PAVEMENT ASSET MANAGEMENT INCORPORATING MACHINE LEARNING MODEL

Final Year Project

By

M.Umair Saleem (GL) NICEBECE2018-257069

Umar Saeed NICEBECE2018-246577

Sohaib Haider NICEBECE2018-247494

Ahmad Shah NICEBECE2018-244721

Advisor: Lecturer Malik Kamran Shakir

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology

Islamabad, Pakistan

2022

It is certified that:

FINAL YEAR PROJECT TITLED

PAVEMENT ASSET MANAGEMENT INCORPORATING MACHINE LEARNING MODEL

Submitted by:

M.Umair Saleem (GL) NICEBECE2018-257069

Umar Saeed NICEBECE2018-246577

Sohaib Haider NICEBECE2018-247494

Ahmad Shah NICEBECE2018-244721

Has been accepted towards the requirements for the undergraduate degree

In

Civil Engineering

Lecturer Malik Kamran Shakir

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology Islamabad, Pakistan

ACKNOWLEDGEMENT

In the name of Allah, the most beneficent and merciful.

Firstly, we would like to express our gratitude to our advisor Lecturer Malik Kamran Shakir, for his precious advice and for helping us look at our shortcomings throughout the project. It was he who made us maintain a high level of competency.

We would also thank Muhammad Naufal and Muhammad Saad from National Highways Authority (NHA) for providing us with the required data for our project.

The efforts of our instructors from the Survey lab cannot be overlooked; they helped us use different software through which we paved our way to the end of the project.

Last but not least, the love and prayers of our parents made it possible for us to gain a steady footing in our academic journey.

DEDICATION

We dedicate this work to our dear faculty advisor Sir. Malik Kamran Shakir, our teachers, parents, and friends

Table of Contents

LIST OF ABBREVIATION

IRI…………………………………………………..……. International Roughness Index

PSI………………………………………………………. Present Serviceability Index

VOC…………………………………………...……..…. Vehicle Operating Cost

SN………………………………………………………………. Structural Number

AADT…………………………………………………. Annual Average Daily Traffic

PAMS ………………. …………………………Pavement Asset Management System

NHA……………………………...………………... National Highway Authority

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The authors have developed a pavement Asset Management System (PAMS) based on life cycle cost analysis and optimisation methods. The project was analysis based, which required data. This data was acquired from NHA, including SN (Structural Number), IRI (International Roughness Index), and AADT (Annual Average Daily Traffic). The project can be divided into three modules.

Module number 1 covers vehicle operating cost (VOC), which was calculated with the help of Hep-Burn method (1991). Traffic data was required for module 1, which was acquired from NHA. Calculating the VOCs gave us an idea about the overall mileage and wear and tear cost currently incurred on vehicles due to present pavement conditions. So, the current VOC and the VOC after maintenance can be compared after any future maintenance.

Module number 2 covers the strategies required to improve the road conditions. The conventional PAMS can be extended to the extraction and management of raw material and end-of-life materials by integrating life cycle assessment and cost analysis. The authors used a lifecycle optimisation model to determine the near-optimal pavement preservation strategy. In this thesis, we propose a network-level PAMS to help decision-makers maintain a healthy pavement network while minimising cost and lifecycle energy consumption within budgetary and other agency constraints.

Module Number 3 encompasses the use of machine learning to minimise equipment usage. Road asset management requires an understanding of the deterioration of roads. A machine-learning algorithm was used to predict the deterioration of the International Roughness Index (IRI) based on long-term pavement performance data. For this analysis, we looked at readily available attributes. Municipalities with limited budgets or expertise may benefit from this approach. A large company or transportation agency could save significant money by eliminating the costs of collecting data in the field and the related safety hazards and risks. This approach can be helpful for smaller communities that may not have the money or expertise.

Moreover, for larger ones and transportation departments, it could save the ever-increasing cost of collecting field data and any related safety risks. Further, we investigated the importance of data analytics in the management of assets by using this

attribute category. Without considering a casual model, can the trend of the data be used to predict IRI deterioration? The algorithms used were the simplest in machine learning – the linear regression model and the accuracy we saw was high provided with the limited data we had, with some reaching above 85%, which shows that the model can be relied on furthermore, due to the division of data into different regions, the importance of variables and the accuracy of the model changes. Reducing the number and size of prediction classes (level of deterioration) improved accuracy while increasing the span of prediction decreased accuracy. The model automatically calculates and predicts IRI and presents informative or important features for prediction.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pavement Asset Management is an established, documented procedure treating many or all pavement management activities in a systematic and coordinated manner. A PMS encompasses a broad spectrum of activities included in the planning or programming of investments on pavements, design, construction, and maintenance of Pavement, and periodic performance evaluation.

PAM is a technique to increase the design life of a highway by occasionally checking out the condition of the road. The pavement condition deteriorates with time as heavy vehicles' movement on the road increase. Different strategies are then devised and implemented to improve road quality. Maintenance activities are carried out once the road condition is not up to the mark.

The increasing deterioration of roads adds up to the maintenance and repair cost; hence timely and proactive maintenance strategies decrease the overall maintenance cost, so Pavement asset management is quite a helpful process as far as the economy is concerned. This is why even the wealthiest countries use this process because of the high cost of new Pavement.

1.2 1REHABITATION OF ROADS

Rehabilitation of roads is one of the important steps in extending the life of our roads. This process usually reduces the deterioration of the Pavement. The load-carrying capacity and service life of existing Pavement are extended as this process consists of structural/non-structural enhancement.

Rehabilitation projects may include structural overlays or increasing pavement thickness to strengthen existing pavement sections to accommodate existing or projected traffic loading conditions. Minor rehabilitation is done to remove slight surface undulations and eliminate minor surface cracks, a non-structural enhancement process. On the other hand, major rehabilitation is done to strengthen and increase the load-carrying capacity of the Pavement. The heavy and light rehabilitation reduces the ageing of the Pavement and restores serviceability.

1.3 PAVEMENT CONDITION ASSESSMENT BASED ON IRI

An evaluation of pavement condition should be conducted regularly to determine the existing Pavement's performance and predict future pavement performance, as well as whether the Pavement provides efficient services, is safe, is structurally capable of supporting traffic loads, and is resistant to environmental impacts.

Pavement condition parameters are mainly evaluated objectively using road roughness. It is relatively easy to obtain road roughness data and is highly correlated with vehicle operating costs. In the long run, these data are most relevant for evaluating the functional condition of roads.

The International Road Roughness Experiment held in Brazil in 1980 led to the development of the international roughness index in 1986. Almost every country in the world now uses IRI to measure how rough roads are.

According to the definition of the IRI, standard vertical movement (mm or inch) is measured against the distance travelled by the vehicle (m, km, or miles). There are four general classes of road roughness measurement methods. These are direct measurements, indirect measurements, IRI estimations based on correlation equations, such as the response type road roughness measurement system (RTRRMS), and subjective judgments based on the opinion of the assessment group. Vibration sensors on smartphones, such as Roadroid, can measure road roughness like RTRRMS.

Roadroid is an Android-based innovative phone application developed by the Swedish National Road Administration that can be an alternative to obtaining road roughness data that becomes an indicator of road conditions for grades 2 and 3 with easier and less costly. In Table 1, one can find the criteria for pavement conditions using IRI values for various types of asphalt surfaces.

Condition Term Categories	IRI (In/mile)	
	Interstate	Others
Very Good	<60	<60
Good	60-94	60-94
Fair	95-119	119-170
Mediocre	120-170	170-220
Poor	>170	>220

Table 1. 1 Pavement Condition Thresholds Using IRI

From Table 1, we can quickly determine our pavement condition for different roads. The table shows that as the IRI value increases, the state of the roads starts getting worse. An IRI value less than 60 indicates that our road is in excellent condition, while the value above 170 in interstate shows our road condition is very poor. An IRI above 220 puts the other roads in poor condition.

1.4 PAVEMENT CONDITION ASSESSMENT BASED ON PSI

The condition of the road or the functional capacity of a highway can be judged on another parameter called PSI (Pavement serviceability index). Its value ranges from 0-5. PSI is the first objective measure of road condition before this road condition was measured subjectively by PSR. The equation developed to measure the PSI is given below.

$$PSI=5.03-\log(1-SV)-1.38(RD)^2-0.01(C+P)^{1/2}$$

Which is,

PSI=The present Serviceability index which is the statistical estimate of the mean of the present Serviceability ratings given by the panel

SV= Slope variance over the section from CHOLE profilometer (Slope variance is an early roughness measurement

RD= Mean rut depth (in)

C=Cracking (ft/1000 ft^2) (flexible)

P=Patching (ft/1000 ft^2)

Now the PSI can be used to determine the road conditions, and hence the corresponding strategies can be developed respectively. With the help of PSI, we can accurately perform proactive strategies which increase the design life of a highway, as shown in fig 1.1

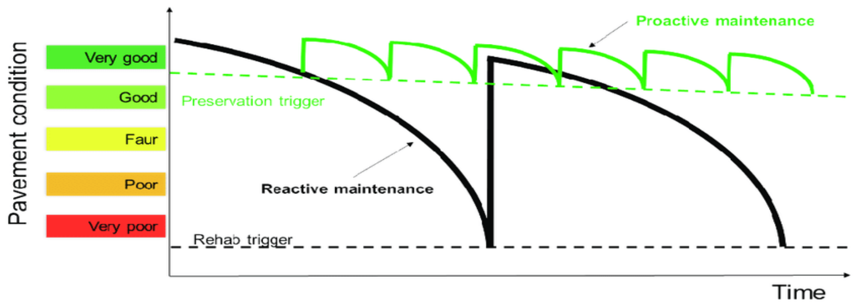


Figure 1.1 application of the maintenance strategies on the design life of a pavement

Figure 1.1 illustrates the effect of timely and untimely application of the maintenance strategies on pavement design life. If road conditions deteriorate up to the level preservation trigger (i.e., its condition demotes from very good to good) and repair I carried out, design life increases and cost decreases. Similarly, this also decreases the cost because a road in less bad condition requires a relatively smaller budget than a pavement whose condition has deteriorated significantly. These strategies are typically carried out at a PSI of 3-4.

