Prince Mohammad Bin Fahd University

College of Engineering

Civil Engineering Department

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Learning Outcome Assessment-III/CIV.

Condition Assessment Model for Road Networks

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ABSTRACT

This project is a part of Infrastructure asset management practice, which is new in Saudi Arabia. During the current time, many developments and constructions in road networks have been progressing. Nevertheless, do they provide the required level of service? Do they provide the required performance? Do they match the required maintenance standards? Condition assessment of infrastructure provide answers to questions raised. Condition assessment of infrastructure is the evaluation of the assets throughout its service period. The condition of the asset refers to the measurement of the asset’s physical state, while the performance of the asset refers to the capability of the asset to produce the required level of service to the users. These forecasts the remaining useful life of an asset and generates a plan for required maintenance strategy. The main data for the project were collected from Al-Shatie area in Dammam, Eastern Province. The mathematical models are used in the project to quantify the condition assessment for road and network. The models are developed using decision making Theories such as SMART and AHP. The results obtained in the project are compared to the municipality road condition in 2013 and the team’s experiment using the municipality method in 2017.

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NOMENCLATURE

i. **CA**: Condition Assessment

ii. **W**: Weight

iii. **S:** Score

Chapter 1: Introduction

1.1 Overview

Condition assessment of infrastructure is the evaluation of the assets throughout the period of their service validity. *The condition of the asset* refers to the measurement of the asset's physical state, while *the performance of the asset* refers to the capability of the asset to produce the required level of service to the users. These evaluations are critical for providing crucial information regarding the asset management of the asset. These evaluations forecast the remaining useful life of an asset and generate a plan for possible future outcomes and actions. Several factors are thought to be correlated with condition assessment of infrastructure. Some examples include risk management, maintenance management planning, evaluation, and depreciation of the asset (National Asset Management Steering Group. 2011; IPWEA NAMS.AU. 2012).

In Saudi Municipalities, the practice of construction management departments is lacking and this is validated by *Engineer Almotairi*, a Maintenance Manager in Al-Amana Municipality. The lack of infrastructure asset management department in the region creates an obstacle in developing the condition assessment method. The department has shown an astonishing outcome in countries such as Australia and Canada. Those countries have a high caliber of service and performance due to their departments of infrastructure asset management (Infastrucure Austraila, 2016). Here the attention falls on the condition of the asset and how to deal with it, by analyzing the condition, determining the risk, and collecting the data needed for this asset to capacitate prioritization within work distribution, and the management of such priorities among the assets.

In Saudi Arabia, each asset has its own ministry, and all that work needs to be carefully studied and restricted to one department to judge which asset has a priority.

1.2 Project Design Objective

The predicted result of this research – if applied – will assist with the distribution of the country's budget for maintenance across all municipalities, thereby maintaining the assets at the required standard. Each city in the province has different assets in need of maintenance regulation. This is the main reason why each municipality should have an Infrastructure Asset Management department; to study the condition assessment of the assets. Furthermore, it is vital to distribute the financial resources based on the results and priorities proposed through different types of studies. To achieve that, a variety of methods and technologies should be employed to study the condition of the assets. Creating a guide which help establishes an enhanced method of condition assessment to help allocate resources and establish budgets needed to support strategic initiatives. An objective summary is shown in the following:

1. Studying the current practices applied by the municipalities in the region.
2. Applying the current practices on the roads network.
3. Developing **C**ondition **A**ssessment **M**odel (**CAM**) for selected roads in Dammam.
4. Developing **C**ondition **A**ssessment **M**odel (**CAM**) for Road Network.
5. Providing Comparative Results

1.3 Project Organization

The project will start with the Chapter 2 *Literature Review* which includes the *previous studies* and *current practices and their limitations*. Following is the chapter 3 *methodology*. In Chapter 3, the beginning is the project flow chart. Then model development is introduced. Next is *the Data Collection* with sub-sections which are *field data, conducting condition Assessment surveys and analytic hierarchy process* (AHP). Moving forward, in Chapter 4 is the *Model Implementation* which is followed by *Final results* in addtion to *Analysis* and finally *vaildation.* Concluding with Chapter 5 discussing the *Conclusion*, *limitations* and *Recommendations.*

Chapter 2: Literature Review and Current Practices

2.1 Previous Studies

Condition grading/rating are standards that identify the asset's condition based on the required criteria. The condition assessment provides results that are based on qualitative descriptions and quantitative grading of the asset. This data is translated to a scoring system as an indicator for condition and performance. Depending on the user's guidelines for condition rating, a suitable scale is produced. The scale can be represented as numbers (1-5 or 0-100%) or alphabets (A+ to F). There are three rating models that describe the assets based on the required practices. The first model is known as The Simple Condition Rating Model (The Core Approach). The International Infrastructure Management Manual (NAMSG, 2011) and Asset Management Condition Grading Standards (Saskatchewan Ministry of Municipal Affairs) represent the first model as a top-down system. The grading system is represented by a scale that indicates the best condition/performance of an asset to the worst case scenario. A description of the condition is provided alongside the scale to show the condition/performance indication and the required practice for consideration. The model usually includes a visual assessment of assets to validate existing data. This approach is typically used to represent information about asset register information, geological maps, performance monitoring data, etc. Any further descriptions require a more sophisticated approach. The simple approach is illustrated in Table 2.1 (NAMSG, 2011).

Table 2.1 Simple Condition Rating Model (NAMSG, 2011)

Rank	**Description of Condition**
1	Very Good Condition Only normal maintenance required
2	Minor Defects Only Minor maintenance required (5%)
3	Maintenance Required to Return to Accepted Level of Service Significant maintenance required (10-20%)
4	Requires Renewal Significant renewal/upgrade required (20-40%)
5	Asset Unserviceable Over 50% of asset requires replacement

The second model of condition grading is called *The Intermediate Approach*. The intermediate approach enhances the ranking of assets based on significant factors or problems. The scale utilized in this model is expanded to indicate a certain significance within a certain condition. This approach uses the expansion to befit information like asset types, failure modes, evidence of distress, etc. The assessment of assets included in the model is usually visually assessed. The International Infrastructure Management Manual (NAMSG, 2011) represents a model that describes the level of maintenance needed for the assets. The intermediate approach example is illustrated in Table 2.2 (NAMSG, 2011).

Table 2.2 Intermediate Condition Rating Model (NAMSG, 2011)

Rank	Description of Condition	
3.0 3.4 3.8	Level of service maintenance	Minor Average Significant
4.0 4.2 4.4	Requires Major Upgrade	Minor Average Medium

4.6 4.8		Substantial Significant
5.0 5.2 5.4 5.6 5.8	Asset Basically Unserviceable	Minor Average Medium Substantial Significant

The third model is a *Sophisticated Condition Assessment Model* (advanced approach). This approach develops a sophisticated condition monitoring for assets. The produced model includes a detailed expansion of the assessment. Unlike the first and second methods, the data acquired is more advanced by virtue of the non-destructive techniques in combination with visual assessment employed. These advanced procedures allow users to assess up to ten different parameters with more detailed scales (example: 0-1000). The scale can be simplified to a basic grading of 1 to 5 if needed. Among the applications of the advanced model are multiple-faceted ranking systems, like *Pavement Management Systems*; specification for assessing roughness, deflection, rutting and surface texture (NAMSG, 2011). The advanced condition assessment may not be eligible for all assets since some factors viz. financial availability and time are involved. An example of the advanced approach is illustrated in Table 2.3 (NAMSG, 2011).

Table 2.3 Advanced Condition Rating Model (NAMSG, 2011)

Base Ranking	Roads (0 - 100)	Drains, sewers (0 - 200)	Water Mains (0 - 500)	Buildings (0 – 10)	Parks (0 – 125)	Plant (0 – 100)
1	0 – 200	0 – 40	0 – 100	0 – 2	0 – 25	0 – 20
2	200- 400	40 – 80	100 - 150	2 – 4	25 – 50	20 – 40
3	400 – 600	80 – 120	150 – 200	4 – 6	50 – 75	40 – 60
4	600 – 800	120 – 160	200 – 300	6 – 8	75 – 100	60 – 80
5	800 - 1000	160 - 200	300 - 500	8 – 10	100 – 125	80 – 100

Another term that is important to consider is the Level of Service (LOS). Many agencies report the condition of assets in terms of the LOS that is being provided. In this approach, the LOS must be defined for each asset. In some cases, levels of service are reported in terms of letters similar to those used in a report card (such as A, B, C, D, and F). They may also be reported using a numerical system with "1" being the highest level of service and "5" being the lowest. In general, LOS is defined in terms related to customer services, such as safety, convenience, aesthetics, comfort, or mobility (Zimmerman, 2007).

To develop a new manual and coding system associated with the project, different infrastructure asset manuals should be compared. This is due to the similarities in the principles of the condition assessment of infrastructure. Road manuals such as the International Infrastructure Management Manual (NAMS, 2011), contain information about different road defects, inspections tools, condition assessment procedures, etc. Pipe manuals such as the New Zealand Pipe Inspection Manual (NWWA, 2006), include a description of all types of pipe defects, new technological inspection methods, pipe condition rating, etc. Combining and analyzing information from multiple manuals will assist in establishing a new condition assessment manual and coding system for the research.

According to the research done by Al Barqawi and Zayed in 2006, evaluating municipal water mains' performance, *Analytic Hierarchy Process Models* (AHP) simulates human decision-making processes. The techniques used in the model generate solutions to complicated problems by assembling the information and data available to a hierarchical system. The information includes thoughts, knowledge, experience and professional judgments. This generates a comparative model which utilizes considerations for both qualitative and quantitative human decision-making processes.

In the research (Al Barqawi and Zayed, 2006), the authors used the AHP model to produce an evaluation of the water mains performance. A condition assessment scale of 1-10 was used to assess the condition based on several variables. Per this research work, a 10 on the condition assessment scale, indicates a healthy condition, while a 1 indicates a worst case scenario. Based on the values obtained from the scale, an action or a response is generated. The actions can vary from “do nothing” to “complete overhaul required”. Though this model was used in water mains assessment, it can be used to assess other assets like road, facilities, etc. It should be noted that the model does not provide any type of analysis, but rather evaluates the condition based on the selected criteria.

Simple Multi-Attribute Rating Technique (SMART) is a decision-making theory developed by Von Winterfeldt in 1986 (Lootsma 1997). According to the research Reliability-Based Management of Water Distribution Networks (Salman, 2011) “The SMART method is a simple implementation of the multi-attribute utility theory (MAUT) in a linear format (Backer et al. 2001).” This method determines the evaluations of various factors. This is done by assigning a value to each factor on a unified scale (Salman, 2011). This will result in a score which is multiplied by the weight of the factor to produce a rating. This method has been redeemed essential for the condition assessment of roads. This is because roads have multiple factors that should be considered during the condition computation.

The inspection of the asset's condition entails destructive and non-destructive techniques. Destructive techniques are used when a sample of the asset is required for analysis, for example, road cone holes for pavement strength test. On the other hand, non-destructive techniques are used when the asset is highly sensitive, for example, airport runways. The non-destructive methods are also used in most infrastructure assets nowadays regardless of their sensitivity. Choice of method depends on time, cost and other variables. According to Engineer Mokhahed, project manager at *Dammam Amana*, the new non-destructive methods proved to be a simple way to collect data. However, he stated that not all new sensors provide accurate data, thus normal manual methods might be preferred in this case. Furthermore, as new technologies are utilized in inspections; the cost increases dramatically.

According to Saskatchewan Ministry of Municipal Affairs, there are four main factors in the investigation and assessment of roads. The first factor is the structural capacity of the roads. The structural capacity is mainly focused on the pavement in which determined by field test with equipment such as Benkelman Beam, the Dynaflect®, and the Falling Weight Deflectometer. Such tests are conducted by measuring pavement deflections under a load. The second factor for consideration is the condition. The condition is usually inspected visually to measure the pavement distress. Surface defects, cracking, patching, etc are the most recurrent defects. The third factor is pavement roughness. Pavement roughness is an indicator of the level of serviceability and riding comfort. In the past, roughness was measured by driving along the road and generating Riding Comfort Index (RCI) from the expert's opinion. Finally, the last factor is pavement safety. Pavement safety includes skid resistance, ruts, lane demarcation, etc, which are quantified using several methods usually visual.

2.2 Current Practices and Their Limitations

The eastern province has a municipality for each city, and all of them are considered as the executive authority of each city. They acquire the budget and orders from Al-Amana for the Eastern Province by focusing on roads (one of the horizontal assets) and studying their condition. Al Amana is a highly hierarchical governmental organization that follows directly under the ministries and controls all the municipalities in the region. Road construction and maintenance are conducted by different contractors. This was verified in a meeting on the 26th of January 2017, with Doctor Issam Abkar, a Technical Manager in the municipality.road According to Dr.

Abkar, the basic information for the roads including the physical properties (age, thickness, material, etc) is not documented in the municipality. The information is usually available with the contractor who participated in the construction and maintenance of the road. This creates an obstacle due to the road data being stored at the ministry of transportation and cannot be easily accessed for assessment.

Pavement Management System (PMS) is the system used for the roads' condition assessment. The system is a modified version of MicroPaver software. This modified system was created by the municipality of the Eastern Province in coordination with the Information Technology department at King Fahd University of Petrol and Minerals (KFUPM). PMS system works by sending surveying teams to the roads to collect physical data. The data represents the distress and defects from the roads in area size based on PMS manual. The manual is developed by *Al-Hazim* consulting company based in Jeddah, Saudi Arabia. The process begins by visual inspection and then recording the data in a specific surveying form (Fig 2.1 and Fig 2.2). The condition assessment in the municipality of the Eastern province is conducted every 3 years. The duration can change depending on circumstances such as an increase in civilian complaints. Also, the media can affect the duration, thus reducing the period of inspection to the most transient time-frame possible.The distress collected from the site will be filled in a specific form shown Fig 2.1 and Fig 2.2.

Eastern Municipalities Pavement Evaluation and Maintenance Management System

SECTION INFORMATION SURVEY FORM

SURVEYOR NAME (1)		SURVEY DATE: (2)			
CHECKED BY: (3)		CHECKING DATE: (4)			
CITY NAME: (5)		CITY NO: (6)		ZONE NO: (7)	
AREA NAME: (8)		AREA NO.: (9)		SECTION NO: (10)	
STREET NAME: (11)		STREET NO.: (12)			
SECTION LENGTH IN (M): (13)		SECTION WIDTH IN (M): (14)		SECTION AREA IN (Sq.M): (15)	
RANK: (16)		FEATURE NO.: (17)		NO. OF LAYER: (18)	

LAYER TYPE AND THICKNESS (19)

Bit. Wearing Course: ☐ Bit. Base Course: ☐ Agg. Base Course: ☐

Sub-Base: ☐ Sub-Grade: ☐

CONSTRUCTION DATE: (20)		NO. OF OPERATING TRAFFIC: (21)			
PERCENTAGE TRUCKS: (22)		NO. OF LANE (23)		TOTAL NO. OF SAMPLE UNIT: (24)	
NO. OF SAMPLES TO BE INSPECTED: (25)		PROJECT LEVEL:		NETWORK LEVEL:	

* IS ROAD USED BY VIP'S? (26) ☐ YES ☐ NO

* IS ROAD NEAR OFFICIAL / PUBLIC BUILDINGS? ☐ YES ☐ NO

* IS ROAD PASSING THROUGH CBD? ☐ YES ☐ NO

* IS ROAD HAS ALTERNATIVE ROUTE AT TIME OF MAINTENANCE? ☐ YES ☐ NO

FEATURE (27)

Local Street, Utility Street

01 LR Local Road
02 UR Utility Road

Main Road

03 RL Right Lane
04 LL Left Lane
05 ML1 Middle Lane 1
06 ML2 Middle Lane 2
07 ML3 Middle Lane 3
08 ML4 Middle Lane 4

Median and Sidewalk, Service Road

09 MC Median Center
10 SL1 Service Road 1
11 SL2 Service Road 2
12 SL3 Service Road 3
13 SR Sidewalk Right
14 SL Sidewalk Left
15 SM Sidewalk Median

Parking, Intersection, Roundabout

16 ONP On Road Parking (Paved)
17 OFP Off Road Parking (Paved)
18 SRP Service Road Parking (Paved)
19 ONPU On Road Parking (Unpaved)
20 OFPU Off Road Parking (Unpaved)
21 SRPU Service Road Parking (Unpaved)
22 INT Intersection
23 RND Roundabout

DIRECTION

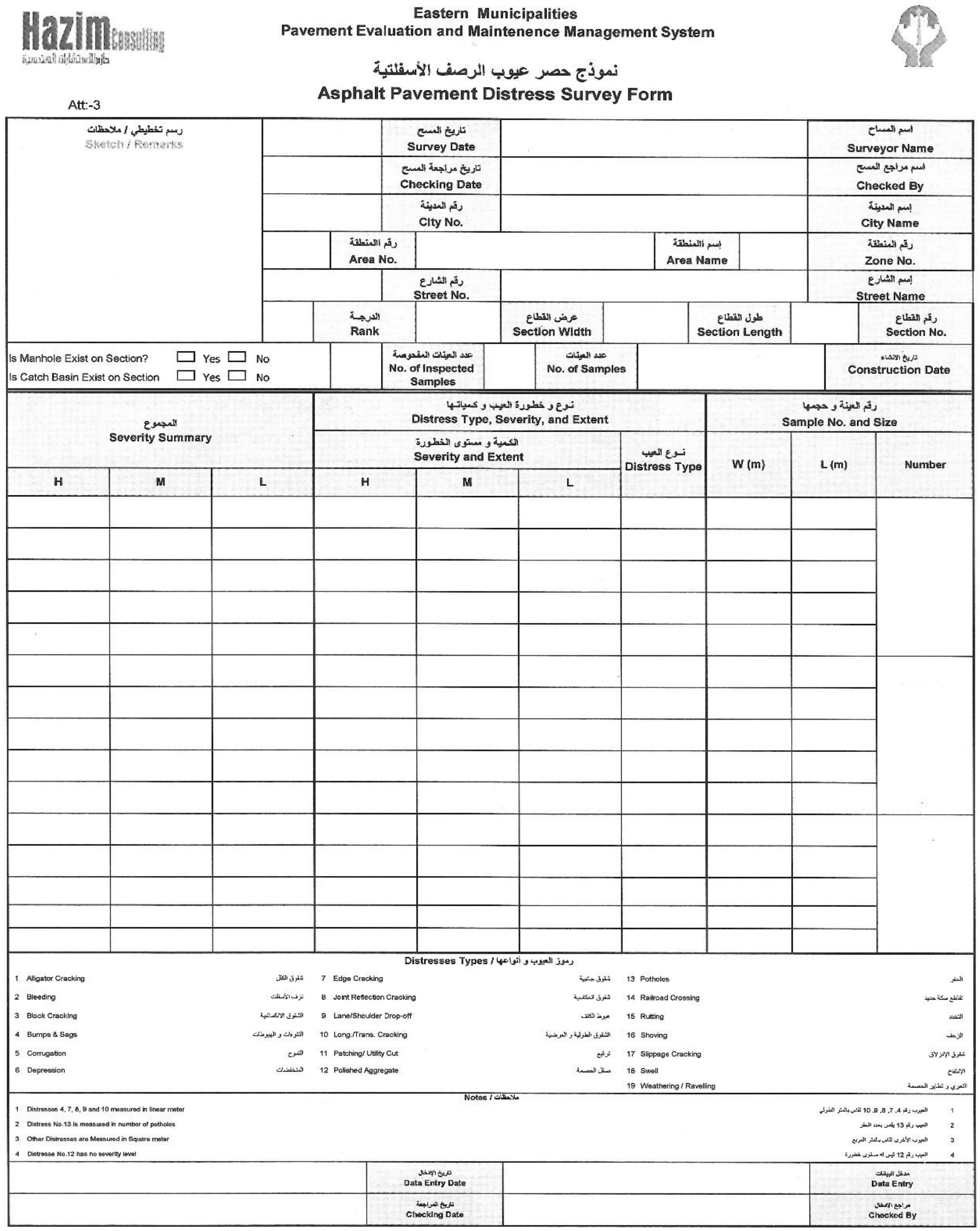
01	NB	North Bound	09	BNB	Both North Bound	17	ALB	All North Bound
02	EB	East Bound	10	BEB	Both East Bound	18	AEB	All East Bound
03	SB	South Bound	11	BSB	Both South Bound	19	ASB	All South Bound
04	WB	West Bound	12	BWB	Both West Bound	20	AWB	All West Bound
05	NEB	North-East Bound	13	BNEB	Both North-East Bound	21	ANEB	All North-East Bound
06	ESB	East-South Bound	14	BEWB	Both East-West Bound	22	AESB	All East-South Bound
07	SWB	South-West Bound	15	BSWB	Both South-West Bound	23	ASWB	All South-West Bound
08	WNB	West-North Bound	16	BWNB	Both West-North Bound	24	AWNB	All West-North Bound

DATA ENTRY: (28)		DATA ENTRY DATE: (29)	
CHECKED BY: (30)		CHECKING DATE: (31)	
REMARKS (32)			

Doc. Ref: HC/J12-003/AMF02
Issuing Date: 15.06.2012

Fig 2.1 Surveying Form part 1

(Operation & Maintenance of Pavement Management System of Eastern Province Municipality, PMS Manual, 2017)



Eastern Municipalities
Pavement Evaluation and Maintenence Management System

نموذج حصر عيوب الرصف الأسفلتية
Asphalt Pavement Distress Survey Form

Att:-3

رسم تخطيطي / ملاحظات Sketch / Remarks		تاريخ المسح Survey Date		اسم المساح Surveyor Name
		تاريخ مراجعة المسح Checking Date		اسم مراجع المسح Checked By
		رقم المدينة City No.		إسم المدينة City Name
		رقم المنطقة Area No.	إسم المنطقة Area Name	رقم المنطقة Zone No.
		رقم الشارع Street No.		إسم الشارع Street Name
		الدرجة Rank	عرض القطاع Section Width / طول القطاع Section Length	رقم القطاع Section No.
Is Manhole Exist on Section? ☐ Yes ☐ No Is Catch Basin Exist on Section ☐ Yes ☐ No		عدد العينات المفحوصة No. of Inspected Samples	عدد العينات No. of Samples	تاريخ الانشاء Construction Date

المجموع Severity Summary			نوع و خطورة العيب و كمياتها Distress Type, Severity, and Extent				رقم العينة و حجمها Sample No. and Size		
			الكمية و مستوى الخطورة Severity and Extent			نوع العيب Distress Type	W (m)	L (m)	Number
H	M	L	H	M	L				

Distresses Types / رموز العيوب و أنواعها

1 Aligator Cracking شقوق الكلل	7 Edge Cracking شقوق جانبية	13 Potholes الحفر
2 Bleeding نزف الأسفلت	8 Joint Reflection Cracking شقوق انعكاسية	14 Railroad Crossing تقاطع سكة حديد
3 Block Cracking الشقوق الانكماشية	9 Lane/Shoulder Drop-off هبوط الكتف	15 Rutting التخدد
4 Bumps & Sags النتوءات و الهبوطات	10 Long./Trans. Cracking الشقوق الطولية و العرضية	16 Shoving الزحف
5 Corrugation التموج	11 Patching/ Utility Cut ترقيع	17 Slippage Cracking شقوق الإنزلاق
6 Depression المنخفضات	12 Polished Aggregate صقل الحصمة	18 Swell الإنتفاخ
		19 Weathering / Ravelling التعري و تطاير الحصمة

Notes / ملاحظات

1 Distresses 4, 7, 8, 9 and 10 measured in linear meter — العيوب رقم 4، 7، 8، 9، 10 تقاس بالمتر الطولي
2 Distress No.13 is measured in number of potholes — العيب رقم 13 يقاس بعدد الحفر
3 Other Distresses are Measured in Square meter — العيوب الأخرى تقاس بالمتر المربع
4 Distresse No.12 has no severity level — العيب رقم 12 ليس له مستوى خطورة

	تاريخ الإدخال Data Entry Date		مدخل البيانات Data Entry
	تاريخ المراجعة Checking Date		مراجع الإدخال Checked By

Doc. Ref: HC/J12-003/AMF02
Issuing Date: 15.06.2012

Fig 2.2 Surveying Form part 2

(Operation & Maintenance of Pavement Management System of Eastern Province Municipality, PMS Manual, 2017)

The city shall be divided based on a serial numbering system. From here on, the numbering order will represent the location of each city. Then the order divides the city into zones and then into the area within which the street of concern is located. The serial number is then followed by road and section numbers. Lastly, the number indicating the direction and features respectively follow. This creates a system in which roads can be easily identified and designated for any operational or maintenance purposes. An example of a road serial number is illustrated in Fig 2.3.

