budget.

The rehabilitation costs for those roads colored on QGIS were calculated as well as the total cost for fully milling and overlaying the roads by a 50 mm asphalt instead of applying maintenance and rehabilitation. The calculations can be seen in Table 13.

Table 13: Prices for Milling and Asphalt Overlaying

Road Types	Total Area (m^2)	Milling Price (TL) (5tl/m2)	Weight (tons)	HMA Price (TL)	Total Price(TL) (Milling+ Asphalt)*
Red	189,739.40	948,697.00	22,768.73	2,846,091.25	3,794,788.25
Blue	643,092.60	3,215,463.00	77,171.11	9,646,388.75	12,861,851.75
Green	205,760.40	1,028,802.00	24,691.25	3,086,406.25	4,115,208.25
			Total Price :	15,578,886.25	20,771,848.25

*Average unit price of hot mix asphalt is 125 TL/ton in 2016.

According to municipality data, the square meter cost for milling was 5 TL while asphalt price per ton was 125 TL. The total price gives the sum of the milling price and the HMA asphalt price in Table 13. For completely milling and asphalt overlaying the red roads, 3,794,788.25 TL is needed while the blue roads need 12,861,851.75 TL, and the green roads require 4,115,208.25 TL. This equals to a sum of 20,771,848.25 TL which is approximately 13 times more than the annual budget of 1,600,000 TL.

The green roads are the newest roads that do not need urgent attention for M&R. The red colored roads should be attended first and urgently and the blue colored roads should then be treated with maintenance and rehabilitation. Figure 17 illustrates the length of time required to mill and overlay all colored roads with the current budget of 1,600,000 TL.

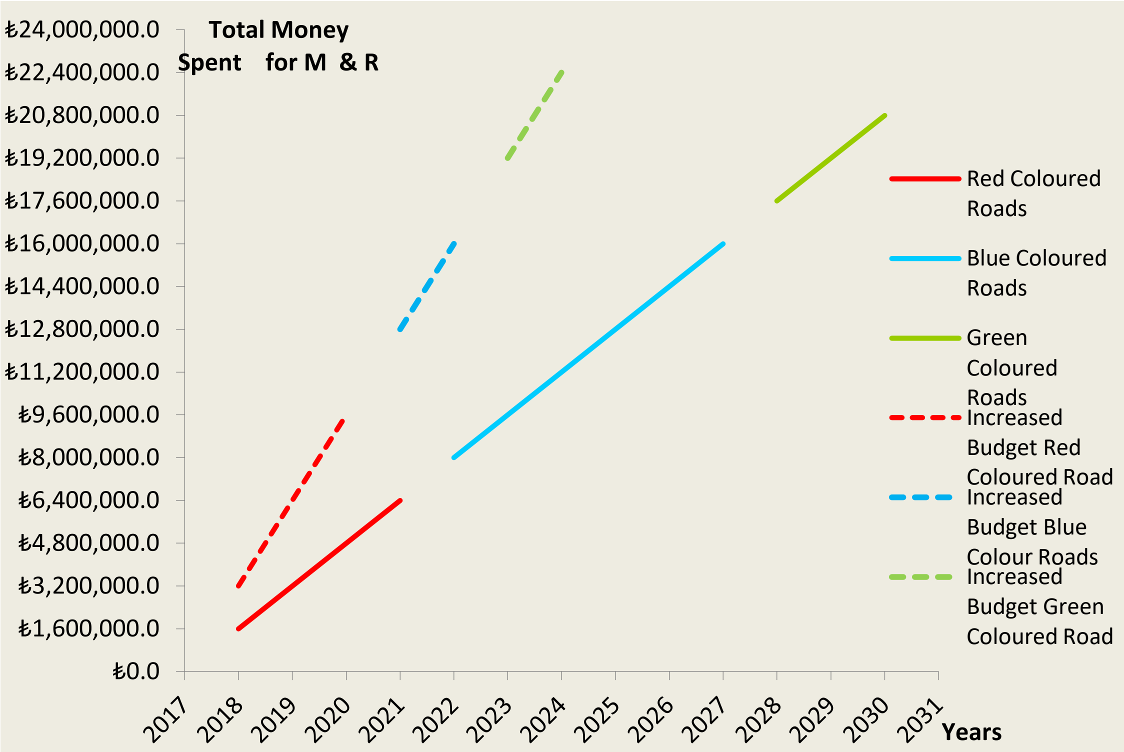


Figure 17: Total Money Required for M&R

It would take about 13 years to mill and overlay all colored roads and it would cost 22 400,000 TL for rehabilitating all colored roads. However, it should also be taken into account that as the roads age, the PCI levels decrease. The lower the PCI level corresponds to a poorer condition and a higher the cost needed for rehabilitation. The higher the budget, the less time is needed for the repairing of the pavements. It should also be taken in consideration that with a low budget, the maintenance work will not be effective, since until the oldest roads with the worst conditions are repaired, the condition of the intermediate roads get worse. In Figure 17, the dotted lines are produced with doubling the current budget of the Nicosia Turkish Municipality. By doing so, it is theoretically shown that with a higher budget, it takes almost half the time to rehabilitate all pavements.

Time plays a vital role for the maintenance and rehabilitation work. Figure 18 shows the graph plotted to show the correlation between the PCI levels and the age of the roads.

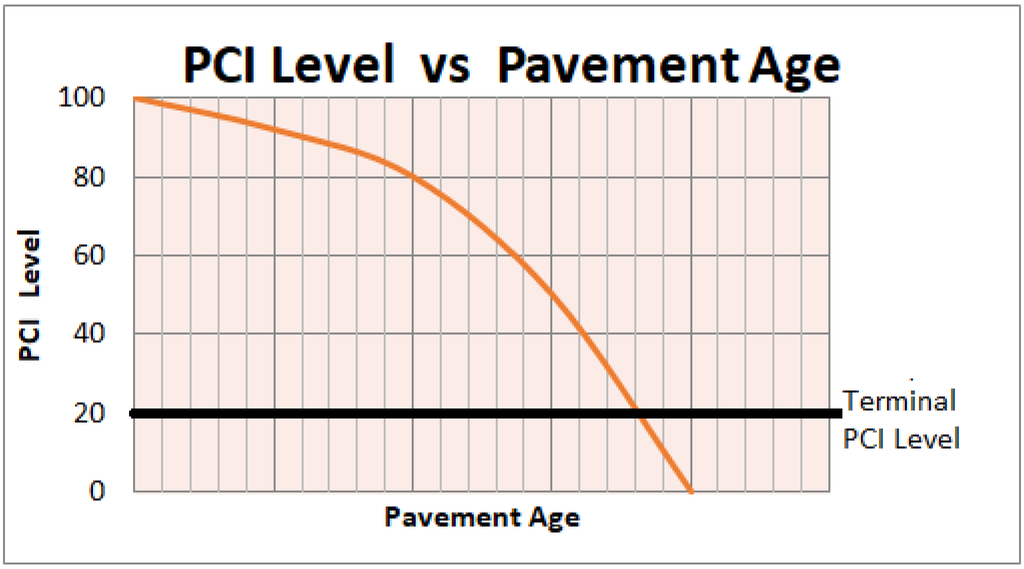


Figure 18: PCI level vs. Pavement Age

The costs for rehabilitating the alligator cracks were calculated to be able to compare the two different suggestions for rehabilitation. The ways for rehabilitation are repairing the alligator cracks or milling and overlaying the whole road with a 50 mm asphalt layer. M&R works are directly related with PCI level of the road. The age of the road adversely effects the PCI levels. Once the PCI level of the road drops to 20 or lower, the M&R costs increase dramatically. Therefore, it would take less money and time to re-construct such a road than applying M&R. It is important to note that the roads should be addressed before the PCI level reaches 20 to maintain the road in a reasonable condition.

Assuming that a PCI level of 20 needs urgent maintenance and rehabilitation work, the following measures can also be taken:

i. create alternative routes to reduce the traffic volume on a low PCI level road, to keep the PCI level high.
ii. enforce weight limit to prevent further deformation of the pavement,
iii. make roads with low PCI levels one-way to reduce the traffic volume on the road so that the deterioration rate could reduce.

The prices for repairing the alligator cracks are calculated by taking the following prices as a basis. Table 14 shows the prices were gained from the Nicosia Turkish Municipality according to their previous work done for roads.

Table 14: Prices of Each Layer

Material	**Price(TL)***
Asphalt Surface course (for patching)	160TL/ton
Asphalt Surface course (for overlay)	125TL/ton
Base course	48TL/m^3
Sub-base course	46TL/ m^3

*Average prices for 2016 are taken into consideration for materials.

A density of an asphalt is 2400kg/m^3 , therefore 1 ton of asphalt is equal to 2.4ton/m^3

Repair cost of an alligator crack:

In order to repair a 1m^2 of alligator crack, asphalt surface course, base course and sub-base course need to be replaced. Prices given below shows the price of each layer according to their specific thickness. The formula below helps us to convert the tons into m^3.

$$Denisty = \frac{Mass}{Volume}$$

- $1m^2$ Asphalt (h=110 mm) price = 1*1*0.11*2.4*160TL = 42 TL

- Base Course 1*1*0.2*48TL = 9.6 TL

- Sub-base Course 1*1*0.3*46TL=13.8 TL

- Total price to repair alligator crack = **65.4 TL/m^2**

Repair cost for 50 mm overlay:

- $1m^2$ (50 mm) overlay price = 1*1*0.05*2.4*125 = **15 TL/m^2**

Therefore;

- **Price difference = 65.4 TL-15 TL =50.4 TL**

- **$1m^2$ alligator crack repair cost = $4.36m^2$ overlay cost**

From the calculations it was concluded that it takes 65.4 TL per m^2 to repair alligator cracks, while it takes 15 TL per m^2 to totally overlay the road with a 50 mm asphalt base. Therefore, instead of spending money to repair the alligator cracks, it is worth renewing the roads with a 50 mm asphalt overlay as it would cost 50.4 TL less that equates to 23% less than repairing the alligator cracks. The budget scenarios that can be considered by the authorities are:

i. Scenario 1: Do nothing.

If no action is taken towards repairing and rehabilitating the roads, which would exert no expenditure on roads, the PCI levels will start dropping and will reduce according to the traffic loads and the usage of the pavements. This will therefore lead the authority to totally reconstruct the pavement after a certain time. However, until a whole new construction is needed, no budget will be spent on the roads which can be saved for the final work that will be more costly. This scenario is the least likely scenario to be considered as the pavements fade off and not treated on the correct time. The fading of the pavement will therefore lead for the need of a whole new construction of the pavement which will cost more than the maintenance and rehabilitation services.

ii. Scenario 2: Fix the worst first.

If the roads are attended according to their severity levels, the lowest PCI level pavements will be fixed urgently. This will prevent the pavement from eroding and will increase the PCI level of the roads. By fixing the pavements, the safety of the road increases accordingly. By safety it is meant that the traffic accidents will decrease leading to a safer communal life. However, if the road is not used often by the vehicles, even though it is in the worst condition, it might be better to fix those pavements who are not as bad but are used more often. All in all, while fixing the worst roads, the ones that are in a reasonable state will start getting worse which would later require larger budgets for repairing.

iii. Scenario 3: Fix the high traffic volume sections first.