If the value of PSI falls to 2.5, then reactive maintenance may be carried out, which is costly compared to the maintenance due to the preservation trigger. This happens when the pavement condition is poor.

Finally, when the PSI value falls below 2, the Pavement loses its structural capacity, and R&R will be done. Rehabilitation is the most expensive strategy, and the Pavement should be maintained such that the need for rehabilitation is reduced to a certain extent; this also reduces the Pavement's design life.

1.5 PROBLEM STATEMENTS

STATEMENT 1:

With time, the Pavement deteriorates due to the passage of light and heavy vehicles and the weather conditions like heavy rainfall in the area. Suppose the Pavement is left without any maintenance. In that case, the road condition worsens, and a large budget is required to take back the Pavement to its original condition, which becomes a burden on the country's economy and the Vehicle Operating Cost increases.

To avoid this if we do timely maintenance of the Pavement to avoid the high cost at once. For this, a system should be developed to keep Pavement under observation and do not let it go to the worse stage.

STATEMENT 2:

For examining the Pavement, measuring devices like profilometers and LASER instruments are unavailable to every researcher. For this, a Machine Learning Model with sufficient accuracy should be trained on the available data to help the researchers not wait for the equipment.

Three main Modules are achieved in our work which are

1.6 MODULES (OBJECTIVES)

OBJECTIVE 1

MODULE 1 (VOC)

Module 1 of our project covers the VOC. Data of AADT was acquired from NHA for Karachi to Torkham Highway(N-5). The highway segment was chosen from Sangjani Toll plaza to Attock Bridge. Initially, we had data in the form of videos. AADT (Annual Average Daily Traffic) was then worked out from the videos. The AADT was then used to calculate the VOC based on Hep-Burn Model (1991). VOCs were calculated for every 1km section and added up to get the total VOC. Speed was an important factor in calculating the VOC, so the average speed we took was 80km/hr, the normally observed speed on N5 in the above-mentioned section. Another important parameter is the division of traffic into trucks and cars, which was to be done through the videos. In our observations of videos, nearly 30% of traffic was trucks while the remaining was cars.

OBJECTIVE 2

MODULE 2 (STRATEGIES ON THE PAVEMENT)

After calculating the PSI values from the IRI range, we developed some road maintenance and rehabilitation strategies. The PSI range between 4 to 5 is considered good, and there is no need to do any rehabilitation or maintenance for this section of the road. The PSI range between 4 to 2.5 is not that much deteriorated, but we still need rehabilitation to achieve good condition. We advise minor to routine maintenance for this section. Some techniques used for this section are micro-surfacing, chip seal and non-structural overlays. Now the PSI range below 2.5 is considered the section which needs serious attention, and we need to do major rehabilitation or some reconstruction. This required more budget and more time. This increases the structural capacity of the road.

OBJECTIVE 3

MODULE 3 (MACHINE LEARNING)

In this era of advancement and technology, using expensive machines in transportation should not be a hurdle for researchers. A new alternative for all these machines is Machine Learning Models, which have adequate accuracy levels and can prove time and cost-saving. These models are trained with the data acquired with all those expensive machines and similarly generate results. It is easy for researchers to get hands-on with these models.

CHAPTER 2

LITERATURE REVIEW

This chapter includes a review of key Research Papers based on the Pavement Asset Management System (PAM). This literature review aims to overview developments in the said field. The papers selected for the review touch on various aspects of the Pavement Asset Management System, from financial to the technical Aspects and from working on the previously developed methodologies of assessing the Pavement to the newly developed methods of incorporating New Tools to evaluate the Pavement.

2.1 CONSIDERING VEHICLE OPERATING COST IN SUSTAINABLE PMS IN URBAN AREA

This paper discusses designing plans for maintaining, preserving, and rehabilitating urban roadways using an easy-to-use Pavement Management System (PMS). The suggested method entails compiling a road network inventory, conducting visual pavement surveys, and using the Pavement Condition Index to assess the Pavement (PCI) condition. The technique aims to provide road managers with a helpful tool for comparing different maintenance strategies and doing a network priority analysis. This approach calculates the Vehicle Operating Costs (VOC) using a written correlation between PCI and the International Roughness Index (IRI).

2.2 FOR THE ROADS SECTOR, ASSET MANAGEMENT- A PAPER WRITTEN FOR OECD

This paper includes a review of asset management systems as they apply to the road sector and an analysis of survey results from countries represented in an OECD Working Group on Asset Management Systems. This report highlights the importance of road administration maintaining, maintaining, improving, replacing, and conserving this asset while managing the limited financial and human resources necessary to attain these goals. The paper enlists a detailed Introduction to Asset Management, different Components of asset pavement management (inc. goals, data, resources and budget details), Data Requisition and Analysis Procedures, Performance monitoring and benefits of Asset Management Systems. This long document can be used as a guidance paper for carrying out the Pavement Asset Management PAM.

2.3 APPLICATION OF GEOGRAPHIC INFORMATICS SYSTEM (GIS) TO PRIORITISE PAVEMENT MAINTENANCE USING A NEW APPROACH AT A NETWORK LEVEL

The benefits of PMS and GIS integration include the ability to graphically show the findings of pavement management analysis on a road network map, examine pavement conditions through dynamic colour-coding of road sections, and the graphical map display.

2.4 PAVEMENT CONDITIONS INFLUENCE ON THE EFFECTIVE STRUCTURAL NUMBER OF IN-SERVICE PAVEMENTS

The primary purpose of this research was to see if there was a link between Pavement distresses as performance indicators, pavement condition indices, and the effective structural number of in-service pavements estimated through FWD testing. FWD was used to test 50 pavement sections in Louisiana to assess their structural capabilities. The Pavement's cracking, rutting, and roughness were all evaluated, as well as the Pavement Condition Index (PCI) was calculated as a performance indicator. According to this investigation, the coefficient of variation (COV) in SN estimations in the 50 pavement sections was extremely high, ranging from 14 to 63 per cent, with an average COV of 35 per cent. The statistical analysis results in this study revealed that the most significant parameters impacting the effective structural number of a pavement section were AC thickness, alligator cracking, IRI, and base thickness. On the other hand, rutting and patching did not influence the computed structural number. When the specific spots with low moduli in places with relatively low SN values, SN exhibited a high connection to the AC modulus in most sections; however, when the average SN and the average AC modulus for the pavement sections were compared, there was a weak correspondence.

2.5 PAVEMENT CONDITION ASSESSMENT ON A NATIONAL ROAD IN SUMENEP REGENCY USING THE IRI FROM ROADROID AND THE SURFACE DISTRESS INDEX METHOD

The paper focuses on using the Roadroid Mobile Application to obtain International Roughness Index (IRI) Values. Using Roadroid smartphone applications to collect IRI values can be a convenient way for road operators to keep track of road conditions. The paper compares the SDI (Surface Distress Index) and International Roughness Index (IRI) Values. The paper uses the SDI and IRI comparisons. Then, based on the comparison, it is concluded that Roadroid applications can be used as an alternative to obtain IRI values efficiently that can be collaborated with SDI values to determine appropriate maintenance recommendations. Also, the Paper shares some conclusions for a Road where testing was performed in Indonesia (Jenderal Sudirman-Kalianget national road in Sumenep regency) on an 11.3 km long route.

2.6 A NEW FALLING WEIGHT DEFLECTOMETER-BASED METHOD FOR DETERMINING MAINTENANCE AND REPAIR SERVICES AT THE NETWORK LEVEL OF PAVEMENT MANAGEMENT

The paper aims to use different alternatives to maintain and repair road networks. At the network level, pavement condition assessment necessitates structural evaluation, which can be obtained using a Falling Weight Deflectometer (FWD). The convenient maintenance and repair methods (preservation, rehabilitation, or reconstruction) for distinct pavement sections could be decided based on FWD data analysis. The Structural Condition Index (SCI), which is defined as the ratio of Effective Structural Number (SNeff) to Required Structural Number (SNreq), was used in this study to assess whether a pavement needed preservation or rehabilitation (i.e., preservation SCI>1, rehabilitation SCI1).

CHAPTER 3

MODULE 1
VEHICLE OPERATING COST

3.1 INTRODUCTION

VOC significantly influences highway costs of transportation. Vehicle operating cost varies with vehicle usage and its expanses like maintenance of the vehicle, cleaning, repairing and majorly fuel consumption. This chapter identifies the components of VOC, the factors that affect the VOC, and the procedures used for finding vehicle operating costs. Total VOC savings before and after the intervention will be calculated in this section.