City		Zone		Area			Road			Section			Direction		Feature	
0	1	0	2	0	1	4	0	2	6	0	0	1	0	1	0	1
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*

Example: Section No = 01020140260010101

Fig 2.3 Serial Number system

(Operation & Maintenance of Pavement Management System of Eastern Province Municipality, PMS Manual, 2017)

Road evaluation can be carried out by dividing it into segments. Such a division is done to save time, money and effort spent on inspections. The formula used in segmenting a road is expressed as follows:

$$Segment = \frac{Area\ of\ Road}{300}$$

The area of the road is usually computed by the multiplication of its length and width, in the case of rectangular roads. 300 is a constant value that represents the unified area of the segment. All of the segments obtained from the formula will have a total of 300 m^2 of the area.

The mechanism of sample selection from segments depends on a random sample selection factor set by the municipality. In current practice, there are two factors used. The first factor of 25% represents road scanning and inspection for a regular overview of the condition and budget estimation. The second factor of 50% is used when an operation or maintenance needs to be established, which requires the inspection of more detailed samples. Based on those factors, engineers prepare the number of samples to be evaluated based on the result obtained from the multiplication of the number of segments by the factors. The equation is shown below:

$$Number\ of\ \ Samples\ to\ be\ Evaluated = Factor \times Number\ of\ Segments$$

Due to the reduction in the number of segments evaluated, to save time and money, a road under evaluation may not be entirely covered; meaning that not all distresses and defects would be counted. Personal inspection utilizing the visual inspection and hand calculation can result in human error. Also, advanced inspection technologies are not used in all provinces; only in Riyadh city and AlMadinah City. An example of advanced technologies used in AlMadinah pavement inspections is *Falling Weight Deflectometer* (FWD). The FWD measures the pavement's *Structural Capacity* in order to identify deflection caused by loads. According to the eastern region municipality, the equipment is rented from contractors depending on the project, location, and other circumstances.

Processes conducted by the surveyor starts with a field data collection (Road Defects). Each road has its own recognition serial, using the aforementioned serial numbering method. Using the road's serial number, the surveyor may locate and travel to the destination. The surveying team will collect the type of distress and its severity according to the PMS manual. The calculation starts from the equation of segments, then consulting the random selection factor (25% or 50%) to determine the number of segments in need of inspection.

The data obtained from the roads is recapitulated based on the defects and level of severity. This occurs due to the fact that defects can only be input once as a total. This means that each defect needs to be reported in terms of the magnitude of its severity. In current practice, the level of severity is divided into low, medium and high. Each defect has a unique code for identification by PMS. Once the data is summarized, the system requires the total area of the defects based on the same level of severity. The software will then calculate the density of the defect and generate a "deductions" value. The calculations are based on the PMS Manual. Once all deducted values have been obtained, they are summed and then subtracted from 100% (condition of a New Road). The result gained will be the Pavement Condition Index (PCI) which is the actual condition of the road. The process is illustrated in Fig 2.4

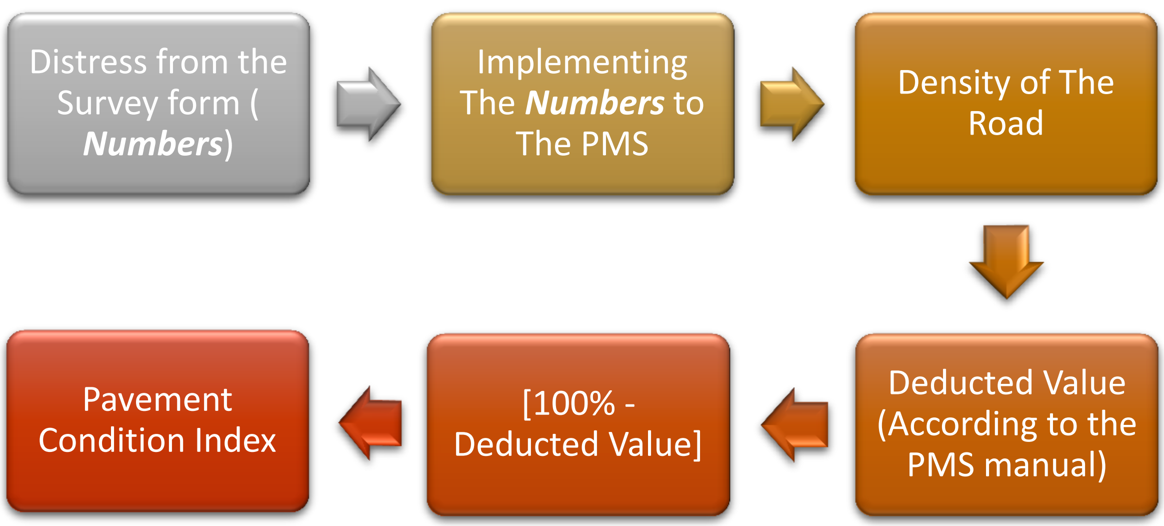


Fig 2.4 PMS System

The pavement condition index (PCI) depends on three major factors: *Distress Type*, *Distress Quantity* and *Distress Severity*. The results from the software (Micro paver) used to calculate the

PCI for the road, are implemented in the form of a *Geographic Information System* (GIS) map. The condition is labeled depending on the PCI value. Each value is evaluated with respect to the chosen scale. The final representation of the PCI is given via colors, where each color has a unique significance and specific responses. The rating process is shown below in Fig 2.5.

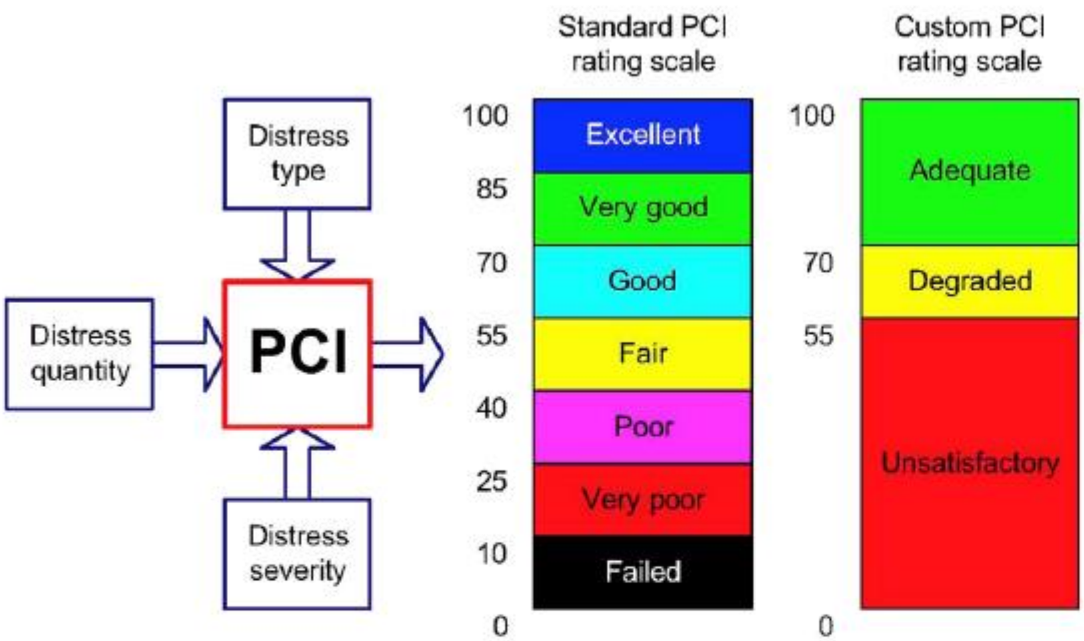


Fig 2.5 Condition Rating
(Operation & Maintenance of Pavement Management System of Eastern Province Municipality, PMS Manual 2017)

The software disadvantages noticed during data collection were concerned with server connections and local usage. The software needs to be always connected to the main server at the Eastern Province Municipality to operate. Any connection shortages would cause system freeze and no results can be processed. Another important limitation is the local use of the system. The software can only be used in the municipality locally. This consumes time and money just to process the required data. As of the first quartile of 2017, the municipality stated that a wireless upgrade of the software is being developed. This would ensure that the surveying team can process the data on-site or away from the municipality through the internet.

Based on the research's objectives, network condition is to be investigated and assessed. The concerned authorities evaluate the roads individually based on the PCI from the PMS software. Afterward, the roads' PCI is summed up and divided by the numbers of the roads (Average). Using the average to find the network condition is not adequate due to differences in the weight of the factors. The factors include the size of the roads, age, condition, etc. Finding the road network condition using the average provides inaccurate information. This information would not reflect the true condition of the network. The network level condition assessment in the research will be evaluated using the decision making theories (AHP, SMART) to enhance accuracy. This can be achieved by considerating the differences between factors' weight.

Chapter 3: Methodology

The condition assessment of the road network is a method to estimate and evaluation the conditions of the roads in the region. Three models to be developed to compare the results according to their variations. The first model represents the current practice applied by the municipality of the region and held in 2013. The second model is an experiment conducted by the research team in 2017 utilizing the local municipality methods. The third model will be developed by the research team using AHP and SMART theories to re-evaluate the roads and establish new results. This method will also be modified to find the condition assessment of the roads network.

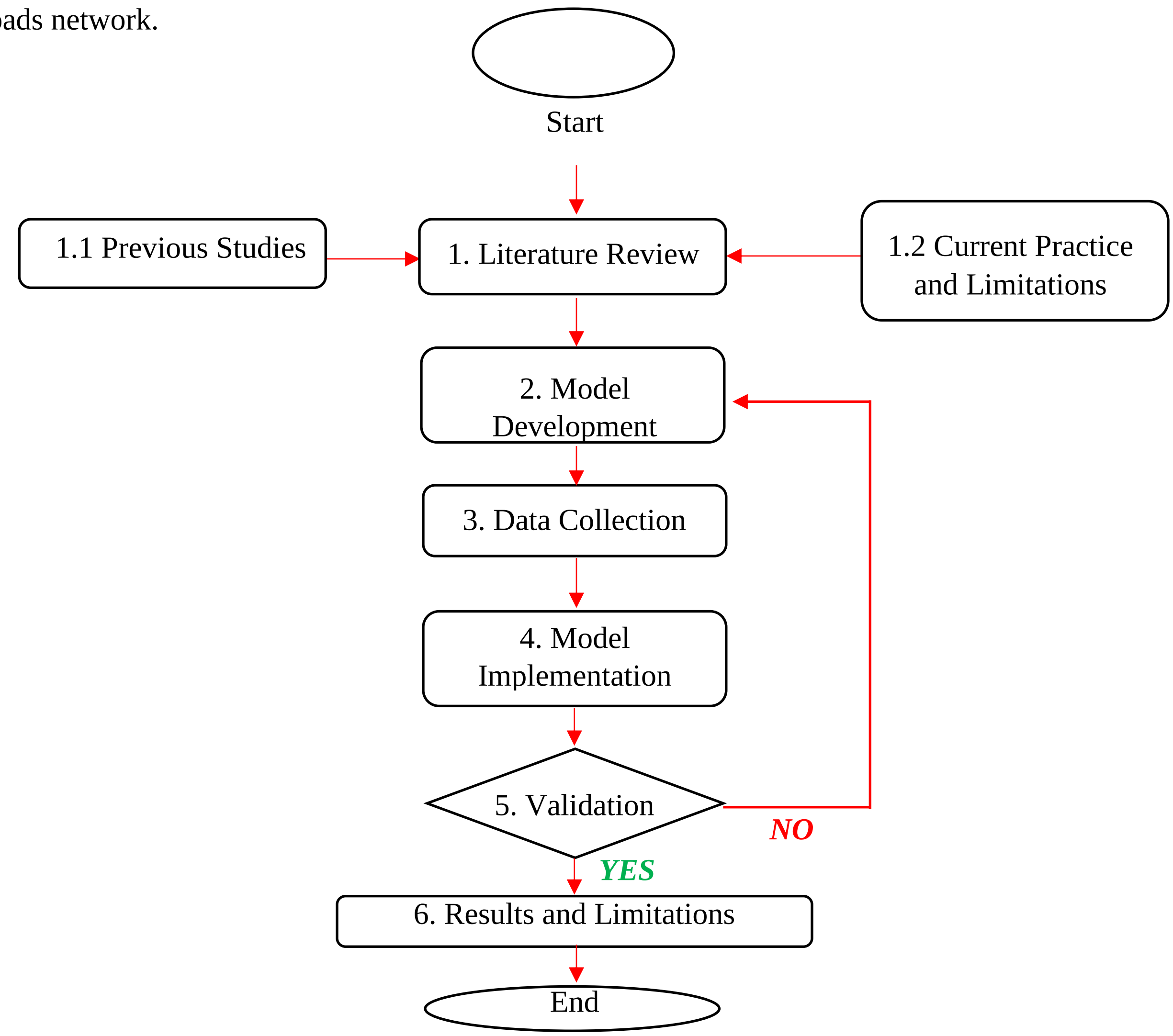


Fig 3.1 (Project Flow)

3.1 Literature Review

Literature Review is discussed in Chapter 2 sections 2.1 (Previous Studies) and 2.2 (Current Practices)

3.2 Model Development

The model is developed based on the decision-making theories AHP and SMART (Salman, 2011). These two methods have been applied previously in research within similar research field. They are used to evaluate the horizontal assets like the pipes networks (Al-Barqawi, 2006). hence these methods can be applied to selected assets, specifically roads. This is due to the fact that the horizontal assets share most of their characteristics and problems. In the new model development, the inspection will be carried out on the entire road instead of 25% or 50%. This is done to find the actual road condition and to provide a new feature in the research. The defects will be gathered from international and local manuals. Then a categorization process will be created for the defects gathered. The main categories chosen for the model development are structure, miscellaneous, environmental and construction. Each category contains a number of distresses to create the failure hierarchy. Fig (3.2) shows the first level of the failure hierarchy. Fig (3.3) illustrates the final failure hierarchy including the first and second level.

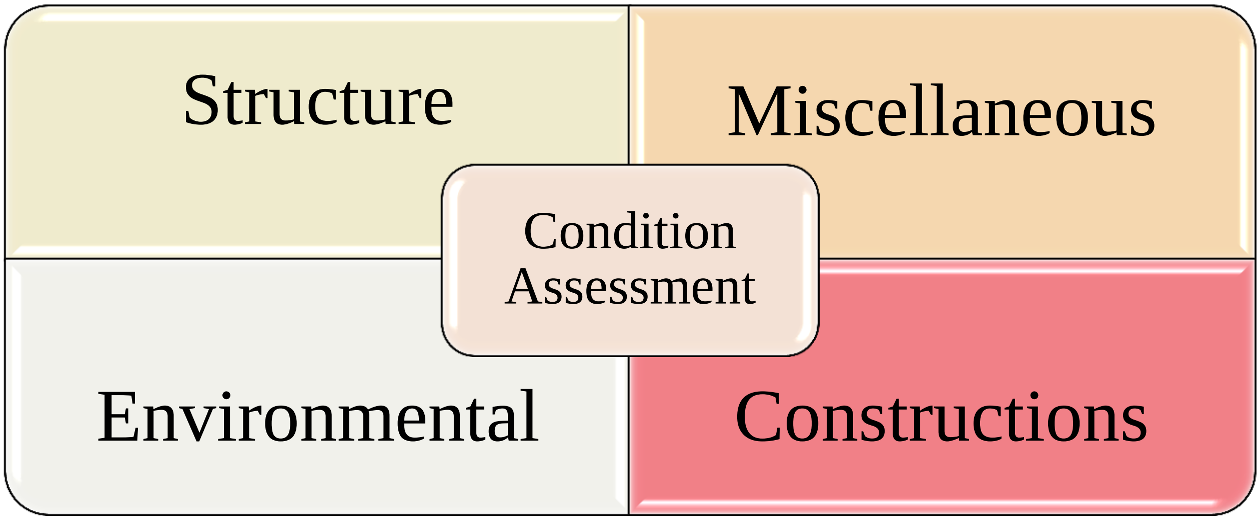


Fig 3.2 Defects Categories

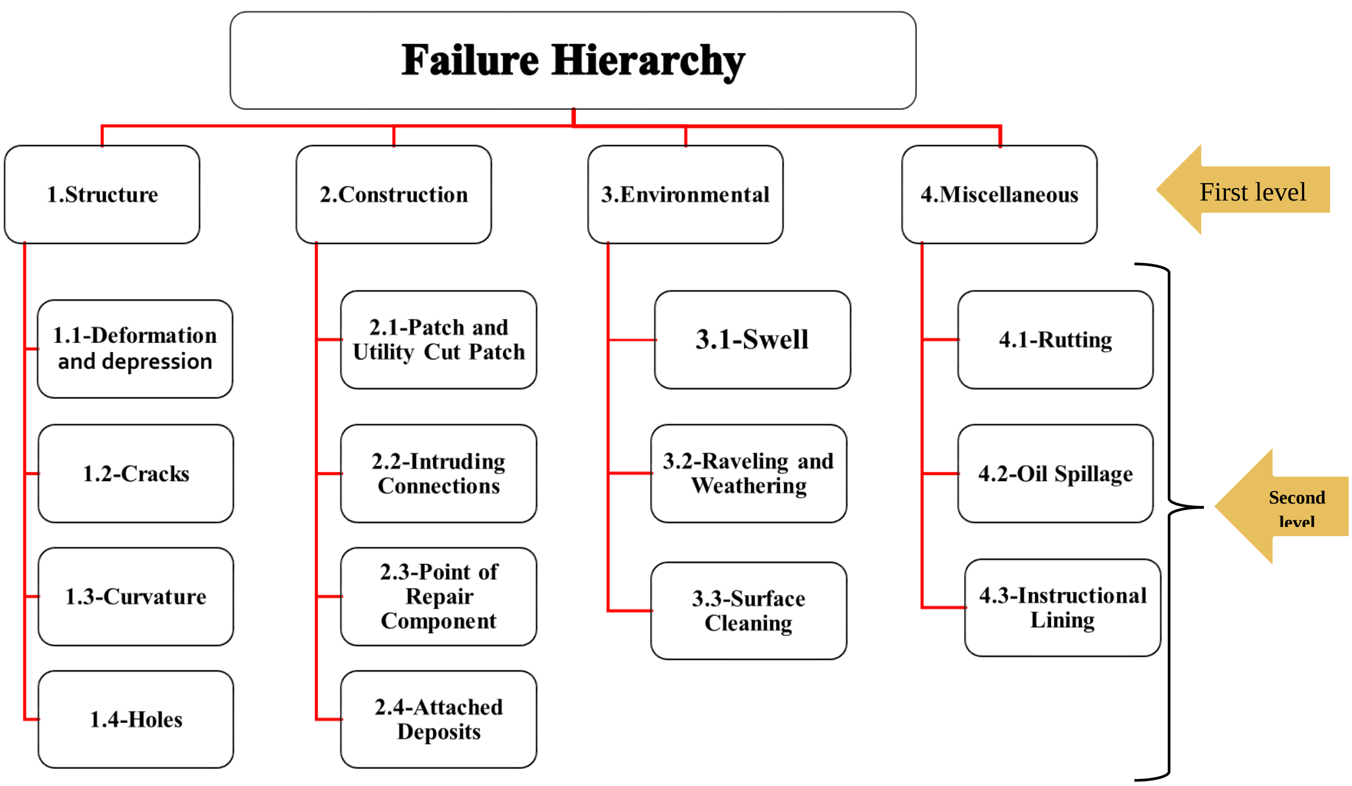


Fig 3.3 Failure hierarchy

The distribution of the defects is based on its effect on the road, depending on its influence on the Structure, Construction, Environment or Miscellaneous. by reviewing the Nordic Sewer System Inspection Manual (Danva, 2005) and Airfield Pavement Inspection Reference Manual (Municiplaity,2017), the distress found related to the roads have been selected carefully to be part of each category. The structure category relates to the defects that influence the layers of the road and design, such as the deformation, holes, cracks, and curvature. Some of the structure defects can be visually inspected if the damage is in the pavement layer or the top of the base layer. For deeper damages, inspection technologies must be used. The construction category contains the defects that are resulted from construction works. This category includes defects such as the Patch and Utility Cut Patch, Intruding Connection, Point of Repair Component and Attached Deposits. This category usually affects the pavement layer and the top of the base layer. The defects can be inspected visually. Environmental category contains the defects that contribute to environmental problems, like swelling, Ravelling and weathering and surface cleaning. These defects can be seen and inspected visually due to its effect of the pavement layer. The final category is the Miscellaneous category. This category contains defects such as Instructional lining, Oil spillage, and Rutting. These defects are caused by usage, wear, and tear of the road.

