

# Application of HDM-4 Model in the Structural, Functional, and Economic Variations using Road Maintenance Alternatives: A Case Study at Selected Road Sections in Addis Ababa City

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**Abstract**—Roadway is one of the most crucial transportation modes to cater to inland movement within a country. The agency mandate is to design, construct, and maintain the road to sustain the traffic up to its design life without further strengthening. However, some factors are affecting the performance of the pavement. Most pavements start to show some traces of deterioration after construction and opening to traffic, but once neglected, the distress portions would be aggravated with corresponding increasing maintenance cost. Thus, the road's maintenance has to be carried out at the place, right schedule, right quality, and at the least cost. Since there are different maintenance alternatives, the best strategy has to be chosen following the road's condition and the severity of the damage. To select the best maintenance alternative, calculations on the pavement layer's property are performed. The Highway Development and Management (HDM-4) tool can do such measures to help decide which option is the best by evaluating the economic and structural conditions. This paper contains two significant areas that are studied. First, it was assessed the procedures followed by the city's road authority to develop the appropriate road maintenance strategies. Questionnaire surveys and interviews are used to collect information from the city's road maintenance departments. Second, the project analysis was performed for structural and economic comparison of different maintenance alternatives using HDM-4. In the analyses, three selected road segments are considered and collected important input data like road condition data, road network data, vehicle fleet data, estimated AADT, and International Roughness Index (IRI). There were five maintenance alternatives have been defined, and proposed maintenance alternatives are compared. The selection is based on the deteriorated pavement, which showed the average roughness for every section of the road network, considering an analysis period of 20 years and cost stream ranking for their Net Present Value and IRR. Results indicated that using a mill and replace, and routine maintenance schedule for the selected road networks is economically viable and structurally significant. Hence, the city's road authority is recommended to apply the different maintenance strategies, providing an economical and better performance for the city's road network.

**Keywords** - Appropriate maintenance strategy, Average roughness, Cost stream, Economic variations, Maintenance alternative.

## I. INTRODUCTION

Road pavement deterioration due to lack of maintenance has become a pressing issue in some developing countries. The problem was presented with length, and the results of a lack of maintenance are well-defined and quantified. Nevertheless, the problem's extent is not fully recognized, and the palliative measures are not commonly understood. To the same degree, the measures required to rectify the shortcomings are under-estimated. These include the scale of support and capacity development required, and the time-scale necessary for establishing an effective road management system. Such a system should halt road network deterioration and ensure that financial, material and human investments are made to maintain the assets' quality and value and improve the network concerning the users' demands and priorities [1].

It is assumed that the decision to carry out rehabilitation or significant maintenance on the road has been made due to a planning process that has identified the 'best' projects to be undertaken in the financial planning period. Such a strategy will have identified roads in need of restoration and rehabilitation and evaluated them based on economic, strategic, and political criteria [2]. Pavements are a crucial component of the inland transport system. It is important to maintain the existing pavement network in its serviceable condition within the available resources. Based on a relative perceived urgency of pavement repair, engineers and managers can prioritize and schedule the maintenance of affected pavement sections. Some decision-making methods have been introduced and implemented under the Pavement Management System (PMS) study to prioritize pavement maintenance activities [3]. Some agencies used the Pavement Management Application that consists of the HD-4 Software and the interface built in the central repository for all network-level data required for the Pavement Management System [4].

On the other hand, an example of a well-developed system has been shown based on the current global HDM 4 model, which can be used for Project Analysis which allows users to assess the physical, functional, and economic viability of specified project alternatives by comparison against a base case, or a without-project alternative, also HDM-4 calculates the economic indicators like NPV, IRR, etc. for every option of the maintenance strategies for the projected analysis period [5].