3.2 COMPONENTS OF VOC

Vehicle operating costs include fuel and oil consumption, tire wear, maintenance, and repair. Significant emphasis was placed on fuel consumption due to its importance as a component of vehicle operating costs.

3.2.1 VEHICLE CONSUMPTION

The last experimental investigation in the United States of the relationship between roadway characteristics and fuel consumption was performed over ten years ago. Since then, vehicle technology has been significantly changed, e.g., unleaded fuel, radial tires, better aerodynamics, more efficient motors, etc. Thus, it was decided to collect primary data on fuel consumption.

3.2.2 OIL CONSUMPTION

This is a relatively unimportant component of vehicle operating cost; thus, no primary data was sought In this research for oil consumption. The basic division of oil consumption for speeds and roadway characteristics was updated based on longer oil change intervals of the current automobile population. Oil consumption information provided by trucking firms was used to update truck oil consumption estimates.

3.2.3 TIRE PRESSURE

To determine tire wear using the forces involved in a given operating condition, the Forest Service developed the slip-energy theory. Different surface types, grades, curves, and speeds were compared using this theory to estimate tire wear differentials.

The National Highway Traffic Safety Administration measured tire wear estimates to calibrate the theory's prediction of tire wear.

3.2.4 MAINTENANCE & REPAIR

The basic procedure used by Winfrey for differentiating vehicle maintenance and repair vas updated with current cost estimates. Automobile maintenance costs were obtained from the Federal Highway Administration. Trucking firms participating in the Volunteer Fuel Economy Program were surveyed to obtain current cost information for trucks.

3.3 FACTORS AFFECTING THE VOC

Below mentioned are the factors which affect VOC:

3.3.1 TYPE OF VEHICLE

- Different types of vehicles have separate ownership and operating costs.
- A truck, for example, has a higher operating cost than a car

3.3.2 SPEED OF VEHICLE

Vehicle speed is the dominant factor affecting vehicle operating costs. Typically, operating costs decrease with increasing speed to a certain point and then supplement with increasing speed.

3.3.3 VARIATION OF SPEED

Change in speed increases VOC. This additional cost is greater when the speed cycling is at greater rates.

3.3.4 GRADES OF ROAD

Grades can be either positive (uphill) or negative (downhill). Positive grades are more demanding on vehicle engines and require greater fuel consumption. This leads to an increase in operating costs. Negative grades may reduce operating costs but may also increase wear on brakes.

3.3.5 CURVES

A highway curve requires greater energy output from a vehicle to counter the centrifugal force—this, combined with additional wear on the vehicle's tires, increases operating costs.

3.3.6 SURFACE OF ROAD

The roughness of the road surface can affect vehicle operating costs by affecting rolling resistance. Rough surfaces can reduce speed, require greater fuel consumption, increase wear on tires, and increase maintenance costs.

3.4 PROCEDURE FOR ACCESSING VOC

Finding miles travelled by vehicle without and with intervention is called VMT.

Finding the unit VOC (Rupees /vehicle-mile).

Speed of the segment.

If speed < 50 mph, use the formula $C+\frac{D}{S}$

if speed > 50 mph, use the formula $a_0 - a_1S - a_2S^2$

Find daily VOC by multiplying Unit Vehicle operating cost with the VMT(Vehicle miles travelled/day)

Vehicle type	C	D	a_0	a_1	a_2
Small automobile	24.8	45.5	27.2	0.035	0.00021
Medium automobile	28.5	95.3	33.5	0.058	0.00029
Large automobile	29.8	163.4	38.1	0.093	0.00033

Table 3. 1: Parameters for VOC-speed Model

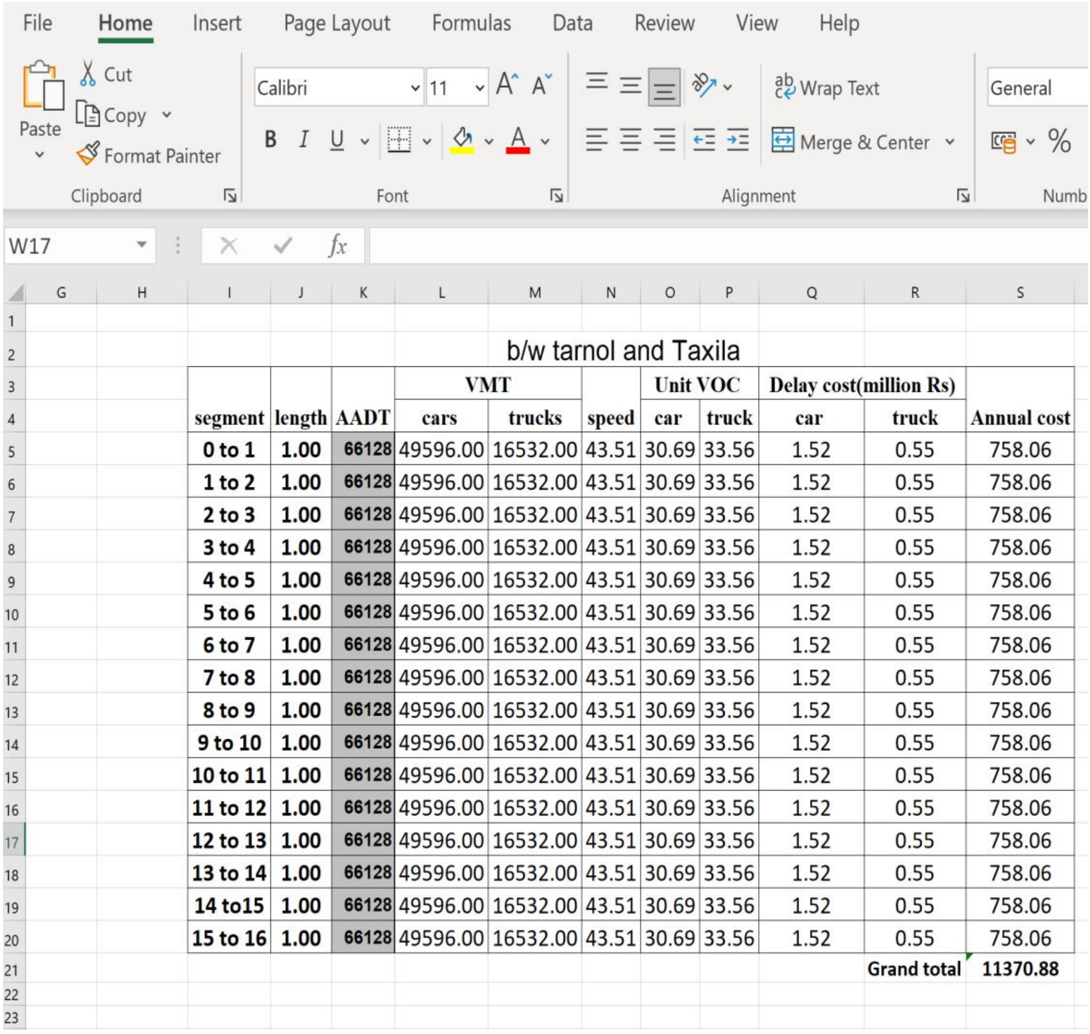
Calculate user VOC benefits of intervention.

All the values calculated from daily vehicle operating cost calculations are added and then multiplied by a factor of 365, which will give us the annual VOC.

3.5 VOC CALCULATION FOR N-5 (SANGJANI TOLL PLAZA TO ATTOCK BRIDGE)

VOCs were calculated per 1km, and all the per km VOCs were added to get the total VOC for that section. The VOCs of each section were then added up. Calculations were carried out in excel.

3.5.1 TARNOL AND TAXILA



b/w tarnol and Taxila

segment	length	AADT	VMT cars	VMT trucks	speed	Unit VOC car	Unit VOC truck	Delay cost(million Rs) car	Delay cost(million Rs) truck	Annual cost
0 to 1	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
1 to 2	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
2 to 3	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
3 to 4	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
4 to 5	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
5 to 6	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
6 to 7	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
7 to 8	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
8 to 9	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
9 to 10	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
10 to 11	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
11 to 12	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
12 to 13	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
13 to 14	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
14 to15	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
15 to 16	1.00	66128	49596.00	16532.00	43.51	30.69	33.56	1.52	0.55	758.06
									Grand total	11370.88

Figure 3. 1: Total cost between Tarnol and Taxila, taking both sides of traffic into account=11370.88m

3.5.2 TAXILA AND HASSANABDAL

b/w Taxila and hassanabdal

segment	length	AADT	VMT cars	VMT trucks	speed	Unit VOC car	Unit VOC truck	Delay cost(million Rs) car	Delay cost(million Rs) truck	Annual cost
0 to 1	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
1 to 2	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
2 to 3	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
3 to 4	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
4 to 5	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
5 to 6	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
6 to 7	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
7 to 8	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
8 to 9	1.00	61166	45874.50	15291.50	43.51	30.69	33.56	1.41	0.51	701.18
									Grand [illegible]al	5609.42

Figure 3. 2: Total cost between Taxila and Hassanabdal, taking both sides of traffic into account=5609.42m

