DEVELOPMENT OF MODELS FOR OPTIMAL ROAD MAINTENANCE FUND ALLOCATION

A CASE OF GHANA

BY

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ABSTRACT

The research was aimed at the development of an optimal road fund allocation model for road maintenance to three road agencies in Ghana. The objective was to compare a novel model by multicriteria analysis (MCA) with deterministic outcome and a model based on preferential analysis to determine optimality. The deterministic model was efficiency based with quantitative analysis from a decision maker's perspective whilst the approach by preferential analysis was equity based with qualitative analysis from stakeholder perspective. The input parameters of the deterministic model were based on the value function method (VFM) and the concept of efficiency frontier. It determined a scaler index for the proportionate allocation of road fund by road type. It was based on a set of attributes including road length, traffic, pavement roughness and percentage of work achievement. The concept of efficiency frontier was used to sub divide the proportion of funds allocated by road type into economic efficiency and equity components based on the Net Present Value/Capital, Vehicle Operation Cost (VOC) and income. The values of the selected attributes were generated from the outputs of HDM-4 analysis. The model based on the preferential analysis was set on the Analytical Hierarchy Process (AHP). It involved pairwise comparison of defined criteria and sub criteria by stakeholder priority at national, district and community levels. Priority vectors were estimated for road fund allocation into efficiency and equity proportions by road type. A comparison of the outputs of the two models on the basis of the impact on pavement roughness performance indicated the stated preference based model yielded better impacts than the model with deterministic approach. It was concluded that road fund allocation based on a well logically determined value judgement with mathematical analysis yields better results.

THIS THESIS IS DEDICATED TO HIM WHO IS ABLE TO DO FAR MORE ABUNDANTLY THAN WE THINK OR WE ASK. TO HIM BE THE GLORY HONOUR AND GRATITUDE FOREVER AND EVER.

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GLOSSARY

ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
AG	AVERAGE AGE
AKM	Average Vehicle –Kilometres / Annum
AMGB	Asphalt Mix on Granular Base
AMSB	Asphalt Mix on Asphalt Stabilised Bas
AMAP	Asphalt Mix on Asphalt Pavement
ART	Articulator
BC	Base Case
BCR	Benefit Cost Ratio
BOT	Build Operate and Transfer
BOOT	Build Own Operate and Transfer
BTE	Baytex Energy Trust
CAP	Capital
CEA	Cost Effective Analysis
CEPS	Customs and Preventive Excise
CIF	Cost, Insurance and Freight
CV	Coefficient of Variation
DBFO	Design Build Finance and Operate
DEG	Degree
DEF	Deflection
DFR	Department of Feeder Roads
DFT	Department for Social Transport
DETR	Department of the Environment Transport and Regions
DIST	Distance
DFID	Department for International Development
DM	Deterministic Model
DUR	Department of Urban Roads
DVLA	Driver and Vehicle Licensing Authority
Econ.	Economic
ECOWAS	Economic Community of West Africa States
ECMT	European Conference of Ministers of Transport
EDIF	Economic Development Investment Fund
EIB	European Investment Bank
Equi.	Equivalent
ESALF	Equivalent Standard Axle Load Factor
EUNET:	European Network for Education and Training
FHWA	Federal Highway Authority
GDRC	Global Development Research Centre
GDP	Gross Domestic Product
GHA	Ghana Highway Authority
HDM:	Highway Development and Maintenance Management Standards Model
HR	Hours
IEG	Institute of Economic Growth
IRI	International Roughness Index

IRR	Internal Rate of Return
KM	Kilometres
M	Meters
MM	Millimetres
MED	Medium
MLG	Ministry of Local Government
MOF	Ministry of Finance
MRT	Ministry of Roads and Transport
M/s	Messers
NDPC	National Development Planning Commission
NGO	Non Governmental Organisation
NO.	Number
NPV	Net Present Value
NTCC	National Transport Co-ordinating Council
OECD	Organisation for Economic Co-operation and Development
PIARC	Permanent International Association of Road Congresses
PCSE	Passenger Car Space Equivalent
PV	Priority Vector
RUC	Road User Charge
RDWE	Road Deterioration and Works Effect
RUE	Road User Effects
RWE	Road Works Effect
STD	Standard
SNP	Adjusted Structural Number
SPM	Stated Preference Model
STAP	Surface Treatment on Asphalt Pavement
STD DEV	Standard Deviation
STGB	Surface Treatment on Granular Base;
TRRL	Transport and Road Research Laboratory
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
UK	United Kingdom
USA	United States of America
VAT	Value Added Tax
VEH	Vehicle
VFM	Value Function Model
VOC	Vehicle Operation Cost
VOL	Volume

CHAPTER ONE INTRODUCTION

1.1 BACKGROUND

Growing economic activities and rapidly changing markets in most developing countries have generated demand for the expansion of public road network. The sustenance of the full benefit of the road network requires adequate maintenance since road deterioration is endemic due to the effects of the weather, traffic volume, traffic loading and inadequate design standards. Effective road maintenance regime requires good management and adequate funding. Adequate funding is mandatory because there is an inevitable, ongoing and never ending consequence of recurrent expenditure for road maintenance needs after the initial road construction.

Sustainable funding for road maintenance has however proven to be particularly difficult for many developing countries. Many developing countries manage a road system which is larger than they can afford, (World Bank, 1981). Therefore there is need to maximise the returns on the limited funds available. Maximisation of available funds is ascertained by the relative effectiveness at which funds are allocated toward the achievement of a set purpose. It requires setting priorities for competing road types such as the trunk, urban and feeder roads on the basis of defined criteria. Day (1988) describes the process as complex and Howe, (1994) notes it to be a binding constraint in the operation of the road maintenance system.

1.1.1 Issues in Road Fund Allocation

Currently, the fiscal strategy for sustainable road maintenance funding in most developing countries is focused on a commercialised road user charging system. This requires ensuring economic efficiency in the allocation of the fund. It also requires that road user priorities are achieved in road fund allocation to commit road users to contribute towards the fund and to achieve equity. Economic efficiency relates to the achievement of economic growth. The purpose is to ensure transparency and objectivity. In conventional transport investment analysis, it is measured by the margin of return on invested capital. Its viability is based on the economic potential of the local economy and the volume of traffic on a road. This makes it suitable for roads in large urban centres and national highways with high traffic levels.

The determination of road user priority is based on subjective judgement on the wider impacts of road investment. It is equity focused and it is aimed at achieving a balanced road infrastructure system to include roads that are not principally an economic investment, (Porter, 2003). The major limitation associated with this is the diversity of preferences with no common metric for measurement and assessment. Generally the factors associated with both economic and equity consideration in road investment decisions are also said to be difficult to isolate, measure in their respective units and predict over a long term. Besides, the application of either the economic principle or the equity principle for justifying road investment decisions in themselves results in leaving some competing sectors worse off than others.

In Ghana the value of the trunk and urban road network constitutes about 70 to 80 percent of the total road asset value. The length of the feeder road network is about 50 percent of the total road network and it serves about 70 percent of the population. Therefore road fund allocation on economic basis alone may result in leaving a huge percentage of the population worse off. On the other hand road fund allocation purely on equity basis could also result in a huge loss in capital asset. There is therefore a need for an expenditure mix across a range of possible alternatives to ensure a balanced road fund allocation system.

1.1.2 Current Decision Paradigms on Road Investment Analysis

Multiple Criteria Analysis (MCA) which combine both economic efficiency and social equity principles is emerging as the preferred approach for road investment decisions. It is regarded as an alternative to the conventional methods of road investment analysis based on single objective functions, (Nijkamp, 1990). So far the application of MCA in transport investment decision for developing countries is focused on the inclusion of wider social impacts. However, it is argued that not all the elements missing from road investment decisions are purely social, (Howe, 1992). There is also a perception that road maintenance does not generate wider social impacts. Thus authors like Leinbach (2003) do not accept the inclusion of wider social aspects in road maintenance investment.

The application of MCA in transportation is also limited with no established principles. It is applied in many forms with varied conclusions. There is continuing discussion amongst practitioners and researchers regarding to which method is more appropriate in supporting decision-making, (Sayers *et al*., 2003; Luskin and Dobes, 1999). So far no MCA method is said to be better than the other and none is considered to be conclusive. Therefore it is recommended for more than one MCA method to be applied in a decision situation to determine optimality.

1.2 PROBLEM DEFINITION

Ghana has established a road fund scheme for sustainable road maintenance funding. The fund is allocated to three road agencies for their maintenance needs annually. There is a funding shortfall at about 50 percent of what is needed for road maintenance, Donkor and Abbey-Sam (2003). This generates a need for optimising the limited funds available. However, there is no particular method for road fund allocation. Road fund allocation is undertaken by a set committee on ad hoc basis with no established guideline. The approach is oversimplified, inconsistent and without merit. The process is not transparent and it is subject to political and administrative manipulation. This result in biases and inefficiencies with some competing road agencies getting dissatisfied with the proportion of funds allocated to them. The consequent impact is distorted maintenance programmes, wastage and neglected maintenance.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 Aim

The aim of the study was to develop an optimised road maintenance fund allocation model for Ghana.

1.3.2 Objectives

The objectives of the research were:

1. To develop a road fund allocation model with deterministic outcomes for road fund allocation.
2. To develop road fund allocation model based on a stated preference model.
3. To validate the deterministic based model with a conventional method for transport investment decisions and the stated preference based model with a similar study conducted under similar circumstances.
4. To compare the results of the deterministic based model and the stated preference based model on the basis of the impact of the outcome of each model on pavement roughness performance to determine which model yields the best results.
5. To compare the results of the two models against the current practice on the basis of the impact of the outcome on pavement roughness performance to ascertain whether the application of a model in road fund allocation gives better results as compared to an ad hoc approach .

1.4 SCOPE OF RESEARCH

This study is about fiscal strategies for maintenance with specific focus on road fund allocation with multiple objective functions to meet the needs of the Ghanaian situation. This is achieved by the comparison of the impacts of the application of two models for road fund allocation in the same decision situation with inputs from MCA applications. The essence was to ascertain the need to include or not to include wider social impacts in road investment analysis for road maintenance fund allocation in the context of a developing economy. The study did not address issues relating to the establishment of definite principles for MCA application in transportation since it was considered to be beyond the time and resource constraints available for this research.

1.5 STRUCTURE OF THE THESIS

The thesis is structured into nine chapters as illustrated in Figure 1.1 and the details are presented in the following paragraphs.

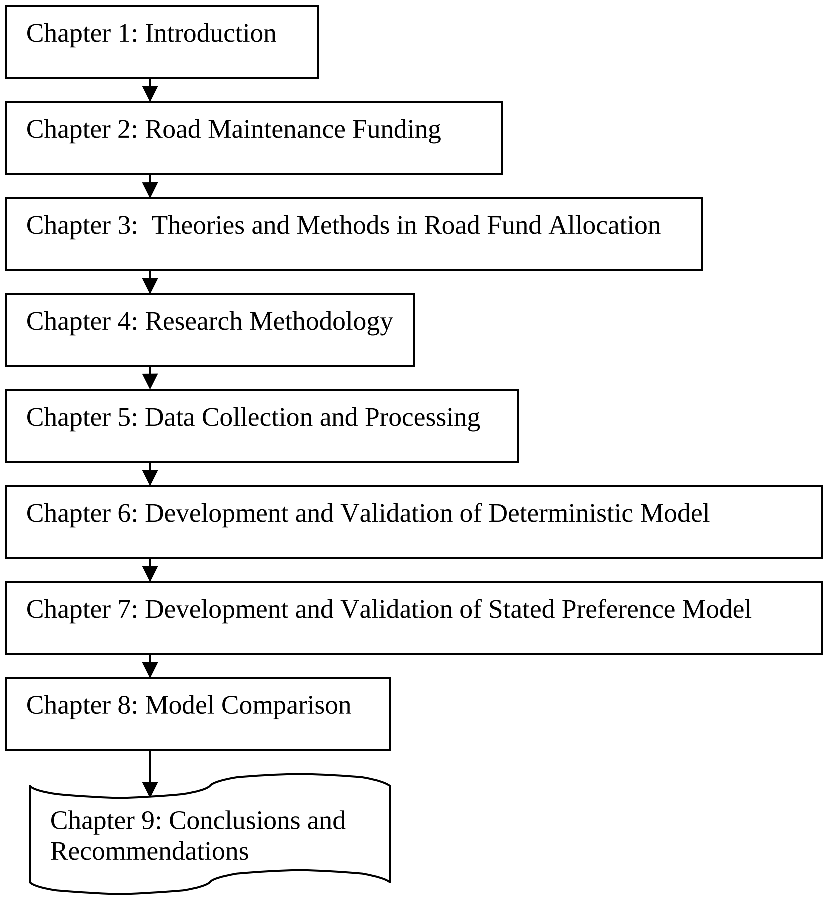


Figure 1.1: Framework for Research Methodology

Chapter One introduces the background to the area of research. It defines the research problem for which it was conducted, the aim and the objectives. It also sets out the scope of the research and presents the expected benefits.

Chapter Two introduces road maintenance within the context of the causes of road deterioration, its impacts, the factors mitigating against the achievement of effective road maintenance and the related consequence. It discusses the various mechanisms for funding road maintenance and the challenges associated with them. It presents the fiscal strategies being pursued for ensuring effective and sustainable road maintenance with emphasis on the importance of road fund allocation.

Chapter Three reviews the literature on the theoretical basis and methods used for road fund allocation. It discusses the differences in the theoretical dimensions, the limitations of current methods, the key challenges and the elements for best practices. It then presents the gaps in current knowledge as it relates to the Ghanaian situation as basis for developing a conceptual framework for optimal road fund allocation.

Chapter Four presents the research methodology. It describes the different components of the research work, the activities involved and the sequence of implementation. It also provides an overview of the analytical tools applied and the data requirements.

Chapter Five presents the methods used for the data collection. It also presents the data processing mechanisms in terms of the trends, patterns and relationships in the data sets with appropriate statistical applications for interpretations.

Chapter Six presents the structural function of the deterministic approach to road fund allocation. It describes the procedures for estimating the input parameters used for the development of the model structure with the Value Function Model (VFM) and the concept of efficiency frontier. A significant test of the model structure is conducted with a new data set. The model is also validated by comparison with a conventional method for transport investment analysis. It then presents a worked example to demonstrate how the model can be applied.

Chapter Seven presents the model structure for the stated preference based approach to road fund allocation. It describes the procedures used to estimate the input parameters with the Analytical Hierarchy Process (AHP) technique. It also presents the validation of the model structure by comparison with a case study in similar circumstances. It then presents a worked example to demonstrate how the model can be applied.

Chapter Eight compares the related impact of the results of the deterministic approach to road fund allocation with that of the stated preference based approach to road fund allocation. This is based on the impact of the outcome of each model on pavement roughness performance. This is to ascertain the optimum model for road fund allocation in Ghana. A further comparison of the outcome of the impact of the two models on pavement roughness performance is also undertaken with that of a 'base case scenario' where road fund allocation is undertaken on ad hoc. This determines whether the application of models in road fund allocation is better than the non application of models.

Finally, Chapter Nine presents the conclusions drawn from the research. It also gives recommendations for further work and explains the limitations of this study.

1.6 RESEARCH BENEFITS

The outcome of this research will provide a model structure for road fund allocation for road maintenance in Ghana. It will also give an indication on the impact of road fund allocation for road maintenance based on different objective functions. It will provide an example of a rational and accountable decision process for road fund allocation for other African countries which are in the same situation as Ghana. Besides, currently MCA application in developing countries for road investment decisions is focused on the inclusion of wider social impacts. The implication of this approach with regards to road maintenance which is considered not to generate wider social impacts is not tested. It is therefore expected that the outcome of this research will add to the knowledge on this by providing a guideline on which impact dimension to include in road investment analysis for road maintenance in developing countries. It is also anticipated that the study will provide a wealth of evidence for subsequent work on MCA schemes designed for developing countries on road fund allocation. It will also afford the possibility of a comparison of two different MCA methods in the same decision situation for a developing country.

CHAPTER TWO: ROAD MAINTENANCE FINANCING

2.1 INTRODUCTION

This chapter presents various aspects of the issue of road maintenance relevant to the problem of road maintenance financing. It defines the road deterioration problem and describes road maintenance interventions. It also reviews the impacts of road maintenance and the causes of poor road maintenance with emphasis on the road maintenance funding problem. It describes the different mechanisms used for road maintenance funding and the related challenges. It presents the fiscal strategies being pursued in some developing countries for sustainable and effective funding for road maintenance. It reviews the fiscal strategies for road maintenance funding by international practices with regards to the need for optimal road fund allocation and the related gaps in current knowledge.

2.2 THE ROAD DETERIORATION PROBLEM

Road pavements are built for an expected design life but deteriorate over time. This causes the road pavement to exhibit a number of fatigue symptoms. The deterioration process continues up to a point where maintenance intervention is applied to remove the defects. Then the cycle repeats itself until the road reaches the end of its service life known as terminal serviceability where it is reconstructed. Road maintenance intervention delays the rate of total failure until the pavement reaches the end of its design life. The process is referred to as the road deterioration cycle (Paterson, 1987) and it is illustrated in Figure 2.1.