This is a considerable scenario if the budget is limited. With the current budget, the pavements with a high traffic volume should be attended first in order to improve security and to increase the PCI level of the high traffic volume roads. By attending to these sections first the number of accidents would decrease and the traffic will move faster, reducing the rush hour.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

Development of a GIS based tool using the Nicosia Turkish Municipality as an example was the starting point of this research. The work of Nicosia Turkish Municipality was analyzed throughout this thesis and a novel dataset was produced using QGIS. Before producing the dataset, all the roads (139,387 meters in total) were included in the QGIS program retreived from the Nicosia Turkish Municipality. Information about the M&R calendar for these roads were also received from the municipality. Sixteen roads were then randomly selected to be included in this research. The PCI levels for these roads were calculated by using the inventory survey sheets. The roads were then color-coded for clear visual representation according to their age and traffic volumes. The distress severity levels were calculated using PCI. The current conditions of these roads visited gave an estimated figure for the M&R techniques to be applied for maintenance.

From the dataset produced, it was forecasted that with the current budget of the Nicosia Turkish Municipality, an 13-year plan should be implemented to rehabilitate the roads of Nicosia. Arguably, the budget of the Municipality for reconstructing, rehabilitating and maintaining pavements should be increased throughout this times to allow new road construction activities and reduce the M&R period of Nicosia Municipality road network.

The budget of a Municipality is calculated annually by taking the revenues and the expenditures into account. City planning should be done carefully before estimating the annual budget. Taking the currency rate in consideration while estimating the annual budget is vital. The currency rates seem to be on increase every year. As the revenues are in Turkish Lira and the expenditures for M&R are in dollars, the discount rate of Turkish Lira should be foreseen before setting the budget for M&R. The revenues for the budget for M&R can be increased by collecting more road tax according to the vehicle types. The Nicosia Turkish Municipality can also increase the parking fees that will be used for M&R. One can put forward that once the parking fees are increased, the use of individual cars will decrease. This means that the people will start carpooling or they will start using public transportation. Therefore, the revenues from public transportation will increase.All in all, the use of public transportation will not only reduce the traffic jam but will also lead to a decrease in the deterioration of the roads.

Condition survey is a time consuming process. For overcoming this problem for future research of the Nicosia Turkish Municipality few actions could be taken. For instance, a public website could be developed where citizens could specify the distresses and location of the roads. This would allow an updated information cycle throughout Nicosia as every citizen who observes a crack on any road can upload the location and the severity on the online system. This system, undoubtedly, would not need any employment of workers to investigate the field personally. Therefore, the conditions of each road can be tracked and restored with rehabilitative methods.

The thesis findings showed that where the severity of the distresses of the road is at a high level, it is economically safer to reconstruct the road than to rehabilitate it.From the municipality perspective, condition surveys should be carried out regularly to allow the tracking of the pavement sections. The data in QGIS should be updated periodically. This will allow effective rehabilitation actions.

The Nicosia Turkish Municipality should include detailed information about the previous M&R applications. For instance, the thickness of the roads, the locations of the M&R applications and the type of the material used for M&R should be entered in the system. The road construction and M&R works carried out by the municipality does not contain the material analysis results. It is vital to carry out material analysis before M&R, as the quality of the asphalt directly affects the life of the pavement.

In order for the municipality to carry out effective rehabilitative actions, an expert lead group should be formed urgently. With the help of this group, all the roads can be surveyed and acted-upon on time. For effective M&R, all the data of the roads should be entered in the system and followed on a regular time-scale to prevent the road from being totally deformed. For instance, working on a larger scale, rehabilitated roads should be marked with their current conditions on the road-network map. As rehabilitation continues, relevant road-markers should all be entered in the dataset. With a functional group, this work can be done within a 4-5 year long timescale. Systematic updates could enable reductions of the cost of rehabilitation as damages would be intervened in a timely manner. Overall, the living standards of the community could increase as the roads will be maintained before the PCI level reduces.

The most common distress type in this research was patching. From the roads observed, it was concluded that patching technique was used to fill the roads after excavation work. The institutions should work in coordination with each other to maintain the roads. Even though the municipality is responsible for the maintenance of roads, a variety of agencies such as the Cyprus Turkish Electrical Agency (KIB-TEK) and the TRNC Telecommunication Office require excavation work to complete their duties. An online automated system could be used to streamline the processes and allow all the agencies to view and mark their work. This would allow the municipality to plan M&R actions after viewing excavation work of other agencies.

The driving-comfort is highly affected by the condition of the road. To increase the living standards of the society, M&R should be done by specialized staff. This thesis provided a basic overview on the roads of Nicosia. With the current budget, it is impossible to apply M&R to all the roads in a short time-scale. On a larger scale, applying M&R on a regular basis will not only maintain the roads in good condition but also for a longer time.

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APPENDICES

Appendix A: Severity Types

Alligator Cracking(fatigue)
Photo:
Figure A1. Alligator crack

Description:

It can be described as a series of interconnected cracks (Federal Highway Administration , 2009). Longitudinal cracks start forming first and then side cracks are formed rooting from the longitudinal crack. The name of this type comes from the look of the crack. When the side cracks occur it looks like an alligator/crocodile back which gives the name of the crack type (Lanham, 2012).

Severity Levels:

Severity levels are used in order to differentiate the extremity of the distress type. Three Severity types that are explained below are seen for the alligator cracking

a. Low: Few interconnecting cracks and there will be no spall. Cracks are less than 6mm in mean width.

b. Medium: Interconnected cracks that complete pattern. Cracks can be slightly spalled and crack width is between 6mm and 19 mm.

c. High: Interconnected cracks forming a complete pattern and crack are slightly or completely spalled. Cracks are wider than 19mm. (Federal Highway Administration, 2009).

Possible causes:

i. High Loading

ii. Poor structural design (inadequate layer thickness for the loading)

iii. Loss of base, subbase and subgrade support due to lack of drainage

iv. Poor construction(poor compaction)

v. Any combination of the above (Asphalt Institute, 2017).

Repair Techniques:

Alligator cracks on a pavement generally need full depth repair in order to solve the problem totally. The repair method to be used can be small localised repair or large area overlay with a full depth repair of a base, subbase and subgrade (Lanham, 2012).

Longitudinal Cracking & Transverse Cracking
Photo:

Figure A2. Longitudinal & Transverse Crack

Description:

Longitudinal cracks are primarily parallel to the centreline of the road. Those types of crack can occur anywhere within the pavement. Transverse cracks primarily occur perpendicular to the centreline of the road and it can be visible in anywhere of the lane (Federal Highway Administration, 2009).

Severity levels:
3 Severity types are seen in this type of cracking. The severity levels indicate the seriousness of the crack.

Low: The mean width of the crack should be less than 6 mm.

Medium: The mean width of the crack should be no smaller 6mm and no wider than 19 mm.

High: The mean width of the crack should be more than 19mm
(Federal Highway Administration, 2009).

Possible causes:

Poorly constructed joints
Reflective crack from the base, subbase and subgrade
Asphalt layer shrinkage
Temperature cycle that occurs daily (Asphalt Institute, 2017).

Repair Techniques: According to the severity level of the cracking the repair technique to be used may change. Low severity longitudinal & transverse cracks can be easily sealed with asphalt emulsion slurry in order to prevent the water entry from the crack. However high severity longitudinal & transverse cracks may need a bigger action of replacing the HMA to reduce improve the condition of the road (Lanham, 2012).

Patching
Photo:

Figure A3. Patching

Description:
Patching occurs when the area of the pavement is replaced with new materials in order to restore the pavement in to its original condition (Lanham, 2012).
Severity levels:
Severity levels of patching are also classified in three different levels as described below:

Low: Patch performs well and is in reasonable condition.

Medium: The vehicles are affected reasonably due to the slightly deformed patch.

High: The vehicles are considerably affected due to the highly deformed patch (Department of Defense, 2004).

Possible causes:

Incorrect repairing of the deformed part of the pavement

Excavation of the road due to repairing techniques or applying a new pipeline, electric line, sewage line, etc.(utility cut)
Use of low quality materials in patch rehabilitation.
Heavily loaded vehicles using the road frequently
Repair Techniques:
Patches are already a repair action that is taken to maintain the roads. However, when deformations start to be seen in patching applying new HMA could be the best way to prevent further cracking of the road. The materials to be used in patching should be selected carefully so as to provide the longest maintenance possible.

Potholes
Photo:

Figure A4. Pothole
Description:
A sharp-edged hole that has a bowl-shape that is formed as a result of a collapse on the surface of the pavement (Lanham, 2012).
Severity levels:
3 severity levels are used to describe the condition of a pothole:
Low: Pothole is not deep and just started to form.

Medium: Potholes start affecting the vehicle tyres and the driving comfort
.
High: Pothole is considerably deep and effects the vehicles and the driving comfort considerably (Department of Defense, 2004)

Possible causes:

Continued deformation of another distress type
Poor quality surface mixture
Weak point in the base or subgrade
The traffic load on a pavement also help the acceleration of the pothole formation (Asphalt Institute, 2017).
Repair Techniques:

Potholes are generally repaired by patching which is also an M&R technique.

Rutting
Photo:

Figure A5. Rutting, (BMT, 2013)

Description:
Rutting generally occur at the wheel path. The pavement surface settles down and creates surface depression which can be described as being a pit on the surface of the pavement (Lanham, 2012).

Severity levels:

Severity levels are used in order to identify the worseness of the distress type. 3 Severity types are used in order to differentiate the potholes condition.

Low: Rut depth between ≥5mm and ≤12mm
Medium: Rut depth between >12mm and ≤25mm

High: Rut depth >25mm. (Federal Highway Administration (2009).

Possible causes:

Consolidation or movement of the subgrade under traffic load
Poor design (thickness problem)
Poor compaction of the base layers
Poor asphalt mixture (Asphalt Institute, 2017).

Repair Techniques:

It can be repaired by milling the problematic part and apply a thin HMA overlay (Asphalt Institute, 2017).

Appendix B: Inputting data in QGIS

This section will focus on the how the program is used. The following steps should be followed to run the program.

-Start up the program by using the desktop icon.