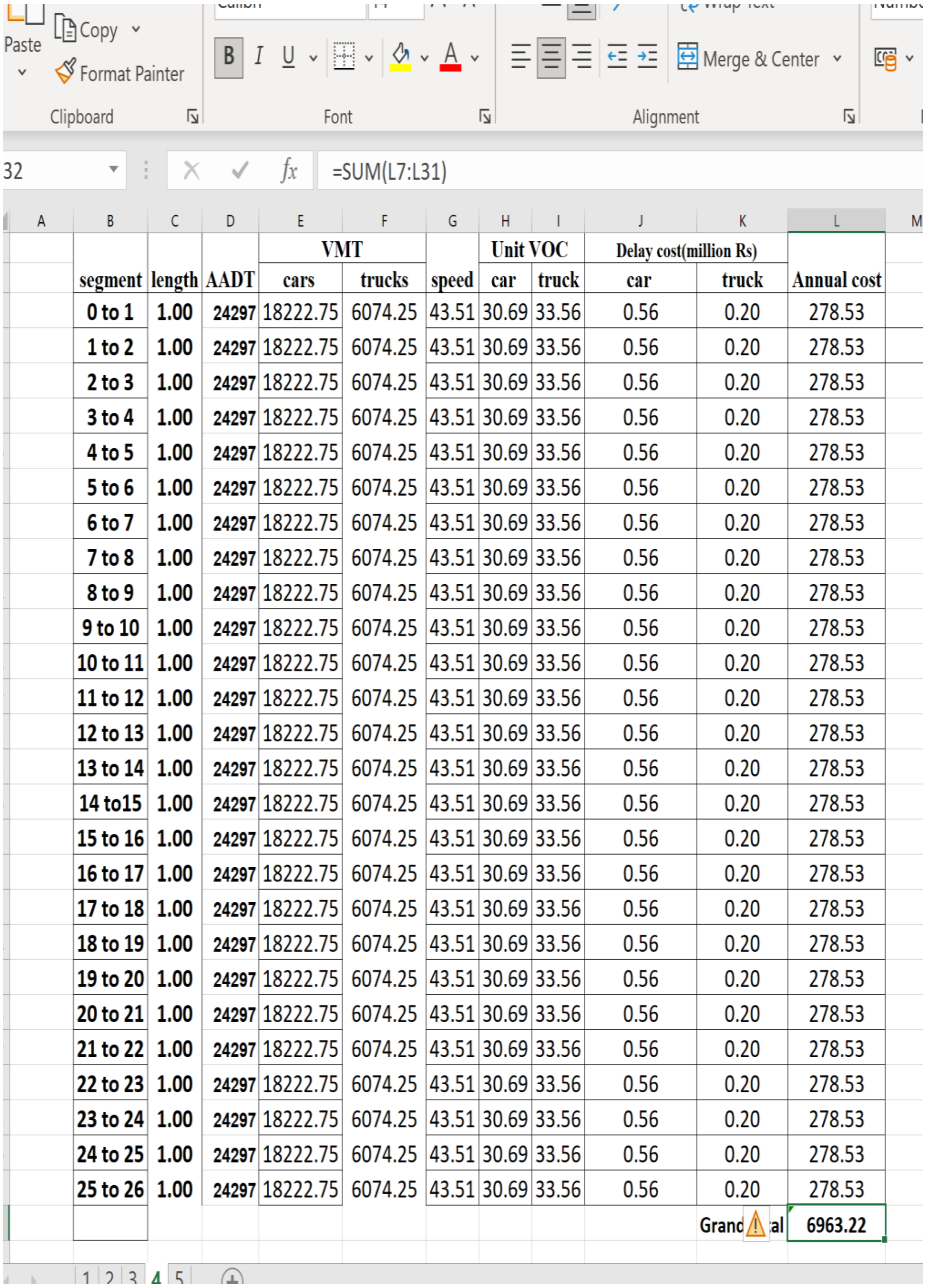
3.5.3 HASSANABDAL AND BURHAN

b/w Hassanabdal and Burhan

segment	length	AADT	VMT cars	VMT trucks	speed	Unit VOC car	Unit VOC truck	Delay cost(million Rs) car	Delay cost(million Rs) truck	nnual co
0 to 1	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
1 to 2	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
2 to 3	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
3 to 4	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
4 to 5	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
5 to 6	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
6 to 7	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
7 to 8	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
8 to 9	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
9 to 10	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
10 to 11	1.00	31372	23529.00	7843.00	43.51	30.69	33.56	0.72	0.26	359.63
									Grand t[illegible]al	3596.33

Figure 3. 3: Total cost between Hassanabdal and Burhan, taking both sides of traffic into account=3596.33m

3.5.4 BURHAN AND KAMRAH



segment	length	AADT	VMT cars	VMT trucks	speed	Unit VOC car	Unit VOC truck	Delay cost(million Rs) car	Delay cost(million Rs) truck	Annual cost
0 to 1	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
1 to 2	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
2 to 3	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
3 to 4	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
4 to 5	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
5 to 6	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
6 to 7	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
7 to 8	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
8 to 9	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
9 to 10	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
10 to 11	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
11 to 12	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
12 to 13	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
13 to 14	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
14 to15	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
15 to 16	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
16 to 17	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
17 to 18	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
18 to 19	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
19 to 20	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
20 to 21	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
21 to 22	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
22 to 23	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
23 to 24	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
24 to 25	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
25 to 26	1.00	24297	18222.75	6074.25	43.51	30.69	33.56	0.56	0.20	278.53
									Grand total	6963.22

Figure 3. 4: Total cost between Burhan and Kamrah, taking both sides of traffic into account=6963.22m

3.5.5 KAMRAH AND ATTOACK BRIDGE

b/w Kamrah and Attock Bridge

			VMT			Unit VOC		Delay cost(million Rs)		
segment	length	AADT	cars	trucks	speed	car	truck	car	truck	Annual cost
0 to 1	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
1 to 2	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
2 to 3	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
3 to 4	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
4 to 5	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
5 to 6	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
6 to 7	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
7 to 8	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
8 to 9	1.00	17118	12838.50	4279.50	43.51	30.69	33.56	0.39	0.14	196.23
									Grand total	1569.86

Figure 3. 5: Total cost between Kamrah and Attock Bridge, taking both sides of traffic into account=6963.22m

3.5.6 TOTAL COST OF ALL SECTIONS

The sum of all the sections is given below, along with the summary of costs of individual sections.

Section	Grand Total (Million)
b/w Tarnol and Taxila	11370.88
b/w Taxila and Hassanabdal	5609.42
b/w Hassanabdal and Burhan	3596.33
b/w Burhan and Kamrah	6963.22
b/w Kamrah and Attock Bridge	1569.86

Figure 3. 6: Section and their grand total

VOC Calculation

Total cost =25070.62241m

3.5.7 IRI AND VOC RELATION

After a thorough examination and careful analysis, VOCs were calculated for each section, and we acquired the IRI values per km. A relation was then developed by making a graph in excel, which is given below. As it can be seen from the graph that there is a direct relation between values of IRI and VOC which means that increasing deterioration of roads increases the VOC

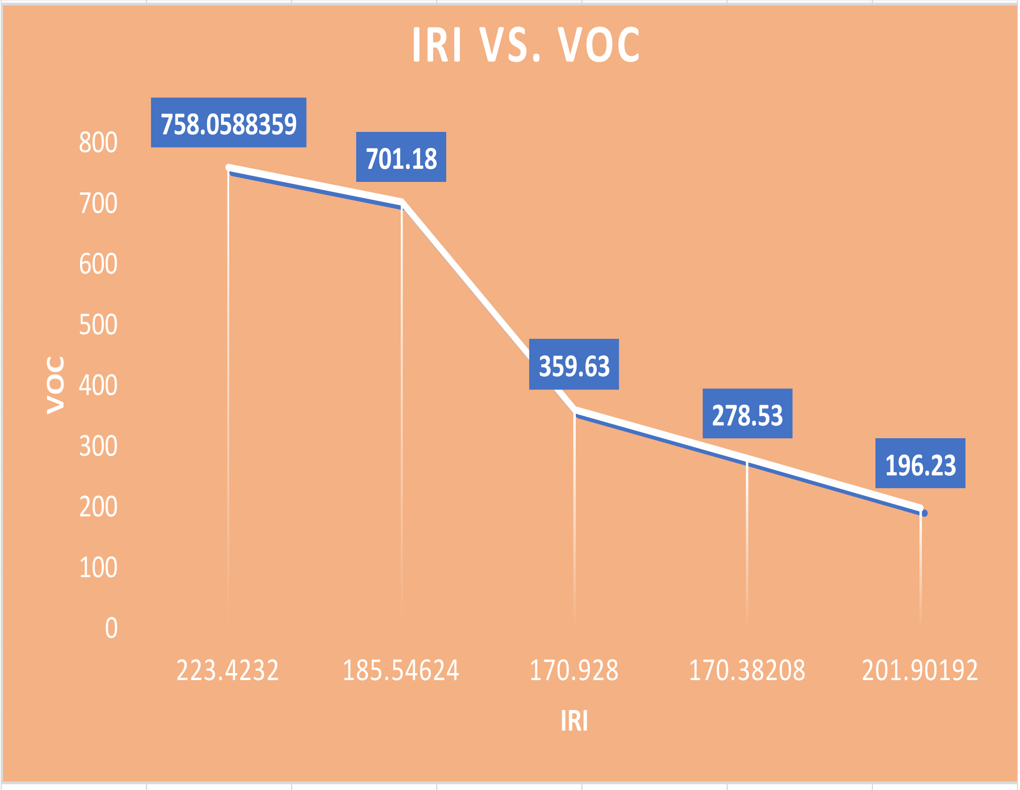


Figure 3. 7: IRI vs VOC

CHAPTER 4

MODULE 2
STRATEGIES

	Type of Activity	Increase Strength	Reduce Aging	Restore Serviceability
Pavement Preservation	New Construction	Yes	Yes	Yes
	Reconstruction	Yes	Yes	Yes
	Major (Heavy) Rehabilitation	Yes	Yes	Yes
	Minor (Light) Rehabilitation		Yes	Yes
	Preventive Maintenance		Yes	Yes
	Routine Maintenance			Yes
	Corrective (Reactive) Maintenance			Yes
	Catastrophic Maintenance			Yes

Table 4. 1: for pavement preservation

4.1 STRATEGIES ON OUR ROAD

From this table, we can understand which type of activities contribute to which type of function. From our data, the values of PSI vary, so we develop a strategy table below.

