Multi-Year Program under Budget Constraints Using Multi-Criteria Analysis

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ABSTRACT

Road investment appraisal requires joint consideration of multiple criteria which are related to engineering, economic, social and environmental impacts. The investment consideration could be based on the economic analysis but however for some factors, such as environmental, social, and political, are difficult to quantify in monetary term. The multi-criteria analysis is the alternative tool which caters the requirements of the issues above. The research, which is based on 102 class D and class E paved road sections in Kenya, is about to optimize road network investment under budget constraints by applying a multi-criteria analysis (MCA) method and compare it with the conventional economic analysis. The MCA is developed from hierarchy structure which is considered as the analytical framework. The framework is based on selected criteria and weights which are assigned from Kenya road policy. The HDM-4 software is applied as decision-making tool to obtain the best investment alternatives and road work programs from both MCA and economic analysis. The road work programs will be the results from the analysis using both MCA and economic analysis within HDM-4 software to see the difference and compare the results between both programs. The results from MCA show 51 road sections need periodic work, which is overlay or resealing. Meanwhile, 51 others need rehabilitation or reconstruction. The five years road work program which based on economic analysis result shows that it costs almost Kenyan Shilling (KES) 130 billion to maintain the class D and E paved road in Kenya. Meanwhile, the MCA only requires KES 59.5 billion for 5 years program. These results show huge margin between two analyses and somehow MCA result provides more efficient work program compared to economic analysis.

Keywords: Multi-criteria analysis, road works program, budget constraints, highway development and maintenance management

1 INTRODUCTION

Road infrastructure has important role in the national development and is the main arteries for moving people and goods. Roads support the social and economic development process by open up access for the individuals and communities to the markets, employment, health, and education facilities. In terms of that importance, roads are positioned as one of the largest infrastructure assets in some countries which consequently need an adequate funding to finance, both constructions and maintenance.

Providing adequate budget is challenging for most of the countries, especially in developing and emerging countries, as the available resources are not sufficient to invest or even maintain the existing road network in good condition. The shortage of budgets in road investment results in high congestion, where the road length growth is less than vehicle number growth. Meanwhile, lack of budget for maintenance results decay of existing road networks. The portion of road funding in national budget itself varies five to ten percent of a government's recurrent expenses and ten to twenty percent of its development budget (Heggie and Vickers, 1998). This shortage of funds has been increasing travel time, vehicle operating costs (VOC), road conservation, pollution, and road accidents.

Planning and budgeting are two of the main keys in road network maintenance. Road budgeting is based on certain planning period or a multi-year program which consists of individual programs in an annual work program (AWP) package. These programs have to be realistic and practical to be delivered within the planned time frame but somehow due to constraints in financing, road budgeting has limitation and specified ceilings during planning period. Considering that constraint, prioritization in investing the budget is needed to achieve maximum impact and value-for-money on road maintenance expenditure (Odoki and Odongo, 2016).

Prioritizing the investment is complex as there are not just one factor that needs to be considered but also factors that are difficult to quantify or subjective. The method that can be implemented is multi-criteria analysis (MCA) which enables to consider not just economic criterion but also social, environmental, and political criteria. The considered criteria will be weighted and be applied to generate road networks program prioritization.

2 LITERATURE REVIEW

2.1 Road Network Management

Road network is the main vein in supporting social economic development, as well as environmental improvement. From this vital role, road network should be managed in appropriate and effective ways, in terms of its improvement and maintenance. The aims of road management are to enable the network to withstand the damage caused by wear and tear, to prevent sub-standard conditions, to ensure that traffic can use the network safely, efficiently and also concern about the environment (DFID, 1998). These processes are achieved through activities that have impacts on the road network.

2.1.1 Management Functions

Functions in road management need to be considered as the basis of management decisions will be made. The functions are focused from the planning through the operations with different scope of management aims, network coverage, time horizon, management staff concerned, and data level. Robinson (2008) defined the functions under Strategic Planning, Programming, Preparation, and Operation Management.

a) Strategic Planning
Strategic planning involves an analysis of road system as a whole within long term period. It estimates road expenditures under various budgetary, economic, and road condition scenarios.

b) Programming
Programming produces estimation of expenditures under different budget heads, which are typically constrained, for different treatment types and different years for each road section. The key aspect of programming is to prioritize road works to find the best value for money in case of a constrained budget. Typically, programming develops budget for annual work programs for the road network within medium term time horizon, on year or multi-year programs.

c) Preparation
Preparation is the phase to packaging schemes and projects, which are selected from programming phase, into implementation. In this phase, budget usually has been approved as design specifications and costs are feasible to be implemented in the final schemes or projects.

d) Operation Management
Operation management covers on-going works activities which focus on individual sections or sub-sections of road. This phase is the detailed and implementation process of the works so the decisions are made in immediate time, typically daily or weekly basis, to monitor and to control the project activities.

