Developing An Optimization Model For Pavement Maintenance Planning And Resource Allocation In Hossana Town, Ethiopia

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***Abstract**: Pavement Management System is designed to provide objective information and useful data for analysis so that road managers can make more consistent, cost-effective, and defensible decisions related to the preservation of a pavement network. During the process of road network maintenance and rehabilitation, road authorities strive to select an optimum maintenance strategy from a number of alternatives. Mathematical optimization models, supported by suitable data, can assist decision making about allocating funds between alternative maintenance tasks and about the size of the maintenance budget. It can be done through the analysis of costs and benefits by comparing the various maintenance alternatives with the help of an optimization method known as solver. The road segment mainly included in study was road from Hosanna Menhariya to Wachemo University and other important access roads. These roads are divided into different sections in not more than 100m length. The Study involves data collection, data analysis and the selection of optimal maintenance strategy by using a method known as Solver (Add-ins in Microsoft excel). In this study, patching was selected as possible alternative maintenance among the other alternatives. The result of solver analysis for patching indicates that as 74,574 birr allocated for the maintenance of pavement per kilometer in different three segments under the municipality having the constraint budget of 152,018.45 birr/km. The optimized solution shows that about 20962.5 birr would be saved in one year per km with in municipality.*

***Key Word**: pavement management system, optimization, pavement maintenance, Solver*

1. Introduction

The earliest Pavement Management Systems (PMS) were developed in the mid to late 1970s as a direct result of the development of modern electronic computers and data base management systems. The late 1950's and 1960's were also a time of intensive road building and pavement construction. Most agencies' construction programs were focused on the construction of new pavements rather than on the maintenance and preservation of their existing pavements. However, by the mid-1960's, some states had begun to change their construction program's emphasis from new pavement construction to pavement preservation [12]. After the construction of urban network, the maintenance of urban roads is an important part of urban traffic management. Nationally, pavements are deteriorating faster than they are being restored because maintenance funding has not been sufficient to take care of all needs. The pavement management system presented in this article aims to find optimal solutions for managing pavement segments, in other words to maintain road segments above a desired pavement.

1.1 Background

A Pavement Management System is a set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time for the least cost [1]. Agencies have always managed some form of pavement preservation activity which could be considered pavement management. In larger agencies, such as a state highway agency, the Agency was subdivided into regions, districts, or areas which normally managed the day-to-day road maintenance planning, design and construction projects. An Agency's pavement maintenance or rehabilitation project was developed from a list of projects developed at the regional level. The list of projects may have been developed based on a wide range of criteria ranging from perceived pavement condition (not measured) and engineering experience, to political necessity. In many cases, the list was developed based on relative pavement condition, maintenance activities, and engineering experience. Each region was allocated a specific amount of funds for each program cycle for their construction program, usually based on their proportion of highway miles of each function class and also with traffic levels sometimes factored in. Planning level cost estimates were developed for each project on the list, and projects were selected from the list until the allocated funds were consumed. The lists and projects were adjusted or massaged a bit to develop the actual construction program. As contract plans were prepared and awarded, some additional adjustments in the program were always required based on the final cost and scope of each project.

Pavement Management System is designed to provide objective information and useful data for analysis so that road managers can make more consistent, cost-effective, and defensible decisions related to the preservation of a pavement network. While a PMS cannot make final decisions, it can provide the basis for an informed understanding of the possible consequences of alternative decisions. An ideal pavement management program for a road network is one that would maintain all pavement sections at a sufficiently high level of service and structural conditions, but requires only a reasonable low budget and use of resources [4].