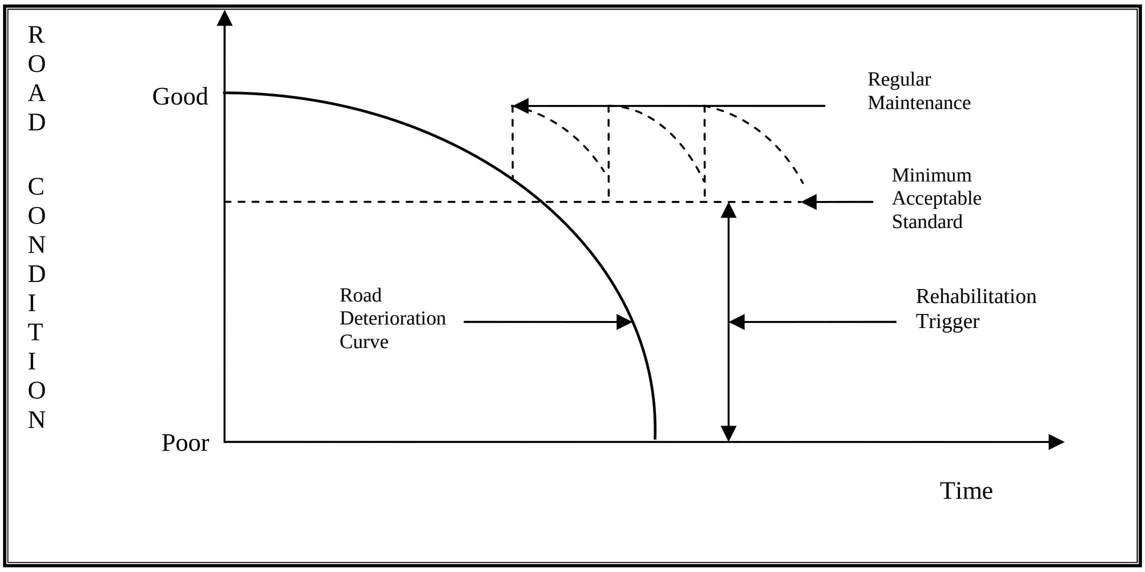


Figure 2.1: Pavement Deterioration Curve (Adapted from Highway Engineering Economy, FHWA, 1983).

2.2.1 Causes of Road Deterioration

Road deterioration is caused by the effects of the physical environment, traffic, material properties, quality of road construction, design standards and the age of the pavement. The details are discussed in the following paragraphs.

2.2.1.1 Environmental Factors

Climatic factors such as rain water, solar radiation, temperature, soil type and terrain may cause roads to deteriorate. Rain water can alter the moisture balance in the sub grade of a road with clayey and silty soils. This may cause swelling and shrinkage resulting in reflective cracking and heaving in the road surface. Sunlight may cause a continuous, slow hardening action on bituminous surfaces. This can increase the cracking process of the surface chip seal. Seasonal changes in temperature or night and day temperatures may cause expansion and contraction of the carriageway. This may progressively cause fatigue, failures and reflective cracks in the road surface, (TRL, Overseas Road Note 31, 1993). The major climatic effects of road deterioration in Ghana include hot equatorial temperatures which cause the rapid formation of corrugations. Torrential rainfall also reduces the load bearing capacity of roads if not well drained on the road side, surface or beneath due to the high clayey content of the soil type, (Metrological Services Department of Ghana (2004).

2.2.1.2 Traffic Volume and Loading

Roads are structures basically built to carry and sustain vehicular loads. Therefore traffic is an important factor that influences pavement performance. The impact of traffic on the deterioration of pavements is caused by vehicle loads and volume. Every vehicle, which passes over a road, causes a momentary but significant deformation in the road structure. This is determined by the magnitude of each of its axle loads, the spacing between the axles, the number of wheels, the contact pressures of the tyres and the travelling speed. The passage of many vehicles has a cumulative effect which causes repeated flexing of the pavement leading to fatigue, crazing and structural failure, (Paterson, 1987).

2.2.1.3 Material Properties and Composition

The choice of materials used for the construction of pavement layers may also cause road deterioration. This is due to inherent variability in the materials used for road construction in terms of soil properties such as strength or load bearing capacity, gradation mix properties, elastic and resilience modulus. Poor choice of materials used for pavement layers can have a drastic effect on the strength of the layers and their subsequent performance, (TRL, Overseas Road Note 5, 1988).

2.2.1.4 Construction Quality

The quality of road construction if not built to the desired specifications can also facilitate road deterioration. For example, failure to obtain proper compaction, improper moisture conditions during construction, poor quality of materials and inaccurate layer thickness (after compaction) all directly affect the performance of a pavement. (TRL, Overseas Road Note 5, 1988).

2.2.1.5 Road Maintenance Standards

The rate of pavement deterioration is directly affected by the maintenance standards applied to repair road defects. When a maintenance standard is defined it imposes a limit to the level of deterioration that a pavement is allowed to attain. Low maintenance standard therefore causes roads to deteriorate at a faster rate, (TRL, Overseas Road Note 5, 1988).

2.2.1.6 Age of Pavement

As pavements age and experience traffic repetitions, pavement distresses begin to accumulate. For example the hardening effect increases the stiffness of asphalt with age making the material more susceptible to thermal cracking, (Yonder, 1975).

2.2.2 Types of Road Defects

Pavement deterioration manifests itself in various kinds of distresses. Pavement distress is defined as any indication of poor or unfavourable pavement performance; or signs of impending failure or any unsatisfactory performance of a pavement short of failure, (Highway Agency, 1997). There are different classifications of pavement distresses with different manifestations but a more comprehensive classification is defined in Table 2.1, (Lecture Notes ST 2DMB, 2008).

Table 2.1: Classification of Pavement Distress

Mode	Manifestation	Mechanism
Fracture	Cracking	Excessive loading, repeated loading, thermal changes, moisture changes, slippage
Disintegration	Stripping, ravelling, edge break, potholes	Adhesion loss, chemical reactivity, abrasion by traffic, degradation of aggregate, failure of binder, environment
Distortion	Permanent Deformation(Rutting)	Excessive loading, repeated loading, consolidation
Profile	Roughness	Structural déformation surface distresses, age, environnent
Friction	Texture depth skid-resistance	Abrasion by traffic, aggregates embedded

An overview of the different manifestations characterising each pavement distress mode is also presented in Table 2.2.

Table 2.2: Types of Pavement Defects

Type of Pavement Deficiency	Description
Surface Distress	
Cracking	These are caused by fatigue failure due to repeated loads, or shrinkage of the asphalt and daily temperature cycling. They may be single or multiple with varying degrees of severity. They are expressed as a percentage of carriageways.
Ravelling,	Raveling is the wearing away of the pavement surface caused by the dislodging (raveling) of aggregate particles and loss of asphalt binder. This generally indicates that the asphalt binder has hardened significantly. They are also expressed as a percentage of carriageways.
Potholing	Potholes are small usually less than one metre in diameter bowl-shaped depressions on the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free water collecting inside the hole. They a produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface quality, weak spots in the base or subgrade. The number of potholes per km expressed in terms of the number of standard sized potholes of area $0.1m^{2.}$
Shoulder Distress	Shoulder elevated over road surface, or excessive gravel wind-rows along roadway edge. Possible causes are loose gravel on road surface combined with traffic action, poor construction and improper maintenance. They are expressed in meters per km.
Deformations Distress	
Rutting	Rutting is characterised by longitudinal depressions in the pavement surface that occur in the wheel paths of a roadway. Poor mix stability, excessive bitumen in the mix and repetitive loading on poorly compacted mix are several causes of rutting. They are as expressed as the maximum depth under 2meter straightedge transversely across a wheel path.
Depressions and Sags,	Depressions are localised pavement surface areas with elevations higher than those of the surrounding pavement. They are also created by settlement of the foundation soil or are the result of improper compaction during construction.
Profile	
Roughness	Deviations of surface from true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage expressed in International Index (IRI m/km).
Friction	
Skid Resistance	Resistance to skidding expressed by the sideways of force coefficient (SDF) at 50km/ph measured using sideways for the coefficient Routine Investigation Machine (SCRIM)
Texture Depth	Average Depth of the surface of a road expressed as the quotient of a given volume of standard material (sand) and the area of that material spread in a circular pattern on the surface being tested.
Drainage	Drainage condition defines the drainage factor as either good fair or poor.
Gravel Loss	Deterioration of unpaved roads is characterised primarily by material loss from the surface.

Source: Odoki and Kerali (2000)

2.3 ROAD MAINTENANCE

Road maintenance may be described as an intervention that reduces the rate of pavement deterioration. The purpose of road maintenance is to enable the continued use of the pavement by traffic in an efficient and safe manner. The characteristics of road maintenance activities are presented in the following paragraphs.

2.3.1 Road Maintenance Activities

Road maintenance activities are categorised according to the frequency of operation, (TRL, Overseas Road Note 1, 1981). It involves minor activities undertaken on routine basis and major activities undertaken on periodic basis to eliminate pavement defects, (Paterson, 1987). It could also be in response to an urgent situation. The road maintenance activities determine the threshold of funding needed for road maintenance. Each activity corresponds to a specific budget head and this determines the threshold of funding required for maintenance.

2.3.1.1 Routine Maintenance

It is a timely intervention to prevent minor faults from further deterioration which might require costly repair. The operations are carried out on a regular or cyclic basis. The frequency may vary in a particular year or season. They are small scale but widely dispersed and require skilled or unskilled manpower. Routine maintenance is funded under recurrent budget heads and its application is aimed at achieving savings in delivery costs. It is considered to be the most effective use of funds to assist the pavement to remain in sustainable condition for further time before periodic maintenance is applied. A summary of the routine activities is presented in Table 2.3.

Table 2.3: Types of Routine Maintenance Activities

Type of Maintenance Activity	Description
Surface Maintenance	-Pothole Patching -Repair of depressions, Ruts, Shoving and Corrugations -Edge failure repairs -Crack Sealing -Break-up Spot Grading of High Gravel Shoulder
Surface Maintenance on Gravel Roads	-Reshaping of Gravel Roads -Grading of Gravel Roads -Sectional Patching
Drainage Maintenance	-Ditch cleaning -Re-excavation of Drainage Ditches -Cleaning and Minor Repairs of Culverts -Crack repairing on drainage structures -Erosion and Scour Repairs
Road Side Maintenance	-Grass cutting
Road Side Furniture Maintenance	-Cleaning, repairing and replacement of traffic signs guide posts and guard rails, road line marking

2.3.1.2. Periodic Maintenance

These are operations that are occasionally required on a section of road after a number of years to protect the structural integrity. It includes development works to expand the capacity of the network, the provision of stronger pavement and the improvement of the geometric characteristics of the road. The timely application of periodic maintenance delays ultimate full reconstruction at higher costs. Periodic maintenance activities are funded under capital budget heads. They include large scale pavement maintenance such as sealing of cracked surfaces, resurfacing, overlay, pavement reconstruction or strengthening, maintenance of drains and road shoulders. Examples of periodic maintenance activities are summarised in Table 2.4.

Table 2.4: Types of Periodic Maintenance Activities

Type of Periodic Maintenance Activities	Description
Regravelling	Placing of adequate subbase gravel on an existing gravel road to strengthen the pavement. (This is usually performed at 3-5 years interval depending on the traffic and climatic condition
Resealing	Placing of a fresh seal coat on an existing bituminous surfaced to seal cracks and improve resistance. (This is usually performed at 5-7 years interval depending on the traffic and climatic condition
Overlay	Placing of asphaltic concrete on an existing bituminous surfaced or asphaltic concrete road to strengthen the pavement. (This is usually performed at 10-12 years interval depending on the traffic and climatic condition.
Partial Reconstruction (Resurfacing)	Scarifying of existing bituminous surfaced road, strengthening the base year with addition of adequate thickness of base material and applying surface treatment.
Minor Rehabilitation	Improvement of an unpaved or paved road including widening, earthworks and construction of drainage structures.

2.3.1.3. Emergency Works

These include works of any nature which arises out of emergency and requires immediate attention. It normally has a lumped sum budget which may be drawn from a special account set for the purpose. It includes activities such as clearing debris and repairing washouts.

2.3.2 Road Maintenance Intervention Criteria

The selection of road maintenance interventions are based on two fundamental rules which determines the timing and limits on the works to be carried out. The rules ensure that a consistent approach is undertaken to planning and specifying works. It also ensures that funds are spent to the greatest effect, Robinson *et al* 1988). The two rules are defined as either scheduled or responsive.

1. Scheduled: Works are fixed at intervals of time or points in time for maintenance and at a fixed time for improvement or construction works.

2. Responsive: Road works are triggered when road condition reaches a critical threshold known as ‘intervention level’. It is considered to be very useful for judicious disbursement of maintenance funds.

2.3.3 The Road Maintenance Process

The approach involves defining activities, planning, allocating resources, overseeing implementation, monitoring and evaluation of works, (Adair, 1983). It normally contains the following components:

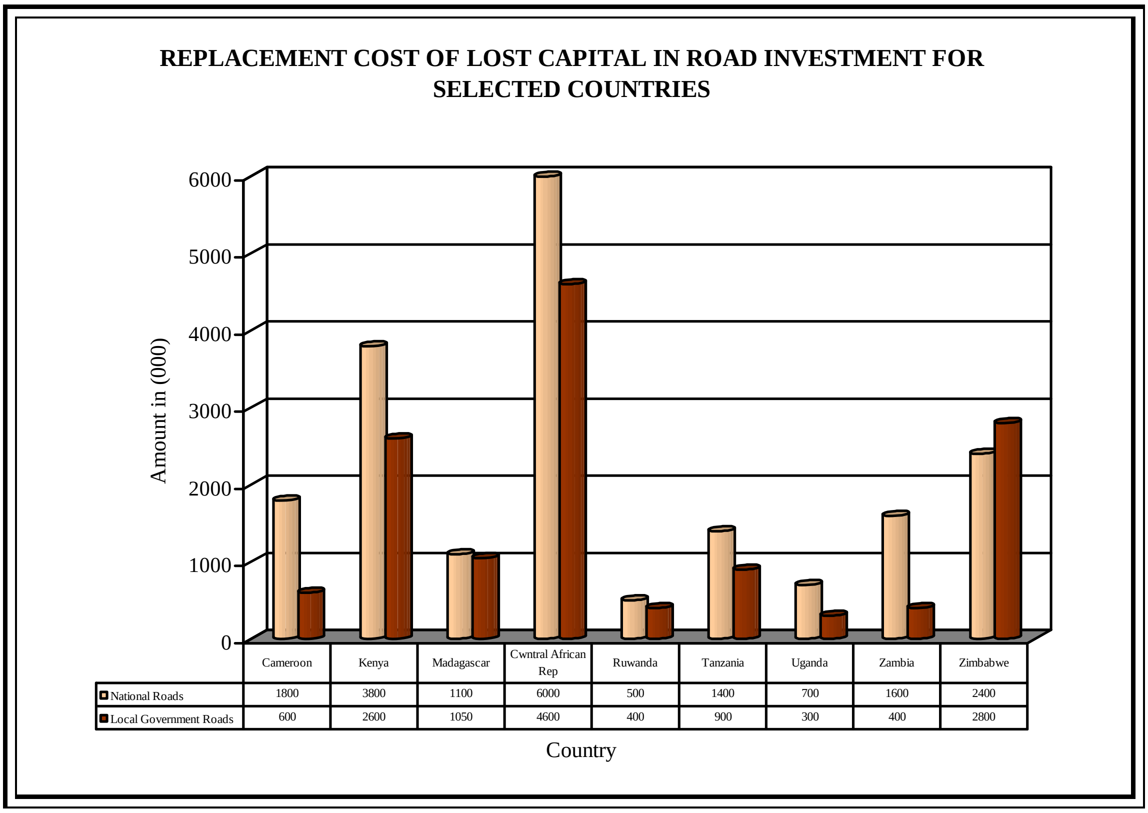
1. Inventory: This is used as the basic reference for planning and carrying out maintenance and inspections. Inspection of road condition is the process of taking physical measurements of defects on the road network in the field.
2. Maintenance needs: These are determined by comparing the measurements of road condition with predetermined maintenance intervention levels that are based upon economic criteria.
3. Costing: Unit costs are applied to the identified maintenance tasks to determine the budget required.
4. Priority setting: If the budget is insufficient for all of the identified work to be carried out, it is then necessary to determine priorities to decide which work should be undertaken and which should be deferred.
5. Execution of works: The work identified is carried out through with the assistance of several systems of scheduling and cost-accounting.
6. Monitoring: Monitoring serves two purposes. That is it ensures that work identified has, in fact, been carried out and it also provides data to enable unit cost and intervention levels to be checked and adjusted if necessary.

2.4 IMPACTS OF ROAD MAINTENANCE

The benefits of road maintenance include the protection of initial capital investment in road construction, reduction in transport costs, traffic safety, environmental sustainability and the facilitation of social and economic development.

2.4.1 Protection of Investments

Road maintenance prevents the loss of investment made in an initial road construction. Routine and periodic maintenance cost for the entire life of a road is estimated to be between 2 and 3 percent of the initial capital investment, (Zietlow and Bull, 1999). However, neglected maintenance could cause this amount to increase. According to Harral and Faiz, (1988) timely maintenance expenditures of US $12 billion in Africa would save road reconstruction costs of $ 45 billion over a decade. A PIARC Publication (1995) estimates the threshold of capital investment which is lost on annual basis from neglected maintenance to be about 1 to 3 percent of GDP of individual countries in Sub Saharan Africa. About 75 percent of this is in the form of scarce foreign exchange. In Latin America and the Caribbean equivalent figures were estimated at $1.7 billion per year in 1992, amounting to 1.4 percent of the individual country’s GDP. A summary of the replacement costs of lost capital from neglected maintenance in some selected African countries is presented in Figure 2.2.