2.1.2 Management Cycle

Road management is a process which integrates the cycles of activity involved in the management functions of planning, programming, preparation, and operation management (DFID, 1998). In performing those management functions, a logical sequence of steps need to be defined then the detailed content in each step depends on which functions will be addressed. Road management cycle as shown in Figure 1 will be applied to within road management as guidance in decision making with accurate information as the core of the cycle and typically completed once annually or in one budgeting period.

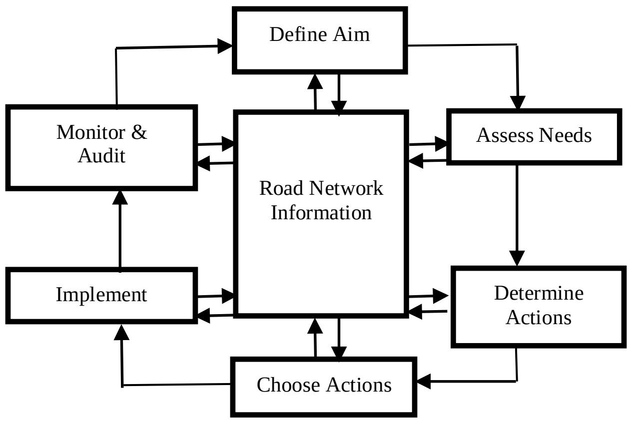

Figure 1. The road management cycle (Robinson, 2008)

This management cycle can be utilized to support decision-making in every management function and is undertaken once for each period of the function (Adiguna, 2017). The description of each step depends on which function of management cycle is addressed. Every step in this cycle is related to the road network data as the core of the cycle.

2.1.3 Management System Integration

Based on the management functions and cycle, it can be seen that management process needs integrated works from one function to another and it can't be separated in one to another level. Figure 2 illustrates how the system is integrated into road management.

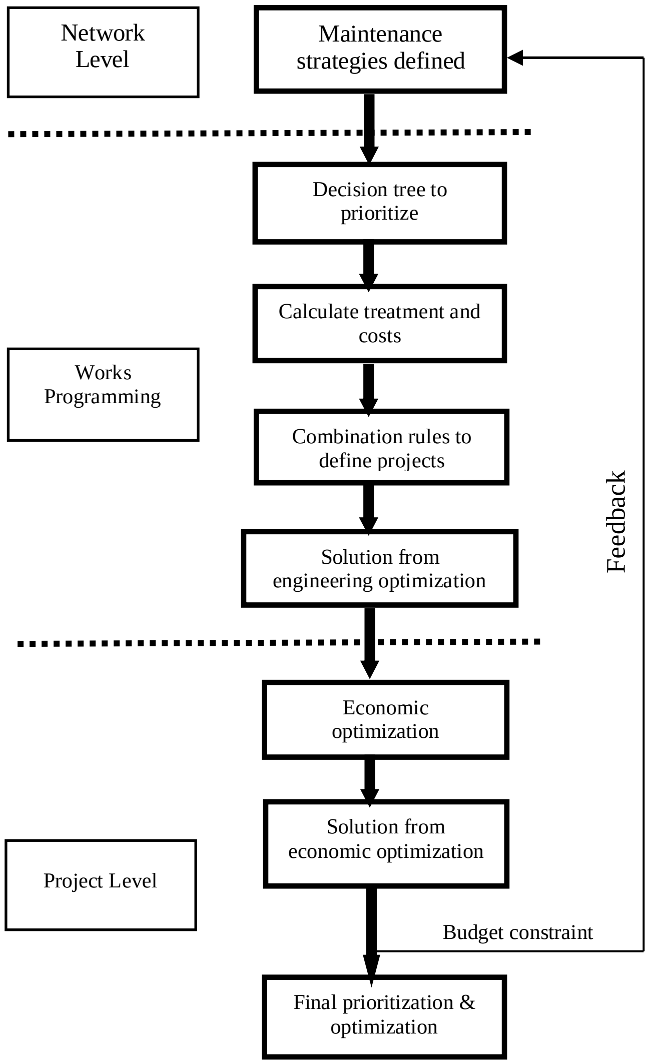

Figure 2. Management system integration (Evdorides, 2016)

2.1.4 Decision Support System

Decision support system is applied within the management functions to assist the tasks within. It divides into three main hierarchies, which are strategic, tactical, and operational. Decision support system basically assists in process, analyze data, and produce outputs from the analysis. This approach is the basis of the HDM-4 which will be applied in this research.