In Addis Ababa, roads are being maintained without assessing the physical, functional, and economic feasibility between different types of road maintenance alternatives, also without calculating economic indicators for every option of maintenance strategies for the projected analysis period, which in turn makes it difficult to know which maintenance alternative is best for the specific road to be maintained. When a road pavement has deteriorated, only routine maintenance like overlay and patching is being applied. These maintenance alternatives are not enough to maintain the city's road. A variety of maintenance alternatives should be applied following the existing road condition to choose the best maintenance alternative strategy.

This paper aimed to assess the structural, functional, and economic variations in using different maintenance alternatives on several roads in Addis Ababa city as a general objective. This paper's specific goal was to identify road sections that are structurally deficient, affecting the service level, and establish Life cycle prediction on the deterioration of the selected three roads in Addis Ababa city. It was made to correlate and analyze the structural performance between different road maintenance alternatives by pavement surface gradual change in their IRI values for the desired analysis period, to determine the projected economic level between various options of maintenance strategies using HDM-4, and to evaluate the procedures followed by the City's Road Authority in selecting the best maintenance alternative for specific roads and to compare with the HDM-4.

## II. RESEARCH METHODS

### A. Study Area

Three road sections were selected within the road network of Addis Ababa. First, along with Bole Airport RA to Bole Michael South Intersection. This road section is located at Bole sub-city with coordinates of 38.79118-38.77522 longitude and 8.987268 - 8.980927 latitude, and an elevation of 2327 meters above mean sea level. The road has a length of 2.1km and a carriageway width of 20 m with a total road Area of 84000 m<sup>2</sup>. It is also called a Ring road, where a lot of vehicles are plying to get to their destination. Second, along with Coca RA to St. Ammanuel Church. This road section is located at Lideta sub-city with coordinates of 38.72991 – 38.72294 longitudes and 9.016615 – 9.027708 latitude with an elevation of 2382 meters above mean sea level. The road has a length of 2.065km and a carriageway width of 5m with a total road area of 20650 m<sup>2</sup>. It is a business area where a lot of people are moving as well as vehicles. Third, along with Future Park RA to Meta Jacros. This road section is located at Bole sub-city with coordinates of 38.81640 – 38.82128 longitudes and 9.003893 – 9.011038 latitude elevation of 2369 meters above mean sea level. The road has a length of 1.065km and a carriageway width of 10m with a total road area of 21300 m<sup>2</sup>. It is known as a dwelling area where there is a limited activity.

### B. Sample Size and Selection

The sampling technique that has been used in selecting road sections was purposive sampling. Three road sections were chosen based on data available on road condition data; based on recent maintenance date and availability of their maintenance costs. Purposive sampling, also known as judgment, selective or subjective sampling, is a non-probability sampling technique. The researcher relies on his judgment when choosing population members to participate in the study. Researchers often believe that they can obtain a representative sample by using sound judgment, which will result in saving time and money [6].

For hypothesized questions on AACRA's Road Maintenance Practices: The samples have been selected from professionals working in Addis Ababa City Road Authority, specifically the Road construction and maintenance department, Road asset management, and Road design department. It helped collect reliable data from professionals from their theoretical and practical background and their organizational relationship to know and improve AACRA's maintenance and rehabilitation activities.

In addition to the study's purpose and population size, three criteria are needed to be specified to determine the appropriate sample size: The level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured [7]. There are several approaches to determining the sample size. These included using a census for small populations, from a sample size of similar studies, using published tables, and applying formulas to calculate the sample size. Since this particular study population is small, Yamane [8] provides a simplified formula to calculate sample sizes (Respondents: Road construction and maintenance department, Road asset management, and Road design department). Considering a 95% confidence level and  $P=0.5$ , so,  $n$  can be calculated as shown in equation 1.

$$n = \frac{N}{1+N(e)^2} \dots\dots\dots (1)$$

Where:  $n$  is the sample size  
 $N$  is the population size  
 $e$  is the level of precision

### C. Data Collection Process

The study used some data sources to produce the following necessary documents: respondents' documents and archival documents. The respondents' comments were obtained using a questionnaire from a client (AACRA). A questionnaire (Open-ended questionnaire) was developed to assess the authority using types of maintenance alternatives. The alternatives used are economical for specific roads and to know if AACRA uses economic maintenance tools like HDM-4. Likewise, a desk study was chosen as one instrument to assess and obtain actual data about using different maintenance alternatives from relevant studies, reports, and documents to support the study's objectives.