-Click "add vector layer" button in the program

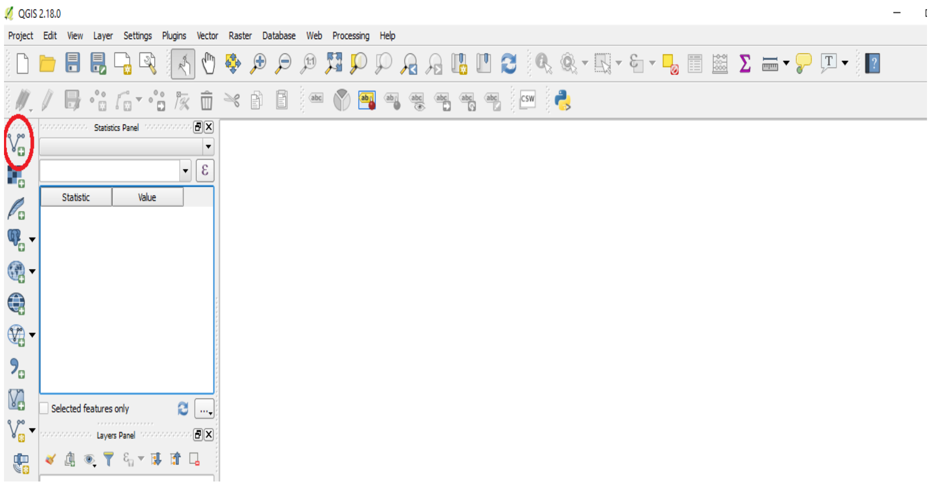

Figure B1. QGIS start page

-Click browse button in order to select and open the layer that to be opened

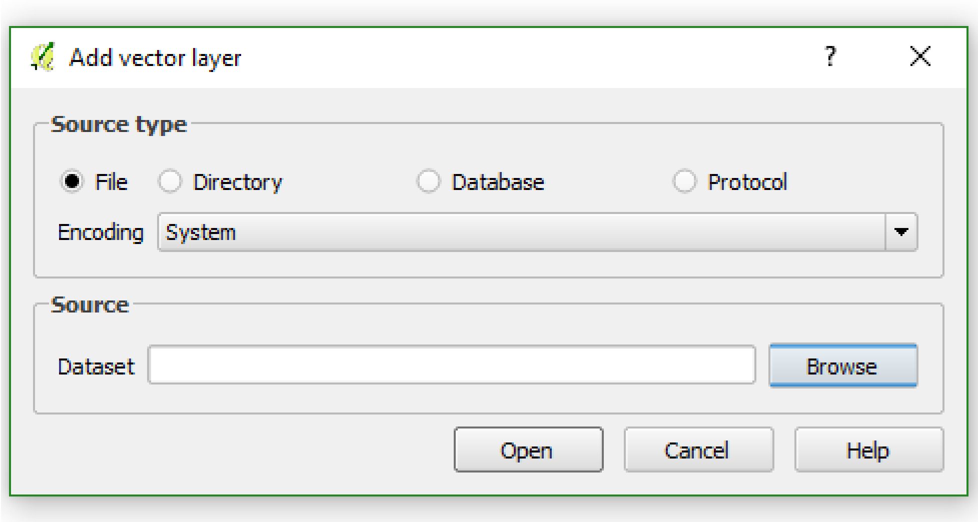

Figure B2. Adding vectors in QGIS

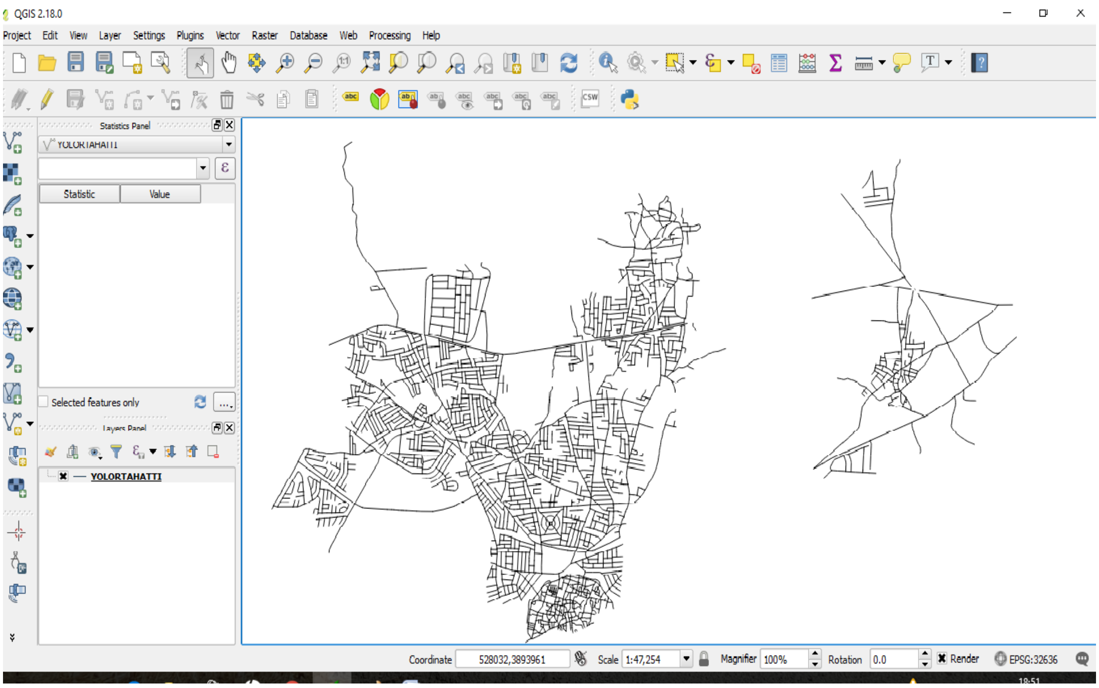

Figure B3. Adding vectors in QGIS

-To start entering the data click "attribute table"  button.

In order to use " tip_1" input data , coding needs to be done to separate the each paved road according to their construction date. The tip_1 column was created to be able to give different colors to the different types of roads according to their codes. Steps of coding are shown below :

1. Click " YOLORTAHATTI", which is the name of the data, on the main screen of QGIS.

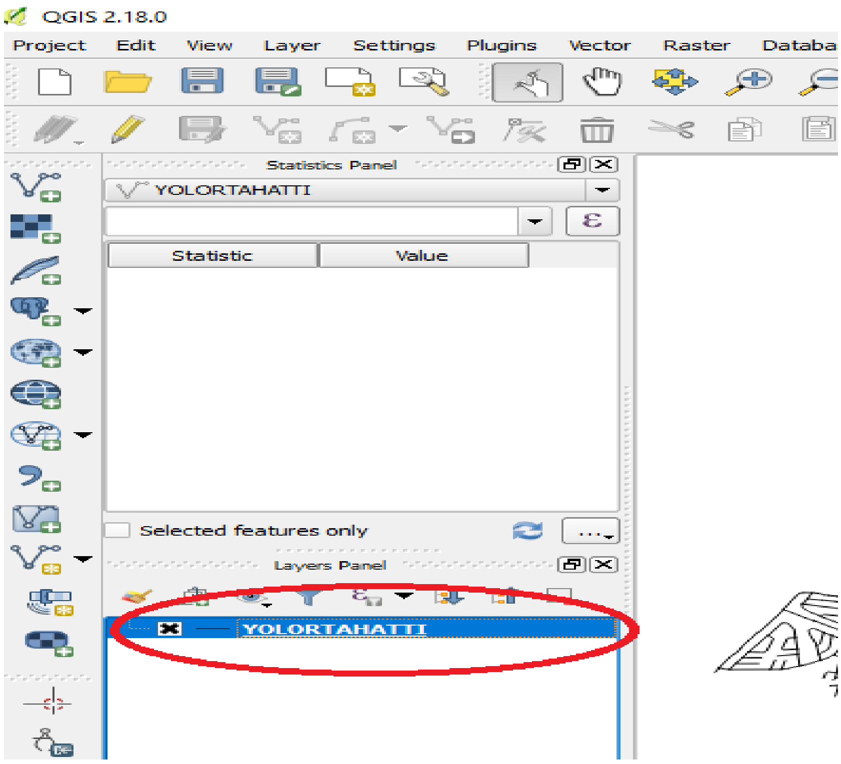

Figure B4. Selection of layers

2. Once the layer properties are opened the "categorized" option should be selected in order to categorize the road according to their coding(ex: 1 , 2, 3)

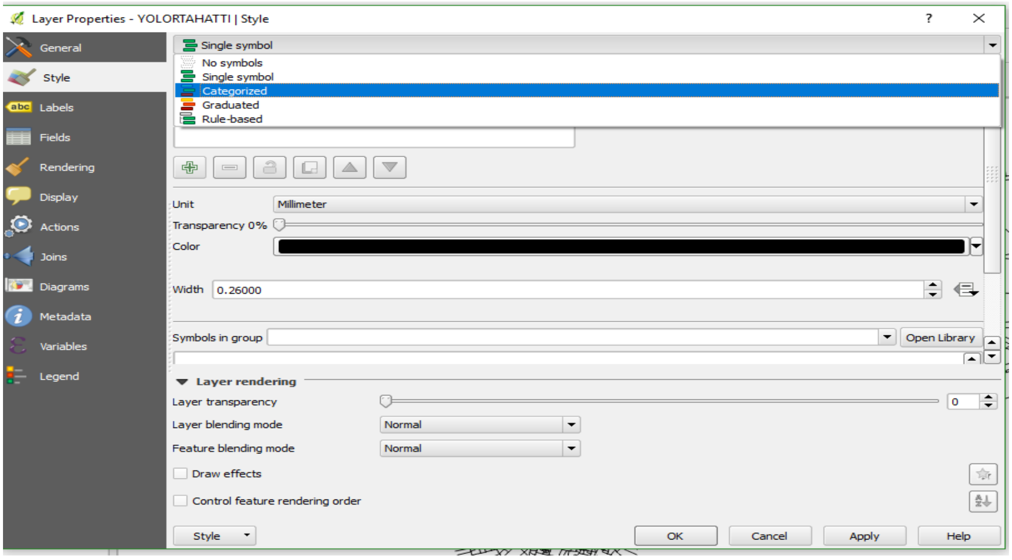

Figure B5. Categorisation of roads

After that the "column" button is clicked and "tip_1" is selected assign different color for different road. For this purpose the classify button is selected. After that classification of the road can be completed.