1.2 Problem Statement

Roadways cause accidents in a variety of ways, mostly due to the fact that they create an enormous hazard to drivers. In many instances, a driver may attempt to avoid a certain situation, like a pothole or pooling water which could cause a serious accident. Sudden hazards like potholes and road debris can cause serious (and expensive) harm to the tires and undercarriage, hindering the driver's ability to control the vehicle. The objective function aims at minimizing a generalized cost parameter which includes agency cost, user costs (including vehicle operating cost for fuel consumption, vehicle maintenance and depreciation, travel delay cost, accident cost, discomfort cost) and environmental cost due to pavement deterioration. Optimization is the act of achieving the best possible result under given circumstances. In the study area Hosanna town, the pavement maintenance action was taken in recent days on different road segment. But currently the road segment was going back to its previous distress with in short period of time after maintenance. Optimization answers the question of the right treatment on the right project at the right time raised under the road maintenance. One of the reasons why we have these problems within the optimization area, is the lack of a tool for proper communication between road administrations and decisions makers. Therefore, developing optimization model by carrying out a clear analysis using new statistical approach known as Microsoft excel Add-ins (Solver) improve the existing problem.

1.3 Objective of the Study

1.3.1 The general objective

In light of the research problems described above, the general objective of this study is to develop an optimization model for pavement maintenance planning and resource allocation.

1.3.2 The specific objectives

1. To observe the pavement condition on the proposed road segment.
2. To identify major components of optimization.
3. To collect input data required and performing network analysis.

1.4 Significance of the Study

The finding of this research primarily used to provide a tool that results in better decision-support systems. The recommendation was included at the end on the most suitable approaches and optimization methods for the design of maintenance programs under different scenarios. Hence, this study creates the chance for future researchers who will make the same study to investigate more ideas based on an analysis of the current state of the practice.

1.5 Scope of the Study Area

Scope of the study is limited to main corridor of Hosanna town in four directions. It is located at the southern part of Ethiopia and at 231km away from Addis Ababa which is the capital of Ethiopia. The geographic position of the town falls between 734'59.988"N and 3752'59.880"E longitude with an average altitude 2300m above sea level. Hosanna Menhariya to Wachemo university road segment selected in this study. The reason behind the selection of this road lies on the availability of most of the required data for the analysis. The property of the roads has been studied in detail by dividing the whole covering length into different sections which in turn are divided into small segments each having not more than 100m length.