Archival documents were collected, mostly Road Condition survey data, Vehicle fleet and composition, Road geometry, IRI of the selected road sections, unit cost, and maintenance costs. All of these documents are obtained from Addis Ababa City Roads

Authority, Road Asset Management and Maintenance Department Offices, and WT Consult to use as significant inputs for the analysis in the HDM-4 model.

#### D. Data Analysis

The respondents requested to express their opinion by answering agreements or disagreements on five hypothesized questions, including specific reasons. The questionnaire contains two sections, section-1 about the respondents' general backgrounds, and section two deals about Road maintenance practices of AACRA to develop appropriate maintenance strategy. However, the respondents are asked to respond to their agreement or disagreement in five nominal scales (Likert scale). To simplify the analysis, a comparison was performed on three scales; Agree, Neutral, and Disagree. The response for each of the questions is compared and presented.

On the other hand, the input data, including road network data, vehicle fleet data, maintenance standard, and project analysis, are necessary for the HDM-4 analysis. They are attached to the "supplementary materials" section. Five maintenance standards were defined which have been assigned for each road section; these are: Routine Maintenance (base alternative), Mill and Replace, Crack sealing, Reconstruction, and Scheduled Asphalt Overlay and Patching [9].

Project analysis is used to assess the physical, functional, and economic feasibility of specified project alternatives by comparing a base case or a without-project alternative. The key results of the analysis are indicated below [10, 11]:

1. Life cycle costing of pavement structural performance.
2. Prediction of road deterioration.
3. Estimation of road user costs (vehicle operating costs, travel time, and accidents).
4. Modeling of road works effects and the costs of these to the road administration.
5. Calculation of economic or financial benefits from comparisons of the project alternatives.

This approach aimed to determine which project alternative is most cost-effective and structurally significant. The project analysis was conducted for the three road network defined above. It includes the following key processes; generally, consists of four steps:

- ✓ Define project details
- ✓ Specify alternatives
- ✓ Analyze projects
- ✓ Generate reports

The first part, which was defining project detail, contains four parts. These are the general part, select sections, and choose vehicles and define normal traffic. In the general part, the analysis starting year and the analysis period was defined. In this case, the analysis starting year is 2020, and the analysis period considered is 20 years. The other essential parts are the road network and vehicle fleet data, which are selected and defined. In the next two parts, sections to be analyzed and vehicle were selected. Finally, normal traffic data is defined by providing the initial composition by the percentage of the total AADT and each vehicle's growth rate as an annual percentage increase. The second part was specifying alternatives to be analyzed in terms of section or project analysis. In this case, the investigation by section was chosen since it is needed to define several options for each section. Besides, for each road section, four alternatives are assigned four maintenance standards. The third part was to analyze the projects. It includes specifying the comparisons to be undertaken, such as the discount rate, choices about which car life model to use, what road safety analysis to be conducted, and whether or not to perform car emissions analysis and energy balance analysis and run the analysis.

The outputs from the HDM-4 analysis are produced under Generate Reports/Select Reports. The assigned maintenance alternatives were compared, and the best output is chosen after comparing their NPV and average roughness (IRI).

### III. RESULTS

HDM-4 generates many reports like average roughness by section, economic analysis summary, economic indicator summary, road work summary by project, and section. From these, some of the selected essential reports are discussed below:

#### 1. Deterioration/Work Effect Reports: Average Roughness by Section

This report shows Average roughness (IRI) vs. Year for each alternative for the analysis period 2020 to 2039.