	Cameroon	Kenya	Madagascar	Cwntral African Rep	Ruwanda	Tanzania	Uganda	Zambia	Zimbabwe
National Roads	1800	3800	1100	6000	500	1400	700	1600	2400
Local Government Roads	600	2600	1050	4600	400	900	300	400	2800

Figure 2.2: Replacement Costs of Invested Capital

2.4.2 Reduction in Transport Costs

Empirical evidence suggests that well maintained roads reflect in savings in vehicle operating cost (VOC). This is from reduced fuel and oil consumption, vehicle maintenance, tyre wear and vehicle depreciation, (World Bank, 1998). An illustration of the relative discounted life cycle costs of maintenance spending scenarios is provided in Figure 2.3. For, a traffic level of about 1000 vehicles/day a road in good condition will require 2 percent of discounted total costs to be spent on maintenance. However if maintenance funds are reduced, VOC's are likely to increase by about 15 percent. If there is complete neglect of maintenance, a paved road will eventually start to disintegrate and annual VOC will increase by 50 percent and if continued will result in the need for new road development. Heggie (1995) estimates that each dollar spent on patching on an annualised basis, saves at least US $3. Robinson, *et al*, (1988) suggests a 10 fold or more returns on each dollar spent on patching.

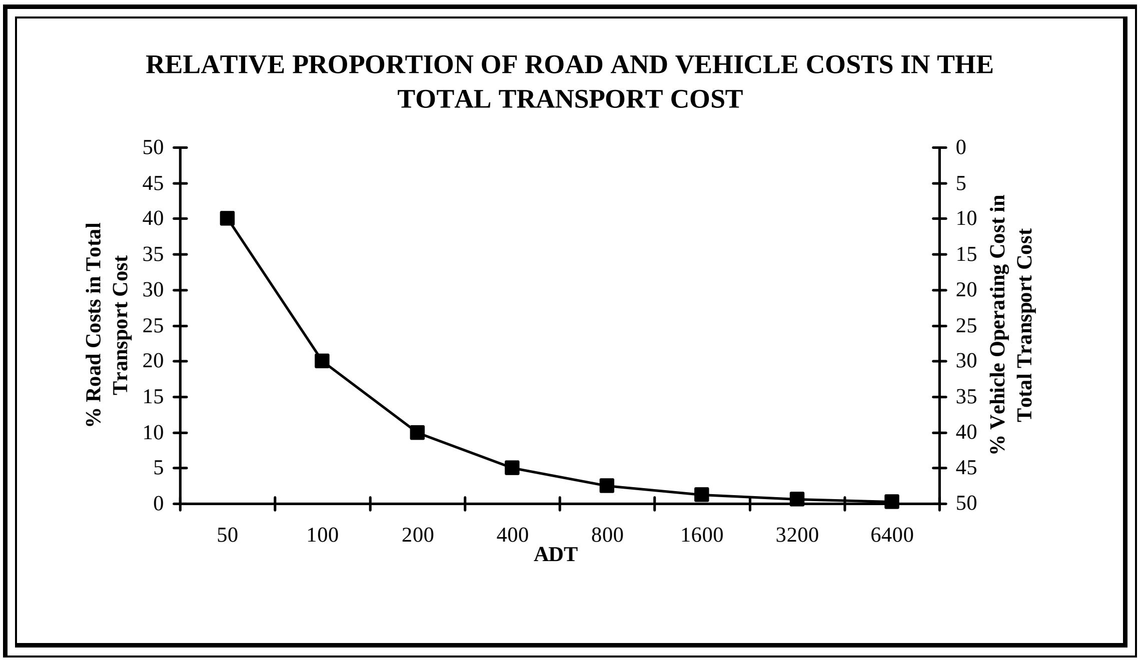


Figure 2.3: Relative Proportions of Road and Vehicle Costs in Total Transport Cost (Adapted from Schliesser and Bull, 1993).

2.4.3 Safety

A significant number of road accidents and fatalities can be directly attributed to the state of the road network. For example, inadequate skid resistance on neglected roads can contribute to traffic accidents. Potholes pose a threat to all road users, particularly to cyclists and motorcyclists. The correction of such defects through road maintenance interventions can reduce the number of road accidents. However, improved riding quality from road maintenance interventions can also have negative impacts from increased speeds which can result in accident fatalities.

2.4.4 Environmental Sustainability

Road maintenance has a positive impact on the environment. For example, well planned maintenance schemes can have good environmental vehicle performance which can reduce vehicular pollution. However road maintenance can also cause negative impacts through environmental damage such as water contamination from oil spillage, poor air quality from dust pollution and noise and vibration during construction.

2.4.5 Facilitation of Social and Economic Development

The road network is the only transport infrastructure that reaches virtually any location. Logically a road is the main provider of individual and goods mobility. Improvement in the quality of road service therefore increase personal mobility and facilitate economic growth which contributes towards poverty reduction in developing countries.

2.5 CAUSES OF POOR ROAD MAINTENANCE

According to the World Bank (1981), the road maintenance problem in developing countries can be attributed to the large size of the road network, the mode of road maintenance management and funding shortfalls,

2.5.1 Road Network Size

Roads built at the beginning of post-colonial period in most Sub Saharan-African countries have been increased due to increased growth. Also though roads are designed for a twenty (20) year life they tend to last for only ten (10) years. This is attributed to traffic growth and the problem of overloading which causes roads to deteriorate at a faster rate. This has resulted in many roads coming to the ends of their design life at the same time, increasing the need for reconstruction, (TRL, 1987).

2.5.2 Road Maintenance Management

Road management is described as the combination of technical and administrative actions for retaining the road in the state that it can perform its required function, (The British Standards Institution 3811, 1984). According to Heggie, (1995) the asset value of the road network in Sub-Sahara Africa is in the order of US $ 150 billion which is a huge asset by any standard. He indicates that, even though the asset value of roads is huge, they are not subjected to market discipline. Most public road administrations responsible for keeping the road networks in good condition do not know the asset value of these roads or the economic consequence of poor maintenance. Roads are therefore administered like a small government department with internal planning, contracting, supervision and the actual execution of maintenance works. This creates operational and structural inefficiencies resulting from overstaffing, lack of discipline and control. Others are lack of accountability which is a disincentive for good performance, (Robinson *et al* 1998).

Asset management is recommended for effective road maintenance management. It is based on enhancing the capital value of the asset. The approach combines management, financial, economic, engineering and other practices for effectiveness. It requires the use of a multi-disciplinary approach to management to develop and implement programmes for asset creation, operation, maintenance, renewal and disposal, over the life cycle of the asset. Performance monitoring is also needed to ensure that the desired levels of service and other operational objectives are achieved at optimum cost, (Kerali, 2002). The general direction of the approach includes the following.

1. Establishing a more autonomous road agency.

2. Identifying clear roles and responsibilities between the autonomous road agency and the parent ministry.
3. Streamlining the structure of the road agency and improving terms and conditions of employment for road agency staff.
4. Separating the planning and management of roads from implementation of road works and replacing force account with contracting of work to the private sector.

According to Frost and Lithgow, (1996), these actions regularly produce cost savings of 15 to 20 percent and exceptionally, may reduce cost by 30 percent or more. However there is no empirical evidence to support this assertion.

2.5.3 Road Maintenance Funding

Many countries in Africa and Asia have invested heavily in road construction over the last fifty (50) years with the help of international funding agencies and donors. Unfortunately, these countries did not succeed in allocating sufficient financial resources of their own to continue the investment in the maintenance of their networks. Hau (1992), intimates that the level of road maintenance is way below an economic optimum.

2.6 ROAD MAINTENANCE FUNDING MECHANISMS

There are different mechanisms for road maintenance funding and these are discussed in the following paragraphs.

2.6.1 The Budget Approach

This involves road maintenance funding by government tax policies. It is applied from the view that road infrastructure assets are publicly-owned and should be funded through general taxation. It is commonly applied in developed countries especially Europe. Most African countries are however moving away from this system to other funding sources due to the following reasons.

1. Different sectors compete for limited Government budget.
2. Tax payers are unwilling to tolerate continual increases in tax rates.
3. Maintenance spending is usually deferred because the road deterioration process is not very visible in the short term.
4. Increased road spending, which has made it impossible for road funds to be fully financed from government budgets, (Heggie and Vickers, 1992).

2.6.2 International Private Finance

The introduction of private finance into infrastructure projects is seen as a new way to ease rising fiscal constraints for infrastructure investment. The modalities of its implementation vary depending on the functions given to the private sector, such as designing, constructing, operating, managing, financing, and maintaining the ownership of the asset. Many different terms are used for private financed road projects. These include the concept of build, own, operate and transfer (BOOT) or build operate and transfer (BOT) in which the private sector finances, designs, builds, maintains and operates a facility for a fixed term before transferring it to the owner (the host government). Sometimes the private sector takes on ownership of the facility in perpetuity, in which case there is no transfer of ownership at a later date but these approaches are less common in the road sub-sector. Appendix 2.1 provides a summary of the conditions for the implementation of BOT.

The initial investment can be raised through equity investments at between 10 and 30 percent of project costs. It can also be raised through debt financing at 70 and 90 percent of project costs from commercial sources. They are usually backed by credit guarantee agencies and bilateral or multilateral lenders. The return on this investment is made by charging road users a toll during the term of operation. It is a requirement for the financial viability of a BOT project over its life to be sufficient to service the project debt. It must also provide a return on the equity that is commensurate with the long term risks of the equity investors. Therefore the extent to which a project can generate toll revenues is critical. The arrangement to increase toll rates with inflation and to deal with the exchange rate risk is also of critical importance. The overall commercial climate in the country is very important to the viability of setting up a BOT project. In this respect industrialised countries are usually in a much better position to adopt BOT type projects.

According to Antonissen, (2000), the major problems relating to its effective implementation are a lack of political will; high construction costs and operating risks; lack of financial viability such as insufficiency of tolling revenue; and lack of experience in the design, construction and procurement of required works on the part of the private financiers. Some of the recommended interventions to address these problems include the establishment of guarantee fund, a balanced allocation of economic risks and standardisation for cost savings. It is commonly practised in the more industrialised developing countries such as Indonesia, Malaysia and Mexico.

The concept is not being applied in sub Saharan Africa due to the lack of mechanisms for addressing perceived risks to the private company.

2.6.3 Private-Public Partnerships (PPP)

With the PPP, the Government introduces the private sector investor into road maintenance by putting their own capital at risk. This is because of private sector management efficiencies which are not fully replicated in the public sector. The private sector is contracted to deliver road maintenance according to the form of specified output. The quality of service is maximised by market discipline or quality standards enforced through regulation or by performance requirements in the contract. This improves the value for money, so enabling the Government to provide more public services and to a higher standard within the resources available. They cover a range of business structures and partnership arrangements, from the Private Finance Initiative (PFI) to joint ventures and concessions. Others are outsourcing and the sale of equity stakes in state-owned businesses.

The major limitations are that in order to reach financial balance, governments have often accepted commercial risks that should have been assigned to the private sector. This has included not only the foreign exchange risk but also demand/traffic risk. At the same time, private parties frustrated with drawn-out negotiations and the continuing renegotiating of clauses have accepted risks that should have been borne by the government, (Guasch, 2004). In developed economies, the problems with this mechanism have included a generous hand of the public sector behind the projects, a variety of subsidies, guarantees, barriers to competition, and contract renegotiation due to substantial errors in demand prediction, (Engel *et al*, 1996).

To attract the private sector to projects located in more uncertain environments, there has also been a need for the introduction of risk sharing agreements between the public sector and private concessionaires. Also, governments at times have needed to assume the liabilities of private sector operators. The Mexican government, for example, took on about 2 percent of GDP of private debt in 1994 to resolve problems faced by the concessionaires' creditors, (Ernhardt and Irwin, 2004). The PPP approach is not common in Sub Saharan Africa due to perceived operating risks.

2.6.4 International Financing Institutions

This relates to funding from multilateral and bilateral financing institutions referred to as donor agencies. This process is normally arranged through a formal agreement between the host government, aid donors and officials of the road sector. The donors may be interested in a particular area of the country, a particular road or wish to give general institutional support for maintenance or planning. Often appraisal requirements will be specified and detailed specifications may be made covering how bidding is to take place, how the work is to be undertaken, how the work should be supervised, how accounting is to be done and sometimes technical audits may be requested as the work progresses. Robinson *et al*, (1988), indicated that donor support for road maintenance funding had been dwindling in most developing countries over the years. He explained that increasing pressure on international aid flows to Sub Saharan Africa could mean that the financial burden on local budgets would increase and erosion of capital will increase. Though this has been noted since 1988, the trend has continued. This is because donors' are increasingly reluctant to finance capital expenditures unless credible arrangements for maintenance are made, Malmberg Calvo (1998).

2.6.5 Cost Sharing

This involves supplementing central government funding at the local level with revenues generated at the local government level for their roads. The approach is to enable the government not to "stretch" its budget. It includes revenue sources such as local property taxes paid by landowners, since local roads not only benefit road users but also adjoining landowners. An example is the octroi system levied on the movement of goods through local government boundaries in South Asia which is known to generate large amounts of funds. A private company will bid for the rights to collect the octroi from an area and each time a truck passes through a local government boundary the company will collect the toll based on the cargo, (ILO, 2007). The practice is not very common in Africa due to the weak capacity to generate local government tax revenue.

2.6.6 Cost - Effective Maintenance Practices

Cost effective mechanisms are also introduced to cut down the cost of maintenance. The options for maintenance are varied according to the type of road and by the type of contracting and procurement systems chosen. These include the following.

(i) 'Term Maintenance': This involves outsourcing road maintenance activities to contractors on a long term basis. The contractor is paid for agreed work done over a specific term according to contracted unit rates. The advantages are that it ensures a more efficient use of available resources, greater flexibility with financing and allows for up front projects to proceed where they have been deferred or delayed under government budgeting. It also allows for greater control of cash flow and lower risk to the principal which generates savings which can be invested in other services. However, without the 'right' performance criteria being established this type of contract can fail because performance cannot be measured nor controlled.

(ii) ‘Performance Based’ maintenance contracts: The contractor makes a bid based on his assessment of the work to be undertaken to keep the road in a specified condition. Provided the road is kept up to standard the contractor will be paid according to the bid irrespective of the work undertaken. Penalties are included if a specified standard is not achieved and special provisions are made for severe road damage due to unforeseen situations such as extreme weather.

(iii) Labour Based Road Construction Methods: According to the International Labour Organisation (1999) comparative studies of employment-intensive and equipment-intensive projects have shown that Labour based methods of road construction are cheaper than equipment intensive methods.

Whilst these methods may be cost-effective, they need careful planning, oversight and support from road management organisations for sustenance in the long-term.

2.6.7. The Road Fund Approach

This involves an off-budget road maintenance financing arrangement created as the main source of finance for road maintenance. It operates on a “user charge” system to generate revenues. It emerged in some developed countries as far back as the early nineties. For example the UK set up a Road Improvement Fund from 1910 to 1920; Japan established the Road Improvement Special Account in 1954; the United States of America (USA) established the Highway Trust Fund in 1956 and New Zealand established their Land Transport Fund in 1953. The advantage is that money can be accumulated and spent over several years on road maintenance without being constrained by the annual government budgeting cycle.

However, most developing countries which applied the system could not provide the expected flow of funding for road maintenance for a number of reasons. This is because according to Richecour and Heggie (1995) the system was purely administrative with no legal backing nor financial rules and regulations. Eklund, (1967) also indicated that there was a weak correlation between earmarking and the proportion of funds devoted to roads. He explained that there was no strict budget discipline and revenues were often not spent on roads but were diverted to other sectors. There was no explicit connection between the rates of taxation and the levels of road maintenance provision and regular work schedules were distorted by the erratic flow of funds. Thus according to Richecour and Heggie, (1995) it was impossible to sustain road maintenance programmes by this approach.

2.7 FISCAL STRATEGIES FOR ROAD MAINTENANCE

Gramlich, (1994) classifies the fiscal strategies for sustainable and effective road maintenance financing into two principal components. These are securing adequate funding threshold and allocating it efficiently. Robinson *et al*, (1998), also defines sustainable and effective road maintenance financing as ensuring alternate sources of funding and the allocation of funds which should satisfy the following conditions.

1. Provision of a secure source of funding for road management.

2. Establishment of direct link between revenue contributions and spending on road management, with prices paid by users reflecting the level of service provided.

3. Efficiency of revenue collection.

4. Independence from political interferences on spending decisions.

2.7.1 Reformed Approach for Securing Road Maintenance Financing

A reformed approach for road maintenance funding defined in a ‘‘second generation’’ road fund has been initiated to ensure sustainable and effective funding for road maintenance in developing countries with the assistance of the World Bank. The aim is to recover the cost of road maintenance by bringing it to the marketplace on a ‘’fee-for-service’’ basis, (World Bank, 1988). The idea is based on a more business-like approach to road maintenance with strong financial management. The fund is justified on the grounds that it allows for long term planning due to stable revenues, ensures value for money, increased efficiency and creates an incentive structure for the behaviour of road users and suppliers. It is set on the following four building blocks.

1. Creating ownership to commit the road user to funding road maintenance
2. Ensuring accountability by limiting spending to what is affordable
3. Securing adequate and stable flow of funds
4. Clarifying responsibilities by establishing who is responsible for what

The advantages of this approach over the ‘‘first generation’’ road funds includes the following.

1. The fund is set on a clear legal foundation with financial administration and technical autonomy.
2. Road user charging is applied with no earmarked taxes.
3. It is managed by a representative board with half or more members representing road users and the business community.
4. Members are nominated by the represented constituencies with an independent chairperson.
5. Financing arrangements are designed to ensure that money is not diverted from other sectors. This is essential to ensure that budget constraints are hard and that expenditure decisions are responsive to users with a strong legal backing.
6. Funds are managed pro-actively by a small secretariat.
7. There are published financial regulations governing the way funds are managed.
8. Charges are adjusted regularly to meet agreed expenditure targets; and
9. There are regular technical and financial audits to ensure efficiency.
10. They are administered under separate conditions from other government tax systems on the basis of the following principles.