In programming level, tactical decision-making is applied to select the most optimal investment alternatives for the road networks. In order to optimize the decision-making, there are several things to be considered (Robinson, 2008):

a) Consistent treatment selection methods across hierarchies in the network which are recognized for most defects.
b) Condition projection methods to predict the performance of proposed treatments.
c) Prioritization methods to get the optimum treatments for the road network under a specified amount of budget.

In making a decision, there are situations when budget is becoming the main constraint which is not sufficient to fund all of the road projects. In this situation, it is important to undertake a method to support the decision making in maximizing investments benefits from the limited budget. Optimization is the process solution by finding the best way of using available resources while not violating any of other constraints.

2.2 Application of Highway Development and Management System (HDM-4)

2.2.1 HDM-4 in Road Management

The Highway Development and Management System (HDM-4), which was developed by the World Bank and other international organizations, is one of decision support tool to evaluate investment options in road infrastructure. It is a road investment appraisal tool that contains individual components of total transport cost within analysis period. This accomplished by combining those components, such as environment, construction standards, geometric standards, and traffic characteristics.

2.2.2 Analytical Framework

The analytical framework within HDM-4 is based on the concept of pavement life cycle analysis and applied to predict road deterioration, road works effects, road user effects, and socioeconomic and environmental effects within typically period of 15 to 40 years depending on the pavement type (Odoki and Kerali, 2006). HDM-4 will predict the life cycle pavement performance under specified scenarios of road maintenance and/or improvement and the resulting agency and user costs.

HDM-4 is designed to make comparison of cost estimates and economic analysis of different investment scenarios within the homogeneous road section. The scenario consists of two or more different road maintenance and/or improvement works for each road section with one option designated as a base case (minimal routine maintenance).

2.2.3 Economic Analysis

Economic analysis is used to give a comparison in economic viability of different alternatives, to provide criteria for economic decision making, and also to investigate technical standards and strategies to be applied in the investment decision. In analyzing economic factor, there are indicators need to be considered to help make decision over the alternative of the projects depend on the characteristics which can be seen in Table 1.

Table 1. Economic indicators summary in road investment (Stannard, 2010)

	NPV	IRR	NPV/C	FYB
Project economic validity	Very good	Very good	Very good	Poor
Mutually exclusive project	Very good	Poor	Good	Poor
Project timing	Fair	Poor	Poor	Good
Project screening	Poor	Very good	Good	Poor
Under budget constraint	Fair	Poor	Very good	Poor

2.3 Multi-Criteria Analysis

Multi criteria analysis is a simple analysis using criteria as attributes assessment can be either qualitative or quantitative assessment. Broadly speaking, the MCA activity consists of several main steps namely: setting goals, criteria, weighting criteria and scoring alternative decisions relating to the criteria (Aprilischa, et al., 2015). Cafiso, et al. (2002) defined MCA as a method which provides a systematic framework for breaking a problem into its constituent part in order to understand the problem and consequently arrive at a decision. MCA can assist the decision maker in road management to pick the best alternative as some of the criteria are not quantified in monetary terms then it combines both quantitative and qualitative criteria into single analytical framework.

The types of MCA methodologies have difference in terms of the preferences on the various criteria are specified, in ranking the alternatives, and also in presenting the results of the analysis. From all of the methodologies, the Analytical Hierarchy Process was selected because it produces a multi-criteria ranking index for every alternative as a measure of utility which is more compatible to be implemented in road maintenance management (Caviso, et al., 2002).

The outputs of MCA process will be multi-criteria ranking for each alternative in each section of the road network for each year of the analysis period. The alternative with highest value multi-criteria ranking number will be chosen for each section. If budget is constrained, prioritization or optimization needs to be considered by applying further analysis.