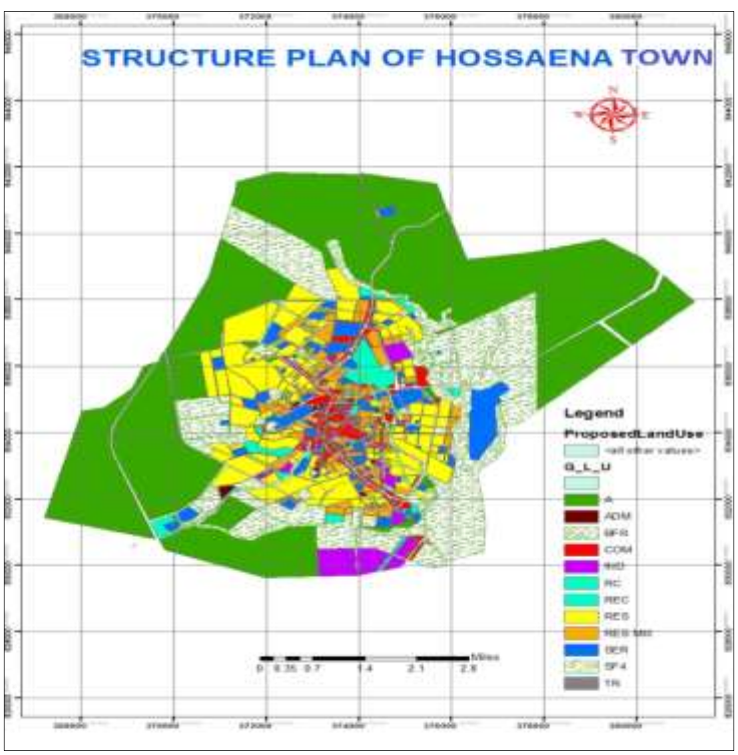

Figure 1.1 The Study Area Map Drawn by Using Arch GIS

2 Literature Review

2.1 Pavement Management System

When pavement is in service, the traffic loads and environment would deteriorate it. Therefore, an amount of funds would be invested to maintain it in an adequate condition to perform its role. If available funds are sufficient, the pavement sections whose condition states are below minimum acceptable serviceability level will get maintenance and rehabilitation in time. However, lack of funding often limits timely repairs and rehabilitation of the pavement. Therefore, the decision making of pavement management is the problem on how to gain maximum condition with minimum costs during the process of road network maintenance and rehabilitation, road authorities strive to select an optimum maintenance strategy from a number of alternatives. An economically acceptable maintenance strategy may be selected among a number of maintenance alternatives. It can be done through the analysis of costs and benefits by comparing the various maintenance alternatives with the help of genetic algorithm, Highway Development and Management tool (HDM-4) and other tools ([2]. The author selected the optimum maintenance strategy by comparing Discounted Net Present Value, Road Deterioration (Roughness progression) and Emission by vehicle Report. According to the study, the results of the analysis has shown that scheduled patching and overlay is the optimal maintenance alternative for both of the selected road networks.

The optimization strategies provided by the developed soft computing tool can help solving agency problems; minimizing costs and maximizing road services [9]. Pavement maintenance is one of the major issues of public agencies. Insufficient investment or inefficient maintenance strategies lead to high economic expenses in the long term. Under budgetary restrictions, the optimal allocation of resources becomes a crucial aspect [16]. Pavement Management Systems are widely used and are continuously being improved because they can lead to considerable fund savings and/or to higher levels of service of road pavements [14]. In this work, a model for pavement maintenance, rehabilitation planning is presented. The objective function aims at minimizing a generalized cost parameter which includes (1) agency cost, (2) user costs (including vehicle operating cost for fuel consumption, vehicle maintenance and depreciation, travel delay cost, accident cost, discomfort cost) and (3) environmental cost due to pavement deterioration. The maintenance and rehabilitation treatments are considered with regard to their cost and effectiveness characteristics.

Xiong, et al., 2012 developed a Compromise Programming Model for Highway Maintenance Resources Allocation Problem and show that the conditions of both pavements and bridge decks are improved significantly by applying compromise programming, rather than conventional methods. Resources are also utilized more efficiently when the proposed method is applied. Mathematical optimisation models, supported by suitable data, can assist decision making about allocating funds between alternative maintenance tasks and about the size of the maintenance budget [11]. It can promote best use of available funds by helping determine the types and timings of treatments to be carried out. At a higher level, it can help determine appropriate levels of maintenance funding. In most countries it is believed to be a political benefit to be in favor of investing money in building new roads. However, maintenance does not have the same status or does not give the same opportunity to stake holders or decision makers to present themselves to the public [13]. Therefore, a researcher have to create a platform for politicians and other decision makers where they can operate and get political benefit from arguing about the importance of maintaining the roads. Good management and decision-support systems are necessary and must be developed. First one has to establish a maintenance standard for the different activities in the maintenance sector.

3 Methodology

3.1 Research Design

The research study conducted by using both experimental and analytical methods. In order to achieve the research objective both qualitative and quantitative studies were employed in this study. Here qualitative study gives the impression of the findings where a quantitative study used to describe the numerical aspects of the research findings.

3.2 Variables Included in the Study

The objective function aims at minimizing a generalized cost parameter which includes agency cost, user costs (including vehicle operating cost for fuel consumption, vehicle maintenance and depreciation, travel delay cost, accident cost, discomfort cost) and environmental cost due to pavement deterioration. Decision variables are the set of MR&R treatments, inventory, and pavement condition. The constraints included were the total available budget.

3.3 Method of Data Collection

In primary, we have used two data collecting methods namely direct measurement and observational survey. An in depth measurement was carried out to collect primary data related to pavement surface condition. The data collection activity was conducted by data collectors in the presence and by closely supervision of the researchers. The field survey was done in detail using base map, photographs and surveying instruments. Types, severity and extent of each type of distress was recorded during data collection as shown in table below. In this research secondary data especially cost data was collected from ERA manual, ERA district and World Bank report.