##### A. Bole Airport RA to Bole Michael South Intersection

###### A.1 (B to B: Section-1)

The road network Bole airport to Bole Michael south intersection is divided into two sections. The deterioration or work effect report of section-1 is shown in figure 1, indicating the average roughness in m/km vs. analysis year.

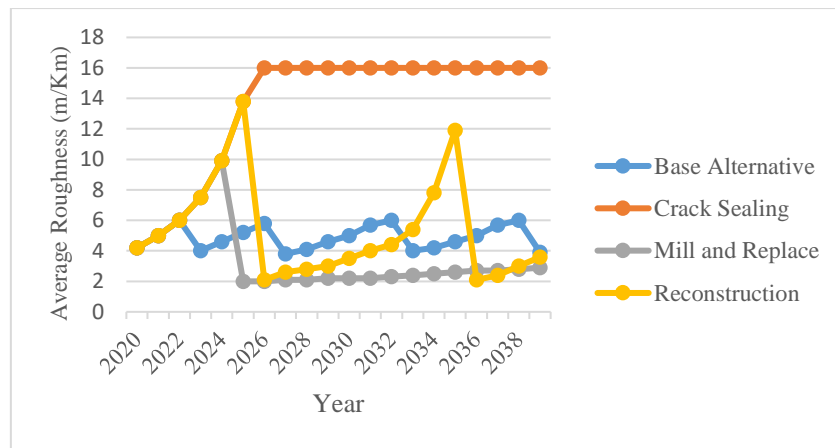


Fig. 1 Average Roughness (IRI): B to B: Section -1

From the above Roughness vs. Year figure, it can be seen that mill and replace (yellow color) is the best alternative since most of the years (15 years), IRI falls below 4, which is very good in terms of riding quality and structural viability.

**A.2 (B to B: Section-2)**

The deterioration or work effect report expressed as average roughness (m/km) vs. the analysis year for the road network (Bole Airport RA to Bole Michael south intersection) for section-2 is shown in figure 2 below.

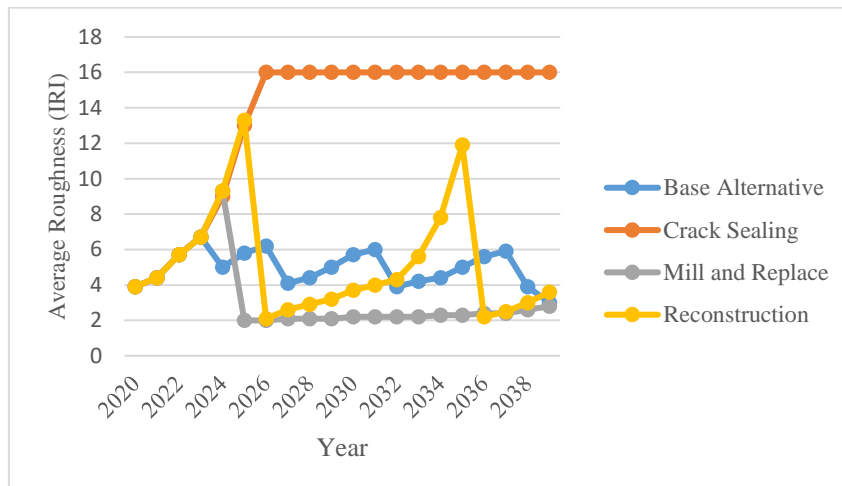


Fig. 2 Average Roughness (IRI): B to B: Section -2

Also, for this section, the above figure shows Mill and Replace is the best alternative.

**B. Coca RA to St. Amannuel Church**

**B.1 (C to S: Section -1)**

The road network Coca RA to St. Amannuel church was divided into two sections. Figure 3 shows the pavement deterioration or work effect report of the section expressed in terms of average roughness in m/km vs. analysis year.