Multi-criteria ranking number will be used in optimization of the program. The value is calculated within HDM-4 as the ratio of utility index to the cost of implementing the alternative. The utility index can be considered analogous to the NPV used in economic analysis and can be used as an indicator for ranking and selecting projects.

3 RESEARCH METHOD

This research starts with identifying aim and objectives then followed by reviewing some literature to understand the concept of road management. The next step is defining data requirement then collect and collate those data. Analyzing data will be based on two methods, both are multi-criteria and economic analysis as comparison, using HDM-4 software.

The economic analysis is used to define the program analysis and prepare the multi-year work programs under budget constraints. In this term, the prioritization is based on NPV/cost ratio as ranking index with analysis procedure is similar to the project analysis as defined before.

The life-cycle analysis was selected as the method to run the program with period of five years. The two scenarios were undertaken, the first one is working program with unconstraint budget scenario and the second one is constraint budget scenario. Then the analysis results will be used as basis data to make road works program under budget constraints.

4 DATA COLLECTION AND COLLATION

4.1 Study Area Description

The data in this research is based on Kenya road network system. This country has about 177,800 km road network and only 63,575 km classified road network (KENHA, 2016). This study covers class D and E roads which are secondary and minor roads based on Kenya road classification.

Kenya Rural Road Authority (2016) defines class D or secondary road as roads which link locally important centers or to more important center or to higher class road. Meanwhile, class E or minor road belongs to roads which link to minor center or local center.

4.2 Data Requirements

Data requirements for MCA will be split into two stages. The first one is the data for HDM-4 inputs and the second one is data to determine relative weight for the MCA.

The data for HDM-4 is based on Information Quality Levels (IQL) related with the level of detail required for each application level (Robinson, 2008). Based on IQL levels, this research conducting a road works program with medium term time phase is defined at IQL-III and IQL-IV for the data needs. The detailed for HDM-4 input data which are required are road network characteristics, vehicle fleets, traffic, and road works.

Another required data is weightings in MCA. The roads policy has main aim for Developed Connectivity. The main aim is supported by these following objectives, accessibility, safety, economy, quality, congestion, and environmental impact and will be achieved by determining work alternatives for each object based on criteria on HDM-4.

4.3 Data Collection and Collation

The data for HDM-4 is obtained from consultancy project data which is based on Kenya road work project.

4.3.1 Road Network Characteristics

The details of the network are described as follows.

a) Functional Classification: The roads are classified by function and in this case, it is classified as secondary and minor roads.
b) Pavement Class: The road pavement is classified as paved and unpaved roads with different kind of surfacing material types. The homogenous road sections classified it into paved roads with Asphalt Mix on Granular Base or Surface Treatment on Granular base as pavement type.
c) Pavement Condition: It is determined on basis of roughness level (Table 2) which is measured by the International Roughness Index (IRI) and classified into this standard.
d) Traffic Levels: The Average Annual Daily Traffic (AADT) was compiled from consultancy data and was categorized in Table 3.
e) Pavement Strength: The pavement strength is measured by Adjusted Structural Number (SNP) and the value was based on Kenya HDM-4 Configuration.
f) Road Distress Coefficient Factors: This is adopted from Kenya HDM-4 Configuration.

Table 2. Roughness level (Kenya HDM-4 Workspace)

Road Class	Good	Fair	Poor
Class D & E	4	4-6.5	6.5

Table 3. Traffic levels (Kenya HDM-4 Workspace)

Traffic Band	AADT (Number of Vehicle)	
	Class D	Class E
Low	480	250
Medium	1300	750
High	2850	1725

4.3.2 Vehicle Fleets

The relevant motorized vehicles were defined with eleven vehicles as the representatives in Kenya HDM-4 workspace. Equivalent Standard Axle Load Factors also has been defined for each fleet based on axle load data from weighbridges in Kenya.

4.3.3 Traffic Data

Traffic data were defined from the consultancy data. The traffic growth rate data was inferred based on historical records of vehicle-km for traffic within the corridor in Kenya. Table 4 below shows the traffic growth for the analysis.

Table 4. Traffic growth forecast (Kenya HDM-4 Workspace)

Motorized Vehicle Type	Growth Rate (%)
Articulated Truck	3.5
Heavy Truck	3.5
Medium Truck	3.5
Light Truck	3.5
Large Bus	3.5
Small Bus	3.5
Mini-bus (Matatu)	3.5
Pickup Utility	2.5
4 Wheel Drive	2.5
Car	4.4
Motorcycle	3.9

4.3.4 Road Works Data

In this research, maintenance work standard was defined for each road section. The maintenance standard consists of three alternatives as shown in Table 5. This maintenance work standard intervention was developed based on the time interval, the traffic level, and pavement condition itself.