Table 3.1 Maintenance Activities Set by the Ethiopian Road Authority Source

Category	Scope	Ref. No.	Maintenance Activity Type	Unit	Unit Price ETB for the year (2003)
Routine Maintenance	Pavement	210	Asphalt Patching (Seal Coat)	m^2	25.15
		211	Asphalt Patching (Single Surface Treatment	m^2	28.81
		212	Asphalt Patching (Double Surface Treatment)	m^2	49.74
		213	Asphalt Patching (Cold Mix)	m^3	2,137.12
		214	Asphalt Patching (Hot mini-mix))	m^3	2,433.69
		215	Crack Sealing (Individual cracks)	lm	22.85
		216	Pothole Reinstatement (Double Surface Treatment)	m^2	48.09
		217	Pothole Reinstatement (Cold mix)	m^3	2,264.72
		218	Pothole Reinstatement (Hot mini- mix)	m^3	2,541.69
	Drainage	230	Ditch Cleaning (Machine)	km	2,814.99
	Road side	240	Shoulder Blading	km	463.38
		241	Shoulder Rehabilitation	m^3	94.29
Periodic Maintenance	Pavement	309	Sand seal coat	m^2	13.8
		310	Single Bituminous Surface Treatment(SBST)	m^2	1.01
		311	Double Bituminous Surface Treatment(DBST)	m^2	35.29
		312	Mix-in-place overlay (cold mix)	m^3	1,414.29
		313	Asphalt Concrete overlay	m^3	2,064.46
		314	Bitumen Prime Coat	Lt	15.8
		315	Bitumen Tack Coat	Lt	16.72

(Source: ERA, 2003)

Types, severity and extent of each type of distress were recorded during data collection as shown in table below. The pavement condition surveys and investigation along the study area revealed that different types mainly: potholes, surface defect, rutting, cracking and problems related to road failures along the road side have been existed. In order to carry out the detailed pavement condition survey, four road segments were selected as shown in the table below. For the uniform sections are relatively short like St. Mariam church to Taywan (Indoven), the detailed condition survey was carried out over the entire length of the section. However, for long sections the representative 1 kilometer lengths of road was used to identify the cause of pavement distress. The lengths of road investigated by this method represent 10 percent of each section (blocks). The maximum block length used was 200m.

Table 3.2 Economic Cost Estimation for Entire Area

No.	Segement	Type of distress	Area covered (m^2)	Possible maintenance type	Economic cost (birr/m^2)	Economic cost for entire area (ETB)
1	Nigist Eleni Hospital to Lucy	Alligator Crack	51.7	Patching	432	101563.2
		Longitudinal Crack	7.8	Fog spray	163	38321.3
		Edge failure	65.0	Slurry seal	107	25155.7
		Potholes	16.0	Thin lay	331	77818.1
		Rutting	94.6	Overlay	567	133301.7
		Total	**235.1**	Reconstruction	797	187374.7
2	Nigist Eleni Hospital to Mebrat Hayle	Alligator Crack	63.5	Patching	432	139752
		Longitudinal Crack	28.7	Fog spray	163	52730.5
		Edge failure	83.5	Slurry seal	107	34614.5
		Potholes	54.3	Thin lay	331	107078.5
		Rutting	93.5	Overlay	567	183424.5
		Total	**323.5**	Reconstruction	797	257829.5
3	St. Marry Church to Taywan (Indoven)	Alligator Crack	40.6	Patching	432	116640
		Longitudinal Crack	6.1	Fog spray	163	44010
		Edge failure	82.5	Slurry seal	107	28890
		Potholes	20.4	Thin lay	331	89370
		Rutting	120.4	Overlay	567	153090
		Total	**270.0**	Reconstruction	797	215190
4	Wachemo University to 18 - Mazoria	Alligator Crack	118.0	Patching	432	247276.8
		Longitudinal Crack	91.3	Fog spray	163	93301.2
		Edge failure	54.8	Slurry seal	107	61246.8
		Potholes	94.8	Thin lay	331	189464.4
		Rutting	213.5	Overlay	567	324550.8
		Total	**572.4**	Reconstruction	797	456202.8

3.4 Methods of Data Processing and Analysis

Data processing was taken by using the problem-solving process of Microsoft excel Add-ins (Solver). Add-ins (Solver) begins with making active these parameters on Microsoft excel and the identification of problem parameters. The first step to set Solver method is to formulate variable types and solving problem. Afterward, the formulating of fitness value is to be set up as objective function, decision variables and constraints for optimization.

