Construction of the road

1. Introduction

Roads are constructed to bring benefits to the people. Investment in roads is huge for which funding most time is limited. Therefore the decision to invest and protect the investment in form of maintenance is important so as to bring optimal benefits and value for money.

In order to maximise the benefits in the choice of investment, road investment appraisal may well be part of the planning process. The purpose of economic appraisal is to determine the investment cost and economic returns expected from such investment. Investment cost consists of construction and annual maintenance costs and are normally shouldered by the road agency. While economic returnsis in form of savings to the road users resulting from new road facility. These costs are referred to as total (road) transport cost or whole life cycle cost (HDM-4 documentation). It is therefore necessary to determine the works that will minimise the total transport cost over the extended analysis period, say expected life of the road.

This report presents the economic analysis of a project to upgrade an existing gravel road to a bituminous pavement. The aim is to assess the economic benefit resulting from the proposed investment. This is to be carried out using Highway Development and Management (HDM-4), a road investment appraisal tool. HDM-4 is known to have the capability which assist with the selection of appropriate road design and maintenance standards that minimises the total transport cost. The support system will also indicate the economic viability of the proposed upgrading. The run will include sensitivity analysis, which involves repeated economic evaluation changing one parameter at a time, to identify the parameter(s) which affect the viability of the road project.

2. Literature review:

2. 1 Economic appraisal of a road project.

Economic appraisal is very important in planning a road project. It enables the road agency knows the investment cost as well as the economic returns of various alternatives, thereby assisting them in the selection of that which gives the highest returns. Total transport cost, also referred to as whole life cycle cost, includes construction and annual maintenance costs as well as road user costs (RUC). The RUC, in most cases, is the benefit due to the provision of a better road facility i. e VOC, travel time, comfort, reduction in accident.

HDM-4 is a decision support tool for the analysis of road management, evaluation of investment alternatives and strategic planning among others. It has four models that are used to predict the effects of road construction and operation.

Road deterioration model considers pavement structure, traffic loading and climate condition to analyse and predict the progression of structural and surface condition variables. Works effects model uses these variables and application of maintenance and construction measures to predict the physical quantities of resources required. These are used to multiply the unit costs specified to obtain the construction and maintenance cost for the analysis period. Road user effect model uses vehicle characteristics, geometric data and the forecast condition variables (e. g. IRI) to calculate the expected travel speeds of the different vehicle types, which in turn affect the vehicle and owners costs. The social and environmental effect model can forecast vehicle emissions and energy consumption.

2. 2 Method of economic appraisal of a road project.

This is usually done in HDM-4 for at least for two mutually alternatives road construction, rehabilitation or upgrade, one of which is referred to ‘ Do nothing’ or ‘ base alternative’. While others are ‘ do something’ or project alternatives. The ‘ Do nothing’ or base alternative is where minimum investment is carried out in form of continuation of current maintenance strategy. This alternative has no construction component but has high maintenance cost and RUC. On the other hand, the ‘ do something’ or alternative project is when the road standard is improved, the choice of which depend on many factors such as the road agency’s standard, traffic level, political and social consideration etc. This would normally have construction cost with both low maintenance cost and RUC.

3. Methodology.

Create Project

Define road network

Section 2

Section 1

Define road sections

Improvement Standard

Mtce Standard (After)

Mtce Standard (Before)

Mtce Standard (Gravel)

Define Work standards

With

Project

Without Project

Define Project alternatives

Run analysis with sensitivity

Generate Outputs

The above flow describes the procedure for the economic analysis of the project using HMD-4.

4. Procedure for project analysis.

4. 1 Project description:

This Project is a 49. 9 km gravel road classed secondary road and it is situated in sub-tropical/humid climate. It passes through varying topography. The road is divided into two sections based on geometric, pavement condition and traffic volume. The traffic and condition data obtained in 2008 are represented in table 4. 1. The road is proposed to be upgraded to bituminous pavement.

Both the degree of conflict between motorised and non-motorised transport and the effect of the road side activities on traffic flow were insignificant.

4. 2 Data Input:

Using the flow chart in paragraph 3 above all the necessary data require for the project analysis is stored in the system in the appropriate folders. These include detailed traffic composition and growth rate which are provided in the Vehicle fleet folder. A uniform growth rate of 4% was used for all vehicle classes on this project.

The sections of the roads are defined under the road network folder. Each of the sections is considered homogenous in terms of geometric, pavement condition, traffic volume and composition. Therefore the physical details of the sections (length, width, and surface class), traffic direction and pattern, pavement type and condition, horizontal and vertical alignment information are among data set in the road network definition. However, only motorised traffic is considered in this analysis.