The purpose of the SMART method is to calculate the condition assessment of the road, by multiplying the score by the weight, the score represents the density of the defects in the roads and the weight represents the expert's judgment and their opinions on the importance of the defects compared to each other. The score is the specific factor it has a range 1-100, the weight is the generic factor taken from AHP method.

SMART method:

$$CA_i = \sum(W_i \times S_i)$$

Where: **CA**: Condition Assessment

W: Weight and **S:** Score

SMART method can be applied on every defect in level two process. The methods work by multiplying the score with the weight to find a certain value. The summation of the outputs represents the score for level one which is the category score. Then each category will have a certain score and weight (from AHP) to have a certain output for each. After that, the summation for the categories output will represent the deductive value. The deductive value is a percentage of the all combined defect affecting the health of the road. It should be noted that the road health is be represented as 100%. The deducted value is then subtracted from 100% to provide the condition assessment. Subtracting from 100% is a modification to the original equation of the SMART method.

SMART method modified:

$$CA_i = 100 - \sum(W_i \times S_i)$$

Where:

CA: Condition Assessment

W: Weight, **S:** Score, **100:** Total Health of the Road

The SMART method will also be applied when finding the condition assessment of the network. In this case, some assumptions are required in order to achieve the results. These assumptions are made specifically for Domestic Areas. They listed in the following:

i. All road capacity are same for residential area
ii. Traffic Flow is constant in the residential area
iii. Thickness of the road is constant throughout the domestic network of roads
iv. Same Pavement materials for domestic roads only.

From those assumptions, the Area can be used as a weight factor for the SMART method. This is because the thickness is constant which means instead of utilizing the volume, the area of the road can be used. To find the weight of each road, the road's area must be measured. Then a summation of all roads area in the chosen network is required. The weight will be computed by the following equation:

$$\boldsymbol{W_N = \frac{Area\ of\ the\ Road}{Area\ of\ the\ network}}$$

The score required in the SMART method will be the condition of the individual road. Then the weight of each road will be multiplied by the score to get a certain value. The summation of these values will result in the condition assessment of the roads network.

The presentation of the condition assessment requires a scale to identify the condition of the asset. The scale utilized in the research is 0% to 100%. The excellent condition level will be from 100% to 81%. The good condition level will be from 80% to 61%. The medium condition level is from 60% to 41%. The poor condition level will be 40% to 21%. Finally, the very poor condition will be from 20% to 1%. The scale is illustrated in fig(3.4)

Fig 3.4 Condition Scale

3.3 Data Collection

The data required for the project are categorized to follow the SMART process. The categories are field data which relates to the score and the expert opinion that relates to the weight. The

field data will be collect from the selected roads from Al Dammam area. The team has chosen a network of roads specifically in the Al-Shatie Al-Gharbi region in Al-Dammam. The network consists of eleven roads which are connected together. For collecting the expert's opinion, a survey was created which will be distributed on transportation field experts. The expert's opinion will be transformed into a value called Weight. The weight will be used as a correction factor for the scores collected.

3.3.1 Field Data

The field data required for collection consists of the area of defects in a road. Depending on the size (m^2) and severity, the defects are collected to indicate the road’s health. To create a comparison between the past and the future, both data are required. The past data are collected from the local authorities, specifically the municipality. The data obtained from the municipality is dated to 2013. The set of data collected includes all road assessment of the Al-Shatie Al-Gharbi region. But only selected roads are chosen due to the size of the area. This should be noted that the municipality collects data from 25% to 50% of the road area depending on the circumstances. More information about the sampling and percentage of road area is presented in the literature review under current practices section.

To gain more understanding about the data collection process, an experiment was required. After several discussions and tutorials, the research team utilized the municipality methods to collect road defects. The information about the defects was also obtained from the municipality. This is to ensure correct identification of the defects present. In this process, each defect was measured visually by a measuring wheel. The instrument's main usage is to measure the length in meters. The accuracy of the instrument is 0.1 meters. Depending on the type of defect present, a suitable measurement was used. The defects were either measure by length or area. This is according to the definition in the Municipality's PMS manual. The area of a defect was measured according to the defect's shape (Square, Circle, Etc). This established a close approximation of the size, due to the fact that some shapes are irregular. Once all defects are measured, the values are summed according to the defect and its severity. The data collected in the experiment only accounts for 25% of the total road area. The information obtained in the experiment is used as a comparison to understand the process and explore the limitation found.

The other set of data required was from the present state of the road. The data was collected from the same roads as the experiment but with different guidelines. The only similarity between the experiment and the required present data is the measuring method. The first difference was the amount of road area selected. Instead of 25%, 100% of the road area was chosen. This decision was made to ensure a proper road assessment and elimination of one of the limitations. The second change introduced was the defects guideline. The research's new manual was used to identify and collect the data. The third change was the transformation of the defects area value into a score. The score represents a value which will be used in SMART Process.

3.3.2 Conducting Condition Assessment Surveys

To collect the data required from experts, a survey should be conducted to reduce the errors in the estimating the score of the roads. The survey will be distributed to transportation field experts. Those experts include academic professional and field professional. This is to ensure mixed balanced results from both practices. The distribution of the survey will be either an interview or sent by E-mails. This is done to reduce the time required for the feedback and to proceed further in the project. The survey consists of the Analytical Heiracy Process (AHP). The AHP will provide specific spaced for the experts to fill in a value. The value entered expresses the multiple of important. This means, how important is X compared to Y? (X and Y are variable introduced for the sake of explanation and does not have any direct relation to the Project or the methods used). The general scale used by the original creators of the AHP varies from 1 to 9. Each number represents a multiple. Another feature of the AHP is the consistency factor. This factor represents a 10% variation between multiples. If the expert uses non-consistent values (Greater than 10% variation), re-evaluation of the input must be established. This is to eliminate any sorts of biased and random inputs. Once all evaluations are successful, a weight for each desired factor is produced. the weight will be used as a correction factor for the scores collected. A sample of the survey is illustrated in Fig.(3.5) The surveys collected are from University of Dammam, Eastern Province Municipalities, and Ansab Est. From the transportation department at the University of Dammam, six surveys were obtained from transportation professors. From

Eastern Province municipalities, four surveys were collected from field engineers to technical managers. Finally, from Ansab Est. seven surveys were obtained from field engineers and managers. The total amount of surveys obtained for the research is seventeen surveys.

Condition Assessment of Road Networks						
Factor	Structure	Construction	Environmental	Miscellaneous	Weight	EVALUATION
Structure	1.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Construction		1.00	#DIV/0!	#DIV/0!	#DIV/0!	
Environmental			1.00	#DIV/0!	#DIV/0!	
Miscellaneous				1.00	#DIV/0!	
Sum	1.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Fig. 3.5 Survey Sample AHP

3.3.3 Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP) is a tool that simulated decision making based on priorities. To generate a priority, several steps should be considered. First, a problem should be defined to determine the type of information sought (Saaty, 2008). Secondly, a decision hierarchy should be established. The order of the hierarchy should start with the decision goal at the top, then expanded towards the bottom. The expansion should provide an explanation of the objective from a broad perspective to the criteria on which subsequent elements dependent on. The lowest level of the hierarchy usually includes a set of alternatives (Saaty, 2008). Finally, a compression model should be constructed to evaluate the higher element in level with the immediate element below. Utilizing the comparison of all elements in the model, an overall or global priority should be generated. This process should be continued until the final priorities of the alternatives at the bottom most level are obtained (Saaty, 2008).

Chapter 4: Calculations and Results

4.1 Model Implementation

The model developed will be implemented under three categories. The first category is the Condition Assesment. This category refers to the calculation of the condition of roads and its network. The first step utilizes the data collected from the field using the developed manual. The utilization of the data includes the summation of all defect value in each road to obtain the road score. This is done by filling field survey with defects under its associated severity. Each severity within a defect is summed. This process is done to all defects for each road. Once the defect with its associated severities is summed, the values are converted to an overall score of the road.

The weight required for the SMART method to be applied for the first and second levels is obtained from the expert's survey. The survey consists of the AHP method which provided a weight to each component compared to other components in the same category. This weight is computed according to its importance and significance to the experts in the transportation field. Once each road has a score and all defects are weighted, the condition can be calculated. This is done by multiplying the defect’s weight with the score associated with it. Then a summation of all second level values is summed under its corresponding category (structure, construction, etc). That summed value is then multiplied by the weight of the first level. The summation of the newly obtained number is called a deductive value. The deductive value represents the damage done by the defects to the road. To find the condition of the road, subtract the deductive value from 100%.

The SMART method will also be used to find the condition assessment of the roads network. The score will be represented by the road's condition while the area of the road will represent the weight. The weight choice is based on the assumptions made in section 3.3 model development.

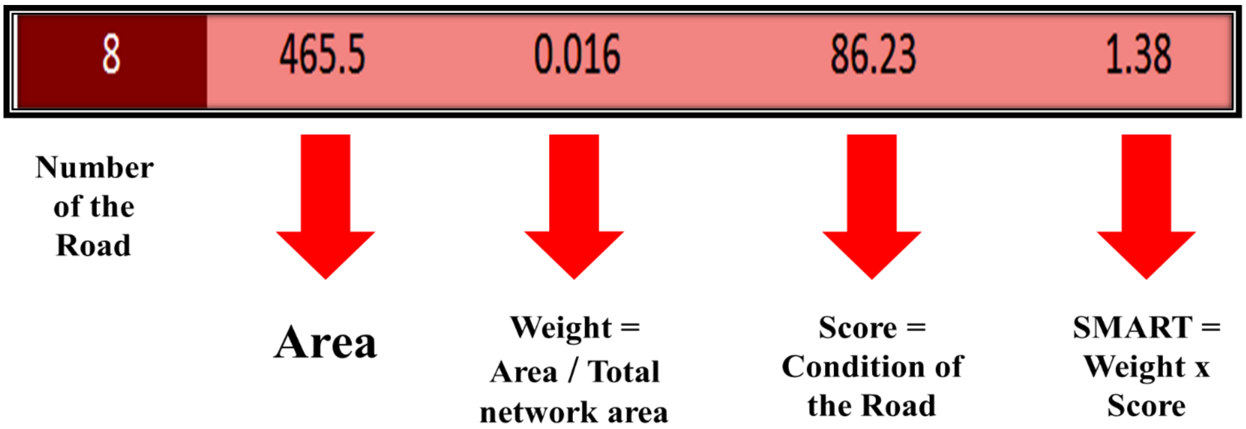


Fig 4.1 SMART for Network's Condition

Fig 4.1 shows a sample road in the calculation of the network's condition. The weight of the road is the area of the road divided by the area of the total network. The next step is to multiply the weight with the score. These steps should be repeated for all the roads in the network. Finally, the summation of all the value obtained by multiplying the weight with the score will result in the condition of the network

The second model implementation category is *ArcMap* (GIS). This software enables the user to implement modification on the *Geographic Information Systems*. This can be used to illustrate the condition and attributes of the road. The attributes can contain a different type of information including size, type, action required, etc. It is a common practice locally and internationally to represent the condition assessment of the road is ArcMap. This created an easy to understand the status of the assets in addition to providing different customization options.

The condition of the road is prepared as an Excel.CSV file as an input. The conditions obtained are converted to a scale from 1 to 5 instead of 0% to 100%. This step makes the sorting of the data in the program easier. Some rules for importing the data are required to be followed like no spaces can occur within a name. Once the Excel file is imported into the software, it can be joined to a Shape file. A shape file usually contains the geographic drawing, in this case, the roads. The joining occurs by selecting a common column name in Excel and Shape files. The results can be illustrated in the symbology section within the properties of the Shape file. In the case of this research, a qualitative comparison scale is used. This scale shows different colors depending on the intervals chosen. Once all the settings are done, the maps illustrate all the road conditions with colors.

The final category in the model implementation is the comparative charts. In order to study the trend of the results, comparative charts will be established for each road and roads network. In each chart, there will be a comparison between the municipality data, team's Experiment using Municipality Method and the newly developed model. This step is important in order to create benchmarks for validation and understanding of the difference between the new model and the municipality data. Finally, the conclusion and recommendations are partially obtained from the comparison.

4.2 Final Results

The results of the research are shown in Table 4.1. The table shows a comparative result for each of the selected roads. The second column represents the municipality data while the third column represents the team's Experiment using Municipality Method. Finally, the fourth column represents the results from the newly developed model. A detailed comparison of each road and the road's network is discussed in the upcoming sections of the results.

Table 4.1 Comparative Results

Road NO	Municipality Condition (2013)	Experiment condition using Municipality Method (2017)	New Model Condition Final (2017)
3	71 %	52 %	38.80 %
4	78 %	37 %	78.98 %
5	69 %	52 %	74.60 %
6	69 %	51 %	85.60 %
7	77 %	90 %	83.60 %
8	65 %	79 %	86.23 %
9	67 %	22 %	75.16 %
21	69 %	46 %	74.98 %
23	73 %	66 %	66.34 %
178	76%	75 %	87.50 %
180	80%	56 %	80.75 %

The results from each road contain a comparison of conditions between municipality (2013), Experiment condition using Municipality Method (2017) and New Model developed (2017). The road results will be categories under expected, balanced and abnormal results. The expected results are those results, which are logical according to the time gap and other factors including wear, declining condition, etc. The balanced results are those results with a small variation in the condition. The variation of the condition should not exceed 5% in this case. Furthermore, the abnormal results are those whose condition are better than the municipality's condition with respect to the time gap.

4.3 Analysis

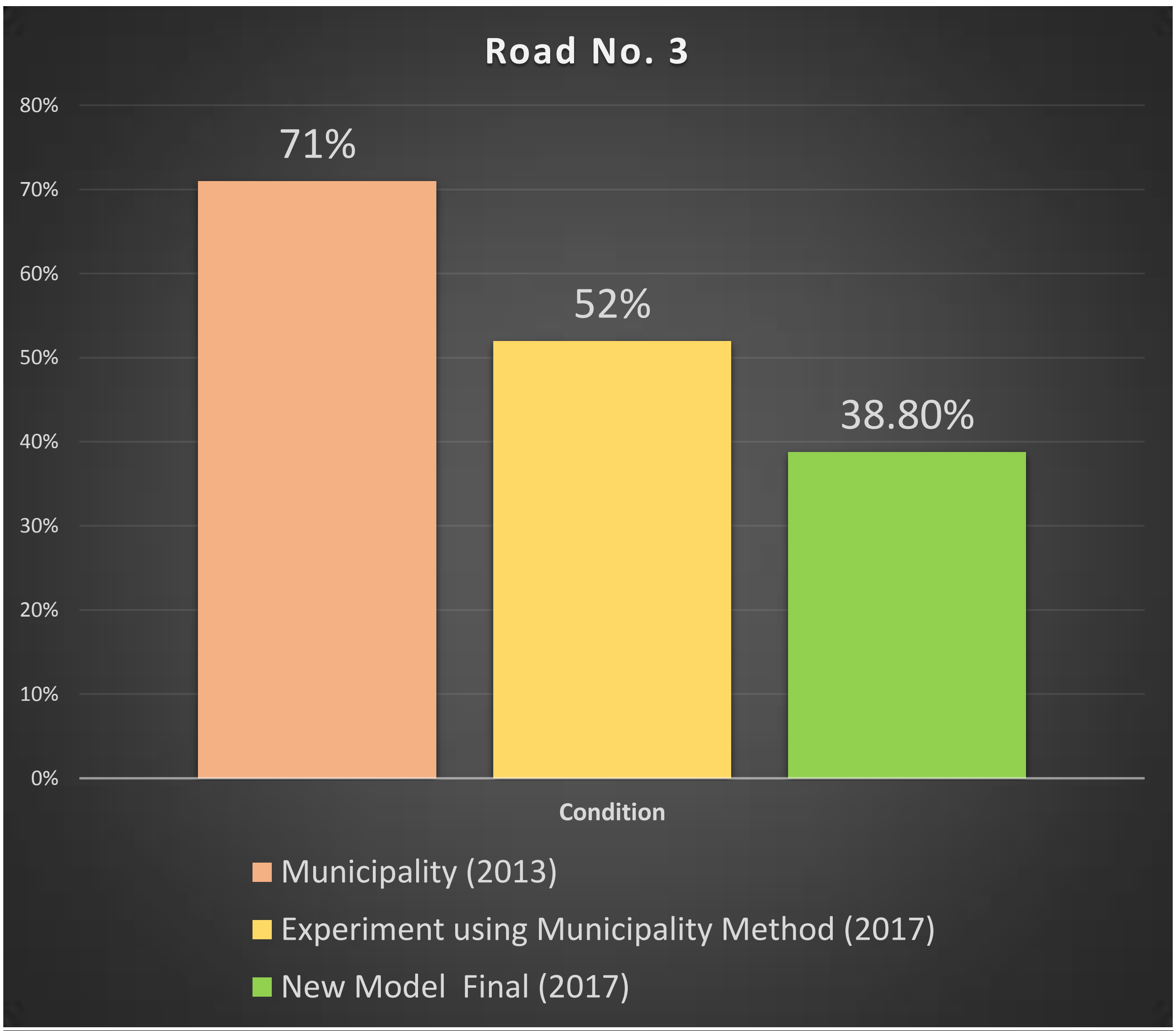


Fig. 4.2 Condition Assessment of Road No.3

Road number 3 is considered under expected results due to the declining condition. In 2013, the municipality condition for road number 3 was 71%. For the research's team experiment using the municipality method, the condition was 52% while 38.80% for the newly developed model. This indicates a drop of 54.65% in the condition of the road.

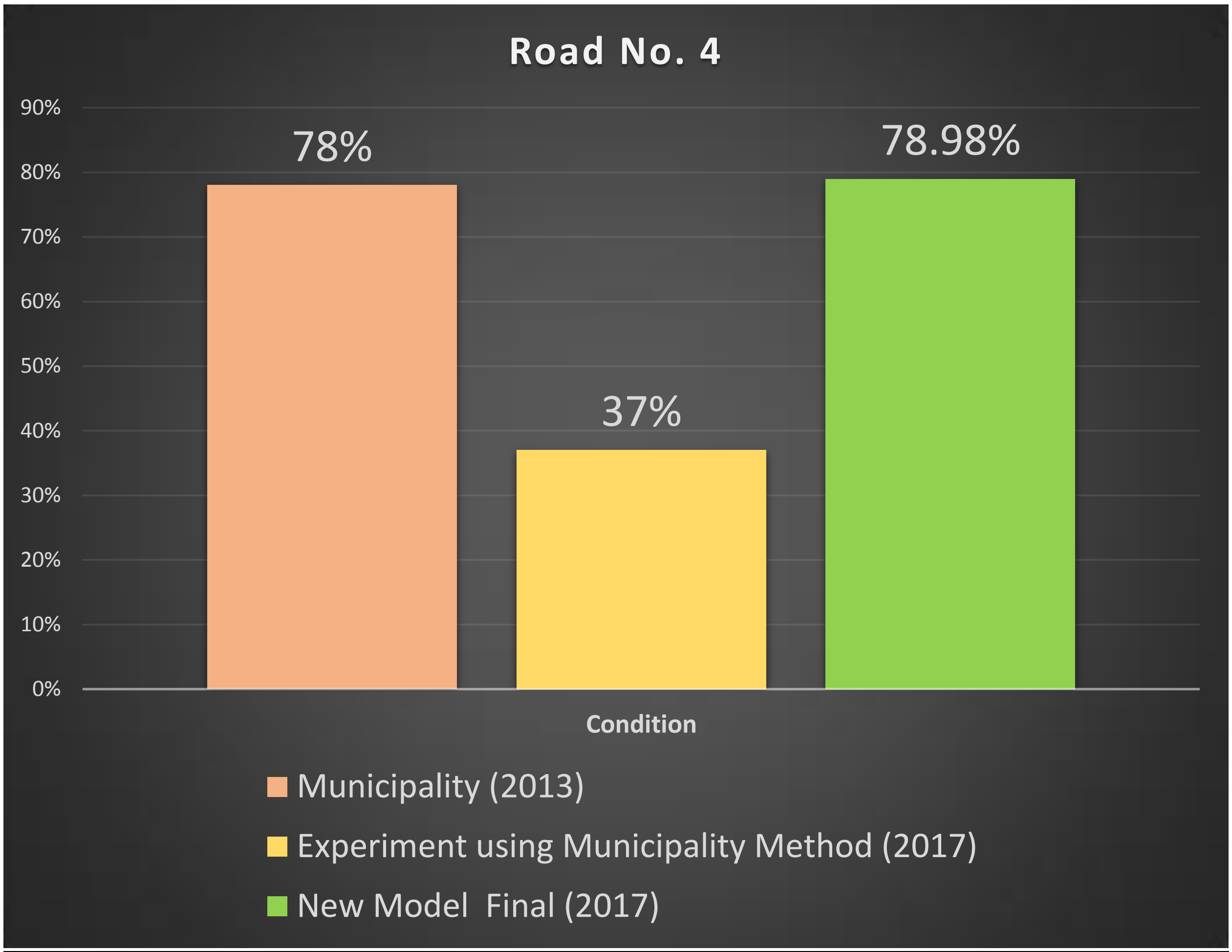


Fig. 4.3 Condition Assessment of Road No.4

Road number 4 is considered under balanced results due to the declining condition. In 2013, the municipality condition for road number 4 was 78%. For the research's team experiment using the municipality method, the condition was 37% while 78.98% for the newly developed model. The results for this road can be discussed depending on the chosen benchmark. If the benchmark was the municipality (2013), the result is balanced with a small variation in better condition for the new model. On the other hand, if the chosen benchmark was the research's team experiment using the municipality method; then it can be considered as abnormal. For consistency, the municipality's data is chosen for the benchmark.