Table 5. Maintenance works standard (Kenya HDM-4 Workspace)

Work Alternatives	Activity	Material Type	Intervention
Routine	Drainage works Edge repair Pothole patching Miscellaneous	- - - -	Once a year 1 m^2 / km ≥ 5 / km Once a year
Periodic	AC Overlay Drainage Edge repair Pothole patching	Asphalt concrete	4 ≤ Roughness ≤ 9 Ruth depth ≤ 20 mm Every 7 years
	Resealing Drainage Edge repair Pothole patching	Single bituminous surface dressing	Roughness ≤ 4 Damage area ≥ 15 % Ruth depth ≤ 20 mm Every 4 years AADT ≤ 3200 vehicle/day Or 4 ≤ Roughness ≤ 8 Damage area ≥ 15% Ruth depth ≤ 20 mm Every 4 years AADT ≤ 3200 vehicle /day
	AC Reconstruction Drainage Edge repair Pothole patching SD Reconstruction	Asphalt concrete	Roughness ≥ 9 Every 10 years Or Ruth depth ≤ 20 mm Every 10 years Or Roughness ≥ 9 Every 10 years Structural cracking ≥ 10%
	Drainage Edge repair Pothole patching	Double bituminous surface dressing	Roughness ≥ 9 Every 10 years Or Ruth depth ≤ 20 mm Every 10 years Or Roughness ≥ 8 Every 10 years Structural cracking ≥ 10%

4.3.5 Developing Analytical Framework

MCA methodology was used in developing hierarchy structure (Figure 3). The following paragraph defines the methodology in developing the structure.

a) Define the main goal of the analysis
The goal in this research defines as Developed Connectivity.

b) Define the objectives
There are six objectives that have been defined. Those objectives are accessibility, safety, economy, quality, congestion and environment impact.

c) Define second level objectives
These objectives define from MCA criteria that supported in HDM-4 analysis. The criteria selected are related to the previous objectives defined before. Those criteria selected are maximised social benefits, reduce accidents, minimize RUC, maximize NPV, good riding quality, reduce congestion, and reduce air pollution.

d) Assigned hypothetical weights for each criterion
The weightings are important to determine the importance of each criterion and based on Kenya road policy which reflects the preferences of decision makers. For this case, RUC is selected as base criteria and the rest criteria are weighted based on the base criterion. The relative weight is shown in Table 6 and the relative weightings for each criterion are shown in Table 7.

Table 6. Criteria relative weights

Criteria	Criteria of Good Riding Quality
Maximize Social Benefits	5
Reduce Accidents	3
Minimize RUC	1
Maximize NPV	1
Good Riding Quality	2
Reduce Congestion	2
Reduce Air Pollution	4

Table 7. Performance index for social concerns (HDM-4 Workspace)

Performance Index	Definition
0	Major dissatisfaction
0.25	Minor dissatisfaction
0.50	Indifferent
0.75	Minor satisfaction
1	Major satisfaction

e) Assigned alternatives for each criterion
The alternatives are based on road works which have been defined before. Three alternatives, routine, periodic, and rehabilitation works, are selected for each road section.