Type of Activity	PSI Range	Colour
Good	5-4	Green
Minor to Routine Maintenance	4-2.5	Yellow
Major Rehabilitation	2.5-0	Red

Table 4. 2: The type of activity carried out on the road based on the PSI range.

We declare the 4-5 PSI range area as good, and there is no need for rehabilitation for this range road. We represent it with green colour.

Now for the range of 4-2.5, we consider it to require maintenance, but it needs minor to routine maintenance, and we declare it with yellow colour.

Now the Road with PSI below 2.5 is represented in red colour, and it requires major rehabilitation or even reconstruction.

4.2 STRATEGIES FOR MINOR TO ROUTINE MAINTENANCE

To solve this [problem, we acquired three strategies to solve the problem of Road with PSI range between 4-2.5. These remedies are discussed below

4.2.1 MICRO-SURFACING

The micro surfacing system comprises a polymer asphalt emulsion mixed with crushed fine aggregate, mineral filler, and other additives. It is used on a 7 to 15 mm thickness surface. This is one of the preventive maintenance techniques.

MICRO-SURFACING IS DONE ON

- Potholes to patch them
- On fatigue crakes to seal them
- On utilities to properly mask them
- On the surface to make it clean

Figure 4. 1: Condition of Road During Micro Surfacing

Figure 4. 2: Condition of Road after Micro Surfacing

BENEFITS OF MICRO-SURFACING

- Chemicals are used in this, so it does not use sunlight for the heat of hydration.
- It hardens quicker than a slurry seal.
- It is used where the road is covered with shade or has less sun heat.
- It takes 1 to 2 hours to harden.
- It improves the skid resistance of the road.

4.2.2 CHIP SEAL

Chip seal is a one-layer treatment that spreads binding agent like bituminous, then spreads rapidly and compacts an aggregate cover of one layer. Its typical thickness is 6 -9.5mm.

It is a particular type of protective surface used on existing roads.

Small Rocks or chips are used as an aggregate.

Figure 4. 3: Manually doing Chip Seal

Figure 4. 4: Manually doing Chip Seal

Benefits

- Skid resistance of road increased
- Give a new look to the road
- Stop the road from early ageing

4.2.3 OVERLAYS

There are two types of overlays.

1. Non-structural overlays
2. Structural overlays

4.2.3.1 NON-STRUCTURAL (FUNCTIONAL) OVERLAYS

In these overlays, the overlays do not do anything with the structural design of the road. They contribute little to the structural capacity of the structure if any.

These overlays are thin surfaces of 0.5-2.5 inches.

Figure 4. 5: Road during Overlay

Figure 4. 6: Road after Overlay

Benefits

- The skid resistance and drainage of the road will be improved.
- Enhance the riding experience.
- The surface defects will be corrected.
- Aesthetic enhancements.

4.2.3.2 STRUCTURAL OVERLAYS

These Overlays are used in Major rehabilitation and improve the structural capacity of the road.

4.3 STRATEGIES FOR MAJOR REHABILITATION

The Road with PSI below 2.5 needs serious attention, which is why it is categorised in the major rehabilitation section.

Some methods include structural overlays, reconstruction, and new construction.

BENEFITS

- Increase the structural capacity of the road
- Increase road life
- Increase skid resistance

Note: as most of the range lies above the 2.5 PSI, our focus is on the Minor maintenance as that is cost-effective.

Chapter 5

MODULE 3
MACHINE LEARNING MODEL

5.1 NEED FOR MACHINE LEARNING MODEL

With time, new technologies are introduced in the engineering field, which helps ease work and save time. Machine Learning technology also mimics machines, and one does not necessarily have to use large machines and take them to the field.

We have introduced a predictive mimicker for ease of work because the equipment used to measure International Roughness Index (IRI) is not that easily available to everyone. So, we trained a Machine Learning Model with the data we acquired from National Highways Authority (NHA).

5.1.1 LACK OF EXPERIENCE

Some measuring devices are not available to everyone, and not everyone gets a chance to get hands-on with them, due to which they cannot use the instruments when provided. To avoid this, the model should be used, which does not need any prior experience and is a user-friendly model.

5.1.2 CHANCES OF ERRORS

With the use of conventional instruments, there were more chances of errors, and more time was wasted in debugging, which also cost more. However, errors can be detected faster with the Machine Learning model, and data augmentation can be done while programming the model.

5.1.3 FEATURES OF THE MODEL

5.1.4 COST-SAVING MODEL

The model is very cheap to use; there is no need to go to the site, and data is easy to extract neither there is a need for transportation, nor charges of the machines are paid; one must input data and get the required output.

5.1.5 TIME-SAVING MODEL

The model is straightforward and consumes a few bits of computer memory, which takes less processing time. The data input is processed in less than one second, and users do not have to wait longer for the results.

5.1.6 USER-FRIENDLY MODEL

The model has an easy user interface and does not include complex data calculations. The model itself will request the data required, and the User just must input the data, and the results will be in a form that the users can easily interpret.

5.2 INTERFACE OF THE MODEL

5.2.1 INPUTS

The input data button is installed in an excel sheet through VBA to allow users to store data in an excel sheet directly. For presentation purposes, a button was also installed in PowerPoint. So, when the excel sheet is opened, the User faces an INPUT DATA button, as shown in fig 5.1.

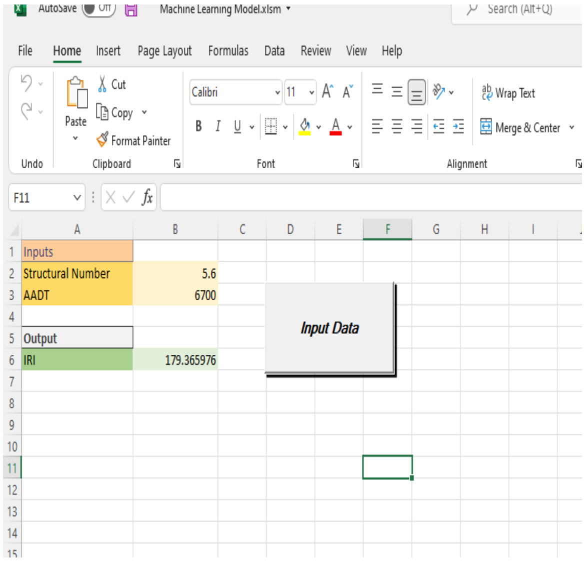


Figure 5. 1: User faces an INPUT DATA button

STRUCTURE NUMBER

When the INPUT DATA button is pressed, the model requires the SN data of the Pavement whose IRI is to be determined. It should be noted that it only takes positive integers and decimals numbers; otherwise, it gives run time error.

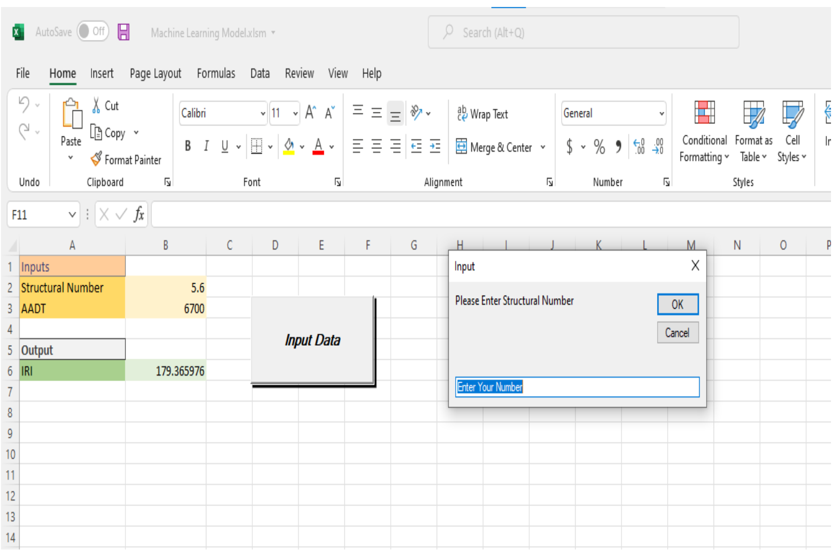


Figure 5. 2: Ask User to put a Structure Number

Run time error is shown when an alphabet is given as an input instead of positive integers and decimals, as shown in fig 5.3

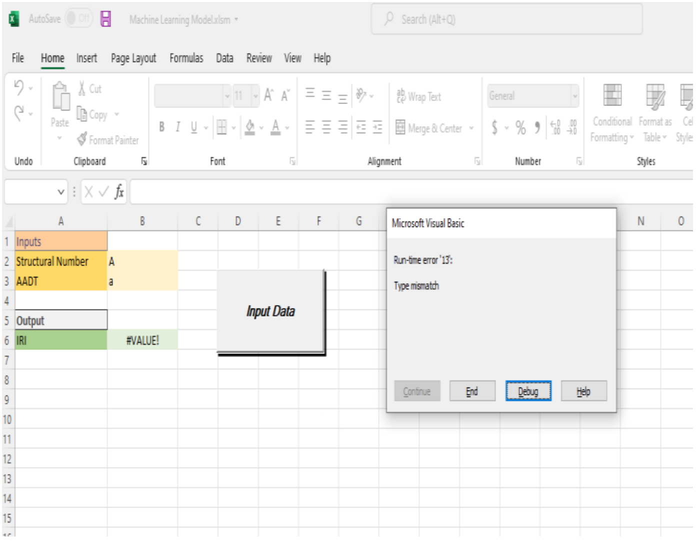


Figure 5. 3: Run time error

A new and valid value should be given to re-run the model.