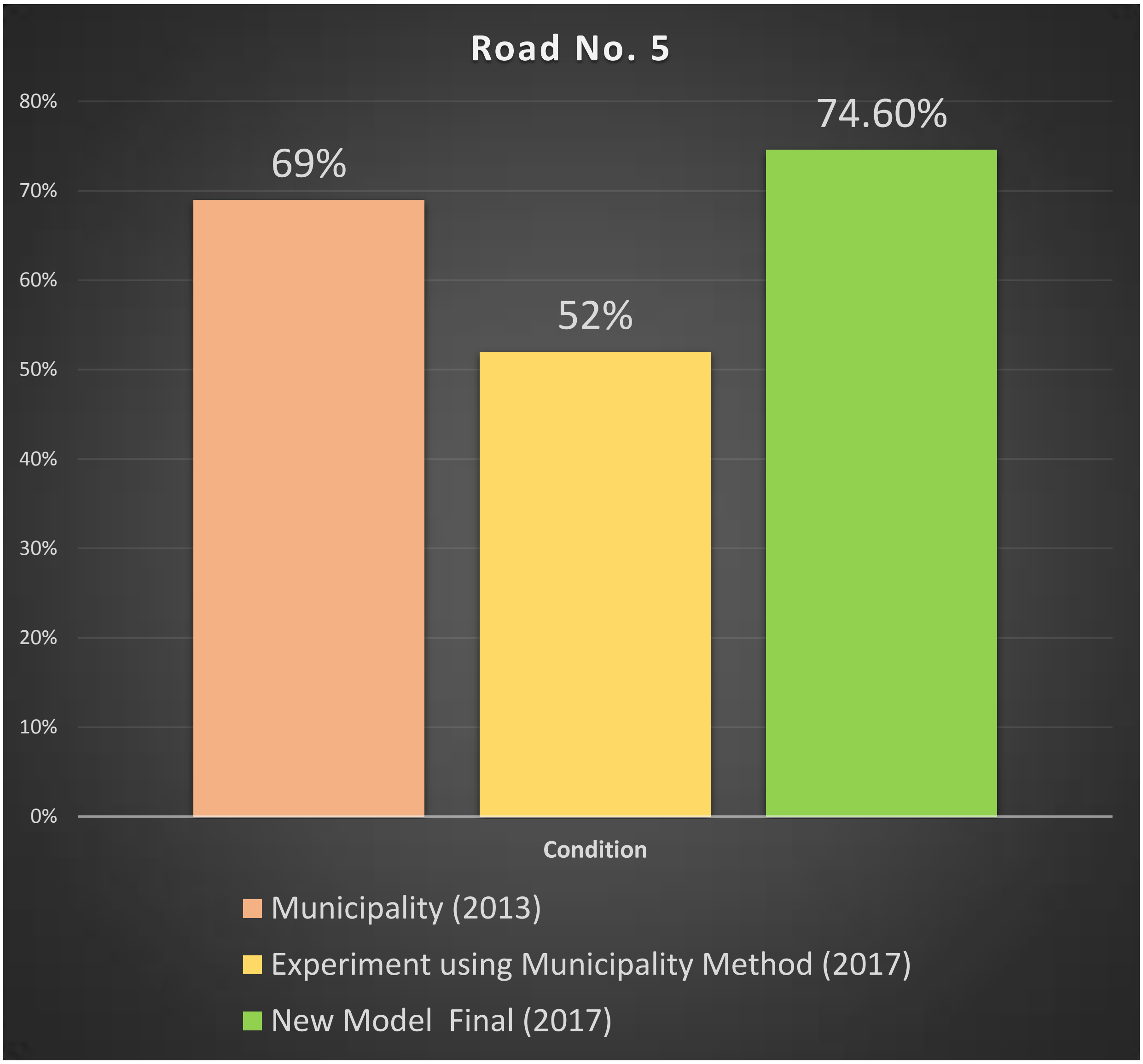


Fig. 4.4 Condition Assessment of Road No.5

Road number 5 should be categorized under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 5 was 69%. For the research's team experiment using the municipality method, the condition was 52% while 74.60% for the newly developed model. This indicates an unexpected jump of 22.6% in the condition of the road from the medium (Experiment using municipality method) to good (New Developed Model).

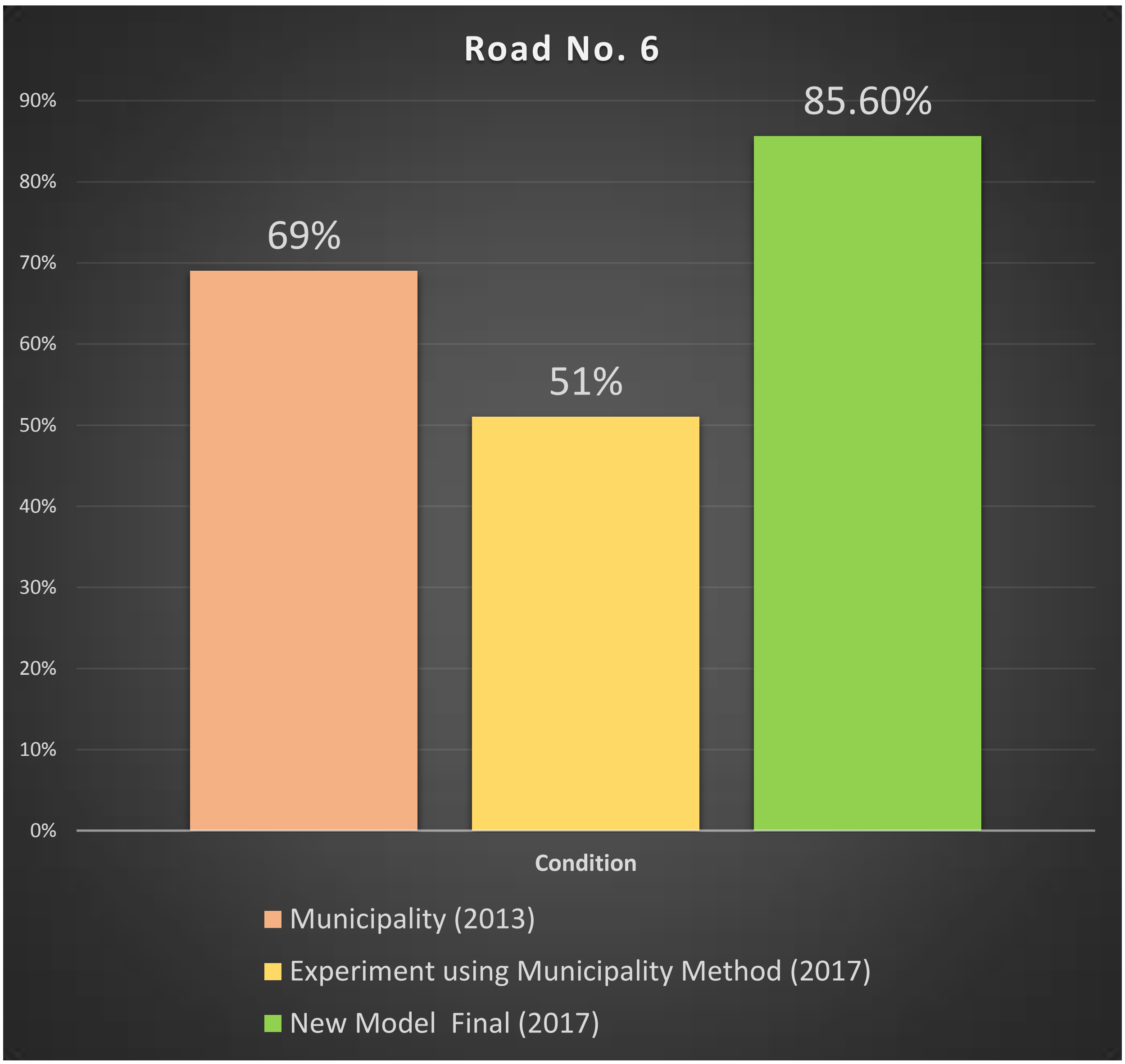


Fig. 4.5 Condition Assessment of Road No.6

Road number 6 is considered under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 6 was 69%. For the research's team experiment using the municipality method, the condition was 51% while 85.60% for the newly developed model. This indicates an unexpected jump of 34.6% in the condition of the road from the medium (Experiment using municipality method) to excellent (New Developed Model).

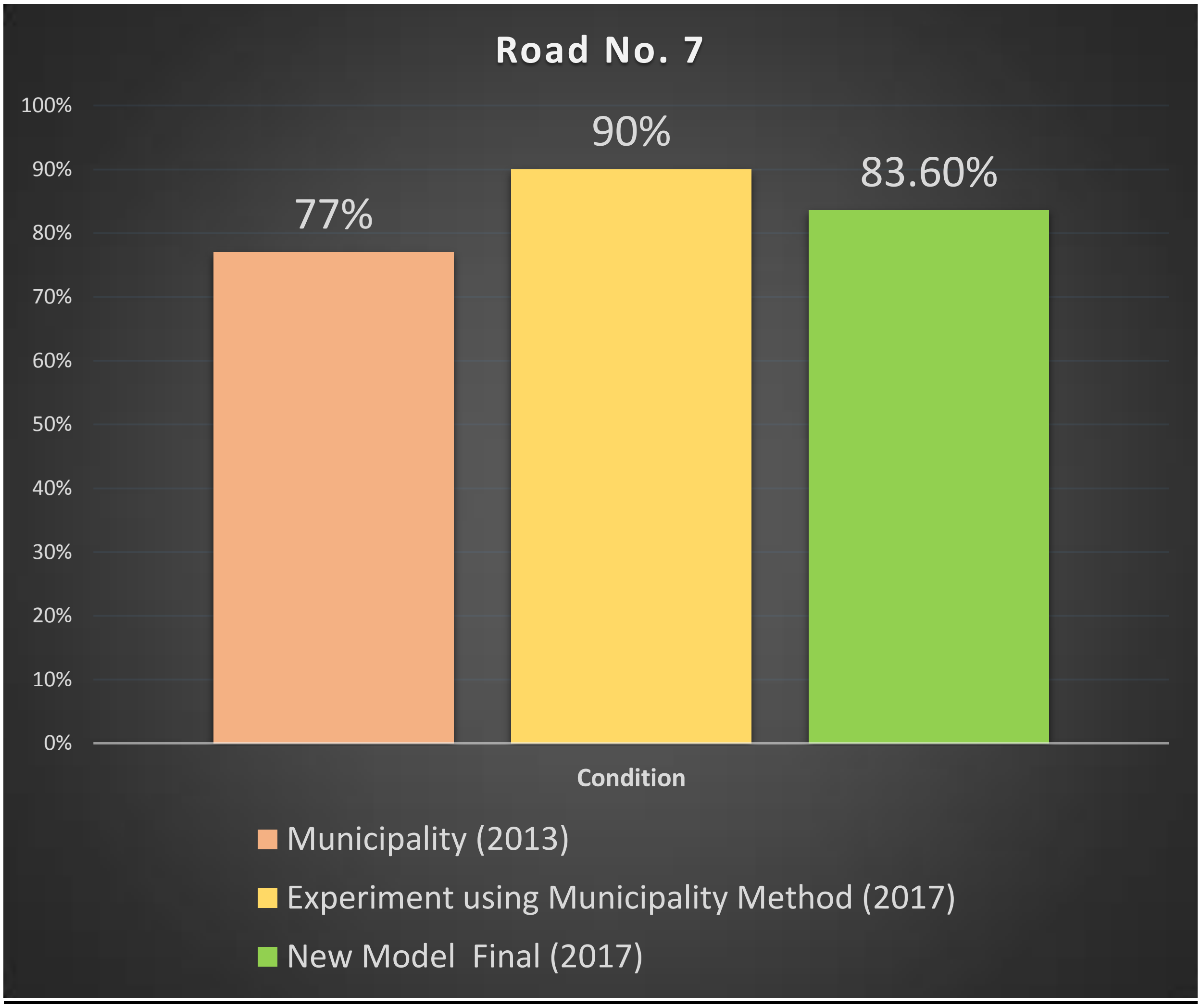


Fig. 4.6 Condition Assessment of Road No.7

Road number 7 should be categorized under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 7 was 77%, which is good. For the research's team experiment using the municipality method, the condition was 90%, which is excellent, and an unexpected jump in the condition of the road while 83.60% for the newly developed model, which is still excellent. This indicates an expected drop of 6.4% in the condition of road, but the condition stays the same in the team experiment and the newly developed model

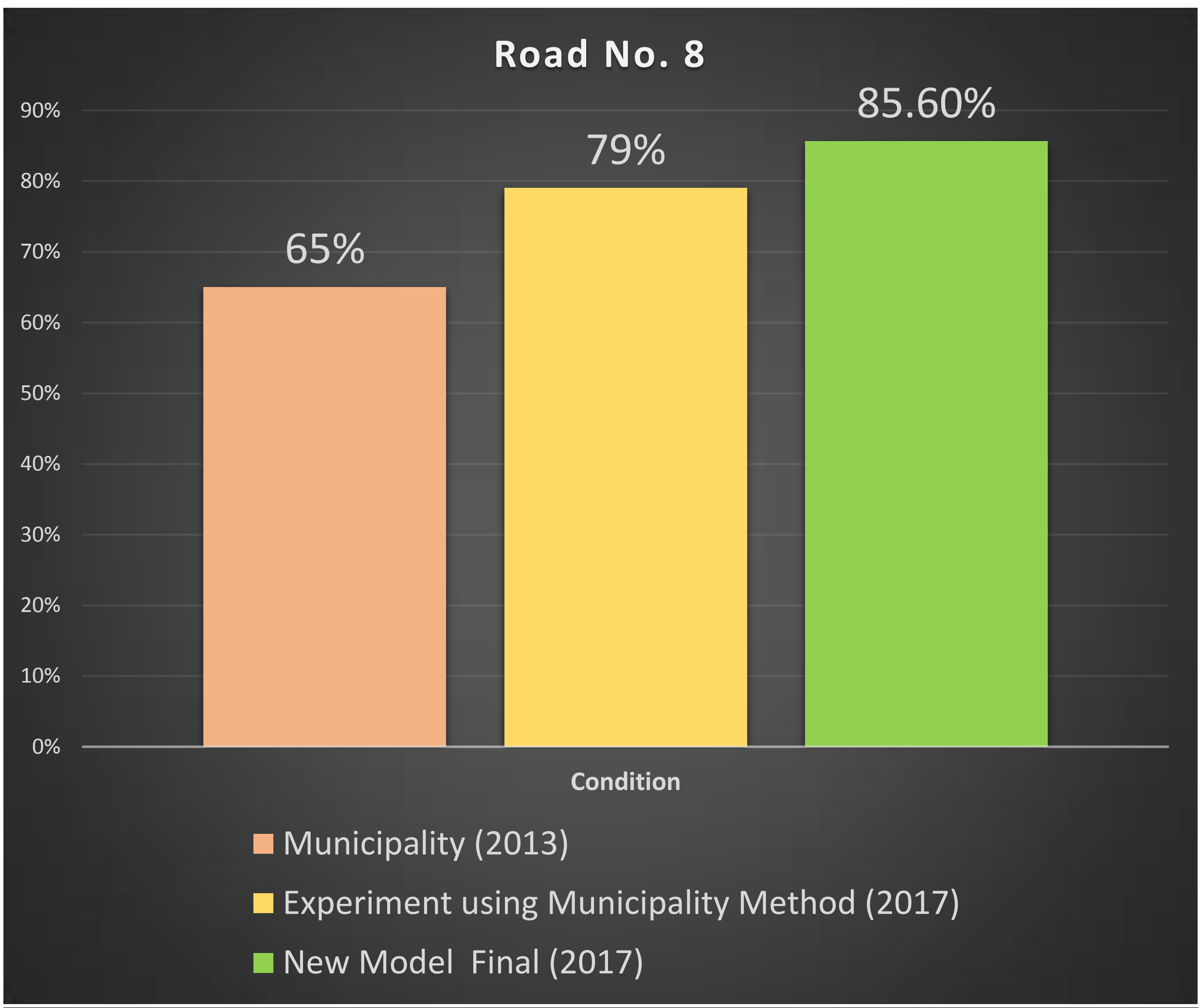


Fig. 4.7 Condition Assessment of Road No.8

Road number 8 follows the trend under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 5 was 65% according to the scale it is good. For the research's team experiment using the municipality method, the condition was 79% according to the scale it is good too while 85.60% for the newly developed model according to the scale it is excellent. This indicates an unexpected jump of 6.6% in the condition of the road from the medium (Experiment using municipality method) to excellent (New developed Model).

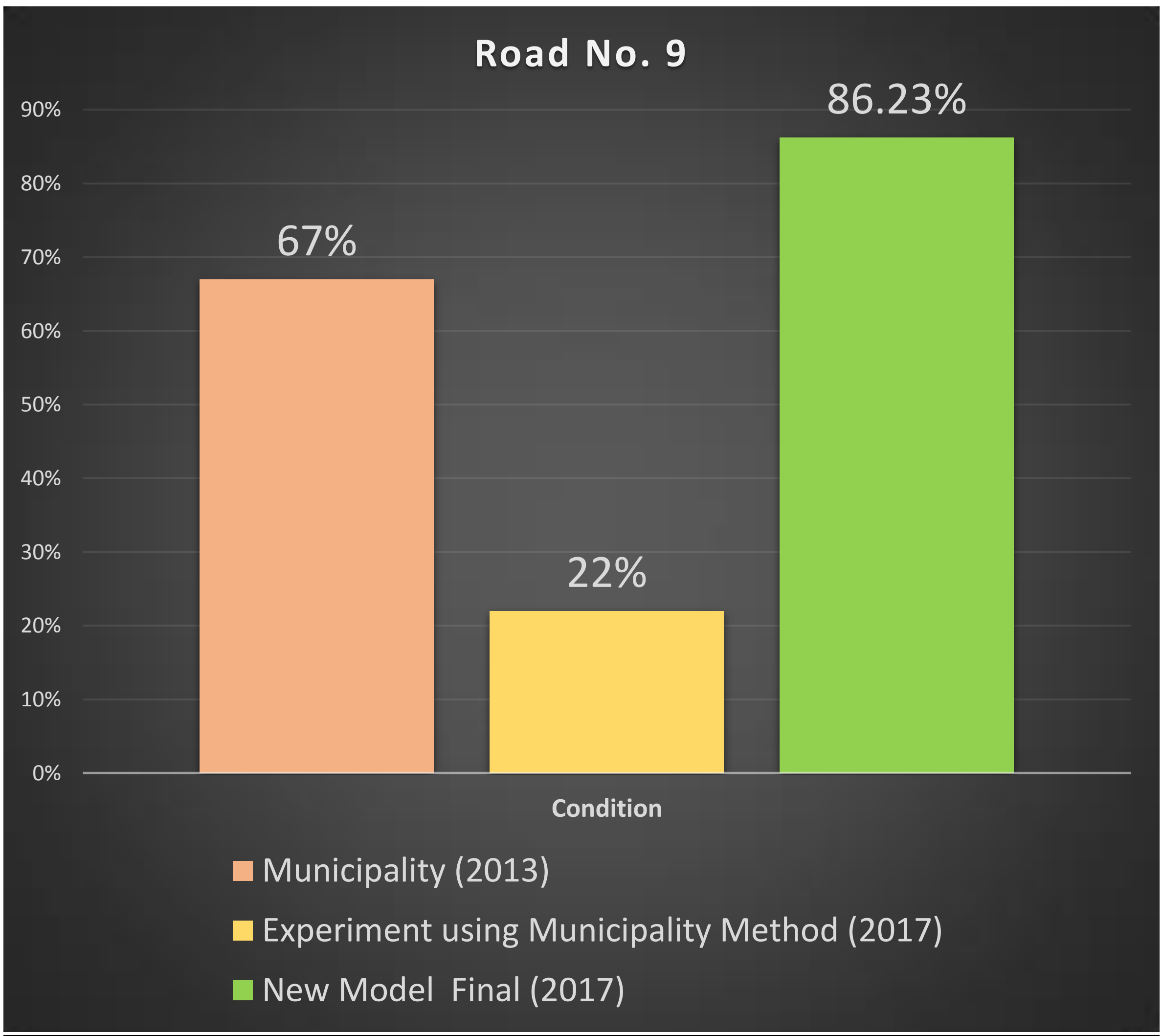


Fig. 4.8 Condition Assessment of Road No.9

Road number 9 should be considered under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 9 was 67%, which is good according to the scale. For the research's team experiment using the municipality method, the condition was 22% according to the scale it is poor (heavy drop), while 86.23% for the newly developed model (excellent). This indicates an unexpectedly big jump of 64.23% in the condition of the road from poor (Experiment using municipality method) to excellent (New developed Model).