4. 3 Defining the works standards:

This is where both the maintenance and improvement standards are defined. The details are on Table 4. 3. The maintenance standards are in the works standard/maintenance standards folder while the improvement standards are specified in the works standard/improvement standards folders. The maintenance standard has great effect on rate of deterioration of a road. Road will continue to perform to standard throughout its design life only when adequate and timely maintenance is carried out. Defining maintenance standard in the system imposes a limit to which deterioration could reach before a trigger. Furthermore the long term performance of a road is also affected by the improvement standard

4. 3. 1 Maintenance standard: There are three maintenance standards under the study. These are Gravel road maintenance, Maintenance before upgrading and routine maintenance after upgrade (crack sealing and patching paved road). These are effective at different time for the two sections of the road as detailed in Table 4. 4.

Scheduled for specified years. Duration is one year.

Both economic and financial costs for each of the work items were stored in the system.

4. 3. 2 Improvement standard: The improvement standard is to upgrade the gravel road to bituminous pavement. However the year of implementation for each of sections 1 and 2 are 2011 and 2012 respectively. These are indicated at the intervention tab while keying the information for each of the section. Furthermore the financial cost for sections 1 and 2 are US$120, 000 and US$150, 050. The economic costs were estimated as 85% of the financial costs. These were stored in the cost tab.

4. 4 Defining the project alternatives.

There are two project alternatives – Without project (maintaining the gravel road) and With project (upgrade gravel road). Each of the alternatives has works standards specified for each of the two sections. The analysis type (by project), start year (2009) as well as analysis period (20 years) were specified. The currency output of US$ was also selected.

4. 4. 1 Analysis method: There are two methods of analysing road investment in HDM-4 – Analysis by section and analysis by project. The formal (analysis by section) is when the sections in the road are considered separately and analyse against a base section. While the latter (analysis by project) is when the entire sections in an alternative are considered against a base alternative. For this case study the analysis is by project. In this instance, the annual cost and benefit are added for the sections in the ‘ With project’ to give the year total. The economic indicators so obtained are then used to compare the base alternative.

4. 4. 2 Without project alternative: This is the base alternative representing a continuation of current maintenance practice. The two sections were defined and assigned a maintenance standard ‘ Gravel road maintenance’ earlier defined under the works standard/maintenance standards folder.

4. 4. 3 With project alternative: This is the alternative where the road is to be upgraded to bituminous pavement. The two sections were defined with both maintenance and improvement standards. Both sections are to be upgraded in 2011 and 2012 respectively. However, they are to be maintained before upgrade according to ‘ maintenance before upgrading’ standard as defined. Furthermore, the period of maintenance after upgrade is also specified.

4. 4. 4 Sensitivity analysis: It is a technique used to find out the effect on the whole project of changes in value of each variable which is considered potentially serious risk to the project. In this case study, three variables –

Traffic growth rates, Construction cost and Initial AADT were considered as sensitive to the project. Therefore each of them was changed at a time by ±20% from 20% to 80% to verify their impact on economic indicators.

5. Analysis concept, summary result and discussion.

5. 1 Project analysis concept

The concept of the project analysis, using HMD-4, is assessing the physical, functional and economic feasibility of the ‘ With project’ alternative and compares it with ‘ Without project’ considered as base case. The system uses Life cycle costing for the analysis period of 20 years. In achieving this cost, the system models and predict the road deterioration, estimates the road user cost, model the road works effects and the cost of these to the road agency as well as calculate the economic and financial benefits from the comparison of the alternatives.

5. 2 Road Deterioration and road works effect modelling

For each year of the analysis period, HDM-4 models the road condition and assigns road works effect using predefined works strategies. Road deterioration prediction is based on the data provided on such variables as the original design, material type, construction quality, traffic volume, axle load characteristics, road geometry, environmental conditions, age of pavement and maintenance standard. HDM-4 does predict change in condition, i. e. distresses, from the initial set conditions as a function of the above named variables.