4 Results and Discussions

4.1 Discussion on Pavement Distress for Sample blocks

Cracking

Alligator cracking: Cracking begins at the bottom of the asphalt surface, or stabilized base, where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. According to ERA, 2002 the severity level can be determined be measuring the length of cracking. The severity level can be categorized one up to which is from low, medium and high severity level. Low: cracks ≤ 6mm in mean width, Medium: cracks > 6mm and ≤ 19mm, High: cracks > 19mm. From the observed value crack width and crack pattern is used to determine the overall severity of alligator cracking or fatigue cracking. The severity level of alligator crack in this study was varying from low up to medium and the extent value was one which is low.

Longitudinal cracks: Cracks predominantly parallel to pavement centerline. Location within the lane (wheel path versus non-wheel path) is significant. From our observation longitudinal cracks which is parallel to the pavement's center line and lay down direction is clearly exist. Longitudinal cracking can be allowing moisture infiltration, roughness, indicates possible onset of alligator cracking and structural failure. Similarly, the severity level of the sub group was low and the extent value is one.

Edge cracking: Edge cracks are parallel to and usually within 0.3 to 0.5 m of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or sub grade near the edge of the pavement. Fairly continuous cracks which intersect the pavement edge and are located within the 0.3m-0.5m the pavement edge, adjacent to the shoulder. The severity level according to the pavement identification manual Low: cracks with no breaking up or less of materials, Medium: crack with same break up and loss of materials for more than 10 percent of the length of affected portion of pavement**,** High: cracks with considerable break up and loss of materials for more than 10 percent of the length of affected portion of the pavement.

Potholes: Potholes are usually caused by water penetrating a cracked surfacing and weakening the road base. Further trafficking causes the surfacing to break up and a pothole develops. Because of the obvious hazard to the road user, potholes are usually patched as a matter of priority. Severity level according to ERA, 2002 manual, Low: <25mm deep; Medium: 25-50mm deep; High: >50mm

Rutting: Load associated deformation or rutting appears as longitudinal depressions in the wheel paths. It is the result of an accumulation of non-recoverable vertical strains in the pavement layers and in the subgrade caused by traffic loads. Low: ruts measured depth ≥ 5mm and ≤ 12.5mm**,** Medium: measured depth ≥ 12.5mm and ≤ 25mm**,** High: measured depth ≥ 25mm. In this study rutting *scored as high and medium severity level relatively in small section of road segment.*

4.2 Global Visual Index (GVI)

The following figure shows the result of Global visual index for sample road segment (From Nigist Eleni Hospital to Lucy). This correction yields a global damage index I_s that qualifies the pavement over the length chosen for the calculation. I_s ranges from 1 to 7. Ratings 1 and 2 reflect good surface conditions that need no work (or at least on which work may safely be postponed). Ratings 3 and 4 represent a rather intermediate surface condition, bad enough to trigger maintenance work in the absence of any other consideration. Ratings 5, 6 and 7 represent very poor surface conditions requiring major maintenance or overlay work. For the determined value of extent and severity, GVI value determined summarized in the table below. It represents a rather intermediate surface condition, bad enough to trigger maintenance work in the absence of any other consideration. Among four road segments, two road segments scored GVI value of 3 and 4 as shown below the table. This represents the road section has an intermediate surface condition, bad enough to trigger maintenance work in the absence of any other consideration. Among four road segment, the remaining two segments scored the global damage index 5 and 7. Therefore, section of road segment from St. Marry church to Taywan and Wachemo University to 18 – Mazoria represents very poor surface conditions requiring major maintenance or overlay work.