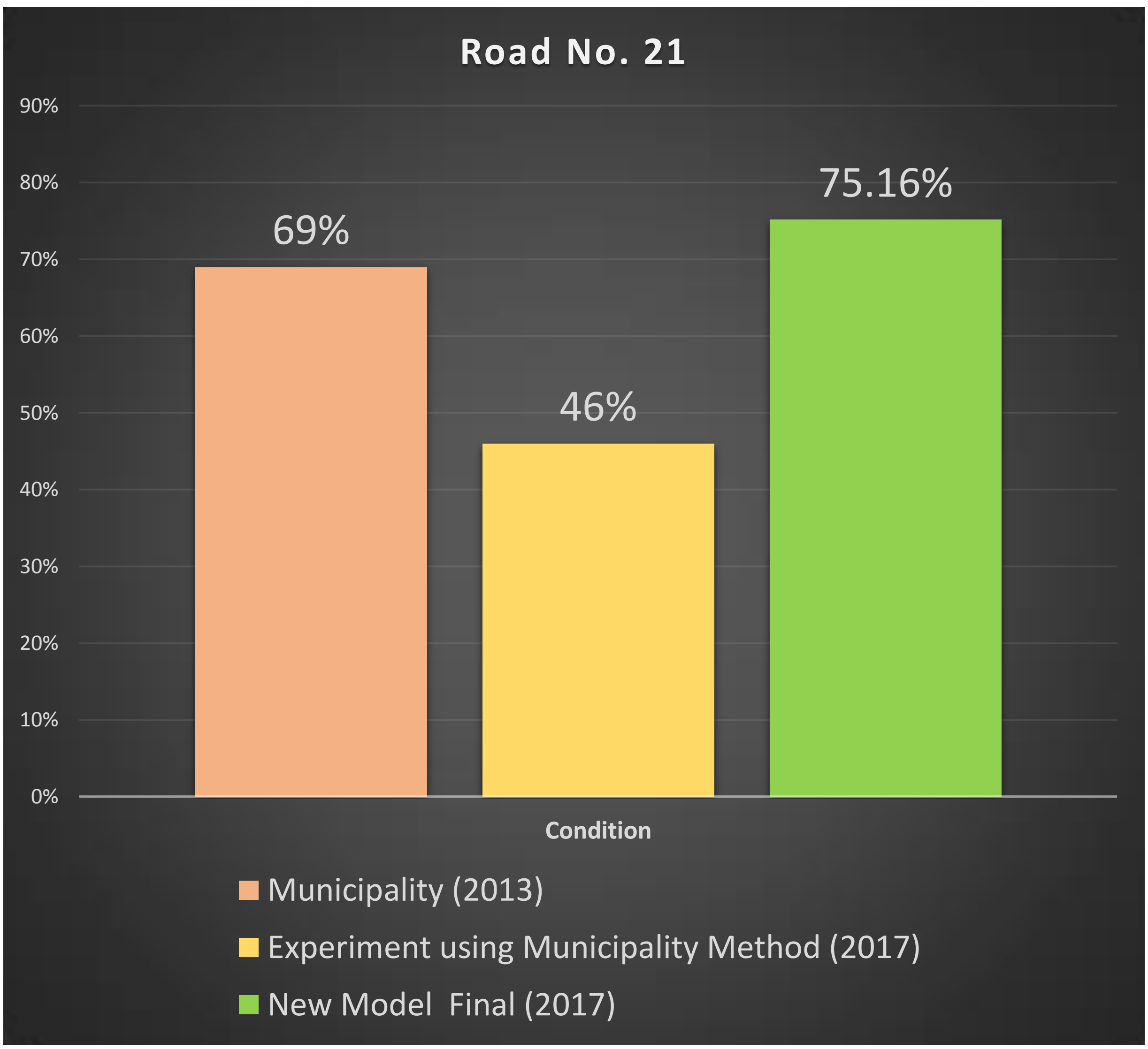


Fig. 4.9 Condition Assessment of Road No.21

Road number 21 is considered under abnormal results due to the comprehensive condition. In 2013, the municipality condition for road number 21 was 69%, which is good according to the scale. For the research's team experiment using the municipality method, the condition was 46% according to the scale it is medium (drop), while 75.16% for the newly developed model (good). This indicates an unexpected jump of 29.16% in the condition of the road from the medium (Experiment using municipality method) to good (New Developed Model).

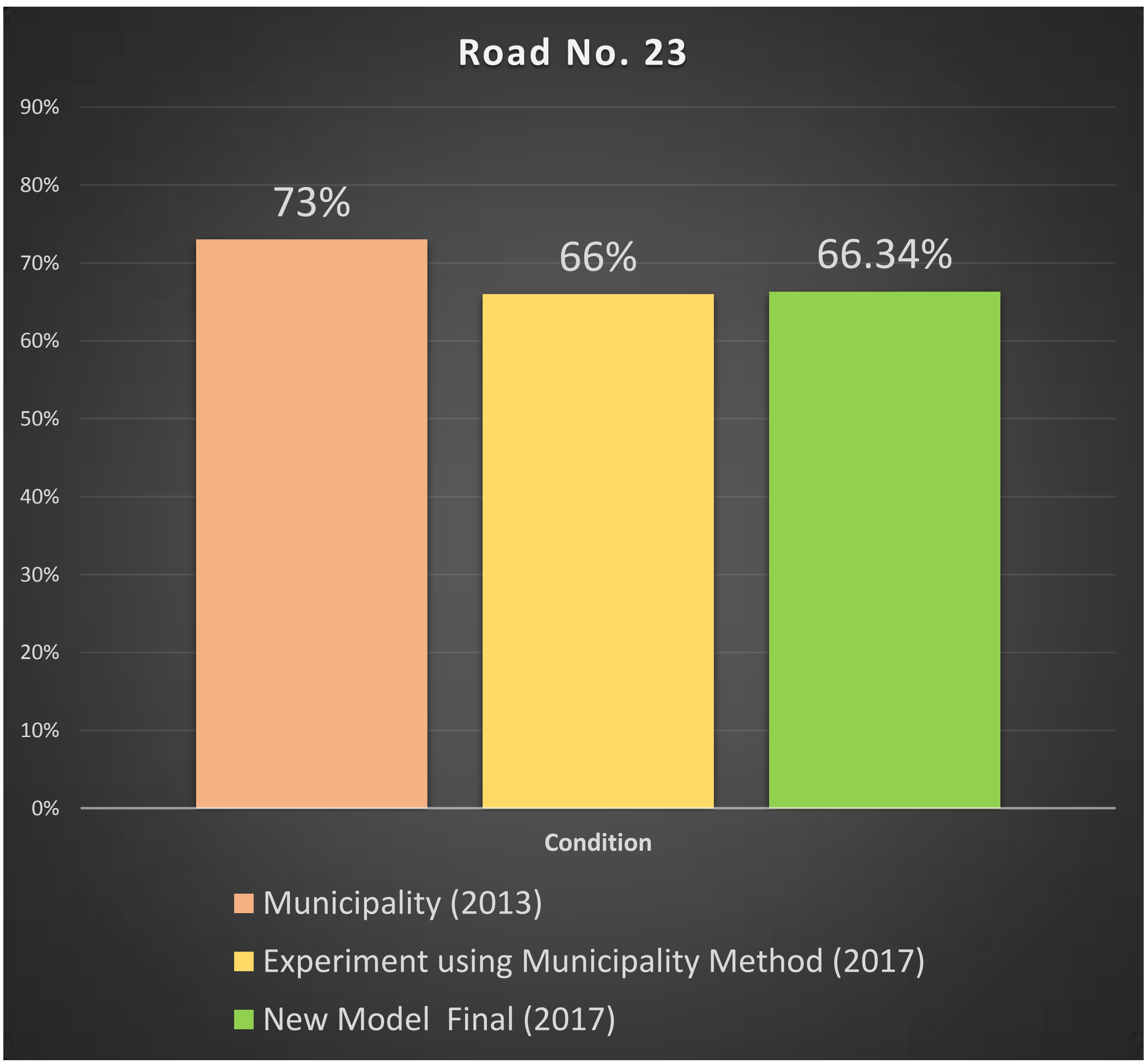


Fig. 4.10 Condition Assessment of Road No.23

Road number 23 is considered under expected results due to the declining condition. In 2013, the municipality condition for road number 5 was 73% according to the scale it is good. For the research's team experiment using the municipality method, the condition was 66% according to the scale it is good while 66.34% for the newly developed model. This case shows all the three models has the same condition, which is good, but with some small variation in the numbers.

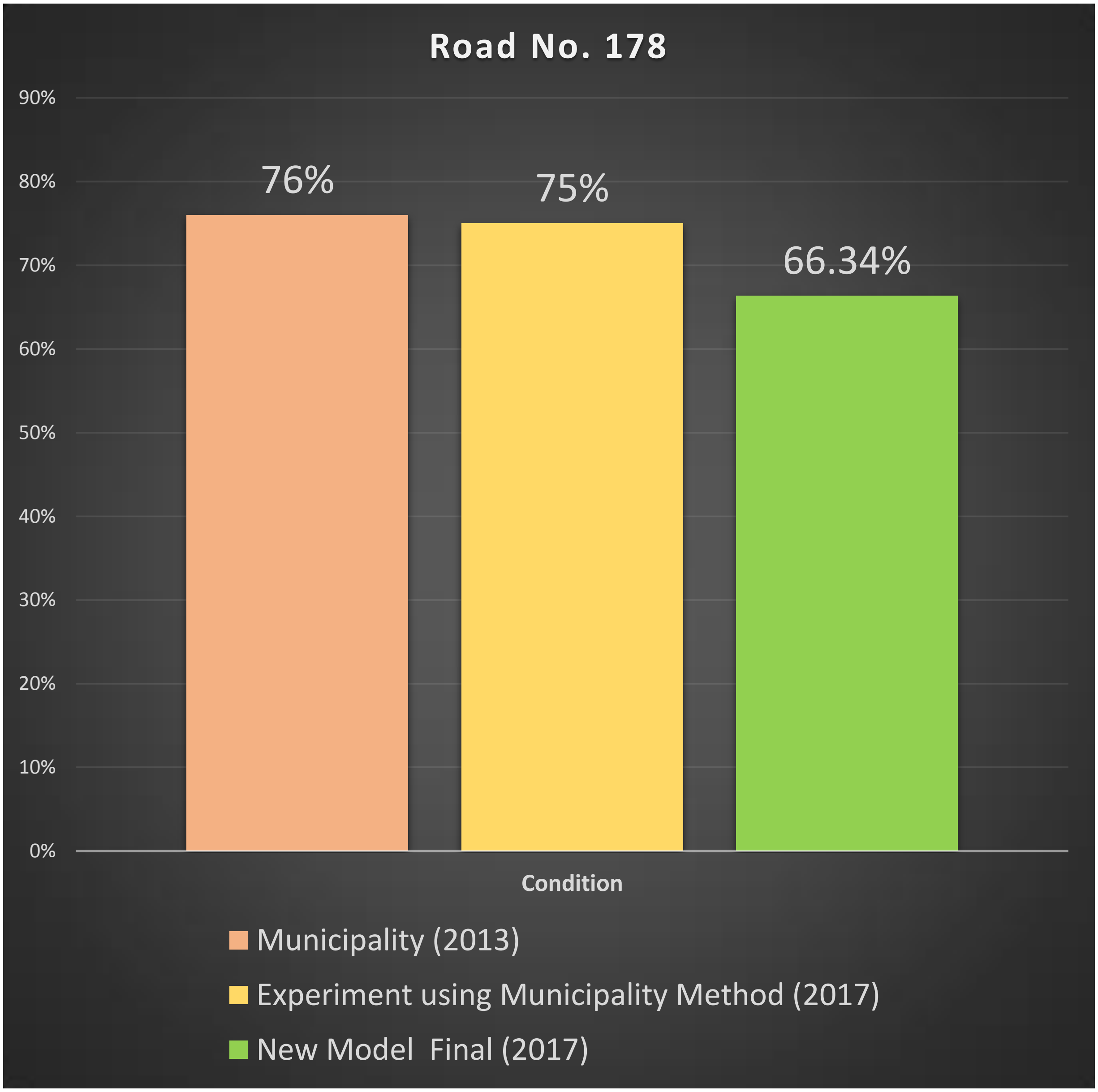


Fig. 4.11 Condition Assessment of Road No.178

Road number 178 is considered under expected results due to the declining condition. In 2013, the municipality condition for road number 178 was 76% according to the scale it is good. For the research's team experiment using the municipality method, the condition was 75% according to the scale it is good while 66.34% for the newly developed model. This case shows all the three models has the same condition, which is good, but with some small variation in the numbers.

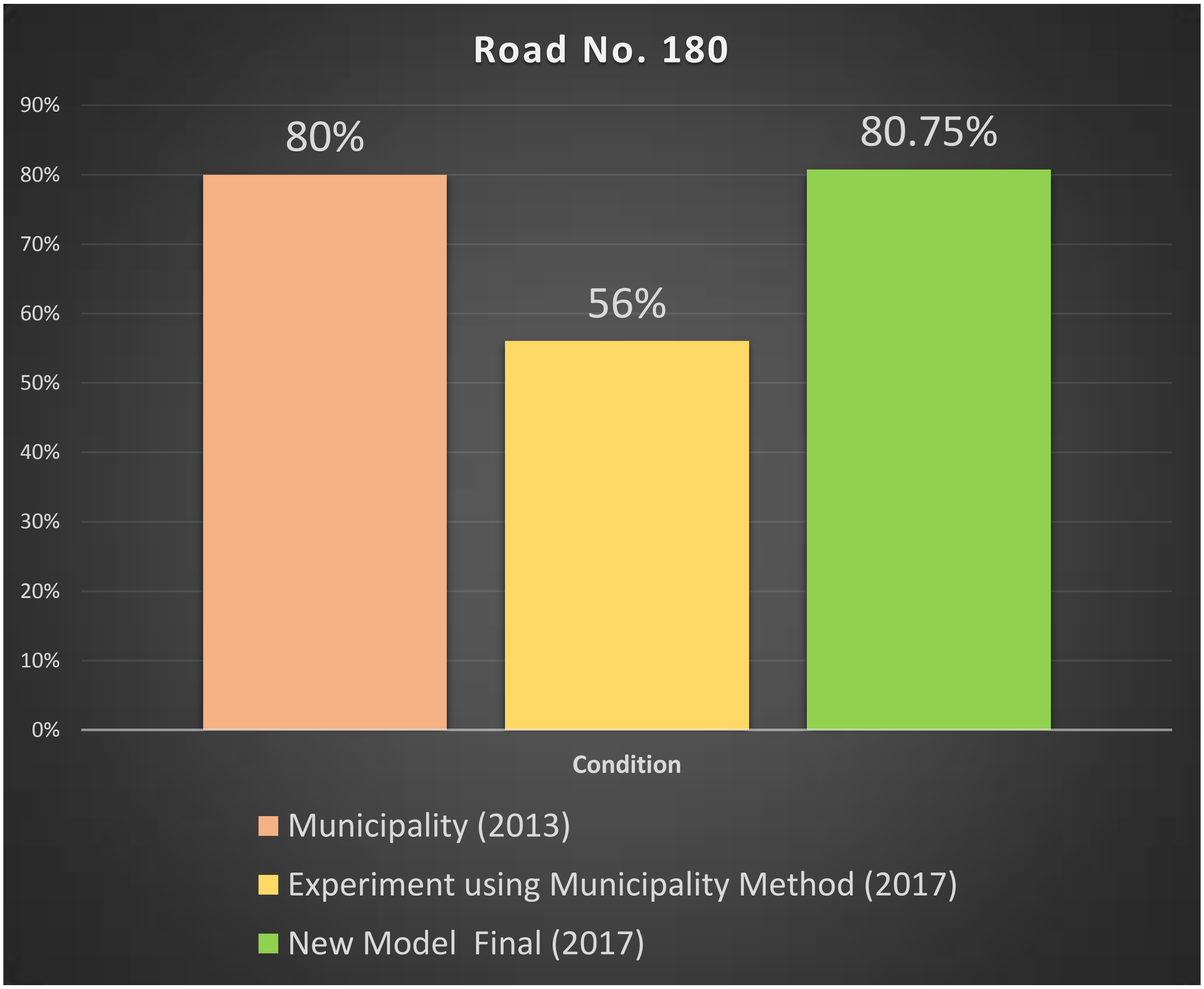


Fig. 4.12 Condition Assessment of Road No.180

Road number 180 is considered under balanced results due to the comprehensive condition. In 2013, the municipality condition for road number 180 was 80%, which is excellent according to the scale. For the research's team experiment using the municipality method, the condition was 56% according to the scale it is medium (drop), while 80.76% for the newly developed model (excellent). There is a similarity between the municipality work in 2013 and the new model, both has approximately the same condition but in the experiment in 2017, there is a certain drop from excellent to medium.

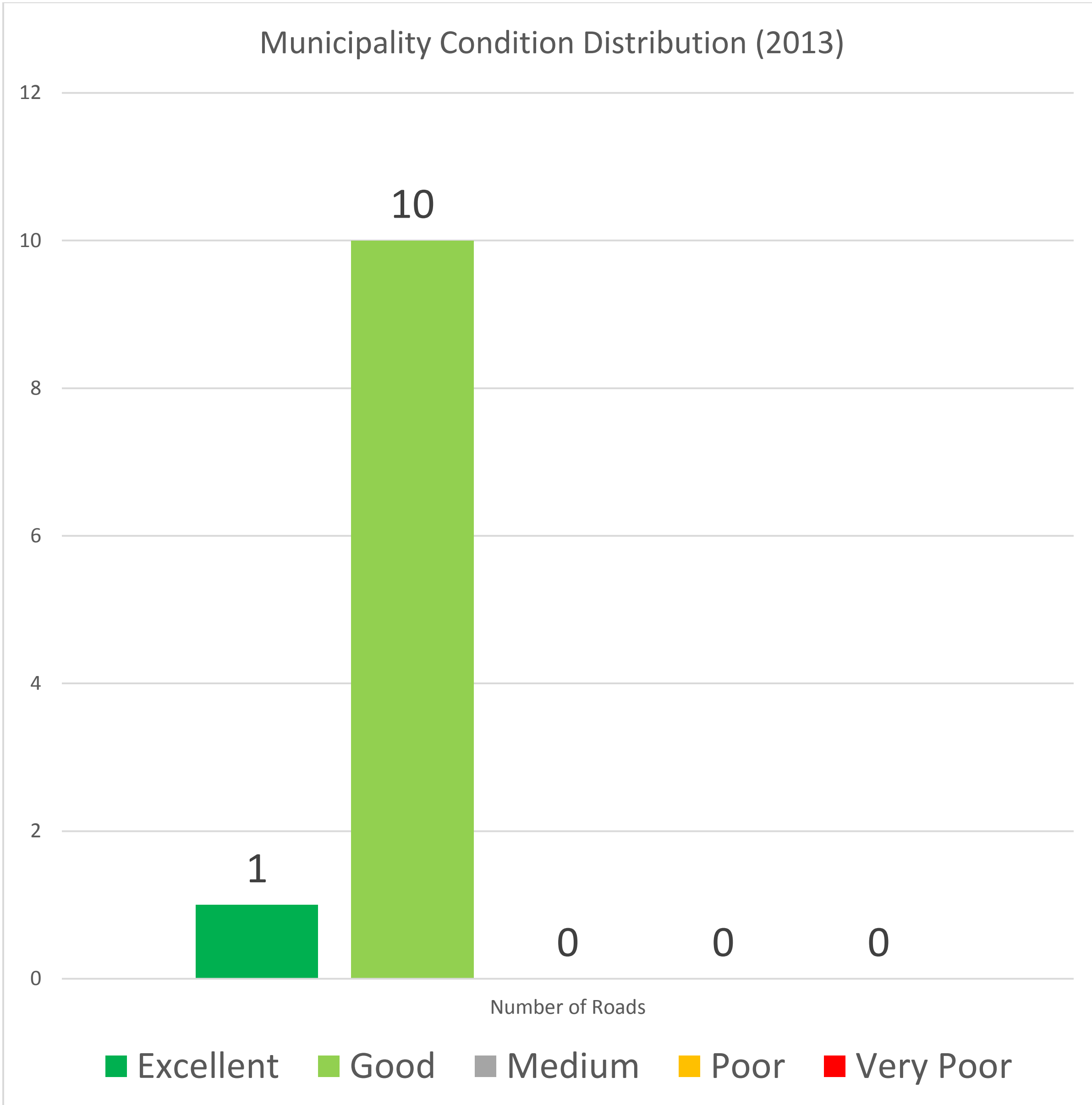


Fig. 4.13 Municipality Condition Distribution (2013)

The inspection in 2013 conducted by the municipality shows that 10 roads are in good condition. In Addition, the numbers are close to each other's values. Only one road is presented in an excellent condition. In four years gap until 2017, many factors will affect the roads as it is shown in the following Fig 4.13.

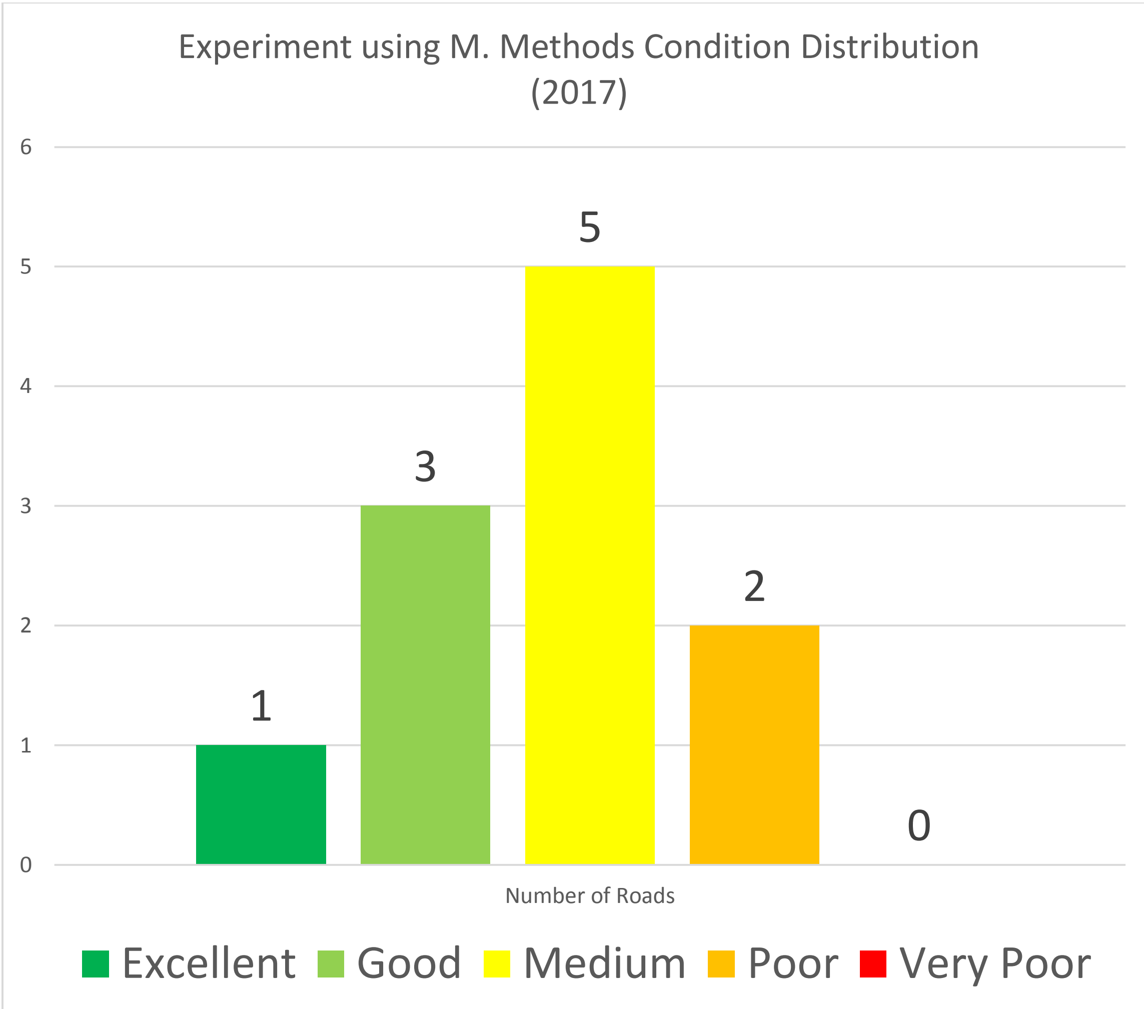


Fig. 4.14 Experiment using M. Methods Condition Distribution (2017)

The team experiment is conducted in 2017 to update the condition of the roads. This is to create the opportunity to compare the results of the current practice and the new model developed. In addition, to the last inspection of the municipality on this network was in 2013 as it is shown in Fig. 4.14. The results are satisfying to an extent, but there are critical changes in this time gap. The results show that one road excellent, while three are in a good condition. Furthermore, five roads are in a medium condition and finally, two are poor.