Appendix C: Pavement Condition Survey Sheets

Nicosia PMS

Data collection form for the City of Nicosia

Inventory Information

Section ID: A	No: 1	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Boris Sokak					# of travelling lanes: 1 | 2 | 3	Length 100 m	
From Sht. Tahir Osman sokak To Hastane Oto Park Girişi		ADT ____	Survey Date: 8/4/2017	Construction Date: _/_/__	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low	1x0.6 0.8x1.2 6x0.3	5m 2m					47 m^2	2482(A), 2483(A).jpg 2489(L)
Medium								____.jpg
High	2x0.5							2486 (A) .jpg

Cross Street__________________
STOP SIGN (YES/NO)

Cross Street__________________
STOP SIGN (YES/NO)

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Page | 1

Pavement Condition Survey Data Sheet					
Street Name	Bariş sokak		Area of Sample = 1036 m^2		
Section ID	A - 1				
Date	10/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L	3.36 m^2	7 m		47 m^2
	M				
	H	1 m^2			

Distress Type	Severity	Density %	Deduct Value
1	L	0.32	12
1	H	0.1	16
2	L	0.68	4
4	L	4.53	9
Deducted Total			41
Corrected Deducted Value (CDV)			22
PCI = 100 - CDV			78 - Very Good

Nicosia PMS

Inventory Information

Data collection form for the City of Nicosia

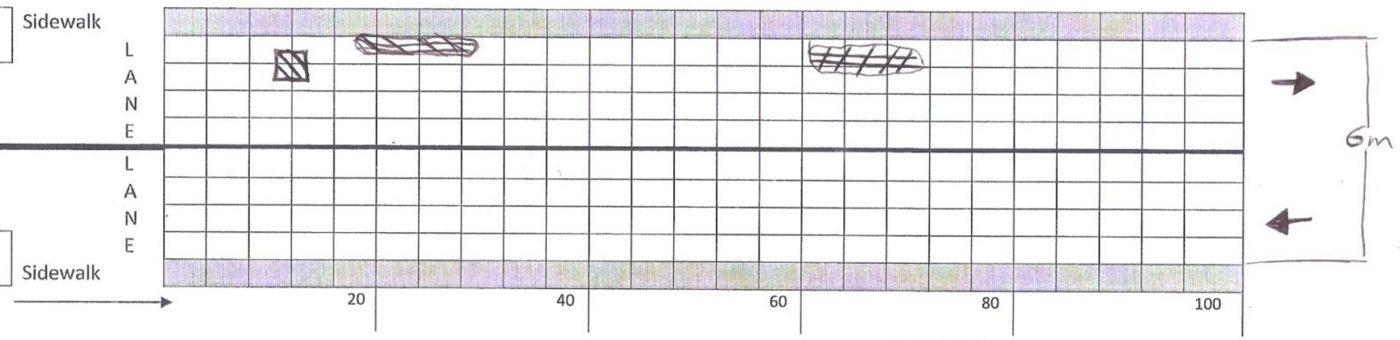
Section ID: A	No: 2	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay	
Street Name Sht Kamil Balkan sokak					# of travelling lanes: 1 | 2 | 3	Length 100 m
From Sht Ecvet Yusuf caddesi		ADT ______	Survey Date: 9/4/2017	Construction Date: _/_/___	Traffic Flow: One Way Two Way	Maintenance YES/NO
To Sivil Savunma Girişinden 50metre geriye						Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low							1.5x1	2520(P) .jpg
Medium	8x0.6 7x0.5							2521(A), 2522(A) .jpg
High								______ .jpg

DRAINAGE YES/NO

LEFT



RIGHT

YES/NO DRAINAGE

SURVEY DIRECTION

Cross Street______

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Cross Street______

STOP SIGN (YES/NO)

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Page | 1

Pavement Condition Survey Data Sheet					
Street Name	Şht Kamil Balkan sokak	Area of Sample = 600 m²			
Section ID	A – 2				
Date	10 / 4 / 2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L				1.5 m²
	M	8.3 m²			
	H				

Distress Type	Severity	Density %	Deduct Value
1	M	1.38	33
4	L	0.25	2
Deducted Total			35
Corrected Deducted Value (CDV)			35
PCI = 100 - CDV			65 – Good

Nicosia PMS

Data collection form for the City of Nicosia

Inventory Information

Section ID: A	No: 3	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay	
Street Name Sht Gazeteci Hasan Tahsin Caddesi					# of travelling lanes: 1 | 2 | 3	Length 100 m
From Ortaköy 7. sokak To Sht Hüseyin Topal sokak		ADT ___	Survey Date: 9/4/2017	Construction Date: _/_/___	Traffic Flow: One Way Two Way	Maintenance YES/NO
						Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low								______.jpg
Medium	40x1 4x0.5							2525(A1), ~~2526(A1)~~.jpg
High	10x1						2x2.5	2523(R), 2524(A).jpg

2526(A1)

DRAINAGE YES/NO
LEFT

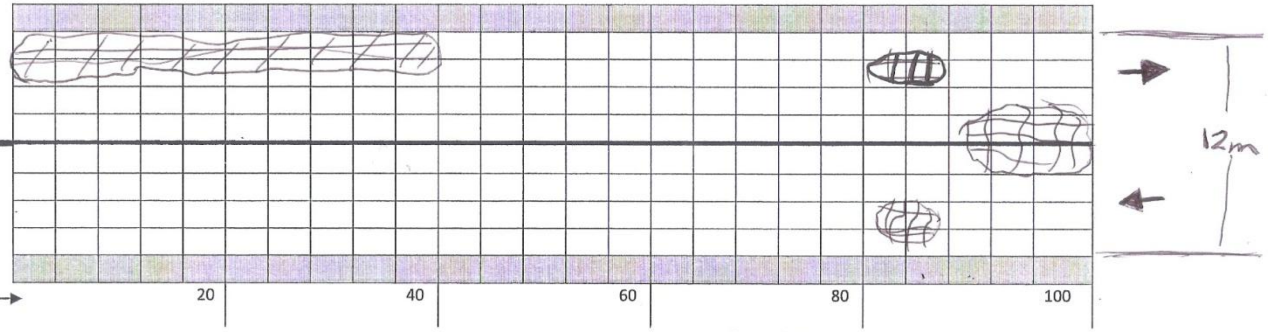
Sidewalk

L A N E

L A N E

RIGHT
YES/NO
DRAINAGE

Sidewalk



SURVEY DIRECTION →

Cross Street___________

STOP SIGN (YES/NO)

Cross Street___________

STOP SIGN (YES/NO)

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Page | 1

Pavement Condition Survey Data Sheet					
Street Name	Şht Gazeteci Hasan T. sok	Area of Sample = 1200 m²			
Section ID	A - 3				
Date	10/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L				
	M	42 m²			
	H	10 m²			5 m²

Distress Type	Severity	Density %	Deduct Value
1	M	3.5	42
1	H	0.83	34
4	H	0.42	17
Deducted Total			93
Corrected Deducted Value (CDV)			59
PCI = 100 - CDV			41 - Fair

Nicosia PMS

Data collection form for the City of Nicosia

Inventory Information

Section ID: A	No: 4	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Sht Gazeteci Hasan Tahsin cad.					# of travelling lanes: 1 2 3	Length 100 m	
From China bazar yanı To Sivil Savunma Çemberi		ADT ____	Survey Date: 29/4/2017	Construction Date: _/_/___	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low		13m, 12m						2544(L), 2545(L).jpg
Medium	(2x0.6), (6x0.6) (2x0.9), (3x1.2)							2540(A), 2541(A).jpg 2542(A), 2543(A)
High	(5x1.5), (2x0.8) (8x2)							2546(A), 2547(A).jpg 2548(A)

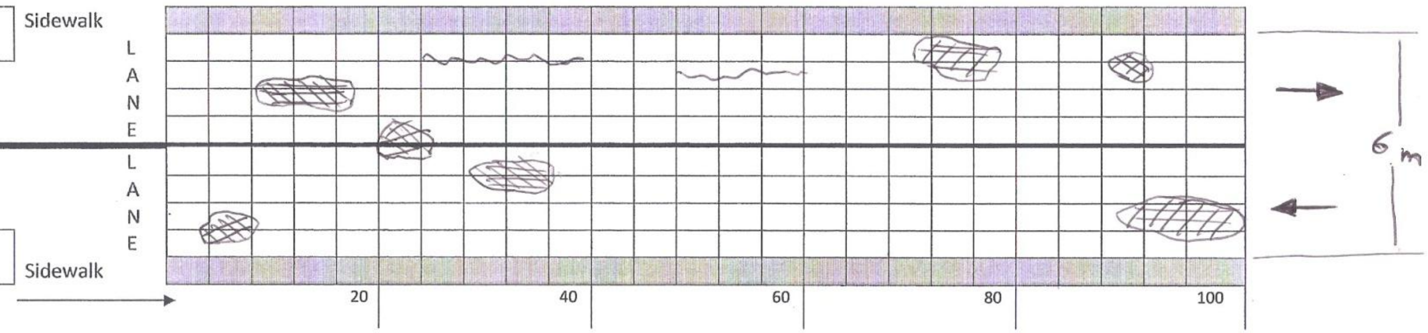
DRAINAGE YES/NO

LEFT

RIGHT

YES/NO DRAINAGE

SURVEY DIRECTION



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STOP SIGN (YES/NO)

Cross Street________________

STOP SIGN (YES/NO)

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Nicosia PMS

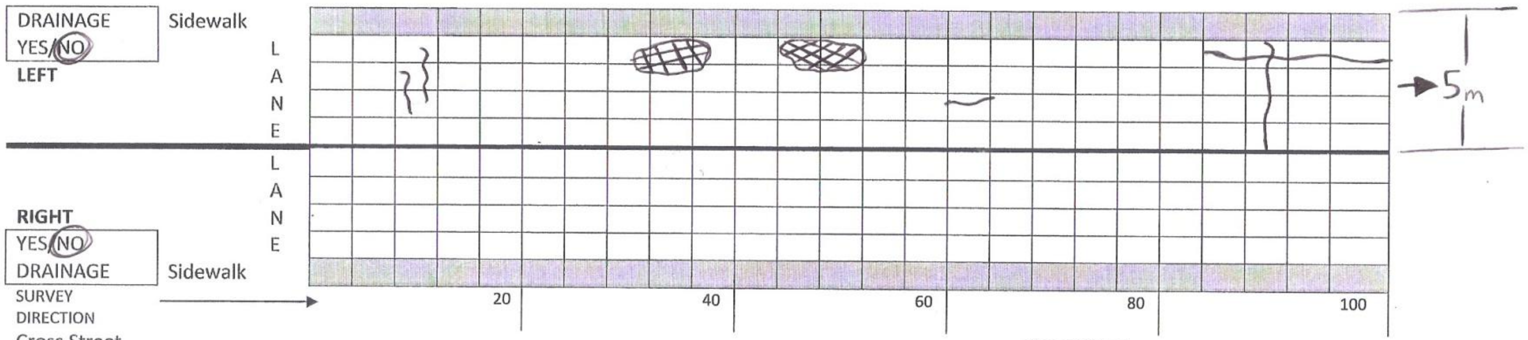
Inventory Information

Data collection form for the City of Nicosia

Section ID: B / No: 1 Street Name: Ortaköy 1. sokak	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay # of travelling lanes: 1 | 2 | 3	Length ____ m
From Ali Rıza Efendi Caddesi To Şht Yüzbaşı Tekin Yurdabak Caddesi	ADT ____	Survey Date: 8/4/2017	Construction Date: _/_/___	Traffic Flow: One Way / Two Way	Maintenance YES/NO / Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low	5x0.4	2m	3m, 4m					2495(L).jpg
Medium	5x0.6	13m						2492(A) 2494(L).jpg
High								____.jpg



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Page | 1

Pavement Condition Survey Data Sheet			
Street Name	Ortaköy 1. sokak	Area of Sample = 500 m^2	
Section ID	B-1		
Date	11/4/2017		

Distress Types
1-Alligator Cracking, m2
2-Longitudinal Cracking & Transverse Cracking,m
3-Rutting,cm
4-Patching, m2

		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L	2 m^2	9 m		
	M	3 m^2	13 m		
	H				

Distress Type	Severity	Density %	Deduct Value
1	L	0.4	17
1	M	0.6	25
2	L	1.8	7
2	M	2.6	18
Deducted Total			67
Corrected Deducted Value (CDV)			34
PCI = 100 - CDV			66 - Good