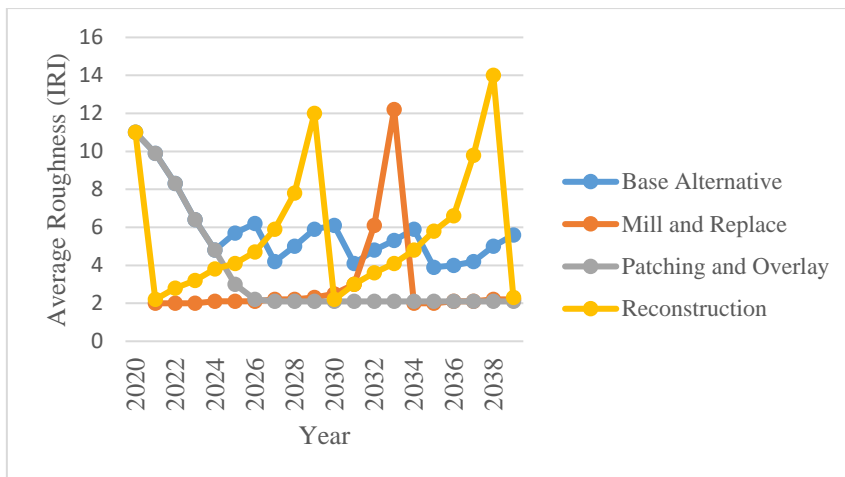


Fig. 3 Average Roughness (IRI): C to S: Section -1

For this section, the above figure shows both Mill and Replace and scheduled routine maintenance (patching and overlay) are the two best alternatives. Mill and Replace are better than Scheduled routine maintenance comparatively since it falls under IRI value 4 for most analysis years.

**B.2 (C to S: Section -2)**

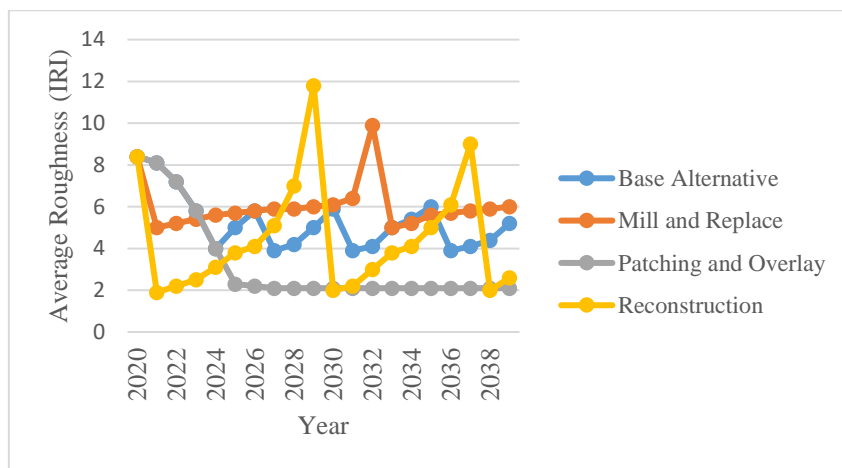


Fig. 4 Average Roughness (IRI): C to S: Section -2

For this particular section, scheduled routine maintenance (patching and overlay) is likely the best alternative since, in most of the analysis period, consistent IRI value is shown (under 2), which is good. However, at the start of the analysis year, it offers a significant IRI value, it starts to decrease eventually until it gets to an IRI value of 2.

**C. Future Park RA to Meta Jacros**

**C.1 (F to M: Section-1)**

Unlike the previously discussed road networks, this road section and Future park RA to Meta Jacross, composed only one section. The deterioration or work effect report of this single section road network is shown in Figure 5, showing the average roughness in m/km vs. analysis year.