(i). Provision of incentives for the reduction in road user charge evasion by keeping the rate as low as possible to avoid corruption and under declaration

(ii) Broadening the tax base by limiting exemptions

(iii) Avoiding large differences in tax rates of similar items

(iv) Simplifying the tax collection structure to reduce administrative costs and effective enforcement.

The 'second generation' road fund is applied through direct and indirect user charges. Direct charges include road tolling and road utilisation charges by vehicle category. Indirect charges include proxy charges based on earmarking on taxation through fuel levies. The major components of the system are discussed in the following paragraphs.

2.7.1.1. Tariff Setting for Road User Charges (RUC)

A fair and equitable RUC is based on charging individual vehicles for the actual cost of the road use. The tariff is set by the standard market model of demand and supply. Different approaches have been advocated by different authors to allocate costs between different vehicle categories. Some authors stress on the differential effects of vehicles on road design and road deterioration while other author ignore this and emphasised other aspects such as the ability to pay. Some of the mechanisms used for calculating road user charging systems include the following methods by Alemayehu *et al*, (1992).

1. Cost allocation on the basis of derived benefit from investing in a road type.
2. Cost allocation on the basis of ability to pay by the road user category such as private and commercial road users.
3. Cost allocation by the total ton-miles travelled by each vehicle class.
4. Cost allocation based on the amount of highway space and time occupied by each vehicle type.
5. Cost-function approach which involves costs allocated to vehicle size and weight distributed on the gross-ton miles travelled.
6. Cost allocation based on Equivalent Standard Axle Load (ESAL) method.
7. The incremental costs incurred approach where costs are estimated to cover variable maintenance costs.

8. Cost allocation where transport users with inelastic demand (i.e. their use varies least with changes in perceived transport costs) are allocated the largest proportionate increase in their transport costs in order to maximise the generation of revenue. The justification for this method is outlined in Heggie and Vickers, (1998). It is subject to a wide margin of error and varies widely from case to case due to difficulties in estimating elasticities of demand.

2.7.1.2 Charging Instruments

The charging instruments for RUC include tolling, fuel levies and vehicle license fees.

1. Tolling: Each vehicle is charged individually according to its usage of any particular road. The best approach is considered to be an electronic tolling system covering the whole road network. Unfortunately, this system is not readily available in most developing countries. Besides, the cost involved is considered to be fairly high and it is dependant on the level of tolls and the number of vehicles per day. The system is economically viable for a small percentage of roads and cannot solve the road maintenance financing problem for a country's whole road network. The contribution of road tolls in Ghana to the road fund is 2 percent.
2. Fuel Taxes: This is a service charge or road maintenance tariff levied and collected together with the sale of motor fuels. The levy is derived from the fuel price build up. Its main attraction is the ease with which they are collected since tax payers are easily identified. The disadvantages are that differential fuel price between contiguous countries and alternative fuel prices can cause evasion. Others are adulterating fuel with cheaper substitutes and mis-

classifying their use under an exempt category. It is generates the highest source of revenue to the road fund in Ghana at 88 percent.

3. Vehicle License Fees: It is deemed to be difficult to administer. This is because compliance cost is high since in some countries the tax payer might have to comply with numerous other regulations. It contributes 2 percent revenue to the Ghana road fund.

2.7.1.3 Limitations of the Road Fund

The road fund is criticised for taking precedence over other sector programmes financed through general taxation revenue. It can lead to a cut back in other government programmes when there is a shortage of general government funding whilst road maintenance continues, (Potter, 1997). It also limits macro-economic budget flexibility so the Government's ability to allocate funding to those areas in most need is in effect reduced. This may generate inefficiency through 'rent seeking' behaviour whereby road agencies will try to protect their own dedicated source of revenues without ensuring their accountability. These arguments are counter acted by Gwilliam and Shazli, (1999) on the grounds that it cannot presume that 'good governance' exists in the management and allocation of funds to other sectors.

2.7.2 The Need for Efficient Road Fund Allocation

The quest for a sustainable funding for road maintenance has also brought to the fore the need to maximise the returns on the limited funds available. Roads are managed under different structures which compete for funding resources for road maintenance, (Heggie and Vickers, 1998). These could be regions, provinces, districts or agencies responsible for road maintenance management. The competition stem from differences in road functions, levels of road service, resource capabilities, need and development objectives. Decisions have to be made on how much money is needed and how to allocate the money to each competing sector, Adler, (1987). This is essential because according to the OECD, (1994) only addressing the first cause of the road maintenance funding problem by securing more funds will not be enough to solve the road maintenance problem. Optimal fund allocation is required both in situations with funding shortfalls and in situations with adequate funding. This is because offering a lot of resources does not necessarily mean fulfilling different points on the risk reward spectrum and misallocation could result in wastage. Limited resources also have to be maximised for optimal returns.

However, the question remains on how much to allocate to the different road agencies involved in road maintenance. This is especially relevant for roads with very low traffic which most likely may have to be allocated a somewhat higher proportion of the fund than the contribution tariffs collected on such roads. Failure to do this will instigate tension amongst the competing sectors but this is not easily achieved. The OECD (1994) intimates that rational allocation of funds in accomplishing a mission that grows complex with budget constraints as with road maintenance remains a challenge.

2.8 INTERNATIONAL PRACTICE

A review of the performance of the ‘second generation’ road funds in 27 countries in Sub Saharan Africa including Ghana indicated that the scheme is still characterised by the following problems, (Benaamar, 2006).

2.8.1 Insufficient Revenue Base

An average shortfall of about 50 percent of the required threshold of road maintenance funds is available for road maintenance in most countries with in place road fund schemes, (Gwilliam and Kumaar, 2003). Table 2.5 gives an indication of the level of road maintenance funding shortfalls in selected countries which are operating the second 'generation road' fund system.

Table 2.5: Road Expenditures versus Planned Programmes

Country	Maintenance Expenditures (US $M)					
	Govt. Grant	Donors	Total Need	Actual	Shortfall	Percentage of Total Need
Argentina	293	40	68	61	7	89
Chile	421	0	760	308	452	41
Ghana	20	121	135	73	62	54
Hungary	97	46	240	127	113	53
Jordan	58	16	31	9	22	29
Kazahstan	81	0	176	101	75	57
Korea	175	0	970	655	314	67
Pakistan	320	75	40	27	13	68
South. Africa	874	0	742	507	235	68

Adapted from: Heggie and Vickers (1998)

2.8.2 Poor Governance and Lack of Operational Efficiency

Some of the operational inefficiencies of the ''second generation'' road fund scheme relate to a lack of control and transparency in the depositing of revenues from the collection points into the fund. Others are lack of satisfactory audit procedures to ensure that only approved contracts are paid.

2.8.3 Tariff setting and Adjustment

In some instances the fuel levy is specified as a fixed percentage of the wholesale price. Thus there is no relationship between revenues generated and maintenance costs. Another problem is attributed to disruptions caused by fluctuations in the price of oil. (Gwilliam and Kumar 2003)

2.8.4 Problem of Inefficient Road Fund allocation

Road fund allocation was also identified to be a problem. It was observed that road fund allocation appear to be biased toward urban and main roads to the detriment of rural and feeder roads. According to Kumar, (2000) in Kenya and Zambia road maintenance funds are diverted from rural road maintenance to rehabilitate roads in the nations' capitals reflecting high political profile and the fact that ardent supporters of the road fund are car owning urban residents. In Burundi there is no allocation for rural roads and Rwanda allocates 60 percent of the fund to urban roads, (RMI Policy Reform Matrix, 2006).

2.8.5 Gaps in Current Knowledge

The rational for the four building blocks on which the 'second generation' road fund is set is that the road maintenance funding problem cannot be solved without the strong support of the road users; and one cannot win the support of road users without taking steps that resources are used efficiently; whilst resource use cannot also be improved unless one controls monopoly power and constrain road spending to what is affordable; and increases managerial accountability which cannot be attained without defined responsibilities.

The major critique of the current methods of road fund allocation in terms of international practice is the omission of road user inputs. (Gwilliam and Kumar, 2003) This is considered as a major disincentive to user contribution towards the road fund. This is because the lack of road user involvement in decisions will not motivate them to contribute to the fund and this might also collapse the concept of the road fund. However, the concept of user participation in decisions on road fund allocation in a commercialised enterprise such as the road fund system is contradictory. There is therefore a need for a road fund allocation method which will ensure both efficiency and road user priorities.

2.9 SUMMARY

This chapter has established the importance of road maintenance and the need for sustainable funding. It has discussed the factors causing the inability to secure adequate funding for road maintenance. The fiscal strategies being pursued to secure stable and sustainable funds for road maintenance in terms of securing additional funds and maximising the productivity of available funds have been discussed. The challenge of funding shortfall with respect to international practices irrespective of the new initiatives and the need to focus ensuring optimised fund allocation which is the objective of this research has also been identified.

CHAPTER THREE THEORIES AND METHODS ROAD FOR ROAD FUND ALLOCATION

3.1 INTRODUCTION

This chapter examines the underlying theories and methods for road fund allocation in literature. It is structured into eight parts. The first part defines optimal road fund allocation. The second and third parts review the theories and methods in road investment analysis. The fourth part identifies the key challenges in road investment analysis. The fifth part determines the elements of best practice for optimal road fund allocation and the sixth part identifies the gaps in current knowledge. Part seven describes the Ghanaian situation and part eight draws on the lessons from literature to define a conceptual framework for optimal road fund allocation for Ghana. An outline of the chapter presentation is illustrated in Figure 3.1.

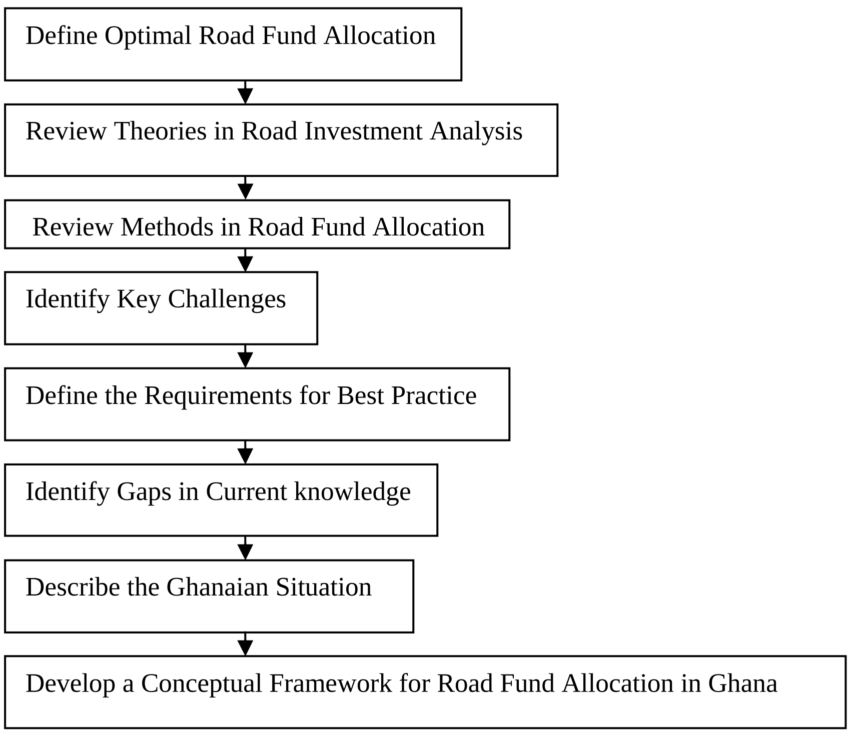


Figure 3.1: Framework of Presentation for Chapter 3

3.2 DEFINITION OF OPTIMAL ROAD FUND ALLOCATION

Road fund allocation is the division of funds amongst the different agencies responsible for road maintenance. According to Varian, (1990), optimal resource allocation is achieved if there is increased productivity without leaving any sector worse off. It requires rational assessment of advantages and disadvantages of choice possibilities. It involves setting priorities for competing sectors on the basis of an established criterion and procedure. The criterion is defined in terms of expected benefits and the procedure is determined with the application of algorithms for scenarios for which this is possible. A competing sector needs to have an advantage over the other in order to receive a higher proportion of the allocated funds. Its underlying theories and methods are drawn from the domain of road transport investment analysis.

3.3 THEORIES OF ROAD INVESTMENT ANALYSIS

The theories on road fund allocation are aligned with the expected benefits of the road investment. Whitelegg (1993) explains that the ultimate goal for investing in road infrastructure is the ability to reach desired goods, services, activities and destinations therefore practical issues relating to how and where the money should be spent and the benefit to society should be based first on this. This is against the backdrop that a road begins with giving an input in a kind of investment including money, time, and human resources. This gives an output in the form of a physical road infrastructure for traffic usage, (Dickey, 1984). The advantage to traffic usage is improved road condition resulting in reduced transport costs, reduced vehicle operating costs (VOC) and travel time savings, (Talley, 1996). These factors in turn have broad ramification that goes beyond the immediate impacts.

According to Eberts and Randall (1986), lower transportation costs, for example, may trigger economic gains which business and industry could translate into higher production. It may lead to increased trading activities through access to wider markets for effective competition and better pricing. Reduced transport costs can also result in improved access to services which could in turn improve the well being of the household. The savings made by a consumer could also be spent on other necessary goods and services for improved livelihood. An illustration of the links between an investment in a road and the potential benefits is presented in Figure 3.2.

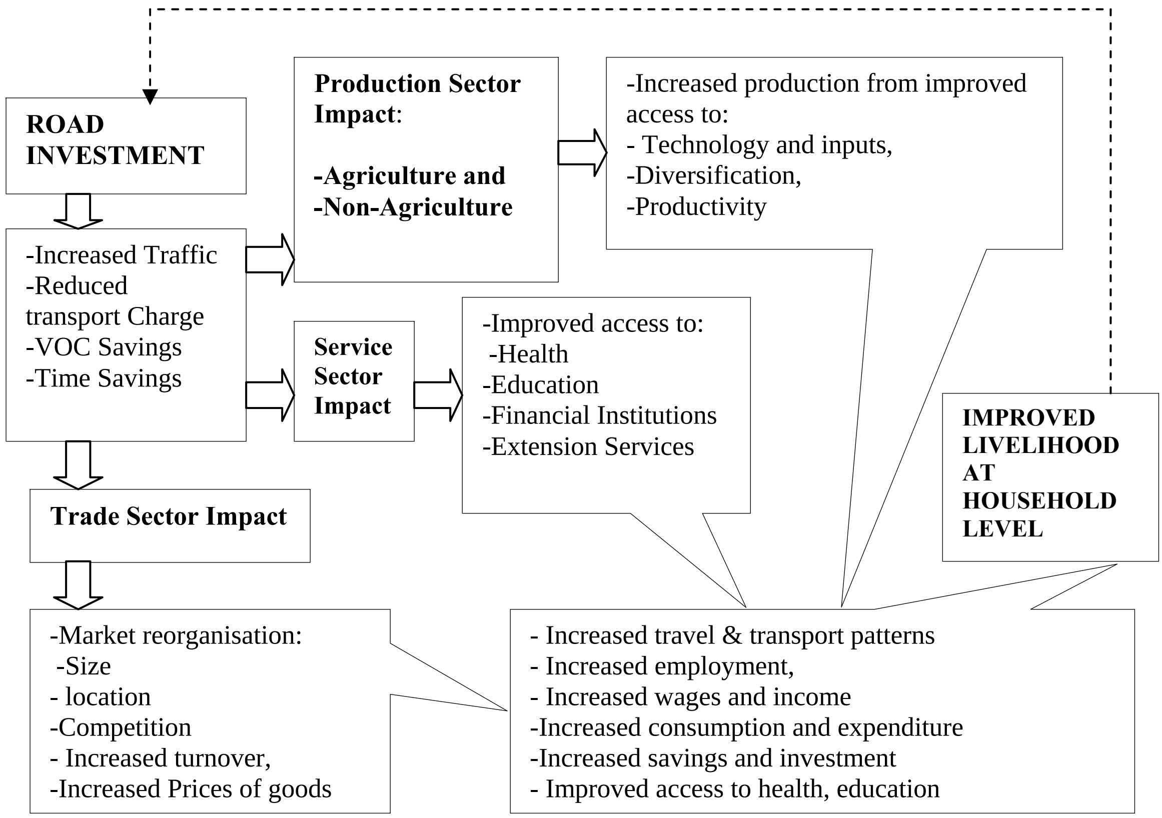


Figure 3.2 Illustration of Road Impact on Development

3.3.1 Classification of Transport Impacts

The links between a road investment and the end impacts are characterised by multi layered relationships and interface. These are categorised into different impact dimensions for purposes of identification, measurement, valuation and comparison to guide decisions. They are broadly classified as direct and indirect impacts, (Potts, 1999). The direct impacts are localised with simple causal and identifiable factors such as initial capital and recurrent costs, VOC and travel time savings. They have numerical values and are classified as quantifiable. Indirect impacts are further removed with wider consequence and less obvious causal processes. They are usually identified beyond the boundaries of the road transport scheme itself. They are classified as qualitative and can be denoted as wider social impacts. The direct and indirect impacts translate into the two main theoretical constructs as economic efficiency or social equity which are tested as development stimulus for road investment decisions, (Gwilliam and Shalizi, 1997).