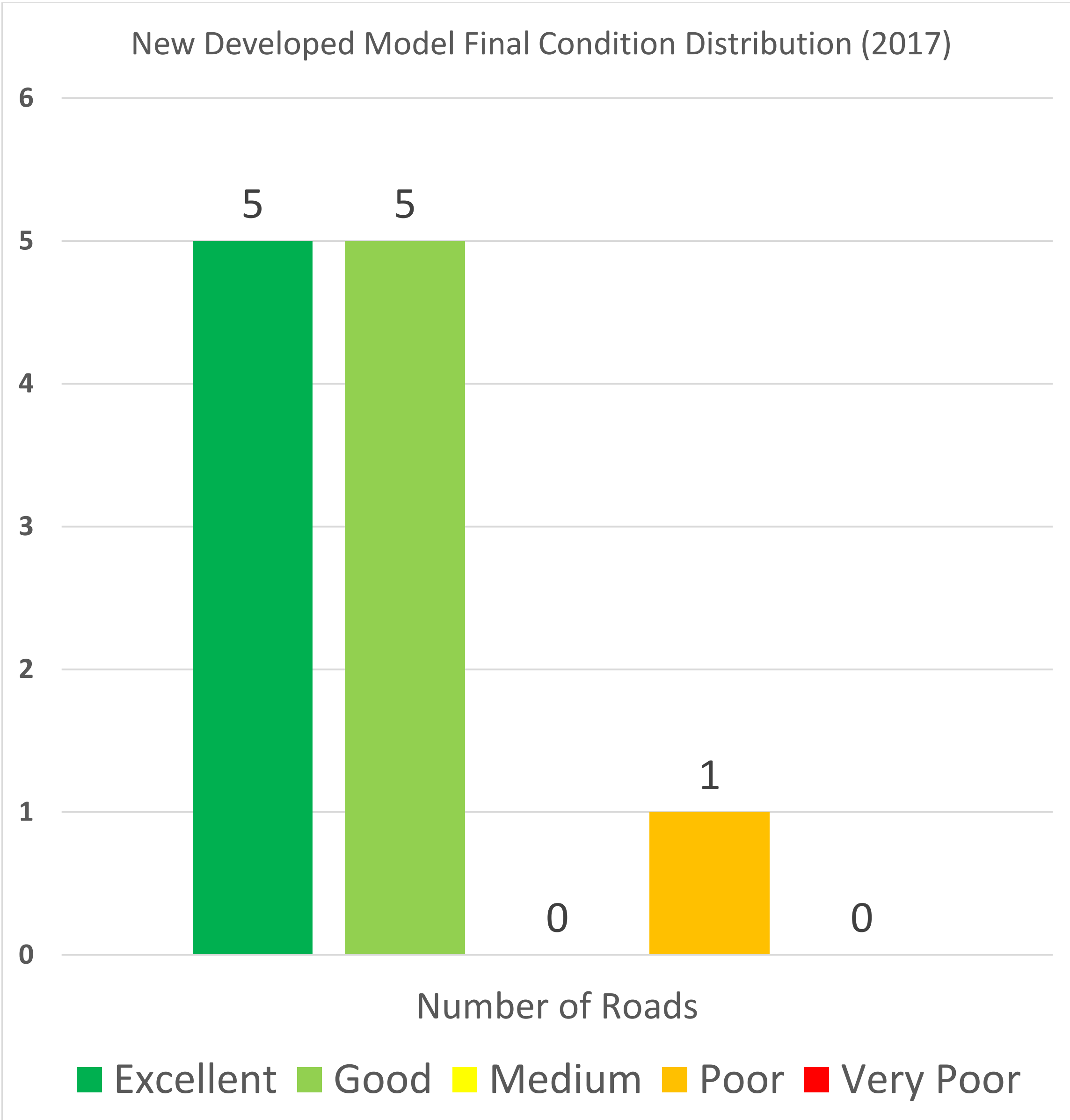


Fig. 4.15 New Model Final Condition Distribution (2017)

In the new model developed the results varies, but it is closer to the inspection of the municipality in 2013. It is noticeable that some roads (five roads) are getting better from good to excellent. In addition to another five roads are remaining good (the same condition). Finally only one drop from good to poor. These results can be caused by various factors including the size of the sample (25% municipality and 100% research team).

4.4 Validation

Validation in this research is the discussion of results with the local municipalities for their feedback. According to the municipality, the results require a benchmark for comparison. Two benchmarks are considered to compare the results conducted in 2017 done by the new model. The first case is the inspection in 2013. This is where all the roads condition was good scaled 4 out 5 approximately. The second case is an update made using an experiment using the municipality method in 2017. The changes introduced is not huge.

According to the benchmarks made, one of the roads (road NO. 3) should be redesigned according to the poor condition. Some roads condition became excellent instead of good (road NO. 6, 7, 8, 23). Having these numbers needs to be investigated and justified, the factors influencing the change in results, are the area of inspection taken. It is more accurate to take the whole street and inspect it, rather than taking 25% only (random samples). In addition, the method used is different and the number of defects also different. But the most influencing factor is the time gap between the two inspection times, representing 4 years gap.

Table 4.2 First Case Benchmark

Road Number	Municipality Condition (2013)	New Model Condition Final (2017)
3	71 %	38.80 %
4	78 %	78.98 %
5	69 %	74.60 %
6	69 %	85.60 %
7	77 %	83.60 %
8	65 %	86.23 %
9	67 %	75.16 %
21	69 %	74.98 %
23	73 %	66.34 %
178	76%	87.50 %
180	80%	80.75 %
Network CA	**72.2 %**	**61.1%**

* Note: colors represent the condition of the road.

The second case is the comparison made between two inspections the new model inspection the current practice experimented by the research's team to update the information, in order to eliminate the time gap. This will make the data more accurate and consistent.

Table 4.3 Second Case Benchmark

Road Number	Experiment condition using Municipality Method (2017)	New Model Condition Final (2017)
3	52 %	38.80 %
4	37 %	78.98 %
5	52 %	74.60 %
6	51 %	85.60 %
7	90 %	83.60 %
8	79 %	86.23 %
9	22 %	75.16 %
21	46 %	74.98 %
23	66 %	66.34 %
178	75 %	87.50 %
180	56 %	80.75 %
Network CA	**56.9 %**	**61.1%**

* Note: colors represent the condition of the road.

By comparing both results, the condition assessment for the roads is mostly changing some of them to the better and some for the worse. In the case of roads getting better (180, 178, 21, 9, 8, 6, 5,4). Roads NO. 9 and 4 shows a critical change. Furthermore, in the case of getting worse Road NO. 3 is considered. The remaining roads are keeping the same condition like Road NO. 23 and 7. The most critical factor is the percentages of the inspection area taken, then the method used to evaluate comes second, where the comprehensive way is more accurate.

Chapter 5: Conclusion, Limitations and Recommendations

5.1 Conclusion

A discussion is required for each road to establishing in order to understand the trend of the data and the defects. The defects identification and definition is available in Appendix C. In the following is the detailed results from each road:

i. Road No. 3

Road number 3 shows a variety of defects in the four categories where the 1.4 holes, 1.1 deformations, 1.2 cracks, 2.1 patches, 2.2 intruding connections, 2.3 points of repair, 3.2 raveling, 3.1 swelling, 2.4 attached deposits and 4.3 instructional lining are available on this road. this will increase the probability of the risk in this case. The total area of defects added is 595 m² and the total area is 10598.4 m². The adjusted area of defects is 61.17 m². The condition assessment is 38.83%, according to the scale, it is **poor.**

Table 5.1 Defects for Road No.3

			Severity		
Road NO	**Area**	**Defect**	**L**	**M**	**H**
3	**883.2 × 12**	**2.2**	**15**		
		3.2	**3**	**8**	**20**
		2.3		**30**	**100**
		2.1	**15**	**10**	
		1.2	**5**	**12**	
		1.1	**5**	**12**	**40**
		1.4		**15**	**60**
		2.4	**15**		**100**
		3.1	**15**	**30**	
		4.3			**100**

ii. Road No. 4

The road number 4 defects include patching with different severities are available on this road, medium and low cracks, the holes some are high severity and some are low severity, the attached deposits here are medium, the raveling in this road is low, and no instructional linings. the total area of defects is 274 m² out of the total area of the road is 831.6 m². The adjusted area of defects is 21.0175 m². The condition assessment is 78.98%, according to the scale, it is **good**.

Table 5.2 Defects forRoad No.4

			Severity		
Road NO	**Area**	**Defect**	**L**	**M**	**H**
4	**59.8 × 14**	**2.1**	**2**	**15**	**30**
		1.2	**15**	**30**	
		1.4	**5**		**40**
		2.4		**30**	
		3.2	**7**		
		4.3			**100**

iii. Road No. 5

The defects contained in road number 5 are attached deposits defect is medium severity in this road, and medium ravelling too, the patches are low in severity and in score, it has some low intruding connections, the swelling exists in this road with high severity and score, medium holes are exists, some point of repair defects with low and medium severities and no instructional linings. the total area of defects is 340 m² out of 1716 m². The adjusted area of defects is 25.4 m². The condition assessment is 74.6%, according to the scale, it is **good**.

Table 5.3 Defects for Road No.5

Road NO	Area	Defect	Severity L	Severity M	Severity H
5	156 × 11	2.4		30	
		3.2		12	
		2.1	8		
		2.2	15		
		3.1			100
		1.4		30	
		2.3	15	30	
		4.3			100

iv. Road No. 6

The road number 6 shows cracks with low severity, low and medium severity patches, medium raveling and no instructional linings. The total area of defects is 190 m² out of 1796.4 m². The adjusted area of defects is 14.387 m².². The condition assessment is 85.6%, according to the scale it is **excellent**.

Table 5.4 Defects for Road No.6

Road NO	Area	Defect	Severity L	Severity M	Severity H
6	149.7 × 12	1.2	15		
		2.1	8	7	
		3.2		30	
		2.2		30	
		4.3			100

v. Road No. 7

The defects in road number 7 contain utility patches with low severity, Low intruding connections, low and high severities in cracks, the surface cleaning in this road is low and needed, the attached deposits with low severity and finally no instructional linings. The total area of defects is 184 m^2 out of 469 m^2. The adjusted area of defects is 16.38 m^2. The condition assessment is 83.6%, according to the scale it is **excellent**.

Table 5.5 Defects forRoad No.7

			Severity		
Road NO	**Area**	**Defect**	**L**	**M**	**H**
7	67 × 7	2.1	4		
		2.2	15		
		1.2	15		20
		3.3	15		
		2.4	15		
		4.3			100

vi. Road No. 8

The defects in road number 8 are low severity patches, deformation with medium severity, low severity cracks, some medium points of repair defects, attached deposits with high severity and score, low intruding connections and finally medium raveling. The total area of defects is 209 m^2 out of 465.5 m^2. The adjusted area of defects is 13.8 m^2. The condition assessment is 83.6%, according to the scale it is **excellent**.

Table 5.6 Defects for Road No.8

Road NO	Area	Defect	Severity L	Severity M	Severity H
8	66.5 × 7	2.1	10		
		1.1		10	
		1.2	15		
		2.3		30	
		2.4			100
		2.2	15		
		3.2		29	

vii. Road No. 9

Road number 9 contains low and medium patches, medium and high severity holes, low and high severity cracks, medium deformation and raveling, finally no instructional linings. The total area of defects is 422² out of 1914 m². The adjusted area of defects is 24.84 m². The condition assessment is 75.16%, according to the scale, it is **good**.

Table 5.7 Defects for Road No.9

Road NO	Area	Defect	Severity L	Severity M	Severity H
9	159.5 × 12	2.1	15	25	
		1.4		12	60
		1.2	15		60
		1.1		30	
		3.2		30	
		4.3			100

viii. Road No. 21

Road number 21 contains medium intruding connections, patches with all severities, medium cracks, medium and high severity holes, attached deposits with low and medium severities, and no instructional linings. the total area of the defect is 273m² out of 2869.9 m². The adjusted area of defects is 25.02 m². The condition assessment is 74.95%, according to the scale, it is **good.**

Table 5.8 Defects for Road No.21

Road NO	Area	Defect	Severity		
			L	M	H
21	220.3×13	2.2		30	
		2.1	3	10	15
		1.2		30	
		1.4		30	60
		2.4	15	30	
		4.3			100

ix. Road No. 23

Road number 23 Low and high intruding connections, medium and high severity points of repair, low and medium patches, raveling in all severities, low and medium cracks, low and high attached deposits, medium and high holes, low-severity surface cleaning and finally no instructional linings. the total area of defects is 573 m² out of 6297 m². The adjusted area of defects is 33.66 m². The condition assessment is 66.34% according to the scale it is **good**.

Table 5.9 Defects for Road No.23

Road NO	Area	Defect	Severity L	Severity M	Severity H
23	419.8×15	2.2	15		100
		2.3		30	40
		2.1	2	9	
		3.2	4	10	40
		1.2	5	8	
		2.4		30	40
		1.4		25	100
		1.1		20	80
		3.3	15		
		4.3			100

x. Road No. 178

Road number 178 shows medium patches, low and high cracks and no instructional linings. the total area of defects is 126 m² out of 1141.9 m². The adjusted area of defects is 12.46 m². The condition assessment is 87.54%, according to the scale it is **excellent**.

Table 5.10 Defects for Road No.178

Road NO	Area	Defect	Severity L	Severity M	Severity H
178	60.1x19	2.1		8	
		1.2	8		10
		4.3			100

xi. Road No. 180

Road number 180 contains attached deposits with high severity, low cracks, and no instructional linings. The total area of defects is 215 m² out of 228.75 m². The adjusted area of defects is 19.29m². The condition assessment is 80.71%, according to the scale it is **excellent**.

Table 5.11 Defects for Road No.180

			Severity		
Road NO	**Area**	**Defect**	**L**	**M**	**H**
180	**30.5×7.5**	**2.4**			**100**
		1.2	**15**		
		4.3			**100**

From the results shown, it is noticeable that the main categories of failure are structure primarily and construction secondly. Many of the road in the sample had a significant amount of cracks, depression, and holes in some cases. Furthermore, the main defects under construction category were Patches and attached deposits. The availability of patch throughout the roads was clearly visible and plenty. The attached deposits were visible, but not huge quantities. It was usually concrete deposits and close to construction sites. These results indicate the usage, reactions to temperature and local trend of the roads. Further studies are required to specifically find the correlation between these factors.

5.2 Limitations

During the research, some limitations were discovered. Firstly, the data was collected in weather changing season specifically in winter season. The winter season in Dammam, Saudi Arabia come with moderate rains and close to cold temperatures. This can cause a variation in the defects size and properties due to the rain. These variations can cause the changes in the results especially if the data were collected on separate days. Furthermore, some road information and data is difficult to find and often confidential which was not included in the research. Some of these data are important to consider especially the physical properties of the roads. This may introduce new opportunities which were unfortunately not used for this research.

According to the Dammam Municipality, the new technologies to identify and measure the road defects are available but not utilized. This can be due to various reasons including cost and transportation. If those technologies were used, an update for the municipality data may have been created. Also, less time would have been consumed in order to collect all data. It influenced the way of the data collection and made it visual inspection base.

Due to the time constraint of the research, limited surveys were collected. This affects the overall weight of the factors in the failure hierarchy. More surveys were required to establish more detailed values for the weight. Also, more surveys can provide a statistical study related to the weight distribution. Another limitation of the research is that to calculate the condition of the roads network, some variable were redeemed constantly in the case of domestic roads. These factors include traffic flow, capacity, thickness and pavement materials. These assumptions are required to change in case of main roads or highways.

Finally, The municipality data used for the comparison study of conditions was created in 2013. This affects the overall comparative results due to the time gap (4 years) and the changes that occurred. The changes can include maintenance or replacement of the roads. This happened due to the unavailability of newly updated data in the municipality. This is critical in order to study the trend and comparison of the results.

5.3 Recommendations

For future improvements and research, some suggestions are recommended. The first suggestion is that more surveys are required to refine the weights used in the model. This step may cause a significant change in the results. In addition, internationally surveys should be conducted, which would provide a refinement to the general weight of each category. The second suggestion should be that a stable weather season is required to obtain the field data with minimum alteration. The suggested season is Spring-Summer due to the little variation that might occur.

The third suggestion is that more factors must be taken into consideration in studying the condition assessment of road network, which includes Road class (Major, highway or domestic). Factor like road thickness, capacity, traffic flow, etc. These factors will affects the results computation for the condition assessment of the roads network. In addition, more Infrastructure manuals utilization is favored to refine the research. This includes manuals from the European continent and infrastructure asset management specialized countries. Another significant recommendation is studying new current practices in different countries. This may introduce more opportunities in the in this field of research and its application in Saudi Arabia. This could be new technologies, a method to collect and categorize the data.

For the fourth suggestion, if further investigation and comparative study are required, the latest data from the municipality is required. This is because the municipality data used were established since 2013. Due to the time gap, many changes and factors must have change. The municipality data that is required in the future research must be within the same timeline of the research. Another change suggested is conducting the scores in different sites with different environments. This will provide a variation in the results, which refines and generalizes the developed model.

Applying the SMART &AHP methods on another type of horizontal assets to enhance the research of infrastructure asset management. The application should be applied for sewage and water drainage systems in Saudi Arabia. This can result in a correlation study between all infrastructure assets.

Utilizing new technologies available in the local market is a recommendation. This will enhance the data collection and the details of the data. It would also reduce the period required to collect the data. In addition, new software should be introduced into future research for data calculation, data sorting, and probability computation. These extra features would introduce a great support and refine the research. Finally, the last recommendation is to conduct a study on maintenance inspection plans. These are the stages of maintenance throughout the lifecycle of an asset. Studying this field will develop the current practice of the region.

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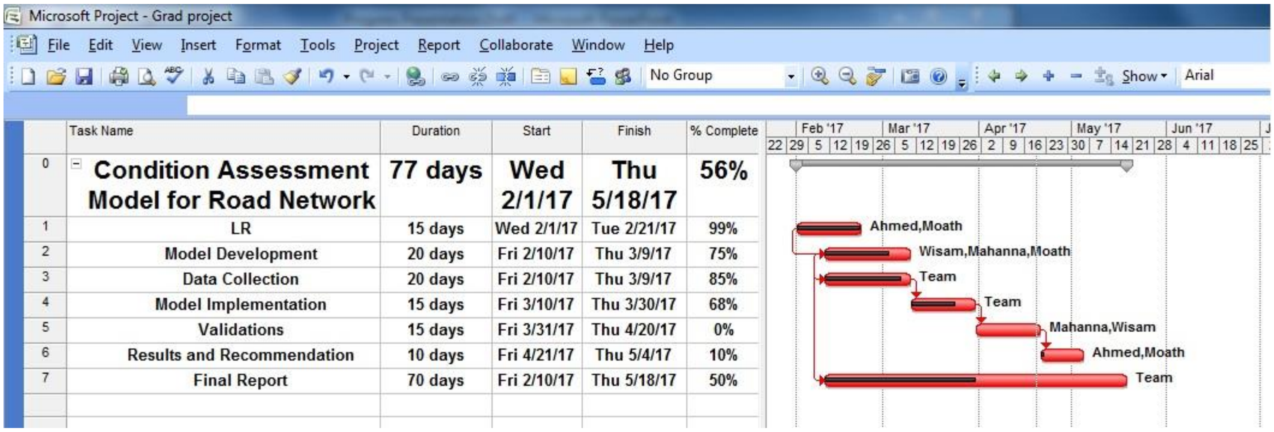
Appendix A: Project Management

A.1 Project Plan



	Task Name	Duration	Start	Finish	% Complete
0	Condition Assessment Model for Road Network	77 days	Wed 2/1/17	Thu 5/18/17	56%
1	LR	15 days	Wed 2/1/17	Tue 2/21/17	99%
2	Model Development	20 days	Fri 2/10/17	Thu 3/9/17	75%
3	Data Collection	20 days	Fri 2/10/17	Thu 3/9/17	85%
4	Model Implementation	15 days	Fri 3/10/17	Thu 3/30/17	68%
5	Validations	15 days	Fri 3/31/17	Thu 4/20/17	0%
6	Results and Recommendation	10 days	Fri 4/21/17	Thu 5/4/17	10%
7	Final Report	70 days	Fri 2/10/17	Thu 5/18/17	50%

Project Plan During Midterm

A.2 Contribution of Team Members

The team members study the current practice very well, where all the team contributed in the data collection in this area. In the model development and analysis, Moath took this task and did some adjustments on the SMART equation in order to adjust the results. Ahmed played a big role in the software parts in GIS ArcMap and Microsoft project, and the writing part was divided among the group. Mahanna and Wisam both played good efforts in data calculation direct after the data collection in order to find the results equally.