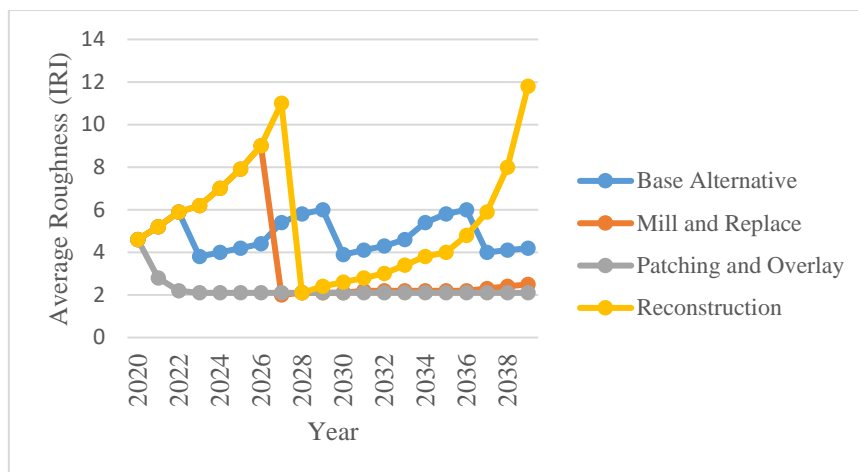


Fig. 5 Average Roughness (IRI): F to M: Section -1

This road network is a single section, as we can observe from the above graph, scheduled routine maintenance (patching and overlay), and Mill and Replace indicated the best result; both are under the IRI value of 4 for the most of the analysis period. Still, comparatively scheduled routine maintenance is the best approach from all of the alternatives since almost from starting the analysis period, it indicated an IRI value of 2.

1. Cost Stream Reports: Economic Indicator Summary

In the Economic indicator summary, the Net Present Value (NPV) and Internal Rate of Return (IRR) for all four alternatives are shown in a tabular format together with all three road networks and their road sections. Besides, an increase in agency costs and a decrease in user costs are also shown. The currency is expressed in million Ethiopian Birr.

A. Bole Airport RA to Bole Michael South Intersection (B-B)

The economic indicator summary and NPV and Internal Rate of Return for the four alternatives for the road network Bole Airport RA to Bole Michael (section -1) are shown in Table I.

TABLE I  
ECONOMIC INDICATOR SUMMARY: B TO B: SECTION-1

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	8.203	8.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	5.833	5.833	-2.370	2.520	0.000	4.890	0.838	0.838	14.6 (2)
CRACK SEALING	0.485	0.000	-7.718	-897.097	0.000	-889.379	-1,834.440	zero cost	No Solution
RECONSTRUC TION	8.688	8.688	0.485	-154.872	0.000	-155.357	-17.882	-17.882	-27.7(2)

Figure in brackets is the number of IRR solutions in the range -90 to +900

Likewise, the economic indicators for the four alternatives for the section-2 of the road network Bole Airport RA to Bole Michael intersection are illustrated as a tabular format in Table II.

TABLE III  
ECONOMIC INDICATOR SUMMARY: B TO B: SECTION-2

Alternative	Present Value of Total Agency Costs (RAC)	Current Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	12.019	12.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	8.822	8.822	-3.196	65.032	0.000	68.228	7.734	7.734	33.6 (1)
CRACK SEALING	0.829	0.000	-11.190	-1,290.070	0.000	-1,278.880	-1,543.269	zero cost	No Solution
RECONSTRUCTION	13.141	13.141	1.122	-171.677	0.000	-172.799	-13.150	-13.150	-36.9 (1)

Figure in brackets is the number of IRR solutions in the range -90 to +900

### B. Coca RA to St. Amannuel Church (C-S)

The economic indicator summary and NPV and Internal Rate of Return for the four alternatives of the road section along with Coca RA to St. Amannuel church (section -1) are shown in Table III.