Nicosia PMS

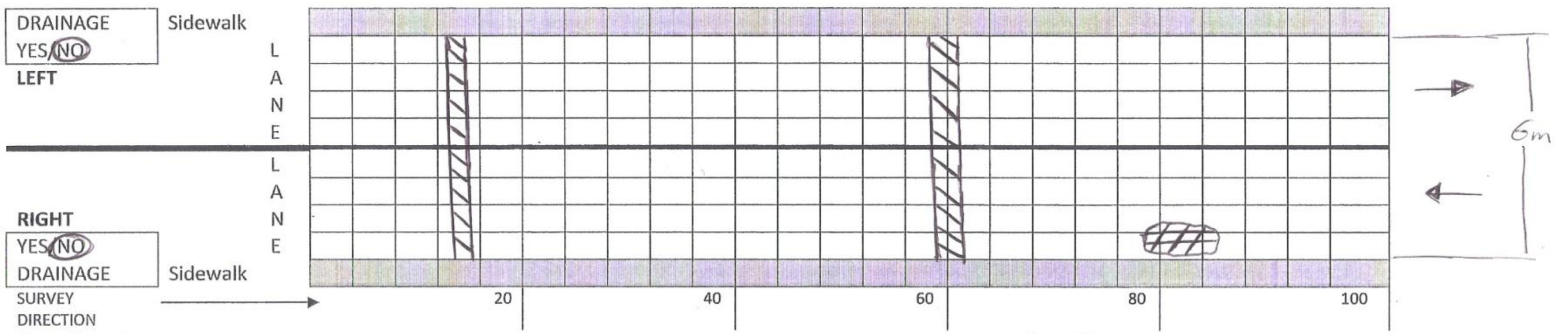
Inventory Information

Data collection form for the City of Nicosia

Section ID: B	No: 2	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Sht. Sabahaddin Kundak sokak					# of travelling lanes: 1 | 2 | 3	Length 100 m	
From Fitne Sokak To Dereli Sokak		ADT ____	Survey Date: 8/4/2017	Construction Date: _/_/__	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low							6x0.3 6x0.3	2496(P2).jpg
Medium	5x0.4							2498(A).jpg
High								____.jpg



Cross Street__________

STOP SIGN (YES/NO)

Cross Street__________

STOP SIGN (YES/NO)

Pavement Condition Survey Data Sheet					
Street Name	Sht. Sabahaddin Kurdak	Area of Sample =	600 m^2		
Section ID	B − 2				
Date	11 / 4 / 2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L				3.6 m^2
	M	2 m^2			
	H				
Distress Type	Severity	Density %	Deduct Value		
1	M	0.33	19		
4	L	0.6	7		
Deducted Total			26		
Corrected Deducted Value (CDV)			18		
PCI = 100 - CDV			82 − Very Good		

Nicosia PMS

Inventory Information

Data collection form for the City of Nicosia

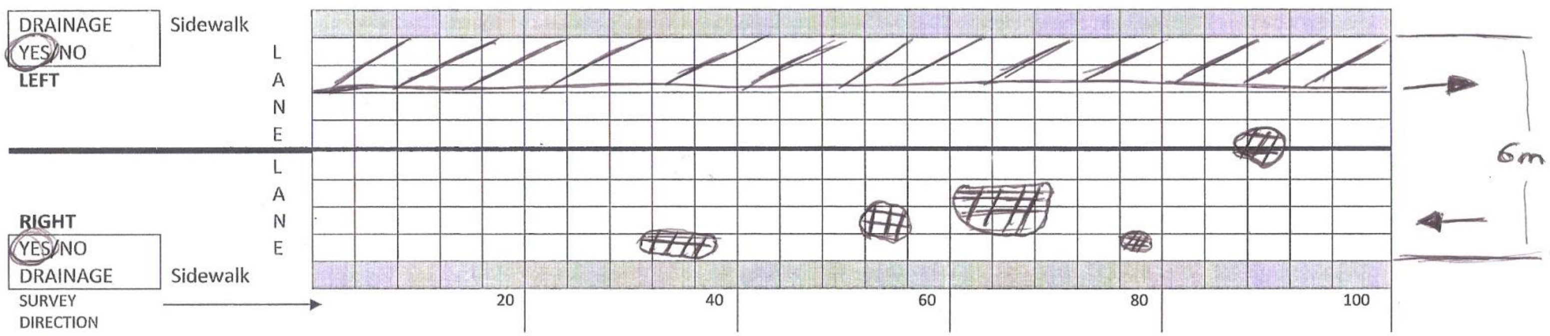
Section ID: B	No: 3	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay	
Street Name Çetin Başar sok.					# of travelling lanes: 1 | 2 | 3	Length 100 m
From Şht Kemal Ünal caddesi To Selvi sokak		ADT ______	Survey Date: 8/4/2017	Construction Date: ~~8/#/2017~~	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low	1x0.6						100x1.2	2500(P) 2504(A).jpg
Medium	4x0.6 2.5x1.2							2501(A),2502(A).jpg 2503(A)
~~High~~	~~4x2.5~~ 1x0.8							________.jpg

(2499 JPG)

2505 JPG
2506 JPG
2507 JPG



Cross Street____________

STOP SIGN (YES/NO)

Cross Street____________

STOP SIGN (YES/NO)

Pavement Condition Survey Data Sheet					
Street Name	Getin Basar sokak		Area of Sample = 600 m^2		
Section ID	B - 3				
Date	11 / 4 / 2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L	0.6 m^2			120 m^2
	M	16.2 m^2			
	H				
Distress Type	Severity	Density %	Deduct Value		
1	L	0.1	7		
1	M	2.7	38		
4	L	20	21		
Deducted Total			66		
Corrected Deducted Value (CDV)			40		
PCI = 100 - CDV			60 - Good		

Nicosia PMS
Inventory Information

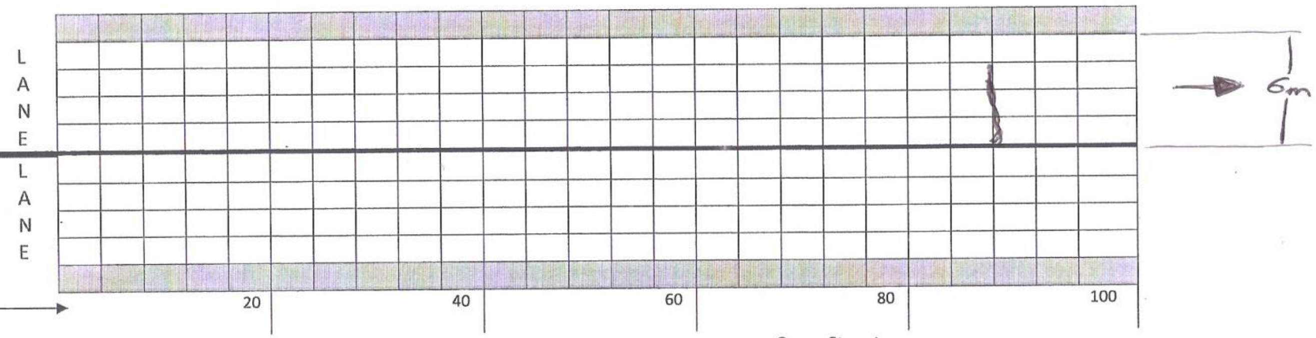
Data collection form for the City of Nicosia

Section ID: B — No: 4	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay # of travelling lanes: 1 | 2 | 3	Length 100 m
Street Name Cengiz Han sokak From Osman Paşa caddesi To Hüseyin Küçük sokak	ADT ____	Survey Date: 29/4/2017	Construction Date: _/_/__	Traffic Flow: One Way Two Way	Maintenance YES/NO — Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low			3m					2530(T).jpg
Medium								____.jpg
High								____.jpg

DRAINAGE YES/NO
LEFT
Sidewalk



RIGHT
YES/NO DRAINAGE
Sidewalk
SURVEY DIRECTION
Cross Street____
STOP SIGN (YES/NO)

Cross Street____
STOP SIGN (YES/NO)

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Pavement Condition Survey Data Sheet					
Street Name	Cengiz Han sokak	Area of Sample = 600 m2			
Section ID	B - 4				
Date	29/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		3 m		
	M				
	H				

Distress Type	Severity	Density %	Deduct Value
2	L	0.5	4
Deducted Total			4
Corrected Deducted Value (CDV)			4
PCI = 100 - CDV			96 - Excellent

Pavement Condition Survey Data Sheet			
Street Name	Şht Cumhur Yüzlü sok.	Area of Sample = 600 m^2	
Section ID	B − 5		
Date	29/4/2017		

Distress Types
1-Alligator Cracking, m2
2-Longitudinal Cracking & Transverse Cracking,m
3-Rutting,cm
4-Patching, m2

		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L				9 m^2
	M				
	H				

Distress Type	Severity	Density %	Deduct Value
4	L	1.5	5

Deducted Total	5
Corrected Deducted Value (CDV)	5
PCI = 100 - CDV	95 – Excellent

Nicosia PMS

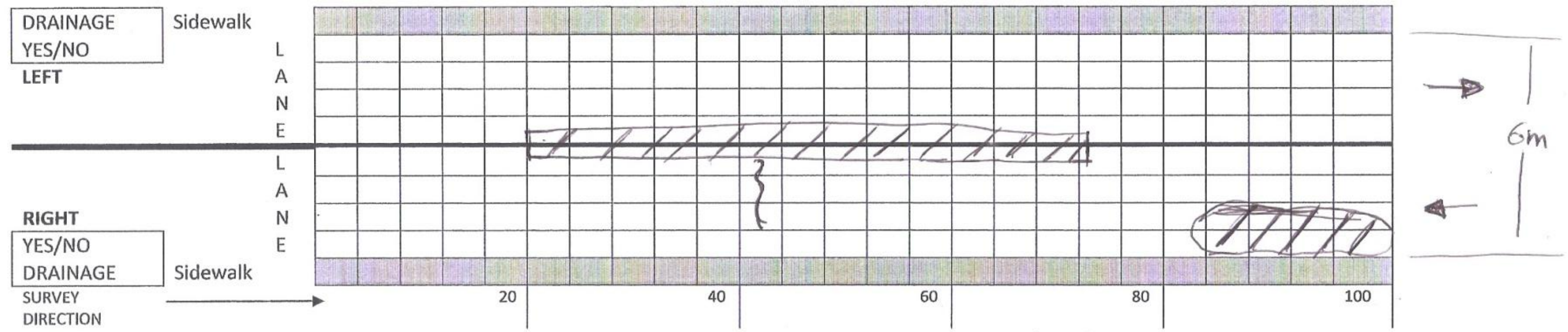
Inventory Information

Data collection form for the City of Nicosia

Section ID: B	No: 6	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay
Street Name Ortaköy 5. sokak					# of travelling lanes: 1 | 2 | 3 — Length 100 m
From Sht Yüzbaşı Tekin Yurdabak cad. To Yeni Yüzyıl ilkokulu girişi		ADT ____	Survey Date: 29/4/2017	Construction Date: _/_/___	Traffic Flow: One Way / Two Way — Maintenance YES/NO — Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low			3m				(55x0.5)	2550(T), 2551(P).jpg
Medium							(12x1)	2552(P).jpg
High								____.jpg