5. 2. 1 Average roughness (IRIav) of project: The deterioration of gravel road is characterised by roughness and material loss. Therefore grading every six

months was specified as one of the work items for its maintenance to keep the roughness within tolerable limit. Spot regravelling work item was to repair areas of severe depression, while gravel resurfacing is performed to augment gravel surfacing due to loss of material. These work items followed intervention criteria specified by the users. This is the logic HDM-4 uses to predict the gravel road deterioration and it is presented in graph 5. 2. This graph correlates Appendix I which shows the pavement condition summary. The pavement condition of ‘ Without project’ is a reflection of the interventions of the work items under continuous maintenance of the gravel road. Grading and Spot regravelling were effective every six month with no significant improvement to IRI values. However, gravel resurfacing was done in 2013, 2016, 2019, 2023 and 2025. There is a drop in IRI value each time the work item was carried out. In general the IRI was consistently high at between 7-13m/km throughout the analysis period for ‘ Without project’ alternative.

HDM-4 also predicts the deterioration of the road after improvement. This is done through surface distresses (cracking and potholing) and deformation distress (roughness). Out of the three work items for the maintenance of the paved (bituminous) road only resealing work item was triggered throughout the analysis period. This is a reflection of the intervention criteria specified. Under the ‘ With project’ alternative there is a drop in IRI values in 2011 and 2012 following the upgrading of sections 1 and 2 at these years respectively. For instance, for section 1 the IRI value was 11. 26m/km in 2010 but drastically reduced to 3. 01m/km after upgrade in 2011. This is similar to the effect of upgrading section 2 in 2012. However, it is noticed that IRI continued to increase steadily subsequently but at low rate. In 2018, 2019, 2025 and 2026 there was resealing which changed the rate of increase in IRI (between 2018 and 2019) and actually reduced the value (between 2025 and 2026). Surface dressing does not necessarily improve the smoothness of road surface hence its effect on IRI is not significant.

5. 2. 2 Road works summary: This summary, as contained in Appendix 2, confirmed graph 5. 1 and reflects the pavement condition summary in appendix 1. It shows the works items as they were triggered with associate quantities and costs (economic and financial). For the ‘ With project’ the maintenance standard before upgrade is reflected in the two sections before the upgrade. Furthermore resealing was also carried out in 2018 and 2025 for section 1, while that for section 2 was in 2019 and 2026. On the other hand in the ‘ Without project’ the average roughness for the project is shown in graph 4. 1. This graph correlates Appendix 1 which shows the pavement condition summary.

Road User Cost (RUC): From the economic indicator shown in Table 4. 3 there is a decrease of US$3. 828 million in Road User Cost (RUC) compared to US$3. 105 million increase in Road Agency Cost (RAC) for the proposed upgrade. This is an indication of the viability for the upgrade.

Cost Streams and Economic Evaluation

Table 4. 3 reflects the economic indicator showing a positive Net Present Value (NPV) of US$0. 723 million, indicative of the project viability. The Internal Rate of Return (EIRR) is US$12. 6 million. The economic indicator summary with sensitivity included in the analysis is provided in Appendix 3

Sensitivity Analysis

As discussed in paragraph 5. 2. 2 above Tables 5. 4a, 5. 4b and 5. 4c show the effects in economic indicators (NPV and EIRR) of changing the percentages of Initial AADT, Construction cost and Traffic growth rates considered as sensitive to the project.

Increasing both initial AADT and Growth rate indicates positive values of NPV and EIRR, while reduction in their values gives negative economic indicators. On the other hand, increase construction cost gives negative NPV and its reduction gives positive NPV.

NPV sensitivity diagram in figure 5. 3 below indicates that the three variables have various degrees of sensitivity on the project, with AADT being most sensitive. An increase in construction cost as well as drop in AADT will affect the chances of achieving the positive NPV values.

Therefore the accuracy of their estimation and forecast is important.

Switching Values: A reduction in percentage of AADT and Growth rate beyond 11. 5% and 25. 6% respectively changes the NPV values from positive to negative. Whereas increase in construction cost beyond 19. 5% also changes NPV from positive to negative.

6. Conclusion:

The economic analysis, using HDM-4, indicates that upgrading the gravel road to bituminous pavement is viable because of the positive NPV value obtained for the analysis period. In implementing the project the gain in RUC outweighs the increase in the RAC when this is compared with ‘ do minimum’ alternative. However, this result can only be achieved if the works are carried out according to the programme.

The Initial AADT, Construction cost and vehicle growth rate have various levels of sensitivity on the NPV. However, AADT is the most sensitive. An increase in construction cost as well as drop in AADT is likely to affect the chances of achieving a positive NPV values. There is also an indication that more benefit could be derived from the project when AADT value grows even as high as by 80% of the initial value. Therefore the accuracy of the construction cost, AADT and its projection are important to getting the benefit from the proposed project