TABLE IIIII  
ECONOMIC INDICATOR SUMMARY: C TO S: SECTION -1

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	9.281	9.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	4.799	4.799	-4.482	134.608	0.000	139.090	28.984	28.984	No Solution
RECONSTRUCTION	7.546	7.546	-1.735	61.865	0.000	63.600	8.428	8.428	3.7 (2)
PATCHING AND OVERLAY	16.859	16.859	7.578	62.800	0.000	55.222	3.276	3.276	678.4 (1)

Figure in brackets is the number of IRR solutions in the range -90 to +900

Also, in Table IV below, the economic indicators used in comparing the given four alternatives for section-2 for the road section along with Coca RA to St. Amannuel church are indicated.

TABLE IV  
ECONOMIC INDICATOR SUMMARY: C TO S: SECTION -2

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	9.281	9.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	4.799	4.799	-4.482	134.608	0.000	139.090	28.984	28.984	No Solution
RECONSTRUCTION	7.546	7.546	-1.735	61.865	0.000	63.600	8.428	8.428	3.7 (2)
PATCHING AND OVERLAY	16.859	16.859	7.578	62.800	0.000	55.222	3.276	3.276	678.4 (1)



Base Alternative	5.105	5.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	2.710	2.710	-2.395	-5.532	0.000	-3.138	-1.158	-1.158	No Solution
RECONSTRUCTION	4.211	4.211	-0.894	26.542	0.000	27.436	6.516	6.516	No Solution
PATCHING AND OVERLAY	9.317	9.317	4.212	27.370	0.000	23.158	2.486	2.486	465.4 (1)

Figure in brackets is the number of IRR solutions in a range  
-90 to +900

### C. Future Park RA to Meta Jacros

The economic indicator like Net Present Value (NPV) and Internet Rate of Return (IRR) are shown in Table V for this single section.

TABLE V  
ECONOMIC INDICATOR SUMMARY: F TO M: SECTION-1

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	4.284	4.284	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILL AND REPLACE	3.014	3.014	-1.270	-7.291	0.000	-6.021	-1.998	-1.998	10.4 (2)
RECONSTRUCTION	4.268	4.268	-0.016	-43.456	0.000	-43.440	-10.177	-10.177	No Solution
PATCHING AND OVERLAY	26.999	26.999	22.715	53.327	0.000	30.612	1.134	1.134	145.7 (1)

Figure in brackets is the number of IRR solutions in the range -90 to +900

## IV. DISCUSSION

From the HDM-4 output results in the above tables, the alternatives are compared based on the Net Present Value (NPV) values. The one with the most significant Net Present Value (NPV) value is taken as the best alternative.

### 4.1. Bole Airport RA to Bole Michael South Intersection:

For section 1, Mill and Replace is the best alternative based on Net Present Value. This result confirmed with the comparison of the alternatives based on average roughness. Also, for section-2, Mill and Replace could be seen as the best alternative. This result also confirmed with the comparison of the options based on average roughness.

On the other hand, section-1, the suggested maintenance strategy by ACCRA, is the application of asphalt overlay, but contrary, the HDM-4 result for the same section suggested Mill and Replace as the best alternative. Therefore, while considering different cost schemes like long-term agency cost, road user costs, mill and replace, had found to be the best alternative for the given analysis period of 20 years. In section-2, the suggested maintenance strategy by AACRA was patching plus (+) overlay, but the HDM-4 result for the same section suggested Mill and Replace. So, Mill and Replace's application is the most viable and structurally capable maintenance alternative for the whole road section.

### 4.2. Coca RA to St. Amannuel Church:

For section-1, Mill and Replace is the best alternative based on Net Present Value. This result also confirmed with the comparison of the alternatives based on average roughness. Section-2, reconstruction of the road (rehabilitation) is the best



alternative but based on a comparison against average roughness, scheduled patching and overlay was a bit better than reconstruction. In section-1, ACCRA's suggested maintenance strategy was patching plus (+) overlay, but the HDM-4 result for the same section suggested Mill and Replace was the best alternative. Therefore, while considering different types of costs like long term agency cost, road user costs, mill and replace, had found the best alternative for the given analysis period of 20 years. While in section-2, the suggested maintenance strategy by AACRA was a reconstruction of pavement (rehabilitation), and the HDM-4 result for the same section also suggested reconstruction of the road.