Cross Street____________

STOP SIGN (YES/NO)

Cross Street____________

STOP SIGN (YES/NO)

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Pavement Condition Survey Data Sheet					
Street Name	Ortaköy 5. sokak	Area of Sample = 600 m2			
Section ID	B-6				
Date	29/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		3m		27.5m2
	M				12m2
	H				
Distress Type	Severity	Density %	Deduct Value		
2	L	0.5	8		
4	L	4.5	9		
4	M	2	7.5		
Deducted Total			24.5		
Corrected Deducted Value (CDV)			11		
PCI = 100 - CDV			89 – Excellent		

Nicosia PMS

Inventory Information

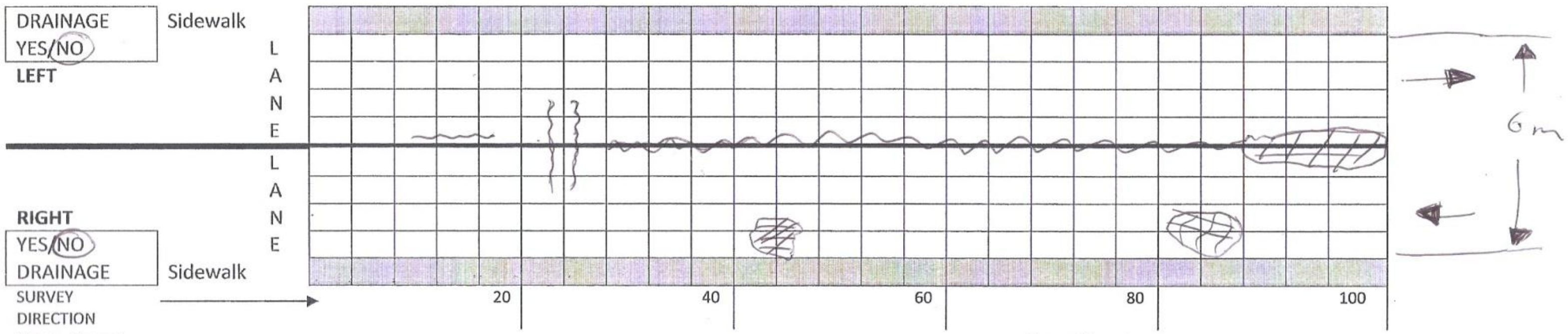
Data collection form for the City of Nicosia

Section ID: C	No: 1	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Laden sokak					# of travelling lanes: 1 2 3	Length 100 m	
From Poncur sok. To Feride hikmet sok.		ADT ____	Survey Date: 8/4/2017	Construction Date: _/_/__	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low		17m	2m, 1m					2508(L) 2509(T).jpg
Medium	6×1 2×0.5 ~~12×0.4~~							2513(A), 2514(A).jpg, 2515(A) başdan
High								______.jpg

(2512 JPG)



Cross Street________

STOP SIGN (YES/NO)

Cross Street________

STOP SIGN (YES/NO)

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Pavement Condition Survey Data Sheet					
Street Name	Laden sokak	Area of Sample = 600 m²			
Section ID	C-1				
Date	11/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		20 m		
	M	11.8 m^2			
	H				

Distress Type	Severity	Density %	Deduct Value
1	M	2	37
2	L	3.3	10
Deducted Total			47
Corrected Deducted Value (CDV)			30
PCI = 100 - CDV			70 - Very Good

Nicosia PMS

Inventory Information

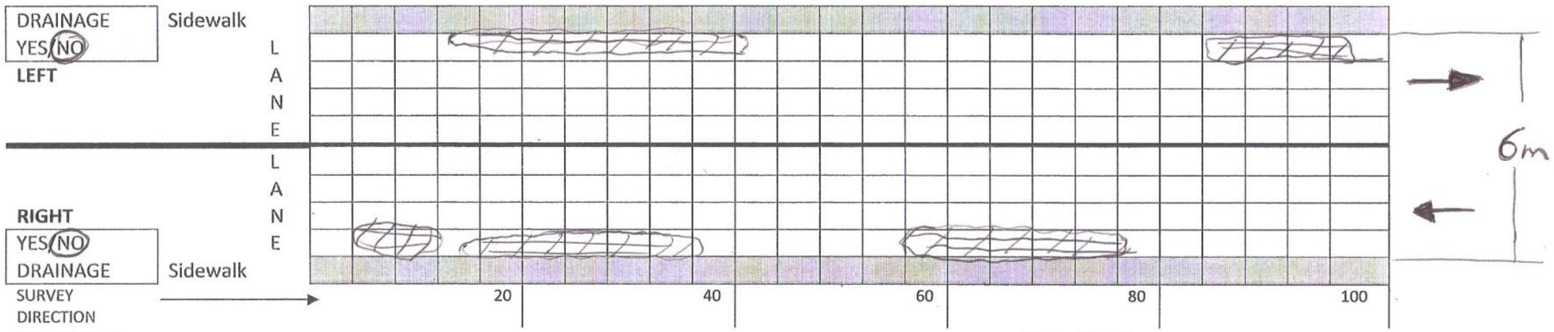
Data collection form for the City of Nicosia

Section ID: C	No: 2	Surface Type	Functional Class	Jurisdiction	Rater Deniz Ulunay		
Street Name Söğüt sok.		01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	01-Arterial 02-Collector 03-Local	LS-Local Street SR-State Road UR-University Road	# of travelling lanes: 1 | 2 | 3	Length 100 m	
From Gelincik sok To Niksar sok.		ADT	Survey Date: 8/4/2017	Construction Date: / /	Traffic Flow: One Way / Two Way	Maintenance YES/NO	Maint. Date: / /

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low	21x0.5 15x0.5							2519(A) .jpg
Medium	5x1, 27x0.4 30x0.4							2516(A), 2519(A) .jpg
High								.jpg

(2517.jpg)



Cross Street

STOP SIGN (YES/NO)

Cross Street

STOP SIGN (YES/NO)

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Page | 1

Pavement Condition Survey Data Sheet					
Street Name	Söğüt sokak		Area of Sample = 600 m^2		
Section ID	C - 2				
Date	11/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L	18 m^2			
	M	27.8 m^2			
	H				

Distress Type	Severity	Density %	Deduct Value
1	L	3	31
1	M	4.6	45
Deducted Total			76
Corrected Deducted Value (CDV)			52
PCI = 100 - CDV			48 - Fair

Nicosia PMS

Data collection form for the City of Nicosia

Inventory Information

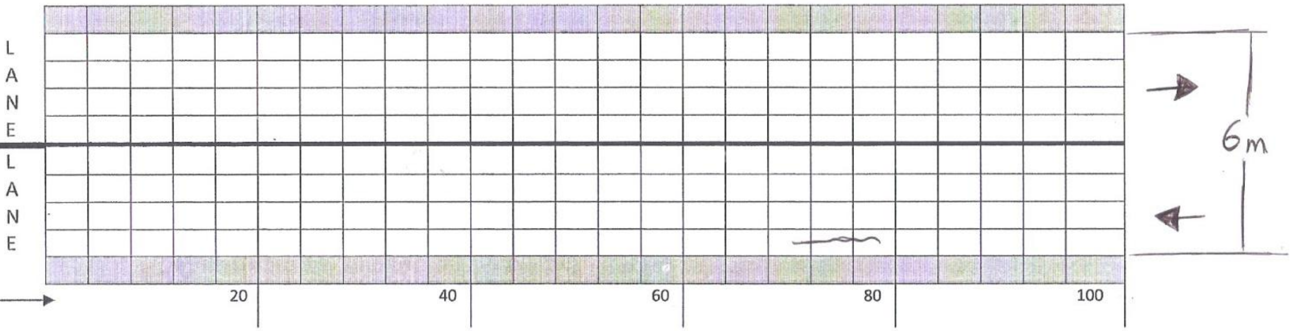
Section ID: C	No: 3	Surface Type 01-Asphalt Concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Şht Ali Çamsöken sok.					# of travelling lanes: 1 | 2 | 3	Length 100 m	
From Gelincik sok. To Okullar Yolu		ADT ____	Survey Date: 8/4/2017	Construction Date: _/_/__	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low		3m						________.jpg
Medium								________.jpg
High								________.jpg

DRAINAGE
YES/NO
LEFT

Sidewalk



RIGHT
YES/NO
DRAINAGE

Sidewalk

SURVEY DIRECTION

Cross Street__________
STOP SIGN (YES/NO)

Cross Street__________
STOP SIGN (YES/NO)

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Pavement Condition Survey Data Sheet					
Street Name	Sht Ali Çamsöken sok.		Area of Sample = 600 m^2		
Section ID	C - 3				
Date	11/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		3m		
	M				
	H				
Distress Type	Severity	Density %	Deduct Value		
2	L	0.5	4		
Deducted Total			4		
Corrected Deducted Value (CDV)			4		
PCI = 100 - CDV			96 - Excellent		

Nicosia PMS

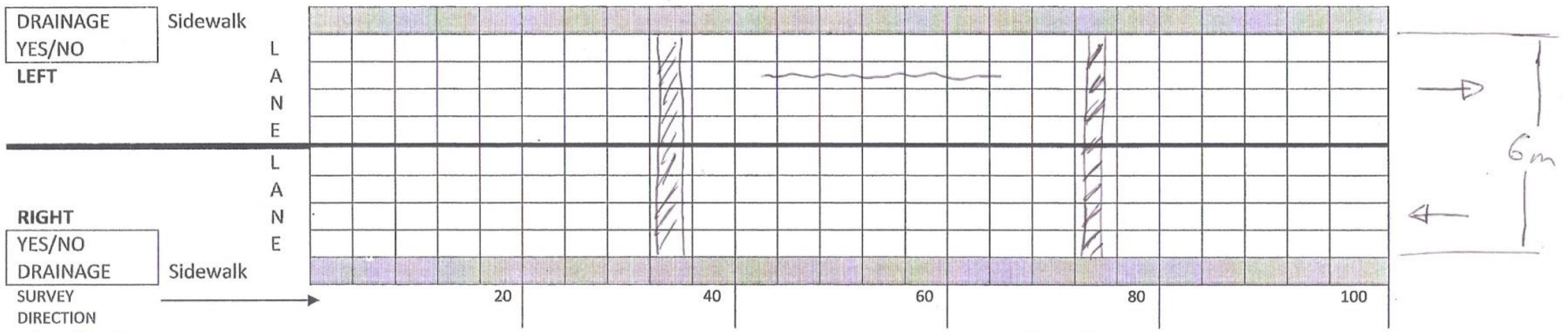
Inventory Information

Data collection form for the City of Nicosia

Section ID: C	No: 4	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay	
Street Name Sht Ahmet Beyaz sok					# of travelling lanes: 1 2 3	Length 100 m
From Mete sokak To Nihat Vasif sokak		ADT ____	Survey Date: 29/4/2017	Construction Date: _/_/___	Traffic Flow: One Way Two Way	Maintenance YES/NO	Maint. Date: _/_/___