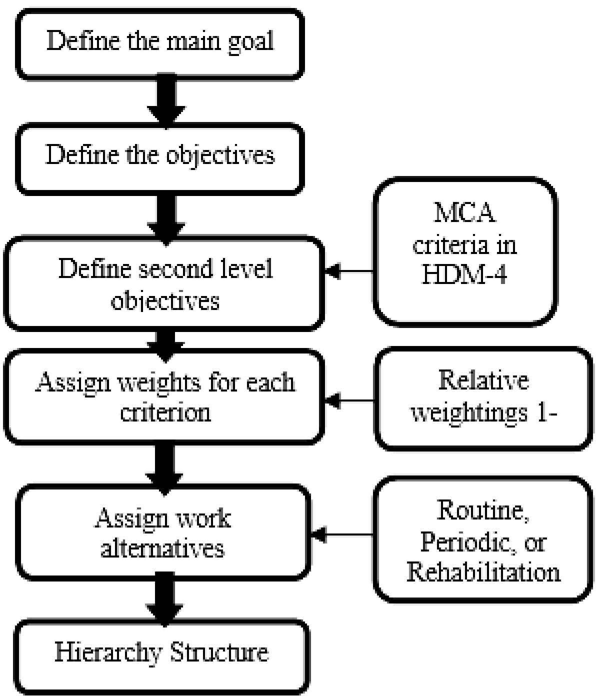

Figure 3 Hierarchy structure development

4.3.6 Performance Indices

For each section alternative or project alternative, and for each criterion, a performance index should be determined. The index indicates whether an alternative is better than another with respect to a particular criterion. The performance indices are calculated internally within HDM-4. Those indices in this research are described below.

a) Road user cost (RUC)
The road user cost is obtained directly from the outputs of HDM-4 run, for each investment alternative. The performance index showing the achievement of the objective to minimise road user cost.

b) Net benefits to society (NPV)
The net present value is calculated in HDM-4 for each investment alternative. The performance index to show the achievement of an objective to maximise benefits to society is the NPV.

c) Safety criterion
The number of road accidents by severity is calculated internally within HDM-4, for each investment alternative.

d) Riding quality
This criterion also calculated within HDM-4. The comfort attribute is the ride number (RN) and is based on the IRI for each investment alternative. This criterion is to show the road functional service with respect to comfort.

e) Road congestion
This criterion is defined by the volume-capacity ratio, VCR, which is calculated internally within HDM-4 for each investment alternative. The performance index is aimed to show the achievement of the objective to reduce road congestion.

f) Environmental Criteria
Quantities of different types of pollutants (vehicle emissions) are calculated internally within HDM-4 for each investment alternative. The environmental impact in terms of air quality index for each investment alternative is based on the concentration of hydrocarbon, carbon monoxide, nitrous oxide, carbon dioxide, Sulphur dioxide, particulates, and lead. Those pollutants have been defined in the HDM-4.

g) Social
The attributes required to calculate the performance index to show the achievement of an objective to maximise social benefits to society are not calculated within HDM-4. Therefore, it has to define the performance index for each investment alternative, based on their own judgment, by choosing from the options given in Table 7.

h) Outputs
The MCA procedure described above will produce multi-criteria ranking numbers for each alternative of each road section included in the study. The alternative with the highest value is selected for each section.

5 RESULT AND DISCUSSION

5.1. Analytical Framework

Analytical framework has been developed as a hierarchy structure as mentioned before. It consists of four levels of structure from the main goal at the top level, followed by the objectives then second level objectives where the weighting is assigned for each criterion. The last step is assigning road works alternatives for each criterion. The result of the developed analytical framework was applied in the analysis using HDM-4 software. Meanwhile, the hierarchy structure of the analytical framework is shown in Figure 4.

5.2. Analysis in HDM-4

5.2.1. Multi-Criteria Analysis

The MCA is proceeded to evaluate the best alternative of three alternatives for each road section in accordance with the relative weightings in each of seven criteria, which are maximised social benefits, reduce accidents, minimize RUC, maximize NPV, good riding quality, reduce congestion, and reduce air pollution. The analysis starts in 2016 with 15 years period time and discount rate at 10%. The sample result of MCA is shown in Table 8. For every section, the alternative with the highest multi-criteria ranking number is chosen as the most suitable work.

The result from MCA analysis defined as the preferred road works alternatively for each section which has the highest multi-criteria ranking number. This preferred alternative can be source for the unconstrained works program. Multi-criteria value for each section and the most suitable alternative has the highest value compared to other alternatives in that section and highlighted to indicate.

Table 8. Sample of MCA results

Sections		Alternatives		
ID	Description	Routine	Periodic	Rehabilitation
FHE2	KE-AC-F-H-E-SHD	0.6389	0.6389	0.6614
FHE3	KE-AC-F-H-E-SHW	0.5279	0.8611	0.6256
FLE	KE-AC-F-L-E-H	0.4167	0.4167	0.8611
GHD	KE-AC-G-H-D-AR	0.5293	0.6389	0.8456
GHD1	KE-AC-G-H-D-H	0.4167	0.814	0.8575

Based on the analysis result, class D and class E paved roads in Kenya are not suitable to be maintained in routine works. From 102 sections has been analyzed, 51 road sections need periodic work, which is overlay or resealing as shown in Table 9. Meanwhile, the half others need rehabilitation or reconstruction.