-Moath: Model development and Implementation, writing the report and organizing meetings, and survey collecting (25%)

-Ahmed: GIS ArcMap and Microsoft Project expert, report writing, Model implementation. (25%)

-Mahanna: Model implementation, data collection, meetings. (25%)

-Wisam: Model implementation, Data collection, Meetings. (25%)

A.3 Project Execution Monitoring

List various activities:

Meetings:

-The meetings with Dr. Alaa Salman was a year before the semester to take classes in construction management and in methods used in this field to prepare the team to face the reality. The meetings from that time until the end of the research are weekly, to update the team's progress.

The team started to search and explore the responsible people, in municipalities, companies and establishments contractors.

-Meeting with Eng. Kamal Batrawi and Eng Mohammed Alnemer to discuss the maintenance procedure.

-Various meetings with Dr. Issam Abkar, Eng Mokaled, Eng. Saud Mokaled and Eng Hamdan Almutairi from Municipality of Dammam to discuss the progress of the work and to observe and guide the flow of the research, and finally, validate the results.

-Meeting with Transportation Department instructors in the University of Dammam to collect the surveys and take their opinions.

Other Activities:

-GIS tutorial with Eng. Saud Mokaled.

-Uploading the GIS ArcMap's on the laptops

-Using Microsoft Project to observe the progress of the team

-Taking a tutorial on how the municipalities collect data from the field and how to use the measurements equipment.

Team meetings:

The team is daily meeting because the schedule is made the same for them in order to stay together and work properly.

-Meetings out of the University are made every two days.

A.4 Challenges and Decision Making

-The availability of the data was challenging to find, and still not the required one, so the team collected the data using the current practice applied by the municipality of the city, to update the data, this wasted a lot of time.

- Reaching to people, required from the team a lot of effort and time, to find the responsible people.

- The weather condition was changing and challenging where the weather affected the results.

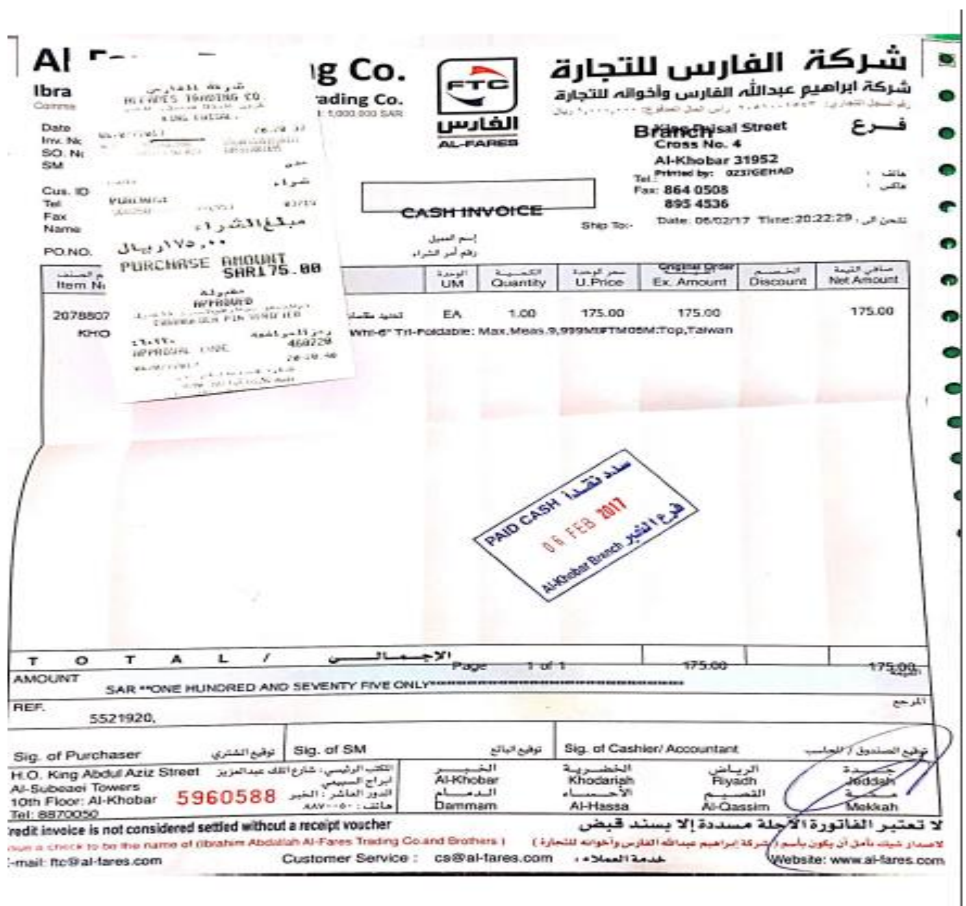
- Organizing the work between the team was challenging, where each member lives in a different city.

- collecting the surveys from a certain class of experts was so challenging and the time was not enough to reach the required number of surveys.

-learning the GIS ArcMap was a challenging experience, and finding the experts in this field was challenging and helpful at the same time.

A.5 Project Bill of Materials and Budget (if applicable)

This Project is funded by Prince Mohammed Bin Fahd University (PMU).



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Invoice for Measuring Wheel used in data Collection

Appendix B: Project Analysis

B.1 Life-long Learning

During the research period, some experiences, information, skills, and software have been utilized, studied and improved. They include the following

- ArcMap (GIS) for geographic illustrations
- Microsoft Project for project planning and scheduling
- Teamwork and communication skills
- Presentation and advertisement skills
- Applying theories taught in practical work
- Meeting new people with great Real-Life experience
- Using new methods and theories in construction management to solve problems and create mathematical problems.
- Time management skill and its importance.

The main source of information was Dr. Alaa Salman, who provided the research for books and information. The Secondary source of information is Google and Google Scholar, where previous researches have been available. In addition, any information regarding the data for the roads in the region is the municipality of Greater Dammam.

B.2 Impact of Engineering Solutions

This research's primary customer is the government. This is because the data collection, analysis, and modeling could provide an opportunity to save cost and time in the future. In addition, if the research is utilized correctly, departments like infrastructure asset management could be implemented. This would provide new jobs for the society and faster processing of asset assessment and maintenance. The secondary customer is the society. They would have a better maintenance plan for assets, which improves the quality of the infrastructure and ultimately satisfies the public.

B.3 Contemporary Issues Addressed

Some road information and data is difficult to find and often confidential which was not included in the research. Some of these data are important to consider especially the physical properties of the roads. This may introduce new opportunities, which was unfortunately not used for this research. Furthermore, the municipality data used for the comparison study of conditions was created in 2013. This affects the overall comparative results due to the time gap (4 years) and the changes that occurred.

Appendix C: New Road Manual with Definitions

1. Structure:

1.1 Deformation and Depression:

Definition: Settlement in foundation and collection of water.

Severity:

N: does not exist

L: 5% of the total volume of the road

M: 30% of the total volume of the road

H: 70% of the total volume of the road

1.2 Cracks:

Definition: longitudinal separation of asphalt layer

Severity:

N: do not exist

L: Surface Fissure 2mm to 5cm

M: Visible Break 5mm to 1cm

H: Collapsed crack 1 cm and above

1.3 Curvature:

Definition: Displacement in parts of the sections of the street horizontally

Severity:

N: both sides are parallel

L: from 1° to 5°

M: from 5.1 °to10°

H: 10.1° and above

1.4 Holes

Definition: A gap with depth within the road.

Severity:

N: not exist

L: Less than 90 mm

M: Between 90mm and 150mm

H: Above 150 mm

2. Construction:

2.1 Patching and Utility Cut Patch

Severity:

N: Not exist

L: Regular shape without convexity or concavity

M: 2cm to 5cm of convexity or concavity

H: more than 5 cm of convexity or concavity

2.2 Intruding Connection:

Definition: Projection in the Transitional area between streets.

Severity:

N: Same level of the connected road

L: 1mm to 2cm projection

M: 2 cm to 5 cm projection

H: more than 5 cm of projection

2.3 Point of repair component:

Definition: change in construction material, dimension, shape or point repair curvature

Severity:

L: Damage does not exist

H: Damage exists

2.4 Attached deposits:

Definition: Material attached to the surface

Severity:

N: No deposits attached

L: 40 cm^2 to 1 m^2 area of attached deposits

M: 1m^2 to 2 m^2 area of attached deposits

H: More than 2 m^2 area of attached deposits

3. Environmental:

3.1 Swell:

Definition: frost action in sub-grade

Severity:

N: No swelling

L: height 2 cm to 4 cm of swelling

M: height 4cm to 6cm of swelling

H: Height 6cm and above of swelling

3.2 Raveling and Weathering:

Definition: wearing of the pavement surface by loss of asphalt binder

Severity:

N: None

H: Exists

3.3 Surface Cleaning:

Definition: presence of solid deposits on the surface

Severity:

N: Clean

L: < 10% garbage from the total area

M: 10% to 20% garbage from the total area

H: more than 20% garbage from the total area

4. Miscellaneous:

4.1 Rutting:

Definition: surface depression in wheel path

Severity:

N: No rutting

H: Rutting exists

4.2 Oil spillage:

Definition: spillage of oil or other solvents

Severity:

N: No Oil Exists

H: Oil Exists

4.3 Instructional Lining:

Definition: Inability to recognize the instructional lines in the road

Severity:

N: Exists and Clear

L: Exist but almost clear

M: Exist but not clear

H: Do not exist

Appendix D: Survey using AHP

Dear Sir/ Madame,

We are senior civil engineering students at PMU (Prince Mohammed Bin Fahd University). We are currently conducting a project on the Condition Assessment of Road Networks in Dammam City. The hierarchy of the proposed model is shown in the next paper. It includes different road defects based on four categories (structure, construction, environmental, and miscellanea).

We would be grateful if you could complete the attached Excel sheet. Please fill only the white spaces with a scale **"1.0"** (Weak Priority) to **"1.9"** (High Priority), similar to the example shown below. This **would take only 5 minutes,** ***and please send it back to Mr.Moath Alrifai (moaathalrifai@hotmail.com) or to Dr.Alaa Salman (asalman@pmu.edu.sa)*** **or** ***Mr. Ahmed Omar*** (***ahmedomar3713@gmail.com***)

Example:

	X1	X2	X3
X1			
X2	**2.0**		
X3	**1.5**	**0.5**	

- X2 is **2.0** important than X1.
- X3 is **1.5** important than X1.
- X3 is **0.5** important than X2.

Please be assured that all information shared will be strictly confidential and used only for academic purposes. Please do not hesitate to contact us if you need any clarification or additional information. Sharing your valuable information is highly appreciated.

Best regards,

Moath Alrefai, Ahmed Omar, Wisam Aldali and Mahanna Alnaimi

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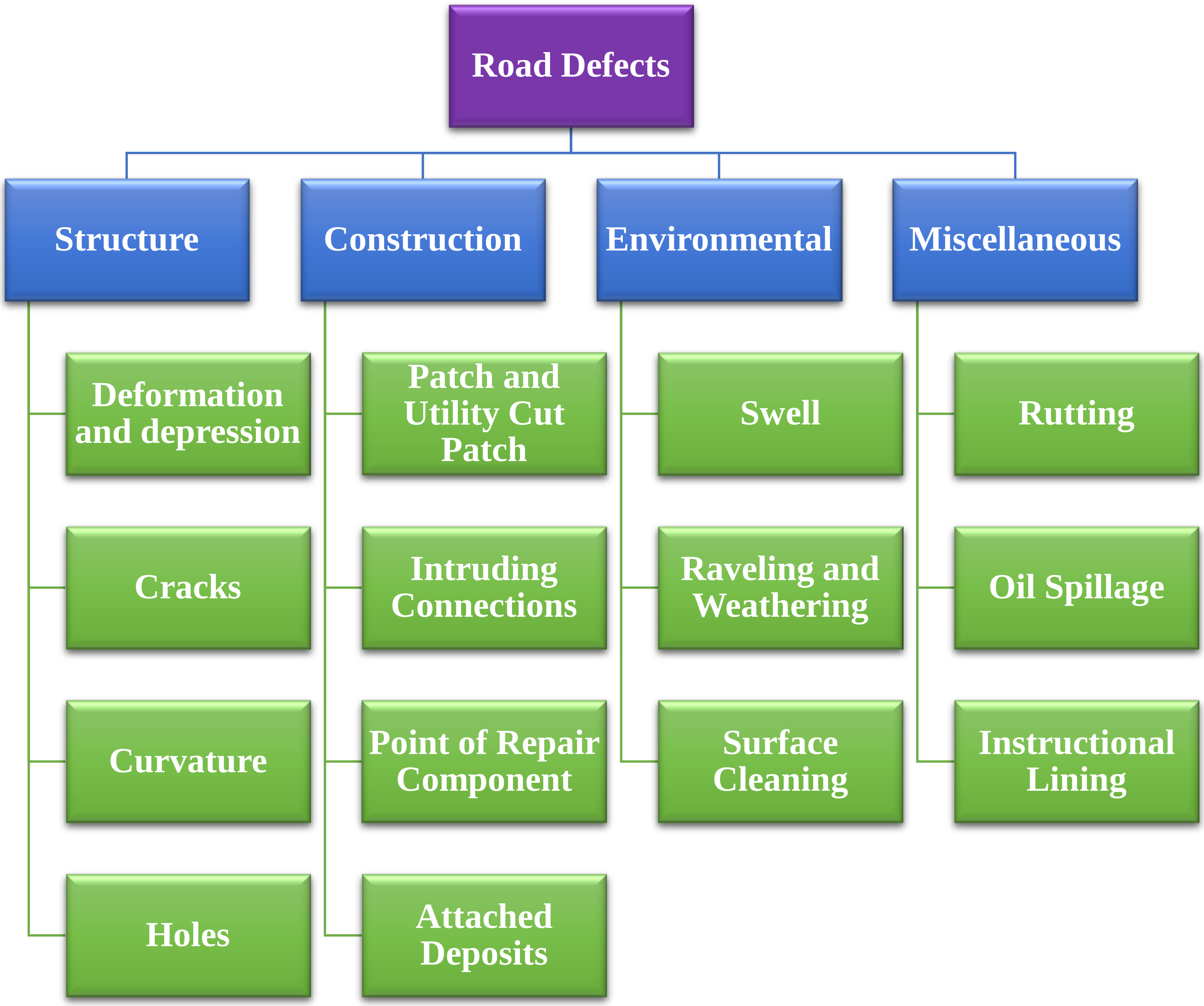
Road Defects
Structure
Construction
Environmental
Miscellaneous
Deformation and depression
Cracks
Curvature
Holes
Patch and Utility Cut Patch
Intruding Connections
Point of Repair Component
Attached Deposits
Swell
Raveling and Weathering
Surface Cleaning
Rutting
Oil Spillage
Instructional Lining

Factor	Structure	Construction	Environmental	Miscellaneous
Structure				
Construction				
Environmental				
Miscellaneous				

Structure	Deformation and Depression	Cracks	Curvature	Holes
Deformation and Depression				
Cracks				
Curvature				
Holes				

Construction	Patching and Utility Cut Patch	Intruding Connection	Point of Repair Component	Attached Deposits
Patching and Utility Cut Patch				
Intruding Connection				
Point of Repair Component				
Attached Deposits				

Environmental	Swell	Raveling and Weathering	Surface cleaning
Swell			
Raveling and Weathering			
Surface Cleaning			

Miscellaneous	Rutting	Oil Spillage	Instructional lining
Rutting			
Oil Spillage			
Instructional Lining			

Appendix E: Survey results using AHP

1-Eng.Mohammed Alrefai (Ansab Est.)

عيوب هيكله	1.00	0.91	0.91	0.91	0.23
عيوب انشائية او اصلاحية	1.10	1.00	0.91	0.87	0.24
عيوب بيئيه	1.10	1.10	1.00	0.77	0.24
عيوب أخرى	1.10	1.15	1.30	1.00	0.28
Sum	4.30	4.16	4.12	3.55	1.00

عيوب انشائية او اصلاحية	عيوب الرقع	عيوب وصلات الطرق ببعضها	عيوب نقط الاصلاح	عيوب المواد المتراكمة	Weight
عيوب الرقع	1.00	0.67	0.59	0.63	0.17
عيوب توصيل الطرق	1.50	1.00	0.63	0.80	0.23
عيوب نقط الاصلاح	1.70	1.60	1.00	0.83	0.30
عيوب المواد المتراكمة	1.60	1.25	1.20	1.00	0.30
Sum	5.80	4.52	3.41	3.26	1.00

عيوب أخرى	التخدد	عيب انسكاب الزيوت	عيوب في تخطيط الطرق	Weight
التخدد	1.00	0.53	0.71	0.24
عيب انسكاب الزيوت	1.90	1.00	0.91	0.39
عيوب في تخطيط الطرق	1.40	1.10	1.00	0.38
Sum	4.30	2.63	2.62	1.00

عيوب بيئيه	عيب الانتفاخ	عيوب التعرية و التجوية	نظافة الطرق	Weight
عيب الانتفاخ	1.00	0.71	0.71	0.26
عيوب التعرية و التجوية	1.40	1.00	0.67	0.32
نظافة الطرق	1.40	1.50	1.00	0.42
Sum	3.80	3.21	2.38	1.00

عيوب هيكليه	عيب الانخفاض و التشوه	عيوب الشروخ	عيوب انحنائية	عيوب الحفر	Weight
عيب الانخفاض و الهبوط	1.00	0.91	0.91	0.71	0.21
عيوب الشروخ	1.10	1.00	0.71	0.59	0.20
عيوب انحنائية	1.10	1.40	1.00	0.56	0.23
عيوب الحفر	1.40	1.70	1.80	1.00	0.35

2-Eng. Mousa Alareed-(Ansab Est.)

Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.77	0.71	0.71	0.19
Construction	1.30	1.00	0.77	0.71	0.23
Environmental	1.40	1.30	1.00	0.71	0.26
Miscellaneous	1.40	1.40	1.40	1.00	0.32
Sum	5.10	4.47	3.88	3.14	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Compone	Attached Deposit	Weight
Patching and Utility Cut Pa	1.00	0.71	0.83	0.83	0.21
Intruding Connection	1.40	1.00	0.71	0.83	0.24
Point of Repair Componet	1.20	1.40	1.00	0.83	0.27
Attached Deposits	1.20	1.20	1.20	1.00	0.28
Sum	4.80	4.31	3.75	3.50	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.91	0.59	0.27
Oil Spillage	1.10	1.00	0.83	0.32
Instructional Lining	1.70	1.20	1.00	0.42
Sum	3.80	3.11	2.42	1.00

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight
Swell	1.00	0.83	0.77	0.28
Raveling and Weathering	1.20	1.00	0.67	0.31
Surface Cleaning	1.30	1.50	1.00	0.41
Sum	3.50	3.33	2.44	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depressio	1.00	0.67	0.71	0.91	0.20
Cracks	1.50	1.00	0.71	0.91	0.25
Curvature	1.40	1.40	1.00	0.91	0.29
Holes	1.10	1.10	1.10	1.00	0.27

3-Eng. Ishtiyaq Ahmed-(Zuhair Fayez Co.)

Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.53	0.56	0.77	0.17
Construction	1.90	1.00	0.59	0.56	0.22
Environmental	1.80	1.70	1.00	0.77	0.29
Miscellaneous	1.30	1.80	1.30	1.00	0.32
Sum	6.00	5.03	3.44	3.09	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	oint of Repair Compon	ttached Deposit	Weight
Patching and Utility Cut Patch	1.00	0.71	0.67	0.77	0.19
Intruding Connection	1.40	1.00	0.77	0.83	0.24
Point of Repair Componet	1.50	1.30	1.00	0.83	0.28
Attached Deposits	1.30	1.20	1.20	1.00	0.29
Sum	5.20	4.21	3.64	3.44	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.83	0.77	0.29
Oil Spillage	1.20	1.00	1.00	0.35
Instructional Lining	1.30	1.00	1.00	0.36
Sum	3.50	2.83	2.77	1.00

Environmental	Swell	Raveling and Weatherinc	Surface Cleaning	Weight
Swell	1.00	0.67	0.56	0.23
Raveling and Weathering	1.50	1.00	0.83	0.35
Surface Cleaning	1.80	1.20	1.00	0.42
Sum	4.30	2.87	2.39	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depression	1.00	0.53	0.83	0.61	0.18
Cracks	1.90	1.00	0.67	0.53	0.22
Curvature	1.20	1.50	1.00	1.00	0.28
Holes	1.65	1.90	1.00	1.00	0.32

4-Eng. Ahmed Abdullah-(Ansab Est)

Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.77	0.67	0.71	0.19
Construction	1.30	1.00	1.00	1.00	0.26
Environmental	1.50	1.00	1.00	1.00	0.27
Miscellaneous	1.40	1.00	1.00	1.00	0.27
Sum	5.20	3.77	3.67	3.71	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Compone	Attached Deposit	Weight
Patching and Utility Cut Pa	1.00	0.83	0.83	1.00	0.23
Intruding Connection	1.20	1.00	0.71	0.71	0.22
Point of Repair Componet	1.20	1.40	1.00	0.63	0.25
Attached Deposits	1.00	1.40	1.60	1.00	0.30
Sum	4.40	4.63	4.15	3.34	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.56	0.56	0.22
Oil Spillage	1.80	1.00	0.83	0.37
Instructional Lining	1.80	1.20	1.00	0.42
Sum	4.60	2.76	2.39	1.00

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight
Swell	1.00	0.67	0.83	0.27
Raveling and Weathering	1.50	1.00	0.67	0.33
Surface Cleaning	1.20	1.50	1.00	0.40
Sum	3.70	3.17	2.50	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depressio	1.00	0.63	1.00	1.00	0.22
Cracks	1.60	1.00	1.00	0.63	0.25
Curvature	1.00	1.00	1.00	0.63	0.22
Holes	1.00	1.60	1.60	1.00	0.31

5-Eng. Qais -(Municipality of Aziziyah)

Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.91	0.83	0.91	0.23
Construction	1.10	1.00	0.91	0.91	0.24
Environmental	1.20	1.10	1.00	0.91	0.26
Miscellaneous	1.10	1.10	1.10	1.00	0.27
Sum	4.40	4.11	3.84	3.73	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Compone	Attached Deposits	Weight
Patching and Utility Cut Pa	1.00	0.83	0.53	0.59	0.17
Intruding Connection	1.20	1.00	0.67	0.71	0.21
Point of Repair Componet	1.90	1.50	1.00	0.91	0.31
Attached Deposits	1.70	1.40	1.10	1.00	0.31
Sum	5.80	4.73	3.29	3.21	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.77	0.67	0.26
Oil Spillage	1.30	1.00	0.91	0.35
Instructional Lining	1.50	1.10	1.00	0.39
Sum	3.80	2.87	2.58	1.00

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight
Swell	1.00	0.83	0.71	0.28
Raveling and Weathering	1.20	1.00	0.77	0.32
Surface Cleaning	1.40	1.30	1.00	0.40
Sum	3.60	3.13	2.48	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depressio	1.00	0.53	0.67	0.56	0.16
Cracks	1.90	1.00	0.83	1.00	0.27
Curvature	1.50	1.20	1.00	0.67	0.26
Holes	1.80	1.00	1.50	1.00	0.31

6-Eng Kamal Batrawi and 7-Eng. Mohammed Al-Nemer-(Ansab Est.)