Table 4.1 Summary of Pavement Condition Survey Result

No.	Road segments		Length (km)	Types of distress	Extent	Severity	GVI
	From	To					
1	Nigist Eleni Hospital	Lucy	1.9	Alligator Crack	2	1	4
				Longitudinal Crack	1	2	
				Edge failure	2	2	
				Potholes	1	2	
				Rutting	1	2	
2	Nigist Eleni Hospital	Mebrat Hayle	1.8	Alligator Crack	1	2	3
				Longitudinal Crack	1	2	
				Edge failure	2	2	
				Potholes	1	2	
				Rutting	1	1	
3	St. Marry Church	Taywan (Indoven)	1.1	Alligator Crack	1	2	5
				Longitudinal Crack	1	1	
				Edge failure	2	1	
				Potholes	1	3	
				Rutting	2	2	
4	Wachemo University	18 - Mazoria	5.4	Alligator Crack	2	3	7
				Longitudinal Crack	1	2	
				Edge failure	1	2	
				Potholes	1	3	
				Rutting	2	3	

4.3 Mathematical Optimization Methods.

The goal of optimization is set in order to minimize the sum of agency cost (AC) and road user cost (RUC) in present value or to maximize the net benefit to people over the analysis period. An objective function considered in this study was minimization of both agency and user costs in road maintenance. Mathematical optimization methods known as solver were used for pavement maintenance in linear programming. A linear programming (LP) technique can maximize (or minimize) an aggregate consequence of individual actions (i.e., an objective function) given a set of limitations or constraints. In other words, maintenance birr can be allocated in a manner that yields the maximum benefit to the given pavement network. The LP problem was formulated as follows:

Maximize expression

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij}C_{ij} \tag{1}$$

Subject to

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij}C_{ijt} \quad \leq B_t \tag{2}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij}b_{ij} \quad \leq B_t \tag{3}$$

and

$$\sum_{i=1}^{n} X_{ij} \geq 0 \quad j = 1\ to\ m \tag{4}$$

t = each year within the planning period

Where;

C_{ij} = Cost to be minimized in implementing strategy I for section j;

X_{ij} = a decision variable in optimization problem (pavement condition)

C_{ijt} = cost of strategy i forsection j in year t;

n = number of strategies for a given section(pavement condition)

m = number of section requiring funding during the t year period;

b_{ij} = budget for corresponding road section in year t.

B_t = budget available in year t for road maintenance

4.4 Optimization Results

This section analyzes the maintenance alternatives of reviewed optimization methods and recommends the most suitable methods and approaches for future implementation in PMS under various scenarios. Maintenance Standards define the maintenance works required to maintain the road network at the target level. Based on estimated global visual index, a possible type of maintenance and corresponding budget analysis was taken also under this section. Having the following budget constraints of federal road and municipality, six alternative maintenance types was used for each road segment selected in the study area. Here are budget per kilometer and type of maintenance; Rehabilitation of trunk roads per km = 4417871.270 ETB, Federal roads periodic maintenance per km = 726472.106 ETB, and budget for municipality per km for 1 year = 152018 ETB. The following section describes different alternative maintenance types for different road segments.

Alternative 1 / Patching/

Surface patching: is used to repair local aggregate loss. Loss of aggregate from the surface of a premixed asphalt pavement is usually due to poor premix quality or poor workmanship. Loss of chippings from a surface dressing may be caused by insufficient binder, use of dirty chippings or insufficient penetration of the chippings into the binder. Loss of aggregate from a surfacing will cause slow disintegration of the layer. Surface patching may be carried out using the same treatment as for local sealing (surface dressing).

Base patching: is used for local restoration of the pavement structure, i.e. to repair severe mesh cracking, deep rutting and depressions, deep edge subsidence, broken edges, potholes and severe shoving. First, all loose material is removed from the damaged area; the depth of the hole is then increased until firm material is found. The sides of the hole are cut back to vertical and the bottom of the hole is trimmed and compacted flat and parallel with the road surface. Any water in the hole must be drained away. As shown in table 3.1 above, the economic cost for entire area if patching treatment type selected the overall cost will be 116640 (ETB) for road segment St. Marry Church to Taywan (Indoven); 139752 (ETB) for Nigist Eleni Hospital to Mebrat Hayle; 101563.2 (ETB) for Nigist Eleni Hospital to Lucy; 247276.8 (ETB) for Wachemo University to 18 – Mazoria. The optimization result for four road segments with patching type of treatment are shown below the table.