ANNUAL AVERAGE DAILY TRAFFIC (AADT)

The model requires the second input of Annual Average Daily Traffic (AADT). It has the same number criteria as the structure number case; otherwise, the User will face a time error.

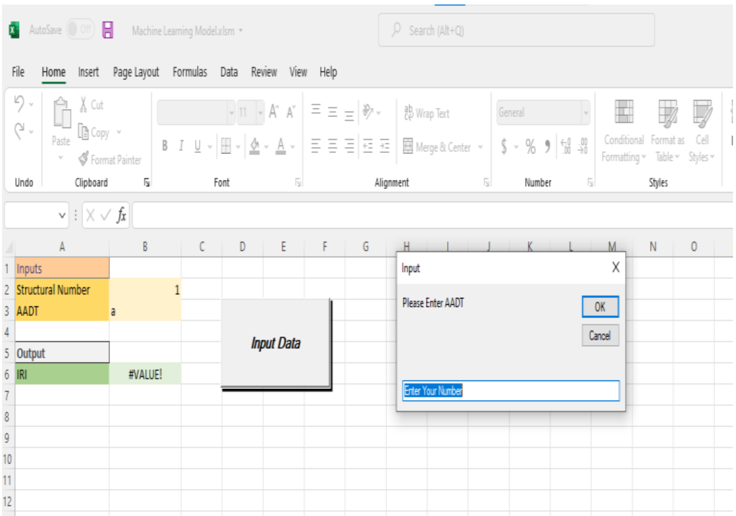


Figure 5. 4: model requires Annual Average Daily Traffic (AADT)

These two were the inputs of our model and should be provided carefully to get accurate data from the model.

5.2.2 OUTPUTS

The Machine Learning Model will give only a single output in the form of numbers which will be IRI in inches per mile of the Pavement whose data was provided as an input.

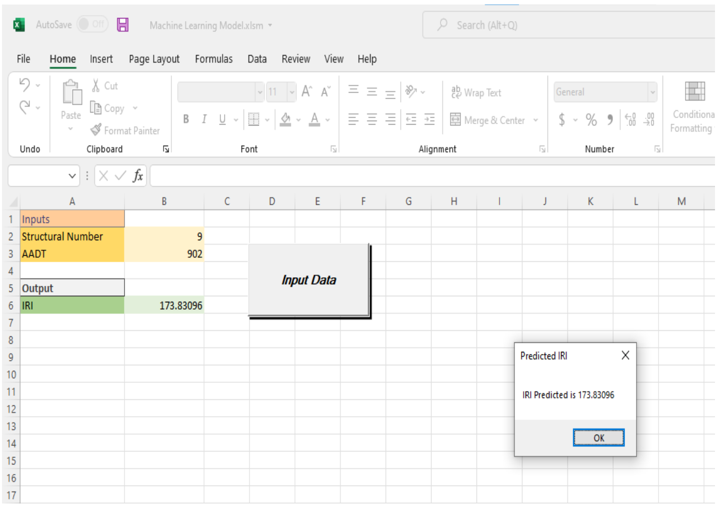


Figure 5. 5: single output in the form of numbers which will be IRI in inches per mile

For instance, our value for SN is 9, and that of AADT is 902. The IRI value predicted by the model is 173.83; we will compare this value with the table to check the condition of the Pavement through ride quality.

	Interstate Highways		Other Highways	
Ride Quality	IRI (m/km)	IRI (in./mi)	IRI (m/km)	IRI (in./mi)
Very good	<0.95	<60	<0.95	<60
Good	0.95–1.50	60–94	0.95–1.50	60–94
Fair	1.50–1.89	95–119	1.50–2.69	95–170
Mediocre	1.90–2.70	120–170	2.70–3.48	171–220
Poor	>2.70	>170	>3.48	>220

Table 5. 1: condition of the Pavement through ride quality

From the figure, we found that our ride quality lies in the mediocre range, i.e. 171-220.

5.2.3 RESULTS

We trained our model with 80% of the data provided by NHA, and the rest of 20% was used to check the model's accuracy. We provided values from 20% of the data to the model and counter-checked it with the actual one. The accuracy of the model turned out to be 85%.

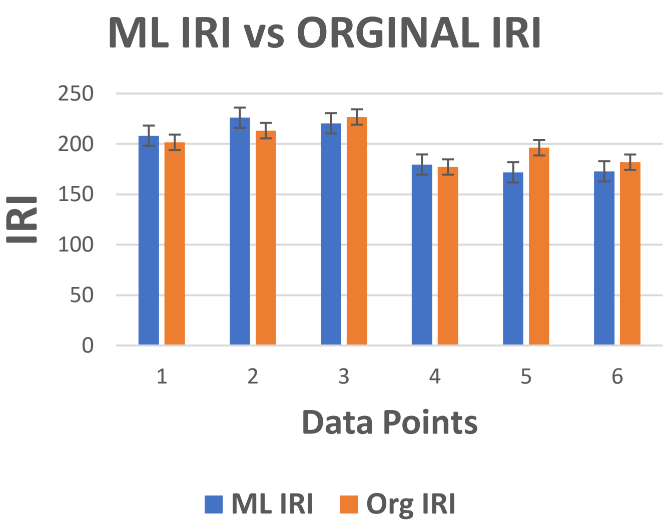


Figure 5. 6: Comparison between the Original IRI vs ML IRI

5.2.4 VBA

A button in excel and PowerPoint is installed through VBA.

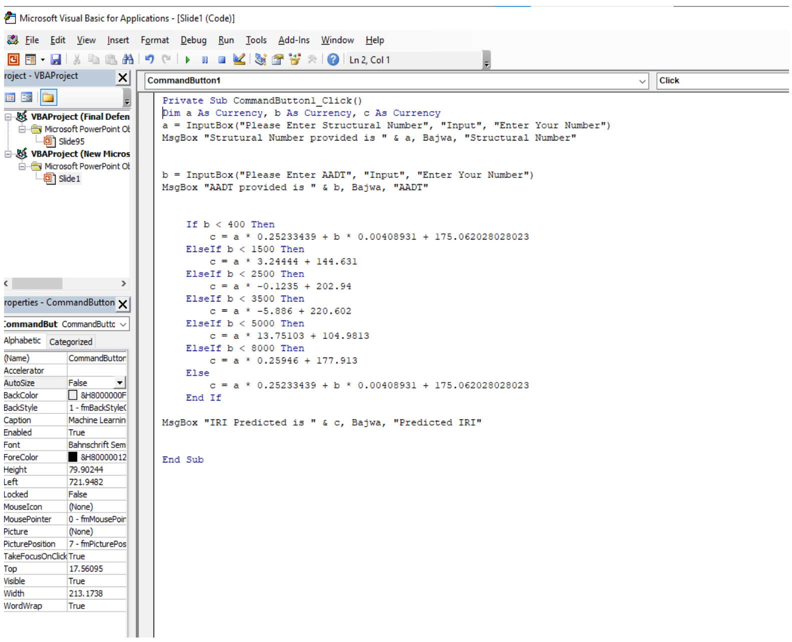
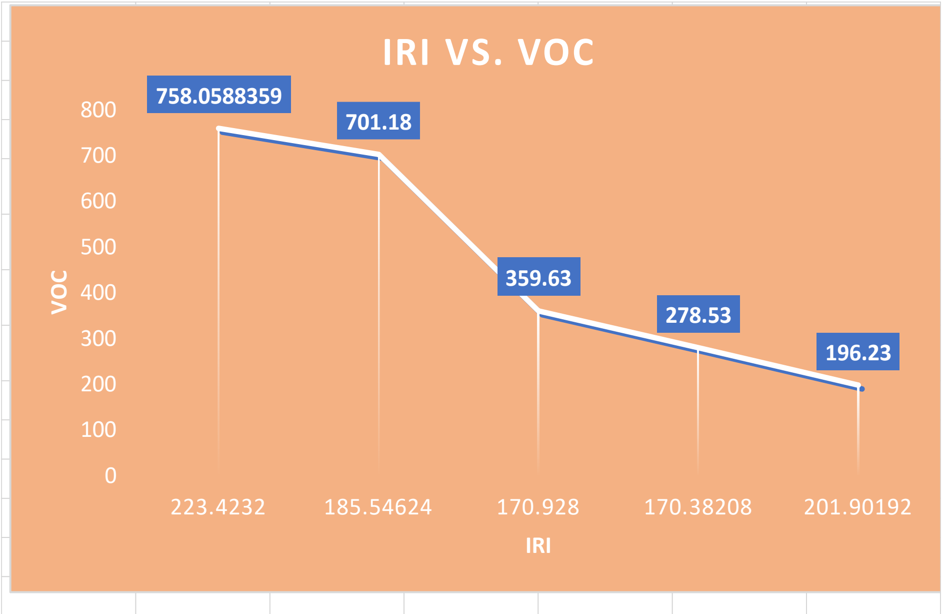