3.3.2 The Theory of Economic Efficiency

The theory of economic efficiency establishes a link between road investment and economic growth, (Rostow, 1960). This is on the grounds that investing in roads which are not sustained by economic conditions results in poor macro economic performance and wastefulness. Therefore there is need for a local economy to have some economic potential for a road to serve its purpose, Wilson (1973). Early writers like Hirshman (1958), compared the role of transport investment as a stimulus to economic or social development and concluded that the economic theory was better due to the difficulty of measuring the capital output ratio of social development.

In recent time organisations like the World Bank, have alluded to the theory. This is on account of the effect of several decades of the socialist led concept of transport investment not yielding the expected economic take-off and growth in developing countries. On the other hand even less well-off regions in the developed economies are able to capture increased levels of economic activity with in-place transport infrastructure, (World Bank, 1981).Generally there is some degree of consensus that underscores the importance of transportation to economic growth. However, the exact relationship is difficult to formally establish and has been debated for many years. According to DeBenedictis and Lynch, (1995), the controversy is more with the extent to which investments in transportation affect economic growth rather than the nature of the relationship itself. The methods used in assessing this relationship are based on econometric models or models aimed at economic welfare.

3.3.2.1. Econometric Models

The econometric models establish statistical links between transport infrastructure investment and factors such as production, employment patterns, income and spatial specialisation functions, (Banister and Berecham, 2002). An example is the production function by Cobb and Douglas (1959). The evidence on this is based on works by authors like Aschauer, (1990) and Munnell (1990) who revealed that highway stock significantly affected state productivity from 1970 to 1986 in the United States of America (USA). However others like Holtz-Eakin and Schwartz, (1995) argue that highway infrastructure is insignificant in a production function due to the lack of control of state and time effects. Most of the results on this are context dependant and are confined almost exclusively to developed countries.

3.3.2.2 Methods by Welfare Economics

This approach focuses on the direct costs and benefits of transport investments which translate into money on transport markets. Examples of the methods applied are presented in the following paragraphs.

1. The Cost Benefit Analysis (CBA): It compares total incremental benefits with total incremental costs of a road investment over the life time using discounted values to determine the economic worth of an investment. The benefits are determined by valuing the direct impacts in monetary terms through a willingness to pay (WTP) mechanism. It is evaluated against a “Base Case” scenario and the validity of a road project is satisfied when the benefit is greater than the cost. The "decision criterion" could be based on the Net Present Value (NPV), the Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR), (Layard and Glaister, 1994). Its major limitations are assumptions on perfect markets situations and errors in valuing benefits and costs which is estimated in the order of 10 to 40 percent, (Lietch, 1977). It is also criticized for extensive data requirement, exclusion of distributive impacts and excessive dependence on traffic which makes it unsuitable for roads with low traffic levels, (Hine and Cundhill, 1994).

2. Consumer Surplus Method: It is based on savings accruing to road users from existing and generated traffic resulting from the road improvement. The total annual benefits from the sum of the two VOC savings are compared to the total annual road investment and maintenance costs to obtain the annual net benefit, (van der Tak and Ray, 1971). There is only a consumer surplus if cost

savings are passed on to consumers through lower fares and freight charges; otherwise they accrue to vehicle operators as producers' surplus, (Lebo and Gannon 1999).

3. Producer Surplus Methods: It calculates the economic rate of return of intended road investments in terms of the value added to increased agricultural production; less the incremental economic costs of production and transportation to local markets; plus reduced transport costs of non agricultural traffic, (Camemark, *et al* 1976 and Beenhakker and Lago, 1983). The major limitation is that increased price may be attributable to other factors, aside the road improvement.

4. Cost Effective Analysis (CEA): It is defined as a surrogate for user benefits due to the difficulties in determining monetary user benefits in CBAs, (Highway Engineering Economy, 1983). An index is obtained as a Cost Effective Index by the measure of consequence over cost in monetary terms with the highest index being preferred, (Fabrycky and Thugesen, 1980). It is limited by the fact that the benefits are held constant.

5. Decision Support Tools for Road Pavement Management: They are integrated comprehensive modular systems designed for rigorous engineering and or economic analysis to relate investment to road performance. Examples include the Highway Design and Maintenance Model (HDM-111) by the World Bank, the Highway Development and Management Model (HDM-4) produced under ISOHDM and the Economic Decision Model (RED) by Archondo-Callao

(1999) for gravel roads. The major limitation associated with some decision support tools is that it cannot satisfactorily allocate maintenance resources for roads with low traffic volumes when funding is extremely limited.

3.3.3 Equity Theory

The equity theory is based on the view of transport being a merit that should be provided at a minimum level to all citizens to avoid the exclusion of any sector, (Banister, 1994). It is derived from early traditionalist view on transport investment as a development initiator needed at the early stages in the development process for any economy to instigate a market widening effect, (Button and Gillingwater, 1986). It is proposed as an antidote for weak regions that lack economic dynamism. The theory is generally classified as utilitarian or egalitarian, (Litman, 2007)

1. Utilitarian Equity: It is defined as the sum of individual utilities which can be used to measure the quality of resource allocation from the view point of social inclusion, Sandholm (1999). It is based on non permanent and non quantifiable social indicators, (OECD, 2005). The methods used utilitarian equity include, decentralisation, impact statements and stakeholder prioritisation. Individual preferences could also be mapped with numerical values for objective analysis. It is described as lacking precision of coverage with biases, (Valadez, and Bamberger, 1994).

2. Egalitarian Equity: It ensures equality in resource allocation without necessarily involving stakeholders, (Young, 1994). It is aimed at satisfying the minimum needs of sectors which are worse off. The methods for assessing this

type of equity include segregation for direct investment, (Pankaj, 2003); the setting of lower decision criteria for target sectors; application of mathematical analysis on strategically selected quantifiable indicators such as population and income. It also includes rural accessibility models such as the time space geographic representation of human activity pioneered by Hägerstrand, (1989). The segregation of part of the road network from the rest of the network is criticised for not ensuring continuous expenditure and network connectivity.

3.3.4 Permissive Theory

The theory is on the view that transport is characterised with a complexity of possible impacts and one theory is not able to generate all the expected outcomes. It is based on a 'directed autonomy' to allow for creativity in individual situations, (Halstead and Rowe, 1999). It allows for the inclusion of broader factors whereby some economic efficiency or equity gains are traded for the other, (Watson and Buede, 1987). It is criticised by Gramlich, (1994) for having ambiguous interpretation with limited corroborating evidence and Howe, (1997) cautions for it to be applied with care.

3.4 METHODS OF ROAD FUND ALLOCATION

The analytical methods for road fund allocation are classified into two broad frameworks as formula and needs based (Heggie and Vickers, 1989).

3.4.1 The Formula Based Method

The formula based method is applied by fixed ratios or indices determined through negotiations, consultations or mathematical formulas. The allocation by consultations and negotiations is subjective and could result in biases. For example, Tanzania applies an initial allocation of 84 percent of the road fund for rural communities and 16 percent to urban centres. The mathematical formulas are based on egalitarian equity. It uses strategically selected parameters such as the length of the road network, volume of traffic, ability to pay, pavement serviceability and quality index, income and population. The formulas are either based on single index aggregation through component regression or by factor breakdown methods, (Setra 1986; Pinard, 2000). A summary of the features of this method is presented in Table 3.1.The method is criticised for not including road maintenance needs.

Table 3.1: A of Review of Selected Formula Based Methods

Allocation Method	Application	Source	Strengths	Weaknesses	Countries Applied
Allocation by mathematical formula	- Criteria are defined by technical and strategic factors	Heggie and Vickers (1989)	-Equity Based -Objective - Simple -Low financial and technical inputs.	-No stakeholder input -Not based on Pavement Condition	-Latvia -Korea -United States
Allocation by bidding, consultations, and negotiations	-Fund is allocated by a panel	Heggie and Vickers (1989)	-Simplicity - Encourages good planning by agencies	-Weaker party gets less -It is subjective -It is not based on maintenance costs	Hungary Zambia Romania Tanzania
Allocation by performance Indicators	A Road Quality Index is set	Nellthorp, and Mackie, 2000	-Rewards high performance -Considers adverse financial ability for equity	-Weaker party might not get anything at all -It only works in situation with equal characteristics	-United Kingdom

3.4.2 The Needs Based Method of Road Fund Allocation

The approach is determined by the cost of treatment works for pavement deficiencies. Estimated maintenance costs could be based on direct pavement assessment or by multiplying the road length by set unit rates for routine and periodic maintenance activities. A more desirable needs-based approach is complemented with some of the economic based methods as summarised in Table 3.2. The direct assessment of the pavement conditions is expensive and the use of unit rates does not reflect actual conditions. The features of this method is summarised in Table 3.2.

Table 3.2: A Review of Selected Needs Based Methods

Appraisal Method	Application	Source	Strengths	Weaknesses	Countries Applied
Cost Benefit Analysis (CBA)	- It assesses economic worth of a road	-Jules Dupuit 1848	-Objectivity -Transparency -Extensively Used.	-Suited to road with high traffic volumes -Excludes a wide range of benefits	International Application
Consumer Surplus Approach	-It is by the calculation of VOC savings, time savings and vehicle cost savings	-Van Der Tak and Ray (1971)	- Objectivity -Transparency	-It is not equity based	International Application
Producer Surplus Approach	-It calculates the economic return on the value added of increased agric. Production and transport cost savings	-Camemark et al (1976) -Beenhakker and Lago (1983)	- Objectivity -Transparency	-It is applied on rural roads -It does not consider other benefits	Developing countries
Cost Effective Method	-It compares alternate costs of different options. -Decision is based on a cost Index	-Fabrycky and Thugesen (1980)	-It uses quantifiable indicators -It is objective	-It excludes benefits -It is acceptable so far as an index is obtained.	Developing countries

3.5 KEY CHALLENGES IN ROAD INVESTMENT ANALYSIS

3.5.1 Identification of Indicators of Assessment

There are no clear definitions of the factors which constitute the different theoretical aspects and the impact factors may be contradictory or overlapping, (DHC, 2004). The classifications are often based on given interpretations with respect to political issues, value judgements, institutional contexts, user and non-user effects, local and global externalities from country to country. For example time, accidents and environment impacts are non financial but are assigned monetary values in CBA applications, whilst some financial variables such as income are classified as social indicators in some social account applications. Examples are the Appraisal Summary Table (AST) by (Nellthorp, and Mackie, 2000) used in the United Kingdom (UK) and the Benefit Indices Table (BIT) by (Morisugi, 2000) used in Japan.

3.5.2 Measurement of Indicators

The diversity of social factors does not offer a generic form of measurability, (Jara-Diaz, 1986; Porter, 2003). The use of money as a common unit for assessing time, accidents and environmental costs in CBA is also criticised for the differences in the values of the rich and the poor which are not accounted for separately, (Jones-Lee *et al*, 1985; Cropper, (1991).

3.5.3 Forecasting

The impact of transport investment extends overtime but there are uncertainties of the impact changes over time. Estathiou and Rajkovic, (1987) considers this as a large restriction for most decision models. According to Hook, (2003), despite more than forty years research, there is no sound basis for forecasting generated traffic due to the uncertainties in road user behaviour. Flyvbjerg, (2003) estimates a 20 percent overestimation in traffic projections.

3.5.4 Target Group Orientation

According to Lifson and Shaifer, (1982), human values and judgments systems should be integral to decision making. However, road investment impact differently on people and the major challenge is the ability to reflect the different priorities.

3.5.5 Analytical Techniques

There is no clearly defined single method that is able to evaluate all the complex aspects of choice possibilities. Varied decision tools are applied in different countries. Typical examples include methods developed by Vickerman, (2000) for Great Britain; Rothengatter, (2000) for Germany; Quinet, (2000) for France; Morisugi, (2000) for Japan; and Kerali, (2003.) for developing countries.

3.5.6 Scale of Application

There are different levels in the links between road investment and its end benefits. However there is no consistency in the magnitude of impact assigned to the different levels. Some experts insist on detailed investment analysis at the highest level to avoid omissions at a later stage, (Vickerman, 2007b; DFT, 2004). Others like Lebo and Gannon (1999) however suggests for limited scope of impacts at the highest level on the grounds that the dearth of data requirement may be too costly and time consuming. In situations of data availability the first option maybe ideal but in situations where there is lack of data the section option may have to be applied. Therefore the best option maybe determined by the prevailing conditions.

3.6 REQUIREMENTS FOR BEST PRACTICE

3.6.1 Principles for Optimal Road Fund Allocation

FHWA, (1999) recommends for the decision analysis for road fund allocation to include; strategic goal, quantitative factors, performance measures, performance prediction capabilities, qualitative issues and link to the budget process using engineering and economic analytical tools. Heggie (1995) defines five principles for road fund allocation as needs based, ensuring economic efficiency, equity, transparency, fairness and simplicity. Howard (1983) suggests for the process to be divided into smaller components for logical analyses to arrive at reasonable conclusions. The essential elements for optimal road fund allocation are illustrated in Figure 3.3.

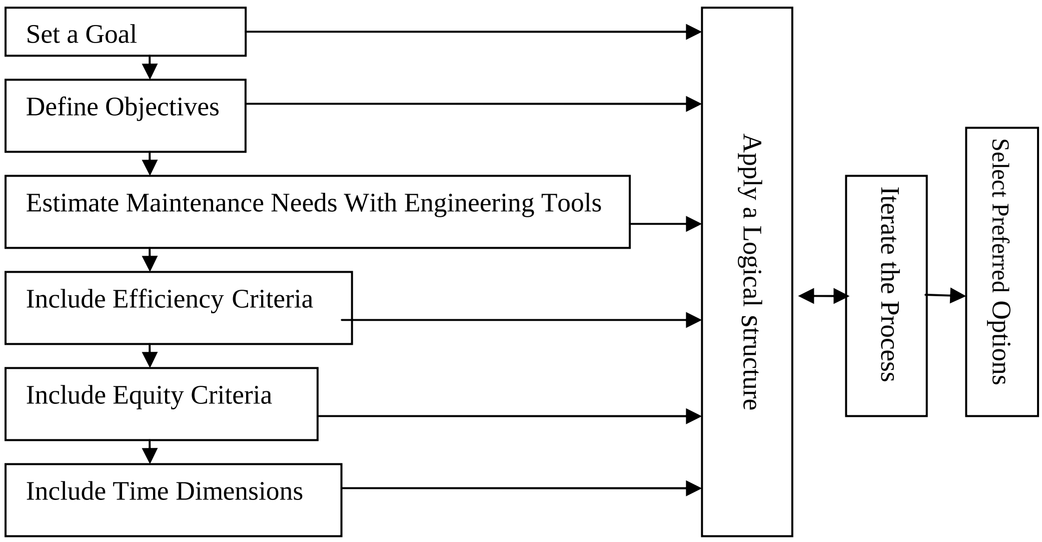


Figure 3.3 Elements of Optimal Road Fund Allocation

3.6.2 Methods for Optimal Road Fund Allocation

Currently Multi Criteria Analysis (MCA) is recommended for optimal road investment decisions, (Nijkamp, 1990). It includes both quantitative and qualitative indicators as well as monetary and non monetary indicators, (Oman, 2000). It also divides the analytical process into smaller components, (Toman, 1998). MCA has various classifications by different researchers including Fandel and Spronk (1985), Vincke (1992) and Hwang (1979). The common categories of MCA's are the Multiple Attribute Decision Making (MADM) and the Multiple Objective Decision Making (MODM). The MADM determines the best alternative from the options by considering multiple and conflicting criteria for realizing only one aim. The MODM determines the best option for realizing a set of conflicting aims, Maccrimmon, (1973). Preference modeling for each category could be by a priori articulation of preferences; a posterior articulation of preferences where an optimizer is selected by compromise from a set of candidate solutions; and interactive or (progressive) articulation of preferences, where decision-making and optimisation occur at interleaved steps, (De Silva and Tatom, 1996). A complete taxonomy of MCA depending on the domain of alternatives by Hwang (1981) is given in Appendix 3.1 and a brief description of selected MCA methods are summarized in Table 3.3.

Table: 3.3 A Brief Overview of Selected MCA Methods

Maximin and Maximax	It is based upon a strategy that seeks to avoid the worst possible performance – or "maximizing" the poorest ("minimal") performing criterion. The objective function for each category is denoted as either $Max\, f_i(a)$ or $Min\, f_i(a)$ for all i where $a \in k$.
Goal Aspiration	It seeks to discover options that are closest to achieving, but not always surpassing, the goals. The function is defined as $\sum_i w_i\left(f_i^+ + f_i^-\right)$ where f_i^+ and f_i^- are the respective over and under achievement of f_i with respective to a prior specified achievement level f_i^0 considered to be the most attractive option.
Lexicographic Method -	It involves a sequential elimination process that is continued until either a unique solution is found or all the problems are solved. That is if there is a sequence of alternatives in an order of preference a_1, a_2 ….a_n based on a first level criteria c_1 and any two of the alternatives have the same rating, then a second level criteria c_2 would be used to order those two. It's The criteria are considered separately so non compensates for the other.
Conjunctive and Disjunctive	The conjunctive and disjunctive methods are non-compensatory, goal aspiration screening methods. They do not require attributes to be measured in commensurate units.
Outranking Models	It compares the performance of two (or more) alternatives at a time, initially in terms of each criterion, to identify the extent to which a preference for one over the other can be asserted. The best known outranking method is the Elimination and Choice Translating Reality (ELECTRE I) (Roy, 1968; Figueira *et al.* 2005). Several modifications of this method have been suggested (ELECTRE II, III, IV, PROMETHEE I and II) (Vincke, 1989).
Pros and Cons Analysis	It is by qualitative comparison which identifies the qualities and defects of each alternative. The alternative with the strongest pros and weakest cons is selected.
Decision Tree Analysis	They are useful tools for making decisions where a lot of complex quantitative information needs to be taken into account
Multi-Attribute Utility Theory (MAUT/MAVT)	It is to find a simple expression for the decision-maker's preferences through the use of utility/value functions which transforms diverse criteria into one common dimensionless scale (utility/value).
The Analytical Hierarchy Process (AHP)	It compares alternatives based on their relative performance on the criteria of interest through quantification of stakeholder preference.
Computer Based Methods	The software has both individual and group decision versions.