Table 4.2 Final Solver Analysis only for Patching

Variable Cells							
	Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
	G8	Corresponding cost Nigist Eleni Hospital to Lucy	32003.8855	0	0.21	1.00E+30	0.21
	H8	Corresponding cost Nigist Eleni Hospital to Mebrat Hayle	24002.9136	0	0.16	1.00E+30	0.16
	I8	Corresponding cost St. Marry Church to Taywan (Indoven)	40004.8563	0	0.26	1.00E+30	0.26
	J8	Corresponding cost Wachemo University to 18 - Mazoria	267647.618	0	0.37	1.00E+30	0.37
Constraints							
	Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
	K1	C1	74014.992	0	152018.44	1.00E+30	78003.464
	K2	C2	91492.416	0	726472.16	1.00E+30	634979.69
	K3	C3	32003.8855	0.21	32003.885	1.00E+30	32003.885
	K4	C4	24002.9136	0.16	24002.916	1.00E+30	24002.916
	K5	C5	40004.8563	0.26	40004.853	1.00E+30	40004.853
	K6	C6	267647.618	0.37	267647.68	1.00E+30	267647.68
	K7	C8	32003.8855	0	0	32003.885	1.00E+30
	K8	C9	24002.9136	0	0	24002.916	1.00E+30
	K9	C10	40004.85643	0	0	40004.8563	1.00E+30
	K0	C11	267647.618	0	0	267647.618	1.00E+30

Having the budget constraints 726472.106 and 152018 birr for federal roads periodic maintenance per km & municipality per km for 1 year respectively, we can save 119992.1634 birr if we use patching type of road maintenance for the corresponding road segment. The total economic cost for this road segment was 605232 birr. The following table describes the objective function result for alternative one maintenance/patching/. The value will be saved in each type of alternative is described in appendix section below.

Table 4.3 Limit Report of Solver Analysis

Cell	Variable Name	Value	Lower Limit	Objective Result	Upper Limit	Objective Result
G8	Corresponding cost Nigist Eleni Hospital to Lucy	32003.88515	0	113271.3476	32003.88515	119992.1634
H8	Corresponding cost Nigist Eleni Hospital to Mebrat Hayle	24002.91386	0	116151.6972	24002.91386	119992.1634
I8	Corresponding cost St. Marry Church to Taywan (Indoven)	40004.85643	0	109590.9008	40004.85643	119992.1634
J8	Corresponding cost Wachemo University to 18 - Mazoria	267647.618	0	20962.54477	267647.618	119992.1634

The other main point shall be raised here is the time value of money. If we have selected the fog spray for maintenance treatment, we could save the economic cost and maintain with low economic cost 228363 ETB but it needs maintenance twice per a year. Maintenance is unlikely to be needed all over at the entire length of the road at the same time. The secret is to apply maintenance at the right time and in the right place. If interventions are too early or too late, money could be wasted. In the case of a new road, its condition deteriorates slowly. Only light maintenance is needed. After that time the road enters a critical phase, which may last for some years. As the running surface fails, re-sealing is needed before it is too late. Otherwise, extensive repairs costing up to 4 times as much are inevitable. This sort of problems is typically seen in networks of any kind, where the weakest point compromises the integrity of the system and thus needs priority attention. In spite of an increased awareness of the impact of neglecting road maintenance, there is still a reluctance to prioritize maintenance. Having similar analysis the alternatives summarized according to their solver analysis are; alternative 2 /Fog spray/, alternative 3 /Slurry seal/, alternative 4 /Thin lay/, alternative 5 /Overlay/, Alternative 6 /Reconstruction/. In alternative 6 economic cost is relatively large to other alternatives even duration is large. By comparing between different levels of road conditions and the effect on road users costs, it is possible to obtain an optimal solution which is the most economic for the society.