Figure 5. 7: A button in excel and PowerPoint

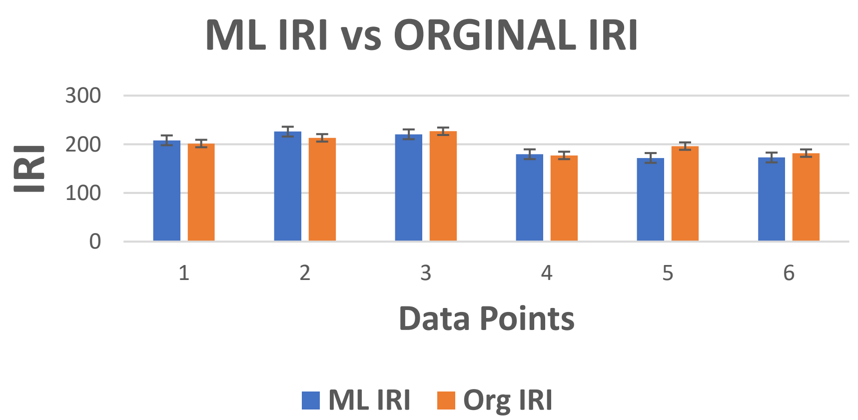
CONCLUSION AND RECOMMENDATION

The multimodule nature of the project draws us to multiple conclusions and recommendations. As far as module 1 is concerned, we conclude that VOC directly relates to the increasing road deterioration-IRI, as shown in fig.



So to fix up the VOC problem, the IRI value must be reduced to the desired range. This can be done by executing the proposed strategies of module 2, i.e. applying techniques based on the road condition and the budget constraint.

As far as module 3 is concerned, there are several recommendations along with conclusions that we, the authors, are putting forward. First of all, the model's accuracy was outstanding, about 85%. The accuracy of some datasets is shown in fig.



Furthermore, if more variables are included In the data and a greater dataset is provided, then the accuracy of the model may be further enhanced.

This thesis intends to assist municipalities in determining their priorities and data collection and maintenance plans. Using the maintenance/rehabilitation history data can significantly influence the predictability of road conditions, according to the results of our analysis. The type and timing of remedial actions are also important pieces of data that municipalities should regularly monitor, in addition to condition data. The study was conducted using data from IRI SN and AADT, acquired from a large region/area. The consistently changing wide weather and the diversity of acquired data and management practices may have increased the disparity in the data because of such acquisition. Therefore, further analysis was conducted on parts of each small geographic area. The accuracy of developed models was higher despite the relatively small data sets used for training to create subsets. Data analytics can be treated as a process and tool to show the advantages and disadvantages of data analytics. While the small municipalities discover data analytics, we made a procedure or framework that includes several steps and features. The quality and quantity of the data affected accuracy. The importance of analysis attributes can be partially qualified by missing or inaccurate data. As well as enhancing the quality of models, data cohesion also contributed to assessing their relative importance. In the case of PCI, this manifests itself in partitioning the data by regions of climate. This separation reduces noise in the data (difference). With the relatively small data set, the data produces a higher level of accuracy. To achieve this, we need to know that data analysis is all about uncovering patterns. Therefore, it is noteworthy to consider the many subsets of data and variations of modelling goals and attribute matching.

ACCURACY OF THE MACHINE LEARNING MODEL

As discussed in the segment of conclusion, data augmentation can increase the model's accuracy, so by dividing the data into different zones or segments, the accuracy can be further enhanced. We recommend that the municipalities and larger transportation departments use the method to increase the predictor's accuracy (Machine Learning model).

Another determinant factor controlling the accuracy is the number of variables. We had limited data, so the model could not be trained to the desired benchmark. Increasing the data surely will help in accuracy.

The number of variables can be increased to further build upon the accuracy. Again we were constricted in the type of data; hence we could afford to provide only two input variables, i.e. SN and AADT, to find IRI. Increasing the number of input variables supplements the accuracy of the mimicker.

RECOMMENDATION FOR VOC CALCULATION

Moving on to the VOC calculation, the speed we assumed was the highway's posted speed on that particular section and not the actual speed of the cars and trucks. Installation of cameras and finding the spot speed of a greater number of vehicles and calculating their average speed could be a better approach for speed. The worked-out speed could then be used for VOC calculation. Keeping in the notice that speed should be calculated separately for cars and trucks

RECOMMENDATION FOR STRATEGY MATRIX

A more practical and realistic strategy matrix can be created if a provision of a real-time project is made, which involves budget constraints by the client. PAMS, as discussed, is an approach to conserving the economy. As we were making a strategy matrix for a section with no provision of budget constraint, there is a high chance a relatively less economical matrix could have been created so that budget constraint can help this sort out.

REFERENCES

Amir KAVUSSI, Mojtaba ABBASGHORBANI, Fereidoon MOGHADAS NEJAD, Armin BAMDAD ZIKSARI. (2015). *A NEW METHOD TO DETERMINE MAINTENANCE AND REPAIR ACTIVITIES AT NETWORK-LEVEL PAVEMENT MANAGEMENT USING FALLING WEIGHT DEFLECTOMETER.* JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT. https://doi.org/10.3846/13923730.2015.1073173

T Arianto , M Suprapto and Syafi'i. (2017). *Pavement Condition Assessment Using IRI from Roadroid and Surface Distress Index Method on National Road in Sumenep Regency.* Universitas Sebelas Maret INDONESIA. IOP Conference Series: Materials Science and Engineering.

https://iopscience.iop.org/article/10.1088/1757-899X/333/1/012091

Karthik Dasari , Saman Salari , David J. Osborn , Mostafa A. Elseifi , Kevin Gaspard. (2013). *Effects of Pavement Conditions on Effective Structural Number of In-Service Pavements.* ASCE Library. https://ascelibrary.org/doi/abs/10.1061/9780784413005.028

Giuseppe Loprencipe, Antonio Pantuso, Paola Di Mascio. (2017). *Sustainable Pavement Management System in Urban Areas Considering the vehicle Operating Costs*. Department of Civil, Constructional and Environmental Engineering, Università degli Studi di Roma, Italy. Research Gate. https://www.researchgate.net/publication/315443428

(2001) *Asset Management for The Road Sector.* ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). https://doi.org/10.1787/9789264193208-en

M. Fakhri, Reza Shahni Dezfoulian. (2017). *Application of GIS for Pavement Maintenance Prioritization Based on a New Approach at a Network Level.* K.N Toosi University of Technology Tehran, Iran. https://www.researchgate.net/publication/317383239

Grégoire, G.; Fraix-Burnet, D.; Valls-Gabaud, D. (2014). *Simple Linear Regression. EAS Publications Series, 66(), 19–39.*

Yao, Linyi; Dong, Qiao; Jiang, Jiwang; Ni, Fujian (2020). *Deep reinforcement learning for long- term pavement maintenance planning. Computer-Aided Civil and Infrastructure Engineering, (), mice.12558.* *https://doi.org/10.1111/mice.12558*

F. Ali and Z. Batool. (2016). *GEOGRAPHIC INFORMATION SYSTEM (GIS) BASED HIGHWAY ASSET MANAGEMENT SYSTEM FOR MOTORWAYS: CASE STUDY OF MAJOR PAKISTAN'S MOTORWAYS.* Department of Transportation Engineering and Management, University of Engineering and Technology, Lahore, Pakistan. Pakistan Journal of Science.

https://www.proquest.com/openview/2188f39ada2765ceaaaf3e13144e9736/1?pq-origsite=gscholar&cbl=1616340

Mahmoud Halfawy and Roberto Figueroa. (2006). *DEVELOPING ENTERPRISE GIS-BASED DATA REPOSITORIES FOR MUNICIPAL INFRASTRUCTURE ASSET MANAGEMENT.* Joint International Conference on Computing and Decision Making in Civil and Building Engineering.

https://www.semanticscholar.org/paper/Developing-Enterprise-GIS-Based-Data-Repositories-Figueroa/bc3ba761a8ec01e7092a42cc88ed6b7096cc8c18

NASIR ALI, AHSAN ALI, SAIM RAZA, RANA JAHANZAIB MUNIR. (2015). *Traffic Analysis: Case Study (N-5 Corridor Rawalpindi, Pakistan).* Department of Civil Engineering National University of Sciences and Technology (NUST) Islamabad, Pakistan.
https://www.researchgate.net/publication/280557823_Traffic_Analysis_Case_Study_N-5_Corridor_Rawalpindi_Pakistan

APPENDIX A- TRAFFIC DATA

Vehicle type	C	D	a_0	a_1	a_2
Small automobile	24.8	45.5	27.2	0.035	0.00021
Medium automobile	28.5	95.3	33.5	0.058	0.00029
Large automobile	29.8	163.4	38.1	0.093	0.00033