#### *4.3 Future Park RA to Meta Jacros:*

This road section indicated that scheduled asphalt overlay and patching is the best alternative based on Net Present Value (NPV). Also, it confirmed that this alternative is viable based on the average roughness index. It suggested a maintenance strategy by AACRA, such as asphalt overlay (i.e., responsive routine maintenance). The analysis of the HDM-4 supported the mentioned strategy by AACRA through scheduled patching and overlay. It implies that AACRA would have been more economical if they have a schedule and apply the routine maintenance activity once a year.

#### *4.4. On Hypothesized Questions on Road Maintenance Practices of AACRA:*

Most of the pavement treatment types applied by Addis Ababa City Road Authority (AACRA) are asphalt overlay and patching along the three studied sections. In 2008 E.C or 2016 G.C, the authority has implemented a pilot project on anti-rut treatment type on the Old Post office road to prevent rutting. The treatment type was applied in the section with a high grade(slope). It was observed that the sudden braking force from the heavy trucks was the primary factor causing a problem of pavement rutting. Likewise, AACRA is planning to perform preventive treatment type on succeeding upcoming projects, while other road sections, Mill and Replace treatment type, will be implemented in forthcoming years. It was known that the road authority had purchased a Milling machine to replace the previous method of removing defected pavement by labor.

Among the different pavement maintenance treatment types that can be used, most respondents agreed that AACRA is implementing patching potholes and asphalt overlay. Besides, AACRA is experimenting with different kinds of pavement treatment types such as Anti-rut and Mill and Replace; most of the AACRA's pavement maintenance projects are sealing cracks, patching potholes, and asphalt overlay. But, these treatments are not adequate to maintain the city's road in good condition. It was also observed that AACRA did not apply specific maintenance treatment selection techniques, which are mandatory for recommending specific and cost-effective remedial maintenance measures.

More so, most respondents agreed that AACRA currently not using different tools or Software to develop the appropriate pavement maintenance strategy. There is various Software used by road agencies worldwide to choose the best maintenance treatment method among different maintenance strategies. One of them is HDM-4, which calculates economic indicators like Net Present Value (NPV), Internal Rate of Return (IRR) for the maintenance strategies within the projected analysis period. The most beneficial maintenance option will be one that gives the maximum economic return.

Hence, considering the study results, AACRA has to strengthen the pavement evaluation method to assist in the treatment selection strategy. It has to determine alternative treatment options and sort out cost feasibility, treatment's ability to the pavement's functional and structural condition while also meeting any future needs or requirements. It is also suggested that Addis Ababa City Road Authority (AACRA) has to regularly carry out routine road maintenance activities known by its relatively inexpensive and significant cost savings methods.

## V. CONCLUSION

Currently, Addis Ababa City Road Authority (AACRA) applies patching, asphalt overlay, and reconstruction as a maintenance strategy on the three road sections studied but did not apply routine maintenance, such as crack sealing, de-clogging of the drainage system, and other routine maintenance activities. Besides, the road authority does not have a formal standard approach of intervention; instead, maintenance work for specific work is based on severity level. The above paper also shows that AACRA currently does not have any software or tools to come up with the appropriate maintenance activities that offers the alternative that is economical or not. The result from HDM-4 shows that applying Mill and Replace is more economical than overlay even though it has more initial cost than the overlay. At the end of the analysis period of 20 years, Mill and Replace provides more excellent Net Present Value (NPV). Hence, the result obtained from HDM-4, scheduled routine maintenance is economically viable and structurally efficient in reducing pavement cracks and keeping the road in good condition. The software result also shows that the Mill and Replace reduces roughness value by a more significant degree than an asphalt overlay.

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