Table 9. Number of road sections in MCA results

Number of Road Sections			
Routine	Periodic	Rehabilitation	Total
0	51	51	102

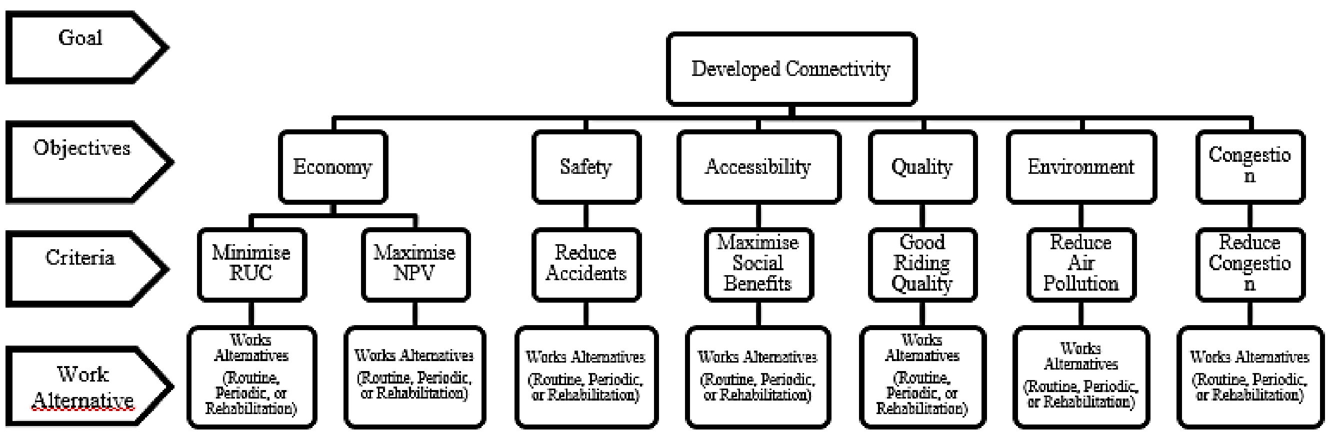

Figure 4. Hierarchy structure

5.2.2. Road Works Program

The economic analysis was implemented to create the multi-year works program for this research. The program is planned for five years period and is set into three different budget scenarios to see the effect of budget constraints. The scenarios are unconstrained budget, 80% of unconstrained budget, and 60% of unconstrained budget. The budget constraints are determined based on the programming scenarios that consist of moderate budget scenario with 80% of total budget and low budget scenario with 60% of total scenario.

The result lists show different type of works and schedule for each road section. These are the effect of different budget scenarios and prioritization in the work programs. The prioritization here is based on NPV/cost ratio as the ranking index. The type of works for each section differs between periodic and rehabilitation works.

The results obtained from the analysis shows that for unconstraint budget scenario needs nearly KES 130 billion for five years period. For the constraint budget scenario was implemented with another two different schemes. The scenarios and the annual budget for each scenario are shown in Table 10.

Table 10. Annual cousts

Budget Scenario	Year	Annual Cost (Mil KES)	Cumulative Cost (Mil KES)
Unconstrained	2016	18,100	18,100
	2017	28,600	46,700
	2018	74,600	121,300
	2019	8,100	129,400
80 % Budget	2016	18,100	18,100
	2017	22,200	40,300
	2018	63,700	104,000
60 % Budget	2016	17,100	17,100
	2017	19,200	36,300
	2018	41,700	78,000

During the 5 years, road works program, the unconstrained budget scenario will maintain the road network from 2016 until 2019 and in 2020 will be minor road work such as routine maintenance. Meanwhile, for the constraint budget scenarios, the major road works will only be held from 2016 until 2018 and the rest will only be maintained by minor road work.

The budget required for the MCA results show different value. In this term, the budget requirement for MCA is lower than the unconstrained economic analysis. The MCA unconstrained works program requires KES 59.5 billion for five years work analysis. The annual budget needed for MCA works program is shown in Table 11.

Table 11. MCA annual costs

Budget Scenario	Year	Annual Cost (Mil KES)	Cumulative Cost (Mil KES)
MCA Unconstrained	2016	25,300	25,300
	2017	23,600	48,900
	2018	2,100	51,000
	2019	8,500	59,500

5.3. Comparison MCA and Economic Analysis

The unconstrained economic analysis result shows that it costs almost KES 130 billion to maintain the class D and class E paved road in Kenya in five years analysis. Meanwhile, the MCA only requires KES 59.5 billion for 5 years program. These results show huge margin between two analyses. This resulted in different schedule and different type of road works for each road section.