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low		21m					(6x0.3),(6x0.3)	2536(P)2537(P) .jpg 2539(L)
Medium								________.jpg
High								________.jpg



Cross Street________________

STOP SIGN (YES/NO)

Cross Street________________

STOP SIGN (YES/NO)

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Pavement Condition Survey Data Sheet					
Street Name	Sht Ahmet Beyaz sok.		Area of Sample = 600 m^2		
Section ID	C - 4				
Date	29/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		21 m		3.6 m^2
	M				
	H				
Distress Type	Severity	Density %	Deduct Value		
2	L	3.5	10		
4	L	0.6	3.5		
Deducted Total			13.5		
Corrected Deducted Value (CDV)			13		
PCI = 100 - CDV			87 – Excellent		

Nicosia PMS

Inventory Information

Data collection form for the City of Nicosia

Section ID: C	No: 5	Surface Type 01-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial 02-Collector 03-Local	Jurisdiction LS-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay # of travelling lanes: 1 | 2 | 3 Length 100 m
Street Name Hüseyin Küçük sokak					
From Hasane Ilgaz sokak To Cengiz Han sokak		ADT ____	Survey Date: 29/4/2017	Construction Date: _/_/__	Traffic Flow: One Way / Two Way Maintenance YES/NO Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low		7m, 6m	1m					2527(L), 2528(T).jpg 2529(L)
Medium								____.jpg
High								____.jpg

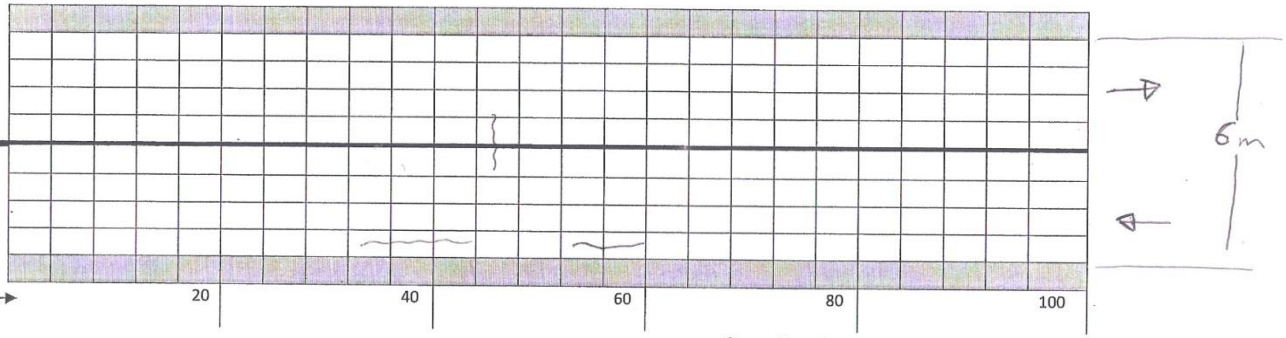
DRAINAGE YES/NO — Sidewalk

LEFT LANE

RIGHT LANE

YES/NO DRAINAGE — Sidewalk

SURVEY DIRECTION →



Cross Street________

STOP SIGN (YES/NO)

Cross Street________

STOP SIGN (YES/NO)

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Page | 1

Pavement Condition Survey Data Sheet

Street Name	Hüseyin Küçük sok.	Area of Sample = $600\ m^2$
Section ID	C-5	
Date	29/4/2017	

Distress Types
1-Alligator Cracking, m2
2-Longitudinal Cracking & Transverse Cracking,m
3-Rutting,cm
4-Patching, m2

		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		14		
	M				
	H				

Distress Type	Severity	Density %	Deduct Value
2	L	2.3	7

Deducted Total	7
Corrected Deducted Value (CDV)	7
PCI = 100 - CDV	93 - Excellent

Nicosia PMS
Inventory Information

Data collection form for the City of Nicosia

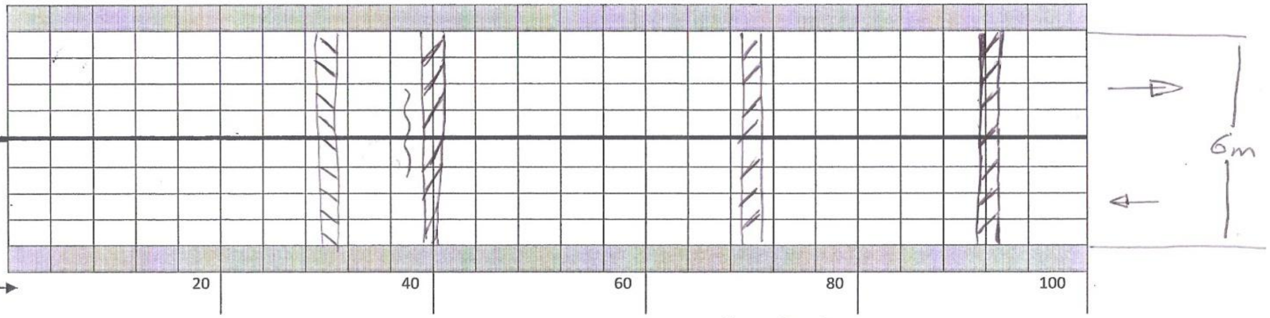
Section ID: C	No: 6	Surface Type (01)-Asphalt concrete 02-Surface Treatment 03-Gravel 04-No pavement	Functional Class 01-Arterial (02)-Collector 03-Local	Jurisdiction (LS)-Local Street SR-State Road UR-University Road	Rater Deniz Ulunay		
Street Name Sht Şener Enver sokak					# of travelling lanes: 1 |(2)| 3	Length 100 m	
From Sht Salih Ali sokak To Çalışma İzin Merkezi önü		ADT ___	Survey Date: 29/4/2017	Construction Date: _/_/__	Traffic Flow: One Way (Two Way)	Maintenance YES/NO	Maint. Date: _/_/__

Distress Levels

	Alligator Cracking m^2	Longitudinal Cracking, m	Transverse Cracking, count	Rutting, cm	Raveling m^2	Potholes count	Patching, m^2	Photograph number
Low			2m				(6x0.5), (6x0.6) (6x0.6), (6x0.5)	2531(P), 2532(T).jpg 2533(P), 2534(P), 2535(P)
Medium								________.jpg
High								________.jpg

DRAINAGE YES/NO | Sidewalk
LEFT
LANE

LANE
RIGHT
YES/NO DRAINAGE | Sidewalk
SURVEY DIRECTION



Cross Street__________
STOP SIGN (YES/NO)

Cross Street__________
STOP SIGN (YES/NO)

Pavement Condition Survey Data Sheet					
Street Name	Şht Şener Enver sok.		Area of Sample = 600 m2		
Section ID	C-6				
Date	29/4/2017				
Distress Types					
1-Alligator Cracking, m2					
2-Longitudinal Cracking & Transverse Cracking,m					
3-Rutting,cm					
4-Patching, m2					
		Alligator Cracking, m2	Longitudinal Cracking & Transverse Cracking,m	Rutting,cm	Patching, m2
Total Severity	L		2 m		13.2 m2
	M				
	H				

Distress Type	Severity	Density %	Deduct Value
2	L	0.33	5
4	L	2.2	6
Deducted Total			11
Corrected Deducted Value (CDV)			11
PCI = 100 - CDV			89 - Excellent