3.6.2.1 MCA Application for Road Investment Analysis

Some examples of MCA applications for road investment analysis include the following.

1. The application of Genetic Algorithm (GA) for the allocation of funds for road maintenance by Chan *et al* (2003). The study solved a multiple objective network level pavement maintenance programming problem. It relates

government goals of minimising maintenance costs and maximising network condition to district priorities of maximising pavement performance and for the allocation of available budget. However, the (GA) is considered not to be a function optimiser. This is because it seeks 'good' solutions to the problem, rather than a guaranteed optimal solution.

2. The Overseas Road Note (ORN) 22 was developed by the (TRL) for rural transport appraisal with the Analytical Hierarchy Process (AHP) using a computerised software tool. (TRL, Overseas Road Note 22, 2004). It evaluates investment alternatives on the basis of social equity through stakeholder participation. It has been field tested in a case study in Uganda to provide operational guidance, (Odoki *et al,* 2008). However, the study was limited to rural roads.

3. The extension of the HDM-4 analytical tool to include wider social benefits by (Cafiso *et al*, (2001). The social impacts are quantified externally by the AHP model before being integrated into the HDM-4 framework. A pilot test of the system was based on the utilities of five main criteria as comfort, environment, safety, road agency costs, and road user costs. However, the defined social parameters were not strictly in the context of a developing economy.

The major criticisms of MCA relate to the assignment of weights. Pelevin *et al* (2001) argues that some weighting methods are arbitrary and subjective. Specifically, the valuation of non numerical units by conversion on cardinal or ordinal scales is noted to distort the end result, (EUNET, 1998). Taplin *et al* (1996), also argues that time effects are treated scantly. The specific issues associated with MCA application in transportation include the following factors.

1. There are no general principles for MCA application in transport. This does not allow for consistent conclusions for policy measures and the scope of misuse could increase overtime.

2. There is no single MCA method likely to produce the right solution. Some authors therefore recommends for more than one method to be applied in a decision situation for comparison. This is on the grounds that each MCA application on its own does not yield a clear conclusion, (Buchanan and Corner, 1997; Salminen *et al*, 1998).

3. Some authors also recommend for MCA applications to be combined with CBA for a more comprehensive analysis. This is attributed to the perception that, modern societies are driven by market forces so decision choices with market signals are considered to be more effective, (Joubert *et al*. 1997).

4. Current examples on MCA applications in developing countries are focused on utilitarian equity with the inclusion of wider social impacts. This is to make up for the omission of wider social impacts in conventional transport investment analysis. However, according to Howe, (2003) the elements missing from conventional cost-benefit analyses are not purely social. Specifically not all the roads in the network require social justification. Also, it is said that road maintenance does not generate the major social changes

associated with new road construction, (Leinbach, 2003). Therefore the application of methods which includes wider social impacts as with the current examples of MCA application in developing countries might not suit investment analysis for road maintenance.

3.7 THE GHANAIAN EXPERIENCE

Currently, Ghana has a total of about 39,669 km that is in a maintainable state which represents 70 percent of the total network. These include trunk urban and feeder roads. Ghana operates a road fund scheme for road maintenance funding. The scheme is administered by a 13 member board with an established secretariat which operates with sound accounting principles including technical and financial audits. Funds are derived from fuel levy, vehicle licensing, road use fees, road, bridge and ferry tolls and international transit fees. The proportion of funds generated from each funding source is presented in Table 3.4.

Table 3.4: Proportion of Road Fund by Source

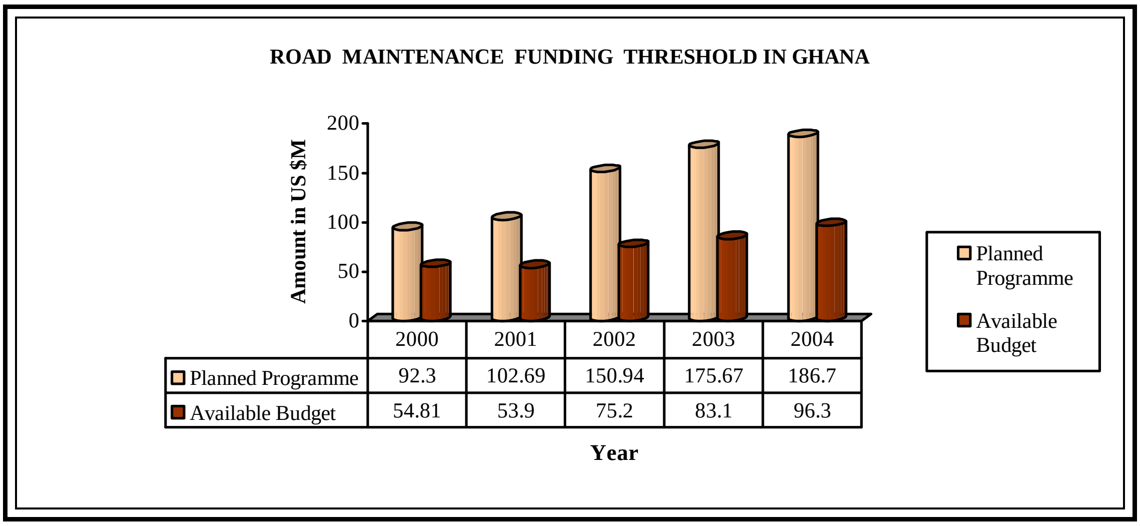
Source of Road Fund	Percentage
Fuel Levy	88
Tolling	2
Transit Fees	7
Vehicle Licensing	2
Vehicle Registration	1
Total	100

The fund is basically allocated for the routine and periodic maintenance of three road types, that is trunk, feeder and urban and road safety activities. The road sub-sector programme under the general direction of the Ministry of Roads and Transport (MRT) is executed by three road agencies and these are the Ghana Highway Authority (GHA), Department of Feeder Roads (DFR) and Department of Urban roads (DUR).

3.7.1 Limitations of Ghana's Road Fund Scheme

3.7.1.1 Funding Threshold

A funding shortfall of 51 percent was estimated from 2000 to 2004, (Donkor and Abbey Sam 2003). Figure: 3.4 give an indication of the financing gap.



	2000	2001	2002	2003	2004
Planned Programme	92.3	102.69	150.94	175.67	186.7
Available Budget	54.81	53.9	75.2	83.1	96.3

Figure 3.4: Road Maintenance Funding Gap in Ghana

3.7.1.2 Tariff Setting

The pace of tariff adjustment does not match anticipated expenditure requirements. For example the downward trend from 2001 shown in Figure 3.5 is attributed to high fluctuations in the exchange rate due to high inflation rates resulting in devaluation of set tax margins. This accumulated into a financing gap over an extended period.

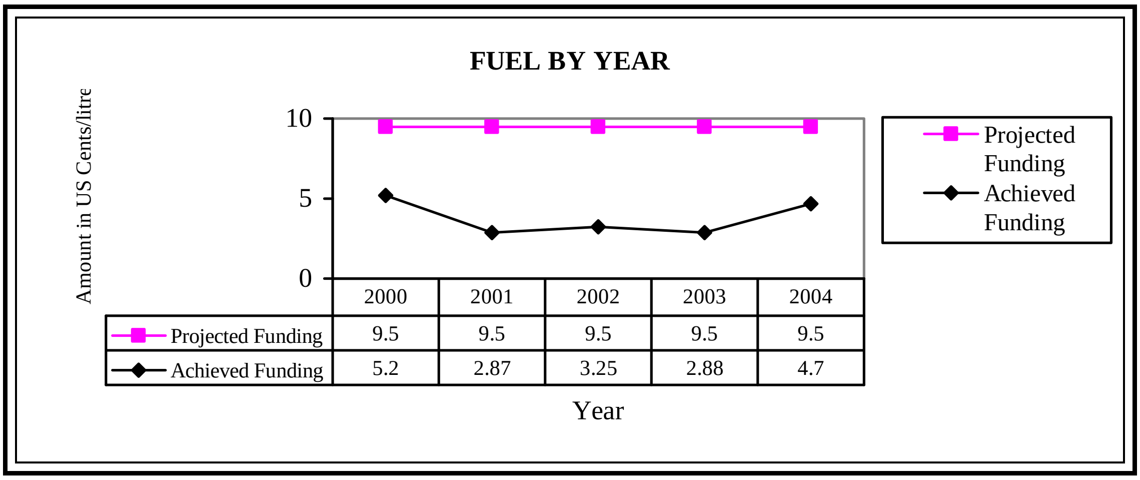


Figure 3.5: Fuel Tariff by Year for Ghana (2004)

3.7.1.3 Method of Road Fund Allocation

In Ghana even though most of the returns from the fuel levies are generated on the highways, the fund is spread to cover all the maintenance needs of all road types. The road fund board in consultation with the Ministry of Roads and Transport (MRT) through a sub committee allocates the fund between the road types. The approach is haphazard with no merit. It is subjective to political and administrative manipulations. The consequent outcome is that the allocation to the competing road agencies fluctuates with each agency not being certain of how much will be allocated to them at different times. This results in inconsistent and distorted road maintenance programmes, wastage and neglected maintenance. The major limitations of the approach to road fund allocation in Ghana are lack of uniformity in road maintenance budgeting, lack of investment analysis, and the lack of consideration for government goals and stakeholder preference and the details are discussed in the following paragraphs.

1. Road Maintenance Budgeting: Different decision support tools are used by each road agency. The Pavement Maintenance Management Programme

(PMMP) is used for trunk roads; the Maintenance Management System (MMS) is used for urban roads and Maintenance Performance Budgeting System (MPBS) is used for feeder roads. Each is based on different work activities, maintenance standards and unit rates and this does not allow for a common basis of comparison.

2. Investment Analysis: Economic evaluation for roads investment is only undertaken for individual road projects. The CBA is applied to trunk roads and some urban road projects whilst diverse appraisal methods are applied for feeder road project selection. An overview the merits and demerits of the examples used for feeder roads appraisal is presented in Appendix 3.2.

3. Application of Government Goals: Currently there are geographical inequalities in accessibility to motorable roads between the endowed parts of the country and parts lagging behind in road development. Appendix 3.3 gives a graphical representation of the distribution of the road network in Ghana and Table 3.5 gives the details of the regional distribution of access to motorable roads. However there are no equity considerations in road fund allocation to address the inequalities.

Table 3.5 Regional Distribution of Road Accessibility in Ghana

Region	Welfare rank	Percentage of Population with no access to Motorable Road
Greater Accra	1	0
Ashanti	2	0
Central	3	0
Western	4	0
Eastern	5	4
Volta	6	22
Brong Ahafo	7	22
Upper East	8	22
Northern	9	37
Upper West	10	40

Source: GLSS Community Survey (1999)

3.8 CONCEPTUAL FRAMEWORK FOR OPTIMAL ROAD FUND ALLOCATION IN GHANA

The following factors drawn from the elements of best practice were considered in the development of the conceptual framework for an optimal road fund allocation for Ghana.

1. Goal: The goal was defined as the development of an optimal road fund allocation model for Ghana.
2. Objectives: The objectives were based on national policy guidelines for road development as ensuring economic efficiency and equity. (GPRSP, 2002)
3. Analytical Framework: The MCA method was adapted to meet the multiplicity of the objective functions and to ensure a structured and a logical analysis.
4. Choice of MCA Methods: A comparison of two MCA applications was made to determine optimality. This was with regard to the uncertainties on the inclusion of wider social aspects in investment analysis for road maintenance. The first model was based on a deterministic approach with considerations for economic efficiency and egalitarian equity. The assumption was that road maintenance does not generate wider social impacts. The second model was based on preferential analysis with considerations for utilitarian equity. The assumption was that wider social impacts are relevant for investment analysis for road maintenance.

3.8.1 Features of the Deterministic Approach to Road Fund Allocation

The features of the deterministic approach to road fund allocation were defined as in the following paragraphs.

1. It was based on only quantifiable indicators for purposes of objectivity and certainty of outcomes.
2. It included economic efficiency and equity indicators.
3. It included engineering attributes and the application of a pavement management system.
4. It considered the time horizon of impacts.
5. It was modelled from a decision maker's perspective.
6. It was set on two stage structure with the following components.

    - The first component applied the value function model (VFM) by Keeney and Raiffa (1976) and von Winterfeldt and Edwards (1986) for the estimation of the input parameters for an initial allocation of the road fund by the three road types in Ghana.
    - The second component involved the use of the concept of efficiency frontier to determine the input parameters for the internal division of the proportion of the road fund allocated to each type by economic efficiency and equity components.

3.8.1.1 Description of the Value Function Model (VFM)

The VFM defines a score for selected attributes which are used to evaluate an alternative element for an investment option. It estimates separate ratio scales described as value scores for the attributes by a dimensionless scale using a defined value form. The set of decision alternatives (a_i) indexed by $a_i = a_1 \cdots\cdots a_n$ are ranked on the set of attributes c_j indexed as $c_j = c_1 \cdots\cdots c_n$. The ratio scale is derived as a value score for each attribute is expressed as;

$$v_j(x_j) \qquad \text{Equation 3.1}$$

Where;

v_j = a value function scaled from 0 to 1 per attribute

x_j = is the measure of effectiveness on an attribute space x.

It is designed to satisfy the functional form;

$$\max imise\{v_1(x_1), v_2(x_2) \ldots\ldots\ldots\ldots v_n(x_n)\} \qquad \text{Equation 3.2}$$

Where;

$v_j \in Rj^i$ is an objective function of n-dimensional attributes with feasible decision solutions. The overall optimisation function for each alternative is expressed in an aggregated form;

$$a_i = \{v_1(x_1) + v_2(x_2) + \ldots\ldots\ldots\ldots v_n(x_n)\} \qquad \text{Equation 3.3}$$

$$i = 1,2,\ldots.n$$

This can be expressed either in a multiplicative form or an addtive form. It is expressed in a multiplicative form where there is weak difference independence between the attributes. An attribute x_1 is weak-different independent of the other attributes $x_2 \cdots x_n$ if the order for preference consequences involving only changes in pairs of x_1 levels does not depend on the levels at which $x_2 \cdots x_n$ are fixed. The multiplicative form is expressed as;

$$1 + kv(x_1 x_2 \ldots\ldots x_n) = \prod_{j=1}^{n} \left[1 + kk_j v_j (x_j)\right]$$ Equation 3.4

Where;

k_i = is an assigned weight on $v_i(x_i)$ and $\sum_{i-1}^{n} k_i = 1, \quad 0 \prec k_i, \prec 1, i = 1,2,\ldots\ldots\ldots n.$

k = is an additional scaling constant that characterizes the interaction effect of different measures on preference.

It is expressed in an additive form where there is preferential independence on the attributes. A pair of attributes $\{x_1, x_2\}$ is preferentially independent of the other attributes $\{x_3, x_n\}$ if the preference order for consequences involving only changes in x_1 and x_2 does not depend on the levels at which $x_3 \ldots. x_n$ are fixed. The additive form is expressed as:

$$v(x_1 x_2 \ldots. x_n) = \sum_{j=1}^{n} k_j v_j (x_j)$$ Equation 3.5

1. Axioms on the Value Function Model: The VFM is set on the axioms of transtivity, continuity and completeness.

(i) Transitivity: This indicates that if an option A is preferred over B and B is preferred over C then A is preferred over C.

(ii) Continuity: This implies that if option A is preferred over B and B is preferred over C. There should be some probability (P) that A will happen and some probability (1-P) that C will happen, so that the agent is indifferent about accepting this probability or being sure of getting B.

(iii) Completeness: If the agent is indifferent between result A and B then it should be able to replace one with the other.

2. Reasons for VFM Application in this Research: The VFM was applied in this research for the following reasons.

(i) It assumes that outcomes are known with certainty and applies quantitative values for reliability, objectivity and transparency.

(ii) It defines a separate weighted value score for each attribute.

(iii) It transforms attributes into a dimensionless scale.

(iv) It offers different dimensions of the value forms which could be linear, exponential or user defined as indicated in Figure 3.6. The exponential function allows for the inclusion of time dimensions in the analysis.

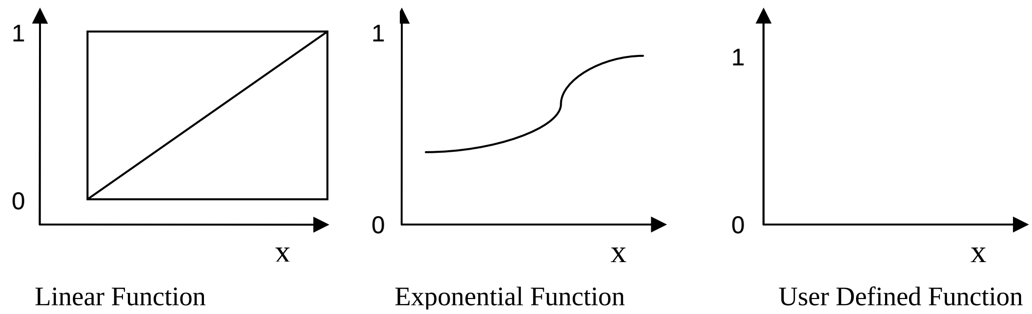


Figure 3.6: Types of Value Forms

(v) The global importance of attributes reflects the importance of an attribute as a stable characteristic that does not depend on a specific stimulus set. The local importance of an attribute reflects the importance in judgment and depends on the stimuli set under consideration.