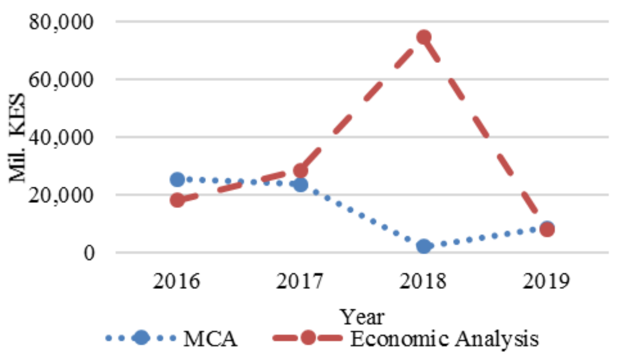

Figure 5. Annual budget comparison

The different budget requirements may happen since the two analyses have different approach to assign the requirements. The Economic analysis uses pavement condition to undertake the program and the MCA considers preferences of relative weights that have been assigned before which may satisfy the high weighted criteria.

In 2016, MCA works program accommodate more road works compared to economic road works program and allocates more than economic analysis program. During this year, MCA works program prioritizes road sections that need periodic maintenance and rehabilitation. Meanwhile, economic analysis only maintains the sections which need rehabilitation.

For the next couple years, economic analysis works program allocates higher than MCA works program. During this period, economic analysis works program manages more road sections due to worsening condition in each pavement. In economic analysis works program, the maintained road networks are 13 with long sections of each network yet for MCA works program only 5 road networks. This condition leads into rocketing annual budget for economic works program, especially for the year 2018 with more than 70 billion KES difference compared to MCA works program (see Figure 5).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The MCA results show that half of the total road networks or 51 road sections need periodic maintenance, yet another 51 sections need rehabilitation or reconstruction. No section is suitable for routine maintenance as all of routine's MCA score is the lowest compared to the other two alternatives. More details, the MCA scoring shows insignificant values between three alternatives in some of the road sections. This condition indicates that weighting preference is crucial as weight in each criterion may lead to different road work preference.

MCA road works program, which is generated from HDM-4, requires KES 59.5 billion for five years program. The first year takes the highest portion of the annual budget as it maintains more networks compared to the following years. Those results show that MCA can be implemented during the road works program preparation. More detailed and comprehensive input is needed in HDM-4, therefore data must be accurate and complete to obtain representative results.

The economic analysis is also applied to define the program analysis and prepare the multi-year work programs under budget constraints. The results obtained from the analysis shows that unconstraint budget scenario needs nearly KES 130 billion for five years period. For the constraint budget scenario was implemented with another two different schemes, each 80%, and 60%. If it is compared with MCA road works program, the economic analysis program has higher allocation with huge margin between them. The difference in allocation effects in the program prioritization and type of road works for each road section. This condition may happen as MCA road works program accommodates more criteria to be considered rather than just economic criterion. For Kenya road works program, MCA is more efficient and giving more analysis options for the road sector stakeholders there.

6.2. Recommendations

Multi-criteria analysis has more efficient road works program if it is compared to the conventional economic analysis but further studies are required, such as:

a) Combining high and low-volume road to see MCA affects the real road works program as this research only analyses low-volume roads (Class D and E) in Kenya,
b) Comparing final road condition resulting from MCA and economic road works program after five years. The MCA road works program has significant lower allocation so it is better to check the road condition after the multi-year programmed has finished,
c) Assessing more comprehensive data with the road sector stakeholders to determine the weights of each criterion in MCA as stakeholders have significant roles in the decision making.

This analysis is applicable in Indonesia as it enables wider factors to be considered. Just like in many countries, Indonesia is also facing an inadequacy of road funding. Directorate General of Highway in Indonesia could implement MCA to create efficient national road works program in Indonesia. The analysis in HDM-4 would be based on the road networks in small working area then it is compiled into provincial program and national program.

Somehow it is challenging to implement the MCA in Indonesia national road works program as Indonesia has long road networks with different characteristics in each region and difficulties in data collection. Therefore, it needs more efforts for the Directorate General of Highway to implement this method as comprehensive and detailed data are important to get an accurate and efficient road works program.

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