The road network of the country is rapidly growing as new asphalt, gravel, rural and community roads are built by ERA, RRAS & WRO respectively every year (ERA 2019). Parallel with rapid expansion of asphalt, gravel, rural & community roads; maintenance need is also growing rapidly. However, shortage of fund has prevented timely and adequate maintenance of roads in the country. The Road Fund Office has been collecting revenue mainly from fuel levy and other sources and been allocating fund to road agencies for maintenance of roads since 1998. The revenue and allocation of the Road Fund Office has steadily been increasing every year but has never been enough to meet the maintenance need of the rapidly growing road network of the country. In fact, the gap between maintenance need of the road network and allocation of fund has been widening from year to year and as a consequence, more & more roads unable to get timely and adequate maintenance every year. Unless, worsening shortage of fund for maintenance because of rapid growth of the road network; both size & quality is addressed as early as possible it would lead to premature loss of investment on infrastructure. Therefore, the Road Fund office should generate and allocate sufficient fund for maintenance of roads by raising fuel levy and diversifying sources of revenue as recommended by Road Financing study. For the decision maker to decide the overall funding needed for road maintenance and its social impacts, one has to bring in the users costs. By comparing between different levels of road conditions and the effect on road users costs, it is possible to obtain an optimal solution which is the most economic for the society. Usually the funding is not adequate for the optimal solution so the budget constraints have to be taken into account.

4.5 Cost Model

In this paper, the cost model was conducted on the optimization in routine maintenance, periodic maintenance, and reconstruction. Based on objective function (maximization of total benefits), decision variables (road surface conditions measured by global visual index) and constraints (budget) different maintenance actions were considered, each of maintenance actions can be applied on individual or combination or both. Having this variables solver was taken in excel. The result of solver analysis was included under appendix section. Optimization models for sealed roads deal with periodic maintenance and components of routine maintenance that affect roughness or the rate of pavement deterioration, in particular patching, crack sealing, pothole repair and overlay.

5 Conclusion and Recommendation

5.1 Conclusion

A road network requires timely maintenance to keep the road surface in good condition onward better services to improve accessibility and mobility. Strategies and maintenance techniques must be chosen in order to maximize road service level through cost-effective interventions.

The highway network of any country is a major public investment designed to support the national economy by enabling industry, business and commerce to transport goods and people. The investment itself is usually undertaken as a result of balancing the various competing costs and benefits. When developed, the road network is expected to meet the national objectives for road transport and at the same time minimize total life costs of facilities and the transport costs of goods and persons. Road infrastructure is thus a significant economic asset. One of the reasons why we have problems within the maintenance area, is the lack of a tool for proper communication between road administrations and decisions makers. The objectives of this analytical system should be: Improve the communication within the road administration - Establish a decision-making model in the administration - Prepare analytical material and methods - Establish working communication lines between the road administration and the politicians. Something has to be done with this situation. We as professional people have to sell the message that maintaining roads are of decisive importance for a country. This study create a platform for politicians and other decision makers where they can operate and get political benefit from arguing about the importance of maintaining the roads. Among six alternative analyzed under result and discussion section, patching was selected as possible remedial action based on: type of distress observed on study area, cost comparison considering service period of each maintenance and their corresponding economic cost, period to deliver maintenance with in a given schedule.

5.2 Recommendation

Under three categorized road maintenance namely; Routine, periodic and urgent it is recommended to use routine maintenance as much as possible before the pavement surface highly distressed. In this way we can save both operation and maintenance cost at the same time. As severity and extent of pavement distress increase, the economic cost to maintain and operate also increase linearly. Therefore using routine maintenance rather than periodic maintenance could solve such problem.

Limitation

The limitations faced in the progress of this research are basically the unavailability of properly documented data specially related to maintenance taken from year to year. Secondly, the pavement maintenance standard was not considered under constraint. So that future study shall also address this variable in addition to budget constraint.

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