(vi) It provides a logical structure

3. Limitations of the VFM: The major limitation is that it does not allow for intransitivity. (Luce and Raiffa's, 1957) but this is not required in the context of application in this study. It is also that argued a single super-value cannot encompass all the different dimensions of the plurality of values (Rosenberger,

2001). Since each attribute is defined on a dimensionless scale this was not considered to be a problem.

3.8.1.2. Description of the Concept of Efficiency Frontier:

The concept of Efficiency Frontier is based on the combination of two variables in possible proportions to determine an optimal decision point for an expected return. The variables are combined in different forms to sum up to a fixed total. The combined option that produces the greatest value closest to an expected return is defined as an efficiency lotus. The mathematical expression of the concept is expressed as;

$$\max \sum_{i=1}^{2} e_i m_i \qquad \text{Equation 3.6}$$

Subject to $\sum_{i=1}^{2} e_i m_i = g$ and $i = 1,2,3....n$

Where;

e_i = is the worth of variable e at a set proportion.

m_i = is the worth of variable m at a set proportion.

g = the fixed total to which the different combinations of e_i and m_i must add up to.

1. Reasons for the Application of the Concept of Efficiency Frontier: The application of the concept of efficiency frontier in this study was to determine an optimal level of combined proportions of economic and equity factors for road fund allocation. The selected indicator for assessing economic efficiency was to maximise Net Present Value (NPV). The equity indicator was based on affordability factor derived from VOC and income per capita.

(i) The Net Present Value (NPV): It is defined as the difference between discounted benefits and costs and estimated as;

$$NPV = \sum \frac{Bt - Ct}{(1+r)^t} \quad \text{Equation 3.7}$$

The NPV was adopted as an indicator for economic assessment on the basis of the following reasons.

- It is an objectively quantified indicator and allows for comparison of alternatives.
- It allows investment alternatives to be ranked in order of their contribution to economic growth parameter;
- It maximises the economic worth of a project subject to budget constraints;
- It focuses on the total welfare gain of a project over the whole life;
- It presents a common unit to all the agencies and it is easy to understand.

The properties of the NPV as compared to other decision indices is summarised in Table 3.6.

Table 3.6: Economic Decision Criteria

	NPV	IRR	NPV/Capital	FYRR
Project Economic Validity	Very Good	Very Good	Very Good	Poor
Mutually Exclusive Projects	Very Good	Poor	Good	Poor
Project Timing	Fair	Poor	Poor	Good
Project Screening	Poor	Very Good		Poor
Under Budget Constraint	Fair	Poor	Very Good	Poor

Source: HDM-4 Version 2

(ii) The affordability Factor was adopted as an egalitarian equity measure to provide leverage for road users with different levels of per capita income. The rational was to compensate those who spend a higher proportion of their income on transport costs by allocating higher proportions of the road maintenance funds to such roads. It was estimated as income per km of travel minus VOC/km. VOC was adopted as a proxy for transport costs for the following reasons.

- Roads in poor condition have higher VOC's and there is a high elasticity between VOCs and transport costs (Pratt, 2003).
- Transport cost is estimated as the sum of VOC and Profit and VOC's constitutes a significant proportion of transport costs. For example, in Ghana VOC is about 83 percent of transport cost. Table 3.7 provides the details.

Table 3.7: Vehicle Operation Cost Components in Ghana

Item	Weight (Percentage)
Fuel	64.04
Cost of Vehicle	10.75
Comprehensive Insurance	3.11
Tyres	2.65
Spare Parts	12.60
Driver's salaries	3.15
Driver's Mate salaries	0.11
Lubricant	3.59
Total	100

Source: National Transport Co-ordinating Council, Ghana, 2004.

- VOC is policy sensitive and a major dynamic driving force that lead to changes in transportation costs (Nijkamp and Blass, 1996);
- VOC presents the single most objective common metric of measurement for all maintainable road projects;
- It responds to long term trends.
- The study is on maintainable roads which are already open to traffic.

(iii) Income was used to adjust the VOC such that those with low income levels who pay higher transport fares due to the high VOC resulting from poor road condition will have higher preference in road fund allocation than others. Income was selected as a strategic variable for the development of the affordability factor because of the following reasons.

- It is a measurable indicator and the information is easily obtained.
- It is highlighted as important in determining social and distributional impacts of transport by the DfT's recent rapid evidence assessment, (DFT, 2005).

Estimated values of the efficiency and equity indicators at constrained budget levels were combined such that for example an efficiency indicator generated at a 90 percent constrained budget level was combined with an equity indicator generated at 10 percent constrained budget level to add up to 100. The process was repeated for all the possible combinations of the corresponding decile proportions at which the budget was constrained to generate the values on each indicator. The efficiency lotus was defined as the combined proportions of the efficiency and equity indicators at a constrained budget level which was closest to the combined proportions of efficiency and equity indicators at unconstrained budget level.

The efficiency variable was defined as the stimuli of the NPV indicator within an I x I impact matrix in the order of S_{ei} where; s is a specific road section, (e) is the NPV/Cap estimated for the road section, (i) is the decile proportion at which budget was constrained to generate the corresponding NPV value. The equity indicator was defined as the stimuli of the affordability factor which was determined within a J x I impact matrix in the order of S_{mj} where; s is a specific road section, (m) is income per capita on a road type minus VOC/km for the particular road section and (j) is the decile proportion at which budget was constrained to generate the corresponding VOC value. Table 3.8 presents the form of matrix representation from which the values the efficiency and equity indicators were generated.

Table 3.8: Impact Matrix on Selected Variables

Road Section	Values of Variables at Decile Budget Proportions (S_{ei} and S_{mj})								
1	S_{e10} S_{m10}	S_{e20} S_{m20}	S_{e30} S_{m30}	S_{e40} S_{m40}	S_{e50} S_{m50}	S_{e60} S_{m60}	S_{e70} S_{m70}	S_{e80} S_{m80}	S_{e90} S_{m90}
2	S_{e10} S_{m10}	S_{e20} S_{m20}	S_{e30} S_{m30}	S_{e40} S_{m40}	S_{e50} S_{m50}	S_{e60} S_{m60}	S_{e70} S_{m70}	S_{e80} S_{m80}	S_{e90} S_{m90}
n	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}	S_{en} S_{mn}

On the basis of Equation 3.6 the combined proportions of the efficiency and equity indicators were estimated as; $\max \sum_{i=1}^{2} S_{ei} S_{mj}$ Subject to $\sum_{i=1}^{2} S_{ei} S_{mj} = g$ and the efficiency lotus was defined as illustrated in Figure 3.7. From Figure 3.7, if the different combinations of S_{ei} and S_{mj} at different decile proportions of unconstrained budget levels are identified as A, B, C, and D and is E is determined as the expected return at an unconstrained budget level, then D is defined as the efficiency lotus since it gives the closest value to E.

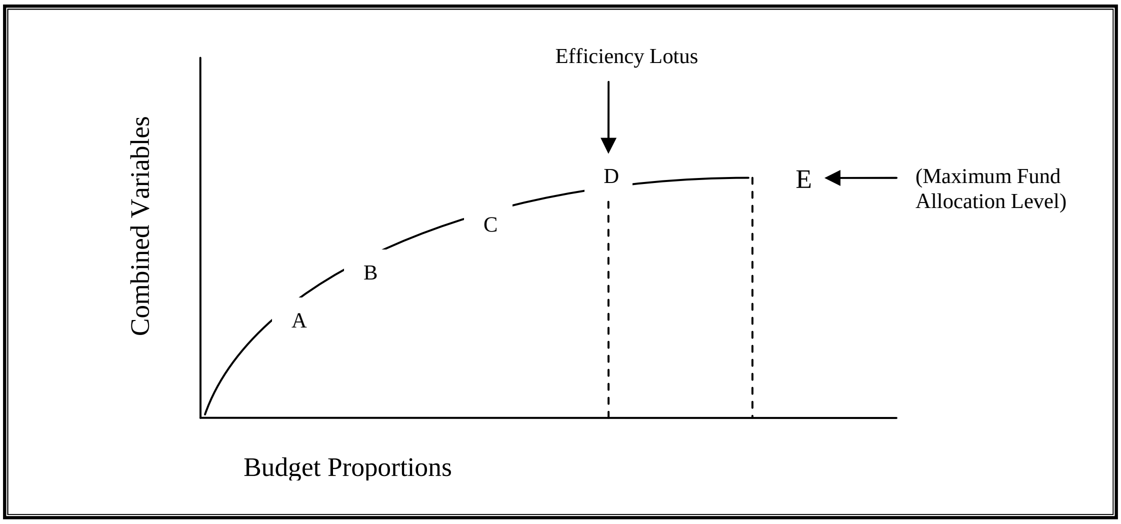


Figure 3.7: Efficiency Lotus for Fund Allocation on Efficiency and Equity Basis

3.8.2 Features of the Stated Preference Based Model

The approach to road fund allocation with a stated preference based method was defined on the basis of the following factors.

1. It was based on qualitative indicators determined from stakeholder account of how road investment impacts are experienced.
2. It included considerations for economic efficiency and utilitarian equity.
3. It was based on a three stage iterative process

The input parameters were generated on the basis of the Analytical Hierarchy Process (AHP) developed by Saaty, (1980)

3.8.2.1 Description of the Analytical Hierarchy Process

The AHP provides a means of using qualitative data for the selection of preferred alternatives in a structured form. It applies a pairwise comparison of decision elements according to their common characteristics. It is based on the following principles.

(i) Decomposition: This principle refers to the structuring of a complex problem into a hierarchy of clusters and sub-clusters.

(ii) Comparative judgments: This is applied to construct pairwise comparisons of all combinations of elements in a cluster.

(iii) Synthesis: The principle of synthesis is applied to multiply the local priorities of elements in a cluster by the 'global' priority of the parent element, producing global priorities throughout the hierarchy and then adding the global priorities for the lowest level elements.

1. Axioms of the AHP: The AHP is also set on three axioms as reciprocal, homogeneity and structured matrices, (Harker, 1987).

(i) The Reciprocal Axiom: The reciprocal axiom, requires that, if PC(EA,EB) is a paired comparison of elements A and B with respect to their parent, element C, representing how many times more the element A possesses a property than does element B, then

PC(EB,EA) = 1/ PC(EA,EB) Equation 3.8

Where;

PC = Pairwise comparison of the elements A and B.

EA = Element A of the defined attributes

EB = Element B of the defined attributes

The pairwise comparison is set in an n x n matrix w where the numbers in row i and column j gives the relative importance of w_i as compared to w_j by the expression:

$$w_{ij} = \frac{w_i}{w_j}, \qquad w_{ij} \ (i, j = 1,2,....n) \qquad \text{Equation 3.9}$$

which also corresponds to reciprocals of the comparison of one element with the other as:

$$w_{ji} = \frac{w_j}{w_i} \qquad \text{Equation 3.10}$$

And can be represented as;

$$\begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \frac{w_1}{w_3} & \cdots\cdots\cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \frac{w_2}{w_3} & \cdots\cdots\cdots & \frac{w_2}{w_n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \frac{w_n}{w_3} & \cdots\cdots\cdots & \frac{w_n}{w_n} \end{pmatrix} \quad \text{Where } w_{ij} \neq 0$$

where;

w_{ij} = is the relative weight of criterion i with respect to j

w_{ji} = is the relative weight of criterion j with respect to i

The relative priorities among the n elements of the matrix are constructed by the "principal eigenvector" of the matrix. Then the eigenvector is normalised by obtaining the "priority vector", which expresses the priorities among the elements belonging to the same level (local priority). The "maximum or principal eigenvalue" of each matrix of pairwise comparisons is computed for checking the degree of inconsistency. The local priorities are then multiplied by the weights of the respective criteria. The results are summed up to get the overall priority of each alternative.

(ii) The Homogeneity Axiom: The homogeneity axiom, states that the elements being compared should not differ too much, else there will tend to be larger errors in judgment.

(iii) It is based on the well-defined mathematical structure of consistent matrices, (Saaty 1980, 1994).

2. Reasons for the Application of the AHP: The AHP was applied in this study for the following reasons:

(i) It was deemed as a best alternative for effective comparison with the deterministic approach since it is the most predominant MCA application used in developing countries.

(ii) The use of mathematical analysis to generate ratio scales as opposed to the arbitrarily assignment of weights reduces subjectivity.

(iii) It has ordered preference and explores consequence to minimise post decision disappointment, (Belton and Stewart 2002).

(iv) The hierarchical structure allows for the inclusion of several objectives to meet local, regional and national situations.

3. Limitations of the AHP: The AHP is criticized for not adhering to the axioms of transitivity and rank reversal. However, according to Luce and Raiffa (1957) and Straffin (1993), the decision maker can choose to rule these aspects out. Another criticism is that the solution provided might be only in the interest of those who did the weighting. In this study different representations were made at all administrative levels. The interpretation given to the application of numbers on values as a ratio scale is also considered to be doubtful, (Stewart, 1992). However, according to Gass and Forman, (2001) the resulting priorities would be on an interval scale and not on a ratio scale.

3.8.3 Overview of Conceptual Framework

The schematic frame for the optimal allocation of road fund in Ghana is as summarised in Table 3.9.

Table 3.9: Schematic Framework for Optimal Road Fund Allocation in Ghana

Element of Best Practice	The Ghanaian Problem	Proposed Approach	Assumptions
Goal Setting	-Swings in current road fund allocation system	-Develop an optimal road fund allocation framework	That there will be transparency and efficiency of fund utilisation
Objective Functions	-Does not relate road fund allocation to development objectives	-Adopt Ghana's development goals as underlying principles	-Ensure Balance
Analytical framework	Absence of an allocation framework	Application of a multi criteria system.	That there is multiplicity of objectives
		-Comparison of two MCA methods	That an optimal method will emerge
Needs Assessment	Lack of uniformity in budget estimates	-Apply HDM-4 analytical framework to all road sectors.	-Provide a common basis of comparison
Economic Efficiency	Application at only project level	-Develop a deterministic framework	-That investments in road maintenance do not generate wider social impacts -That the elements missing in CBA are not purely social
		-Use the VFM and	That there will be objectivity with certainty of values
		Efficiency Frontier Concept	That an optimal threshold of a combination of economic and equity considerations in road fund allocation will emerge
		Use (NPV) as an economic indicator	It will provide an authentic market indicator
Equity	- Application at only project level For rural roads	-Apply an egalitarian type of equity for the DM analysis -Adapt VOC and income as equity indicators	-Due to the need to ensure objectivity in a deterministic framework and the. - That it can be a proxy measure of transport fares.
		Apply a utilitarian type of equity for the preferential analysis with AHP method.	That the diversity of stakeholder preferences can be measured and synthesised for sound decision making
Time Dimensions		-Use exponential functions for the DM analysis	That time dimensions will be address
Iteration		-Use a two component structure for DM analysis -Iteration of different values of NPV/cap and an affordability factor derived from VOC/km and income	Will ensure logical analysis. -That an optimal value will emerge at the efficiency lotus. .
		-Identification of impact categories of road maintenance and pairwise comparison at the national, district and community levels with the AHP.	-That impacts not considered at one level can be addressed at other levels of planning

3.9 SUMMARY

This chapter reviewed the theoretical dimensions and methods for road fund allocation in literature with respect to the outstanding issues and the recommendations for addressing them. It also defined the role of Multi Criteria Analysis (MCA) in achieving this. This formed the basis for the formulation of the conceptual framework by which the research was conducted. The research methodology determined on the basis of the conceptual framework is described in detail in the next chapter.

CHAPTER FOUR RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter describes the research methodology. The procedure adopted involved the definition of the research problem, aim and objectives; a literature review; determination of data requirements; model development and validation, model comparison, conclusions and recommendations. The procedure adopted can be illustrated in Figure 4.1.