Appendix D: QGIS maps, Attribute table and Prices for HMA

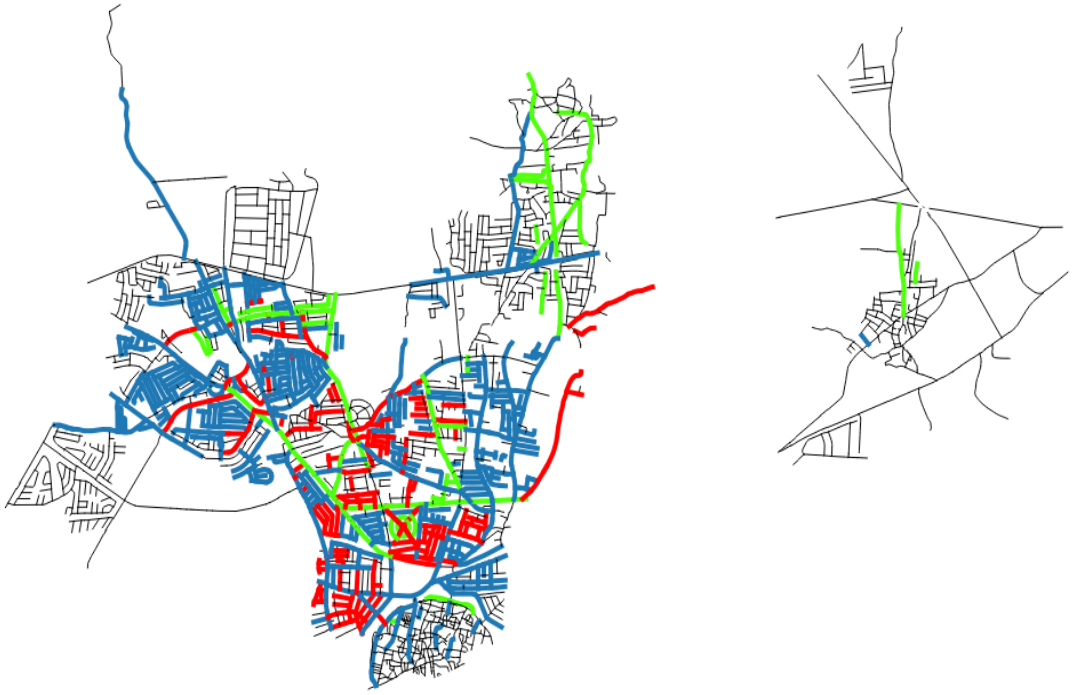


Figure D1. Colored map of Nicosia road network

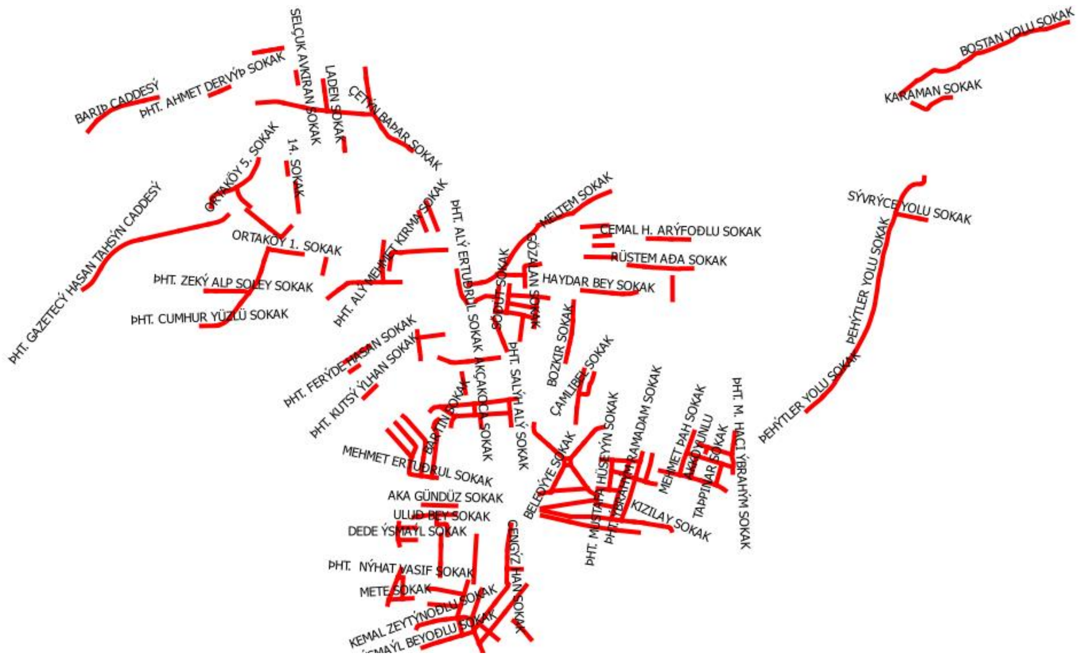


Figure D2. Red colored road network of Nicosia map

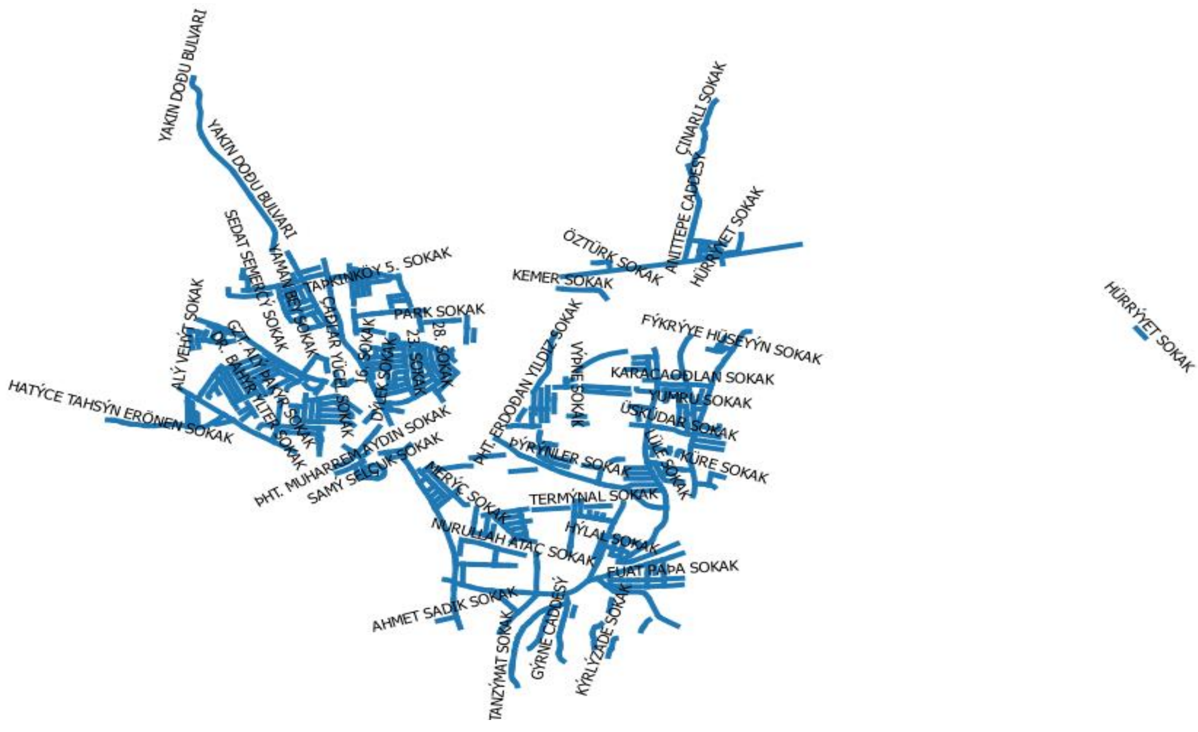


Figure D3. Blue colored road network of Nicosia map

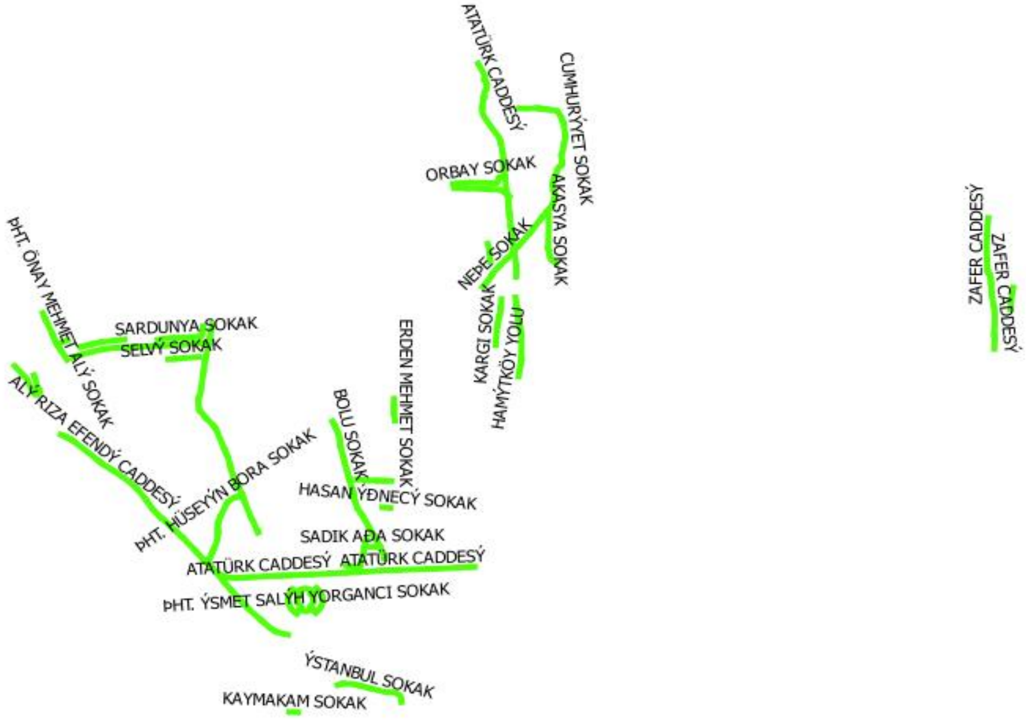


Figure D4. Green colored road network of Nicosia map

	ADINUMARAS	ACIKLAMALA	TIP	SHAPE_Leng	Main. date	Tonnage	tip_1	Road Width	Road Area
1	BOLU SOKAK	K.KAYMAKLI	3	95.91680705510	2003-2005-2009-2014-2015	192-108-387-361-733	3	7	671.417649
2	ÞHT. ÖNAY MEH...	GÖÇMENKÖY	3	52.85822743780	2000-2015	210-67	3	6.1	322.435187
3	ÞHT. ECVET YUS...	KIZILAY	3	96.34580620170	2002-2003-2007-2008-2010-2011-	414-575-1211-400-1228-248-338	3	13.41	1291.99726
4	LEYLAK SOKAK	K.KAYMAKLI	3	51.34876697580	2014	46	3	6.1	313.227478
5	BEDREDDÝN DEM...	YENÝÞEHÝR	3	91.22846771280	1993-2002-2003-2006-2011-2014-	811-1030-110-2951-56-170-484	3	12.2	1112.98730
6	BEDREDDÝN DEM...	YENÝÞEHÝR	3	72.18355933930	1993-2002-2003-2006-2011-2014-	811-1030-110-2951-56-170-484	3	12.2	880.639423
7	ÞHT. HÜSEYÝN B...	KIZILAY	3	50.81447357400	2014	195	3	6.1	309.968288
8	BOLU SOKAK	K.KAYMAKLI	3	62.42869631000	2003-2005-2009-2014-2015	192-108-387-361-733	3	7	437.000874
9	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	50.73000590760	1997-2003-2005-2007-2015	277-372-2432-710-424	3	12.8	649.344075
10	BEDREDDÝN DEM...	YENÝÞEHÝR	3	94.60697355380	1993-2002-2003-2006-2011-2014-	811-1030-110-2951-56-170-484	3	12.2	1154.20507
11	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	77.43957481270	1997-2003-2005-2007-2015	277-372-2432-710-424	3	12.8	991.226557
12	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	72.50175640450	1997-2003-2005-2007-2015	277-372-2432-710-424	3	12.8	928.022481
13	ATATÜRK CADDESÝ	YENÝÞEHÝR	3	95.17208122460	1997-2003-2005-2007-2015	277-372-2432-710-424	3	12.8	1218.20263
14	ÞHT. ÝSMET SALÝ...	YENÝÞEHÝR	3	112.26261828800	2015	100	3	6.1	684.801971
15	BEDREDDÝN DEM...	YENÝÞEHÝR	3	160.06551440600	1993-2002-2003-2006-2011-2014-	811-1030-110-2951-56-170-484	3	12.8	2048.83858
16	ÞHT. ECVET YUS...	KIZILAY	3	104.34773227300	2002-2003-2007-2008-2010-2011-	414-575-1211-400-1228-248-338	3	13.41	1399.30308
17	ÞHT. AHMET AYD...	YENÝÞEHÝR	3	113.99132916100	1993-2015	126-216	3	6.1	695.347107
18	ÞHT. MÜNÜR HAS...	YENÝÞEHÝR	3	146.76967307500	2015	85	3	6.1	895.295005
19	ÞHT. HÜSEYÝN M...	YENÝÞEHÝR	3	108.90519806700	2015	190	3	6.1	664.321708
20	ALÝ RIZA EFEND...	ORTAKÖY	3	38.91315033620	2006-2014	1360-90	3	12.2	474.740434
21	ÞHT. HÜSEYÝN M...	YENÝÞEHÝR	3	131.20747343200	2015	190	3	6.1	800.365587

Figure D5. Sample attribute table

Table below shows the prices for Hot Mix Aspahlt:

BİRİM FİYAT LİSTESİ (TEMMUZ-ARALIK 2016)

Kamyon = 364.87 TL/8 saat Kapasite = 30 ton / yol

Arazöz	56.48	TL/sa
Asfalt Kesme İşleri (uzunluk x kalınlık)	29.59	TL/m2
Astar	4.28	TL/m2
Baca(1.00x1.00x1.20)(Demirli)	313.44	TL/adet
C14	0.00	TL/m3
C16	156.00	TL/m3
C18	159.00	TL/m3
C20	162.00	TL/m3
C25	168.00	TL/m3
C30	174.00	TL/m3
Beton Asfalt		
B.Temel	100.70	TL/ton
B.Temel (plent altı)	87.29	TL/ton
Binder	109.35	TL/ton
Binder (plent altı)	94.85	TL/ton
Aşınma	115.17	TL/ton
Aşınma (plent altı)	100.55	TL/ton
İki El Sathi Kaplama	9.77	TL/m2
Penetrasyon Makadam Asfalt	21.57	TL/m2