عيوب هيكله	1.00	0.91	0.91	0.91	0.23
عيوب انشائة او اصلاحية	1.10	1.00	0.83	0.83	0.23
عيوب بيئيه	1.10	1.20	1.00	0.77	0.25
عيوب أخرى	1.10	1.20	1.30	1.00	0.29
Sum	4.30	4.31	4.04	3.51	1.00

عيوب انشائية او اصلاحية	عيوب الرقع	عيوب وصلات الطرق ببعضها	عيوب نقط الإصلاح	عيوب المواد المتراكمة	Weight
عيوب الرقع	1.00	0.71	0.71	0.71	0.19
عيوب الربط	1.40	1.00	0.71	0.71	0.23
عيوب نقطة الاصلاح	1.40	1.40	1.00	0.71	0.27
عيوب المواد المتراكمة	1.40	1.40	1.40	1.00	0.32
Sum	5.20	4.51	3.83	3.14	1.00

عيوب أخرى	التخدد	عيب انسكاب الزيوت	عيوب في تخطيط الطرق	Weight
التخدد	1.00	0.56	0.71	0.24
عيب انسكاب الزيوت	1.80	1.00	0.83	0.37
عيوب في تخطيط الطرق	1.40	1.20	1.00	0.39
Sum	4.20	2.76	2.55	1.00

عيوب بيئيه	عيب الانتفاخ	عيوب التعرية و التجوية	نظافة الطرق	Weight
عيب الانتفاخ	1.00	0.69	0.71	0.26
عيوب التعرية و التجوية	1.45	1.00	0.71	0.33
نظافة الطرق	1.40	1.40	1.00	0.41
Sum	3.85	3.09	2.43	1.00

عيوب هيكليه	عيب الانخفاض و التشوه	عيوب الشروخ	عيوب انحنائية	عيوب الحفر	Weight
عيب الانخفاض و الهبوط	1.00	0.77	0.69	0.67	0.19
عيوب الشروخ	1.30	1.00	0.67	0.67	0.21
عيوب انحنائية	1.45	1.50	1.00	0.67	0.27
عيوب الحفر	1.50	1.50	1.50	1.00	0.33

8-Eng. Mokaled-(Alhazim Co.& Dammam Municipality)

Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.91	0.91	0.91	0.23
Construction	1.10	1.00	1.00	1.00	0.25
Environmental	1.10	1.00	1.00	0.53	0.22
Miscellaneous	1.10	1.00	1.90	1.00	0.30
Sum	4.30	3.91	4.81	3.44	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	oint of Repair Compon	ttached Deposit	Weight
Patching and Utility Cut I	1.00	0.71	0.56	0.56	0.16
Intruding Connection	1.40	1.00	0.59	0.77	0.22
Point of Repair Compone	1.80	1.70	1.00	0.77	0.30
Attached Deposits	1.80	1.30	1.30	1.00	0.32
Sum	6.00	4.71	3.44	3.09	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.53	0.56	0.21
Oil Spillage	1.90	1.00	0.59	0.33
Instructional Lining	1.80	1.70	1.00	0.46
Sum	4.70	3.23	2.14	1.00

Environmental	Swell	Raveling and Weatherin	Surface Cleaning	Weight
Swell	1.00	0.83	0.53	0.24
Raveling and Weathering	1.20	1.00	0.56	0.28
Surface Cleaning	1.90	1.80	1.00	0.48
Sum	4.10	3.63	2.08	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
eformation and Depressio	1.00	0.91	0.67	0.56	0.18
Cracks	1.10	1.00	0.56	0.53	0.18
Curvature	1.50	1.80	1.00	0.67	0.28
Holes	1.80	1.90	1.50	1.00	0.36

9-Dr. Issam Abkar-(Alhazim Co.& Dammam Municipality)

Structure	1.00	0.91	0.91	1.00	0.24
Construction	1.10	1.00	1.00	1.00	0.26
Environmental	1.10	1.00	1.00	1.00	0.26
Miscellaneous	1.00	1.00	1.00	1.00	0.25
Sum	4.20	3.91	3.91	4.00	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight
Patching and Utility Cut P	1.00	0.53	0.56	0.53	0.15
Intruding Connection	1.90	1.00	1.00	1.00	0.28
Point of Repair Componet	1.80	1.00	1.00	1.00	0.28
Attached Deposits	1.90	1.00	1.00	1.00	0.28
Sum	6.60	3.53	3.56	3.53	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	0.53	1.00	0.27
Oil Spillage	1.90	1.00	0.56	0.34
Instructional Lining	1.00	1.80	1.00	0.40
Sum	3.90	3.33	2.56	1.00

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight
Swell	1.00	0.53	0.56	0.21
Raveling and Weathering	1.90	1.00	0.56	0.32
Surface Cleaning	1.80	1.80	1.00	0.47
Sum	4.70	3.33	2.11	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
eformation and Depressio	1.00	1.00	0.59	1.00	0.22
Cracks	1.00	1.00	0.53	0.53	0.17
Curvature	1.70	1.90	1.00	0.77	0.30
Holes	1.00	1.90	1.30	1.00	0.31

10-Eng. Marwan Alrefai-(Ansab Est)

عناصر العيوب	عيوب هيكله	عيوب انشائة او اصلاحية	عيوب بيئيه	عيوب أخرى	Weight
عيوب هيكله	1.00	0.77	0.71	0.59	0.18
عيوب انشائة او اصلاحية	1.30	1.00	1.00	0.59	0.23
عيوب بيئيه	1.40	1.00	1.00	0.59	0.23
عيوب أخرى	1.70	1.70	1.70	1.00	0.36
Sum	5.40	4.47	4.41	2.76	1.00

عيوب انشائية او اصلاحية	عيوب الرقع	عيوب وصلات الطرق ببعضها	عيوب نقط الاصلاح	عيوب المواد المتراكمة	Weight
عيوب الرقع	1.00	0.67	0.63	0.77	0.19
عيوب توصيل الطرق	1.50	1.00	0.83	0.71	0.24
عيوب نقط الاصلاح	1.60	1.20	1.00	0.53	0.25
عيوب المواد المتراقمة	1.30	1.40	1.90	1.00	0.33
Sum	5.40	4.27	4.36	3.01	1.00

عيوب أخرى	التخدد	عيب انسكاب الزيوت	عيوب في تخطيط الطرق	Weight
التخدد	1.00	0.91	0.91	0.31
عيب انسكاب الزيوت	1.10	1.00	0.53	0.27
عيوب في تخطيط الطرق	1.10	1.90	1.00	0.42
Sum	3.20	3.81	2.44	1.00

عيوب بيئيه	عيب الانتفاخ	عيوب التعرية و التجوية	نظافة الطرق	Weight
عيب الانتفاخ	1.00	0.77	0.59	0.25
عيوب التعرة و التجوية	1.30	1.00	0.67	0.31
نظافة الطرق	1.70	1.50	1.00	0.44
Sum	4.00	3.27	2.25	1.00

عيوب هيكليه	عيب الانخفاض و التشوه	عيوب الشروخ	عيوب انحنائية	عيوب الحفر	Weight
عيب الانخفاض و التشوه	1.00	0.59	0.83	0.83	0.20
عيوب الشروخ	1.70	1.00	0.91	0.83	0.26
عيوب انحنائية	1.20	1.10	1.00	0.71	0.24
عيوب الحفر	1.20	1.20	1.40	1.00	0.29
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

11-Eng. Omar Alshudayyed-(Municipality of Thoqbah)

عيوب هيكله	1.00	0.56	0.83	0.91	0.20
عيوب انشائة او اصلاحية	1.80	1.00	0.67	0.91	0.26
عيوب بيئيه	1.20	1.50	1.00	0.63	0.26
عيوب أخرى	1.10	1.10	1.60	1.00	0.29
Sum	5.10	4.16	4.10	3.44	1.00

عيوب انشائية او اصلاحية	عيوب الرفع	عيوب وصلات الطرق ببعضها	عيوب نقط الاصلاح	عيوب المواد المتراكمة	Weight
عيوب الرفع	1.00	0.91	0.67	0.83	0.21
عيوب توصيل الطرق	1.10	1.00	0.71	0.83	0.22
عيوب نقط الاصلاح	1.50	1.40	1.00	0.71	0.27
عيوب المواد المتراقمة	1.20	1.20	1.40	1.00	0.30
Sum	4.80	4.51	3.78	3.38	1.00

عيوب أخرى	التخدد	عيب انسكاب الزيوت	عيوب في تخطيط الطرق	Weight
التخدد	1.00	1.00	0.71	0.29
عيب انسكاب الزيوت	1.00	1.00	0.59	0.27
عيوب في تخطيط الطرق	1.40	1.70	1.00	0.44
Sum	3.40	3.70	2.30	1.00

عيوب بيئيه	عيب الانتفاخ	عيوب التعرية و التجوية	نظافة الطرق	Weight
عيب الانتفاخ	1.00	0.67	0.77	0.26
عيوب التعرة و التجوية	1.50	1.00	0.67	0.33
نظافة الطرق	1.30	1.50	1.00	0.41
Sum	3.80	3.17	2.44	1.00

عيوب هيكليه	عيب الانخفاض و التشوه	عيوب الشروخ	عيوب انحنائية	عيوب الحفر	Weight
عيب الانخفاض و التشوه	1.00	0.67	0.83	0.59	0.18
عيوب الشروخ	1.50	1.00	0.67	0.59	0.21
عيوب انحنائية	1.20	1.50	1.00	0.53	0.24
عيوب الحفر	1.70	1.70	1.90	1.00	0.37

12-Dr. Abdulhameed

Condition Assessment of Road Networks

Factor	Structure	Construction	Environmental	Miscellaneous	Weight	EVALUATION
Structure	1.00	1.00	2.00	2.00	0.33	
Construction	1.00	1.00	2.00	2.00	0.33	
Environmental	0.50	0.50	1.00	1.00	0.17	
Miscellaneous	0.50	0.50	1.00	1.00	0.17	
Sum	3.00	3.00	6.00	6.00	1.00	OK

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight	EVALUATION
Patching and Utility Cut Patch	1.00	1.00	2.00	1.00	0.29	
Intruding Connection	1.00	1.00	2.00	1.00	0.29	
Point of Repair Componet	0.50	0.50	1.00	0.50	0.14	
Attached Deposits	1.00	1.00	2.00	1.00	0.29	
Sum	3.50	3.50	7.00	3.50	1.00	OK

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight		EVALUATION
Rutting	1.00	1.00	2.00	0.40		
Oil Spillage	1.00	1.00	2.00	0.40		
Instructional Lining	0.50	0.50	1.00	0.20		
Sum	2.50	2.50	5.00	1.00		OK

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight		EVALUATION
Swell	1.00	1.00	2.00	0.40		
Raveling and Weathering	1.00	1.00	2.00	0.40		
Surface Cleaning	0.50	0.50	1.00	0.20		
Sum	2.50	2.50	5.00	1.00		OK

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight	EVALUATION
Deformation and Depression	1.00	1.00	2.00	1.00	0.28	
Cracks	1.00	1.00	0.50	1.00	0.22	
Curvature	0.50	2.00	1.00	0.50	0.22	
Holes	1.00	1.00	2.00	1.00	0.28	
Sum	3.50	5.00	5.50	3.50	1.00	OK

13-Dr. Farhan

Condition Assessment of Road Networks					
Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	1.00	0.59	1.00	0.22
Construction	1.00	1.00	1.00	1.00	0.25
Environmental	1.70	1.00	1.00	1.00	0.29
Miscellaneous	1.00	1.00	1.00	1.00	0.25
Sum	4.70	4.00	3.59	4.00	1.00

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight
Patching and Utility Cut Patc	1.00	0.53	0.53	0.83	0.17
Intruding Connection	1.90	1.00	0.91	0.91	0.27
Point of Repair Componet	1.90	1.10	1.00	0.91	0.29
Attached Deposits	1.20	1.10	1.10	1.00	0.27
Sum	6.00	3.73	3.54	3.65	1.00

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight
Rutting	1.00	1.00	1.00	0.33
Oil Spillage	1.00	1.00	0.59	0.28
Instructional Lining	1.00	1.70	1.00	0.39
Sum	3.00	3.70	2.59	1.00

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight
Swell	1.00	0.91	0.91	0.31
Raveling and Weathering	1.10	1.00	0.91	0.33
Surface Cleaning	1.10	1.10	1.00	0.35
Sum	3.20	3.01	2.82	1.00

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depression	1.00	1.00	0.91	0.63	0.21
Cracks	1.00	1.00	0.83	0.67	0.21
Curvature	1.10	1.20	1.00	0.63	0.23
Holes	1.60	1.50	1.60	1.00	0.34
Sum	4.70	4.70	4.34	2.92	1.00

14-Dr. Sami Abdullah

Condition Assessment of Road Networks						
Factor	Structure	Construction	Environmental	Miscellaneous	Weight	EVALUATION
Structure	1.00	1.00	0.83	0.83	0.23	
Construction	1.00	1.00	0.67	0.77	0.21	
Environmental	1.20	1.50	1.00	0.83	0.27	
Miscellaneous	1.20	1.30	1.20	1.00	0.29	
Sum	4.40	4.80	3.70	3.44	1.00	OK

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight	EVALUATION
Patching and Utility Cut Patch	1.00	0.56	0.56	0.59	0.16	
Intruding Connection	1.80	1.00	0.67	0.77	0.24	
Point of Repair Componet	1.80	1.50	1.00	0.59	0.27	
Attached Deposits	1.70	1.30	1.70	1.00	0.34	
Sum	6.30	4.36	3.92	2.95	1.00	OK

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight		EVALUATION
Rutting	1.00	0.59	0.59	0.23		
Oil Spillage	1.70	1.00	0.91	0.37		
Instructional Lining	1.70	1.10	1.00	0.40		
Sum	4.40	2.69	2.50	1.00		Re-evaluate your matrix

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight		EVALUATION
Swell	1.00	0.91	0.91	0.31		
Raveling and Weathering	1.10	1.00	0.91	0.33		
Surface Cleaning	1.10	1.10	1.00	0.35		
Sum	3.20	3.01	2.82	1.00		OK

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight	EVALUATION
Deformation and Depression	1.00	0.56	0.83	0.59	0.18	
Cracks	1.80	1.00	0.83	0.59	0.24	
Curvature	1.20	1.20	1.00	0.56	0.23	
Holes	1.70	1.70	1.80	1.00	0.36	
Sum	5.70	4.46	4.47	2.73	1.00	OK

15-Dr. Mostafa Elshami

Condition Assessment of Road Networks

Factor	Structure	Construction	Environmental	Miscellaneous	Weight	EVALUATION
Structure	1.00	0.67	0.91	0.91	0.21	
Construction	1.50	1.00	0.91	0.77	0.25	
Environmental	1.10	1.10	1.00	0.59	0.23	
Miscellaneous	1.10	1.30	1.70	1.00	0.31	
Sum	4.70	4.07	4.52	3.27	1.00	OK

Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight	EVALUATION
Patching and Utility Cut Patc	1.00	0.91	0.91	0.91	0.23	
Intruding Connection	1.10	1.00	0.91	0.91	0.24	
Point of Repair Componet	1.10	1.10	1.00	0.83	0.25	
Attached Deposits	1.10	1.10	1.20	1.00	0.27	
Sum	4.30	4.11	4.02	3.65	1.00	OK

Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight		EVALUATION
Rutting	1.00	1.00	1.00	0.33		
Oil Spillage	1.00	1.00	0.59	0.28		
Instructional Lining	1.00	1.70	1.00	0.39		
Sum	3.00	3.70	2.59	1.00		OK

Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight		EVALUATION
Swell	1.00	0.56	0.77	0.25		
Raveling and Weathering	1.80	1.00	0.83	0.37		
Surface Cleaning	1.30	1.20	1.00	0.38		
Sum	4.10	2.76	2.60	1.00		OK

Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight	EVALUATION
Deformation and Depression	1.00	0.83	0.83	0.56	0.19	
Cracks	1.20	1.00	0.83	0.59	0.21	
Curvature	1.20	1.20	1.00	0.56	0.23	
Holes	1.80	1.70	1.80	1.00	0.37	
Sum	5.20	4.73	4.47	2.70	1.00	OK

16-Dr. Moselhi

Condition Assessment of Road Networks					
Factor	Structure	Construction	Environmental	Miscellaneous	Weight
Structure	1.00	0.53	0.71	0.77	0.18
Construction	1.90	1.00	0.77	0.77	0.25
Environmental	1.40	1.30	1.00	1.00	0.28
Miscellaneous	1.30	1.30	1.00	1.00	0.28
Sum	5.60	4.13	3.48	3.54	1.00
Construction	Patching and utility Cut Patch	Intruding Connection	Point of Repair Componet	Attached Deposits	Weight
Patching and Utility Cut Patch	1.00	0.63	0.77	0.63	0.18
Intruding Connection	1.60	1.00	0.77	0.67	0.23
Point of Repair Componet	1.30	1.30	1.00	0.63	0.25
Attached Deposits	1.60	1.50	1.60	1.00	0.34
Sum	5.50	4.43	4.14	2.92	1.00
Miscellaneous	Rutting	Oil Spillage	Instructional Lining	Weight	
Rutting	1.00	0.59	0.67	0.24	
Oil Spillage	1.70	1.00	0.71	0.35	
Instructional Lining	1.50	1.40	1.00	0.42	
Sum	4.20	2.99	2.38	1.00	
Environmental	Swell	Raveling and Weathering	Surface Cleaning	Weight	
Swell	1.00	1.00	0.63	0.28	
Raveling and Weathering	1.00	1.00	0.67	0.28	
Surface Cleaning	1.60	1.50	1.00	0.44	
Sum	3.60	3.50	2.29	1.00	
Structure	Deformation and Depression	Cracks	Curvature	Holes	Weight
Deformation and Depression	1.00	0.59	0.67	0.56	0.16
Cracks	1.70	1.00	0.77	0.59	0.23
Curvature	1.50	1.30	1.00	0.56	0.24
Holes	1.80	1.70	1.80	1.00	0.37
Sum	6.00	4.59	4.24	2.70	1.00

17- Abdulrahman Shawqi

عناصر العيوب	عيوب هيكله	عيوب انشائة او اصلاحية	عيوب بيئيه	عيوب أخرى	Weight
عيوب هيكله	1.00	0.67	0.63	0.59	0.17
عيوب انشائة او اصلاحية	1.50	1.00	1.00	0.53	0.23
عيوب بيئيه	1.60	1.00	1.00	0.56	0.23
عيوب أخرى	1.70	1.90	1.80	1.00	0.37
Sum	5.80	4.57	4.43	2.67	1.00

عيوب انشائية او اصلاحية	عيوب الرقع	عيوب وصلات الطرق ببعضها	عيوب نقط الإصلاح	عيوب المواد المتراكمة	Weight
عيوب الرقع	1.00	0.91	1.00	0.63	0.21
عيوب توصيل الطرق	1.10	1.00	0.71	0.63	0.21
عيوب نقط الاصلاح	1.00	1.40	1.00	0.77	0.25
عيوب المواد المتراكمة	1.60	1.60	1.30	1.00	0.33
Sum	4.70	4.91	4.01	3.02	1.00

عيوب أخرى	التخدد	عيب انسكاب الزيوت	عيوب في تخطيط الطرق	Weight
التخدد	1.00	0.91	0.67	0.27
عيب انسكاب الزيوت	1.10	1.00	0.56	0.28
عيوب في تخطيط الطرق	1.50	1.80	1.00	0.45
Sum	3.60	3.71	2.22	1.00

عيوب بيئيه	عيب الإنتفاخ	عيوب التعرية و التجوية	نظافة الطرق	Weight
عيب الإنتفاخ	1.00	1.00	1.00	0.33
عيوب التعرة و التجوية	1.00	1.00	1.00	0.33
نظافة الطرق	1.00	1.00	1.00	0.33
Sum	3.00	3.00	3.00	1.00

عيوب هيكليه	عيب الانخفاض و التشوه	عيوب الشروخ	عيوب انحنائية	عيوب الحفر	Weight
عيب الانخفاض و التشوه	1.00	1.00	0.71	0.67	0.21
عيوب الشروخ	1.00	1.00	1.00	0.77	0.23
عيوب انحنائية	1.40	1.00	1.00	0.77	0.25
عيوب الحفر	1.50	1.30	1.30	1.00	0.31

Appendix F: Validation Letter from Dr. Issam Abkar