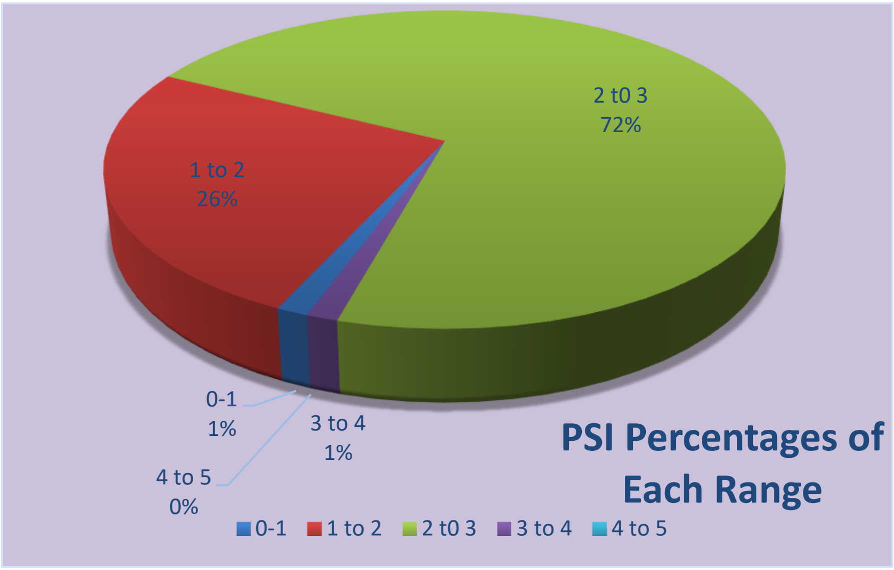
TABLE 1: Traffic Data.

APPENDIX B- IRI RANGES

Pavement Condition	IRI Range (in/mile)	Colour Coding
Excellent	4 To 5	
Very Good	3 To 4	
Good	2 To 3	
Fair	1 To 2	
Poor	0 To 1	

Table 2: IRI Ranges.

APPENDIX C- PSI PERCENTAGES OF EACH RANGE



APPENDIX D-IRI AND PSI

Route	Direction	Km	Remarks	Roughness			
				m/km	Index	IRI	PSI
Route	dir	km	**Rem**	rufmkm	gi	in/mi	in/mi
N-5_ Karachi-Torkham	NB	1561	Bridge	3.840	40	243.3	1.843928
N-5_ Karachi-Torkham	NB	1562		3.181	40	201.5	2.1882244
N-5_ Karachi-Torkham	NB	1563		2.522	30	159.8	2.5968076
N-5_ Karachi-Torkham	NB	1564		3.365	40	213.2	2.0860904
N-5_ Karachi-Torkham	NB	1565		3.212	40	203.5	2.1706733
N-5_ Karachi-Torkham	NB	1566		3.394	40	215	2.0704338
N-5_ Karachi-Torkham	NB	1567		1.998	20	126.6	2.9754803
N-5_ Karachi-Torkham	NB	1568		2.109	30	133.6	2.8909071
N-5_ Karachi-Torkham	NB	1569	Bridge	4.888	50	309.7	1.4044599
N-5_ Karachi-Torkham	NB	1570	Underpass	4.526	50	286.8	1.5429432
N-5_ Karachi-Torkham	NB	1571		3.992	40	252.9	1.7725375
N-5_ Karachi-Torkham	NB	1572		4.487	50	284.3	1.5586546
N-5_ Karachi-Torkham	NB	1573		3.982	40	252.3	1.7771481
N-5_ Karachi-Torkham	NB	1574	Speed Breaker	3.476	40	220.2	2.0267966
N-5_ Karachi-Torkham	NB	1575		3.578	40	226.7	1.9737976
N-5_ Karachi-Torkham	NB	1576		3.870	40	245.2	1.8296136
N-5_ Karachi-Torkham	NB	1577		3.195	40	202.4	2.1802806
N-5_ Karachi-Torkham	NB	1578	Bridge	3.638	40	230.5	1.9432714
N-5_ Karachi-Torkham	NB	1579		1.902	20	120.5	3.0506173
N-5_ Karachi-Torkham	NB	1580	Cat Eyes	2.003	30	126.9	2.971618

N-5_ Karachi-Torkham	NB	1581	Bumps	2.795	30	177.1	2.4190236
N-5_ Karachi-Torkham	NB	1582	Bridge	3.878	40	245.7	1.8258152
N-5_ Karachi-Torkham	NB	1583		3.704	40	234.7	1.9102376
N-5_ Karachi-Torkham	NB	1584		2.982	30	188.9	2.3043206
N-5_ Karachi-Torkham	NB	1585	Bridge	2.259	30	143.1	2.7804254
N-5_ Karachi-Torkham	NB	1586		2.422	30	153.5	2.6651503
N-5_ Karachi-Torkham	NB	1587		2.630	30	166.6	2.5249646
N-5_ Karachi-Torkham	NB	1588		2.756	30	174.6	2.4436559
N-5_ Karachi-Torkham	NB	1589	Bridge	4.422	50	280.2	1.5851966
N-5_ Karachi-Torkham	NB	1590		2.308	30	146.2	2.7452576
N-5_ Karachi-Torkham	NB	1591	Speed Breaker	2.597	30	164.5	2.5467032
N-5_ Karachi-Torkham	NB	1592		2.949	30	186.8	2.3241595
N-5_ Karachi-Torkham	NB	1593	Bridge	2.752	30	174.4	2.4461965
N-5_ Karachi-Torkham	NB	1594		2.205	30	139.7	2.8197038
N-5_ Karachi-Torkham	NB	1595		2.280	30	144.5	2.7652986
N-5_ Karachi-Torkham	NB	1596		2.354	30	149.1	2.7126478
N-5_ Karachi-Torkham	NB	1597		2.165	30	137.2	2.8491562
N-5_ Karachi-Torkham	NB	1598		2.371	30	150.2	2.7006946
N-5_ Karachi-Torkham	NB	1599	Cat Eyes	3.097	40	196.2	2.2364989
N-5_ Karachi-Torkham	NB	1600	Bridge	3.887	40	246.3	1.8215515
N-5_ Karachi-Torkham	NB	1601		2.716	30	172.1	2.4691805
N-5_ Karachi-Torkham	NB	1602		2.314	30	146.6	2.740982
N-5_ Karachi-Torkham	NB	1603		2.220	30	140.7	2.8087378
N-5_ Karachi-Torkham	NB	1604		2.487	30	157.6	2.6205258
N-5_ Karachi-Torkham	NB	1605		2.263	30	143.4	2.7775377
N-5_ Karachi-Torkham	NB	1606	Bridge	2.870	30	181.8	2.3723494
N-5_ Karachi-Torkham	NB	1607	Bridge	2.621	30	166.1	2.5308748
N-5_ Karachi-Torkham	NB	1608	Bridge	2.192	30	138.9	2.8292423
N-5_ Karachi-Torkham	NB	1609		2.872	30	182	2.3711172
N-5_ Karachi-Torkham	NB	1610	Bridge	2.640	30	167.3	2.5184138
N-5_ Karachi-Torkham	NB	1611	Bridge	2.404	30	152.3	2.6776416
N-5_ Karachi-Torkham	NB	1612		2.293	30	145.3	2.7559757
N-5_ Karachi-Torkham	NB	1613		2.432	30	154.1	2.6582358
N-5_ Karachi-Torkham	NB	1614		3.006	40	190.5	2.2899987
N-5_ Karachi-Torkham	NB	1615		2.614	30	165.6	2.5354812
N-5_ Karachi-Torkham	NB	1616		2.420	30	153.3	2.6665353
N-5_ Karachi-Torkham	NB	1617		2.226	30	141	2.8043633
N-5_ Karachi-Torkham	NB	1618		2.542	30	161.1	2.5833508
N-5_ Karachi-Torkham	NB	1619	Bridge	3.849	40	243.9	1.8396219
N-5_ Karachi-Torkham	NB	1620		2.731	30	173	2.4595777
N-5_ Karachi-Torkham	NB	1621	Bridge	2.774	30	175.8	2.4322562
N-5_ Karachi-Torkham	NB	1622		2.917	30	184.8	2.3435604
N-5_ Karachi-Torkham	NB	1623		3.683	40	233.4	1.9206869
N-5_ Karachi-Torkham	NB	1624	Bridge	2.908	30	184.3	2.349046
N-5_ Karachi-Torkham	NB	1625		4.240	50	268.6	1.6619435
N-5_ Karachi-Torkham	NB	1626	Speed Breaker	2.523	30	159.9	2.5961331
N-5_ Karachi-Torkham	NB	1627		3.026	40	191.7	2.2781318
N-5_ Karachi-Torkham	NB	1628		3.530	40	223.7	1.9985634
N-5_ Karachi-Torkham	NB	1629	Bridge	3.321	40	210.4	2.1100715
N-5_ Karachi-Torkham	NB	1630		3.319	40	210.3	2.111168
N-5_ Karachi-Torkham	NB	1631	Bridge	3.675	40	232.8	1.9246827
N-5_ Karachi-Torkham	NB	1632	Bridge	3.204	40	203	2.1751891
N-5_ Karachi-Torkham	NB	1633	Bridge	3.170	40	200.9	2.1944863
N-5_ Karachi-Torkham	NB	1634	Bridge	2.557	30	162	2.573304
N-5_ Karachi-Torkham	NB	1635		2.766	30	175.3	2.4373162

APPENDIX E- IRI VS VOC