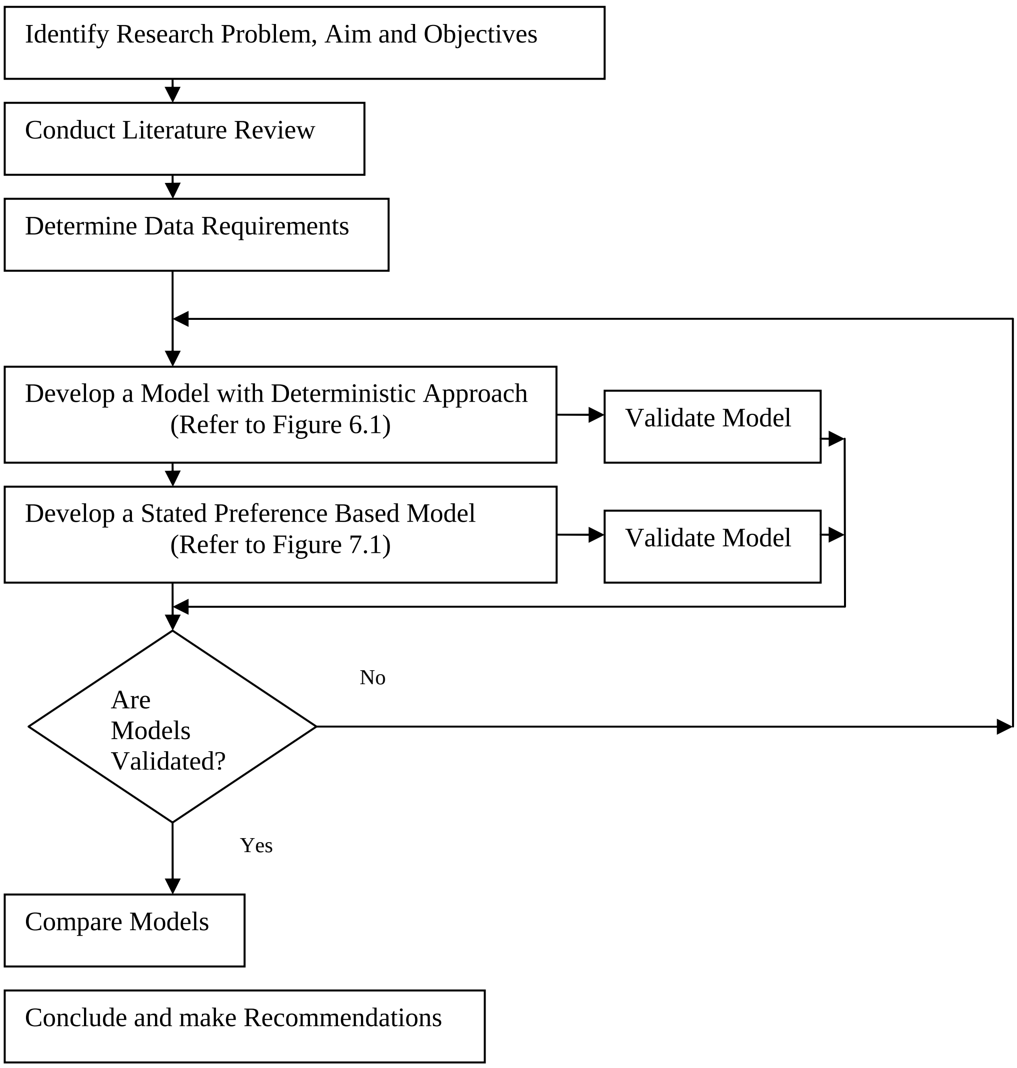


Figure 4.1 Overview of Study Methodology

4.2 PROBLEM IDENTIFICATION AND RESEARCH OBJECTIVES

The definition of the research problem, the aim of the research and the objectives are as indicated in chapter one.

4.3 LITERATURE REVIEW

The review of literature to identify gaps in the current knowledge on road fund allocation and the conceptual framework for the study are as presented in chapters two and three.

4.4 DEFINITION OF DATA REQUIREMENTS

The definition of the data requirements involved the determination of the data types, for the model with deterministic approach (DM) and the stated preference based model (SPM). It also included the data collection and processing methods.

4.4.1. Type of Data for Model Based on Deterministic Approach

The data for the model with deterministic approach was mainly determined from the data inputs for the selected analytical tools. The analytical tools used included the Highway Development and Management Tool (HDM-4) and the Road User Charges Model (RUCM) and the details are discussed in the following paragraphs.

4.4.1.1 Highway Development and Management Tool (HDM-4)

The HDM-4 is a modular based system with the components illustrated in Appendix 4.1. It utilises data on existing road condition, traffic volume and composition to predict road deterioration. It estimates the aggregate costs of specified road construction and maintenance works by the application of unit rates on work activities. The HDM-4 also determines the economic benefits of road investments by CBA. The input output structure of the HDM-4 system is given in Appendix 4.2. It contains algorithms for calculating whole life cycle cost through a period of assessment based the lowest total cost option from a combination of user and agency costs. The road agency costs comprise of costs incurred from road construction costs and future road maintenance costs. The road user costs component includes VOC, travel time costs and other less quantified costs such as accident costs.

The most cost-effective option for project selection is at the lowest point on the curve when the user and agency costs streams are combined. It performs three main applications. These are project analysis for detailed economic appraisal; programme analysis for annual or rolling work programme and a strategic analysis for long term planning. The details are presented in the HDM-4 documentation series volumes 1, 2 and 3. The accuracy of the predicted pavement performance depends on the accuracy by which local conditions are calibration, (HDM-4 documentation series, Volume 5). The data types used for the HDM-4 are presented in the following paragraphs.

(i) The Road Network Characteristics: This refers to the functional and physical components of the road system. This includes the list of the road links, node and route sections with unique coding and naming system and geographical location.

(ii) Pavement Characteristics: The key components include the following features.

- Pavement category that is either paved or unpaved.
- Surface type or type of surface material.
- Pavement structure and the pavement strength.
- Pavement condition in terms of roughness and skid resistance.
- Pavement distress factors as presented in section 2.2.3, Table 2.2.

(iii) Environmental and Climatic Factors: This includes climatic features such as temperature and moisture contents of the area of study.

(iv) Road Maintenance Activities: These are the routine and periodic activities described in section 2.3.1

(v) Treatment Intervention Criteria: These are also described in section 2.3.2.

(vi) Road Maintenance Standards: This involves the properties used for road design such as geometric features comprising grades of vertical alignment and horizontal curvature, drainage, road widths; adjoining terrain of the road; pavement structure thickness and surface characteristics such as the micro and macro texture.

(vii) Maintenance Cost Breakdown: This constitutes the cost of the road treatment interventions applied for maintenance.

(viii) Traffic Characteristics: The traffic data include volume by Annual Average Daily Traffic (AADT), composition and growth. Others are the Equivalent Standard Axle Load (ESAL), the road capacity/speed flow relationships and traffic flow pattern.

(iv) Vehicle Characteristics: This includes data on the physical attributes of the vehicle types, the operational factors and economic costs. The details are as presented in the HDM-4 documentation series volume 4 part E.

4.4.1.2 The ‘Road User Charges Model (RUCM)

The RUCM is a tool developed by the World Bank for setting road user charges, Archondo-Callo, (2000). It is based on matching revenues from user charges with the cost of the effects of different vehicle on road deterioration. It is spreadsheet based with modular components in different worksheets set as predefined input cells. It compares the fixed and variable costs for each vehicle type with revenues generated from specified user charges through an iterative process to determine the required user charges. The RUC was applied in this research to verify the standards adopted in the HDM-4 analysis and the data types used include the following.

(i) Road maintenance costs: This includes yearly needs for recurrent and investment costs such as administrative costs, traffic enforcement costs, debt repayment and grants.

(ii) Current road user charges as described in section 2.7.1.2.

(iii) Vehicle characteristics: It is made up of the national vehicle fleet used on the entire road network.

(iv) Vehicle kilometres: It involves the estimated vehicle kilometres for a two way travel.

4.4.1.3 Other Data Types Used

Other data types used for the deterministic model include data on the income per capita for the different road types and the threshold of available funds for road maintenance.

4.4.2 Data Type for Stated Preference Based Model

The data needs for the stated preference model was based on stakeholder expression of their experience on the impact of road maintenance. The data was categorised on the basis of a five level hierarchical structure developed for the AHP analysis. The hierarchical structure constitutes the goal for the modelling framework; the objective functions for achieving the goal; the criteria and sub criteria on which the objective functions are assessed and the alternatives for which the decisions are made. The data types were defined on the basis of the elements of road maintenance impacts at the criterion and sub criterion levels in the hierarchical structure. Figure 4.2 gives an illustration of the hierarchical structure and the details of the data types at criteria and sub criteria levels are described in the following paragraphs.

1. Data Needs at Criteria Level 1: The data elements at the criteria level 1 was predefined to correspond with the objective functions of Ghana and these were to ensure economic growth and social equity.
2. Data Needs at Criteria Level 2: This was in two categories. The first was based on the importance of economic benefits and costs. The second category was based on the importance of social benefits and costs of road maintenance.
3. Sub Criteria Level 3: The data at the sub criteria were defined as typical elements characterising social benefits and costs.

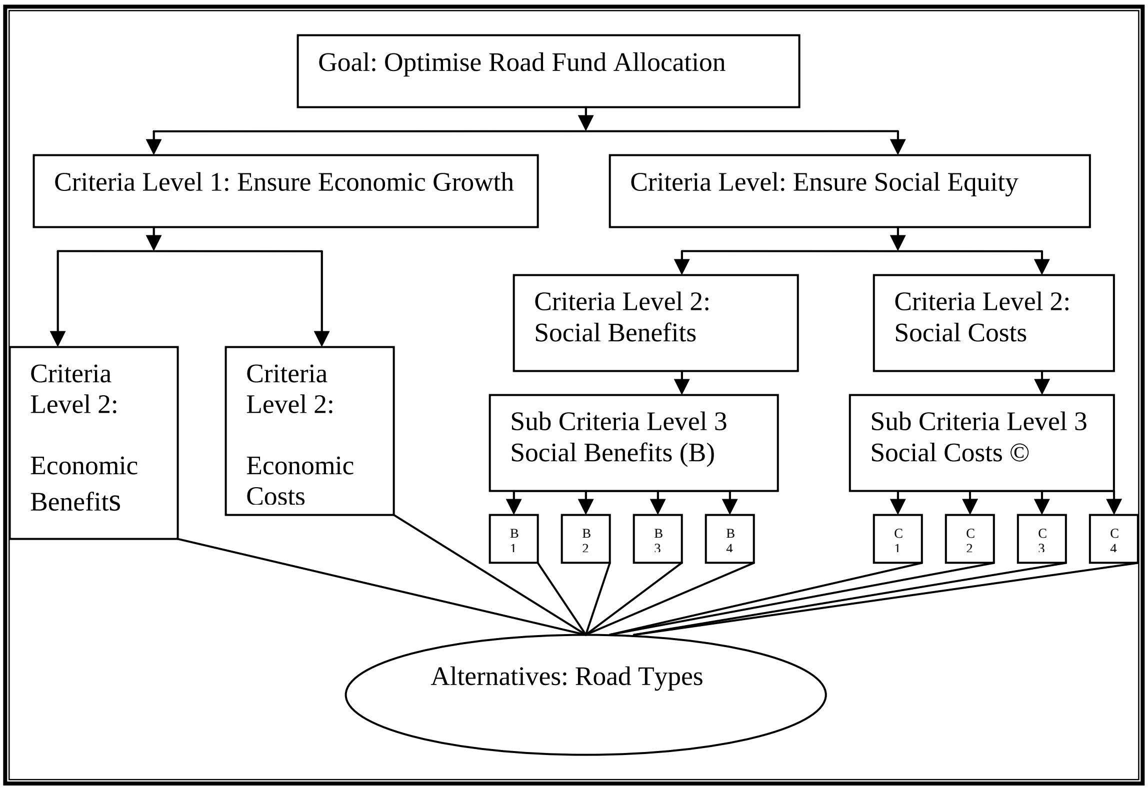


Figure 4.2: Hierarchical Structure for AHP Model

4.4.3 Data Collection

The data used for the two models were collected from both primary and secondary sources and an overview is presented in the following paragraphs.

4.4.3.1 Primary Data Collection

The primary data was collected through field surveys. It involved the administration of questionnaires through personal interviews, key informants surveys and focus group discussions. The personal interviews were based on structured questionnaires. A sample questionnaire for field data collection on vehicle characteristics is given in Appendix 4.3.A sample questionnaires used for the field surveys on stakeholder preferences on the defined criteria and sub criteria is attached in Appendix 4.4.

4.4.3.2 Secondary Data Collection

The secondary data was collected from existing data sources. It involved the collation, adoption and adaptation of data from databases, documentations and reports from the affiliated road agencies and reports on local consultancy studies. Other secondary data sources included calibrated HDM-4 indices for Ghana and some HDM-4 default values. The secondary data collection was successfully undertaken by liaising with the affiliated road agencies within the MRT. It was based on the use of a checklist with a compiled data needs. A catalogue of the details of the type of secondary data and the source from which it was obtained is given in Appendix 4.5.

4.4.4 Data Processing

The collected data were carefully reviewed for, completeness, inaccurate records, omissions, irrelevant data and inconsistencies for replacement, modification and deletion. The data sets for each model component was input in excel worksheets. The variables were defined for the different questions on each survey instrument. Data was aggregated, summarised and presented in the required format. Data reliability was tested on the basis of defined statistical criteria. It was also by benchmarking the results against those of other reliable data sources.

4.5 MODEL DEVELOPMENT AND VALIDATION

The processed data for the HDM-4 analysis was used to run HDM-4 analysis. This generated the data inputs for the value function and the efficiency frontier analysis. The processed data from the stakeholder preference on the impact of road maintenance was used to perform AHP analysis. The validity of each model was also tested with a case study. The case study for the model with deterministic approach was based on a new set of data collected within a different time frame. The viability of the stated preference model was tested with the results of a similar study conducted in a area with similar characteristics as Ghana.

4.6 MODEL COMPARISON

The outcomes of the two models were compared against each other on the basis of their impact on pavement roughness performance to determine the optimal model. Further comparisons were made by comparing the results of the two models against a base case scenario to determine the best option.

4.7 CONCLUSIONS AND RECOMMENDATION

Conclusions were drawn from the results of the study on new observations, new interpretations and new insights that have resulted from to the research problem. Recommendations were made for further research to fill the gaps in this research.

4.8 SUMMARY

This chapter has explained the research methodology. It has described the mode of application of the selected techniques and the procedures followed. The analytical tools and the related data requirements have been defined. An overview of the approach to data collection and processing has been provided and the details are discussed in the next chapter.

CHAPTER FIVE: DATA COLLECTION AND PROCESSING

5.1 INTRODUCTION

This chapter describes the procedures for data collection and processing. It is structured into four parts. The first and second parts describe the data collection and processing methods used for the model with deterministic approach and the stated preference based model respectively. The third part gives a summary of the data outputs used for validating the deterministic model and the fourth section is on the threshold of funding available for road maintenance. A summary of the order of chapter presentation is as follows.

1. Data collection and processing for model based on a deterministic approach.

2. Data collection and processing for stated preference based model.

3. Summary of data outputs for validating deterministic model.

4. Data on available road fund

5.2 DATA COLLECTION AND PROCESSING FOR THE MODEL BASED A DETERMINISTIC APPROACH

The data collection and processing for the model based on the deterministic approach included data on the input variables for HDM-4, data for Road User Charges Modelling (RUCM), data on income per capita and data on available funds for road maintenance. The data collection and processing was undertaken using the methods discussed in section 4.4.1 and 4.4.3 respectively.

5.2.1 Data Inputs for HDM-4 Analysis

The HDM-4 programme requires extensive data inputs. However the data types are structured into sensitivity classes and information quality levels in terms of the magnitude of impacts and the level of detail required for each application level. The details of the data sensitivity classes, the data quality levels, as well as the data collection and processing methods used are discussed in the following paragraphs and the framework of presentation is illustrated in Figure 5.1.

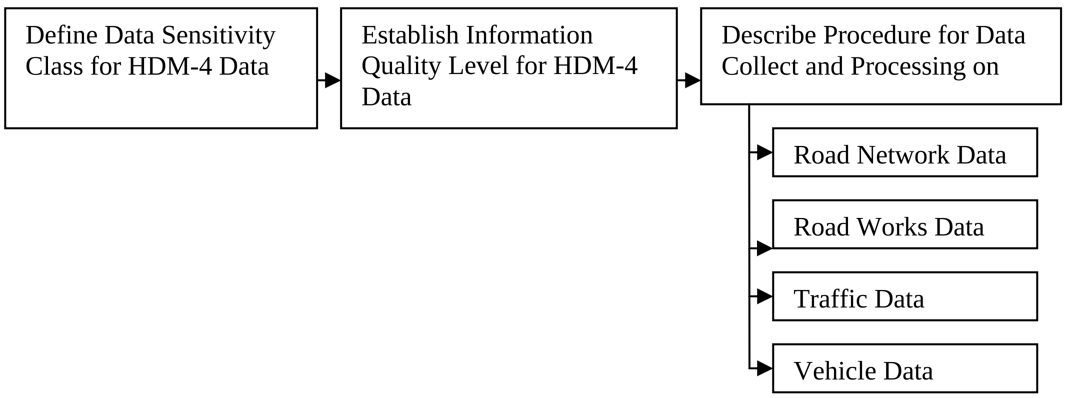


Figure: 5.1 Data Collection Procedure for DM

5.2.1.1 Determination of Data Sensitivity Level

The data input for the HDM-4 analysis is set on four data sensitivity levels. Table 5.1 provides the data sensitivity classes for HDM-4 analysis. The details of the data type defined for each sensitivity class is given in section 4.1 of the HDM-4 documentation series Volume. 5. Each data sensitivity class determines the magnitude of the impact of that parameter on the results of the analysis. The data items with moderate to high impacts (S-I and S-II) require most attention whilst those with low to negligible impacts (S-III and S-IV) are given attention only if time and resources permit. These could be replaced with HDM-4 default values which are considered to be adequate. The data types used for this study were based on the high and moderate sensitivity class and the detail is given in Appendix 5.1.

Table 5.1: HDM Sensitivity Classes

Impact	Sensitivity Class	Impact Elasticity
High	S-I	>0.50
Moderate	S-II	0.20-0.50
Low	S-III	0.05-0.20
Negligible	S-IV	<0.05

Source HDM-4 Documentation Series Volume 5

5.2.1.2 Definition of Data Quality Level

The data quality level for HDM-4 is set on the basis of the concept of Information Quality Level (IQL), (Paterson and Scullion, 1990). The IQL level defines the data quality level required for each analytical application. It is set at four levels and the details are discussed in the following paragraphs and illustrated in Figure 5.2.

- IQL-I: This refers to data with most comprehensive level of detail. It requires high level staff, skills and resources. It is mostly applied at the project operation level over short term duration.
- IQL-2: It involves data with sufficient detail. Data is collected with semi automated equipment over lengths suitable for comprehensive preparation of works. It is mostly applied at the project and programming levels over short to medium term operations.
- IQL-3: It involves data with a simple level of detail. Data collection is based on semi automated or combined automated and manual methods. It is used for programming and strategic operations in medium to long term.
- IQL-4: It is the most basic data level of data involving low effort data collection involving manual and semi automated data collection techniques. It is used for programming and strategic operations in the long term.

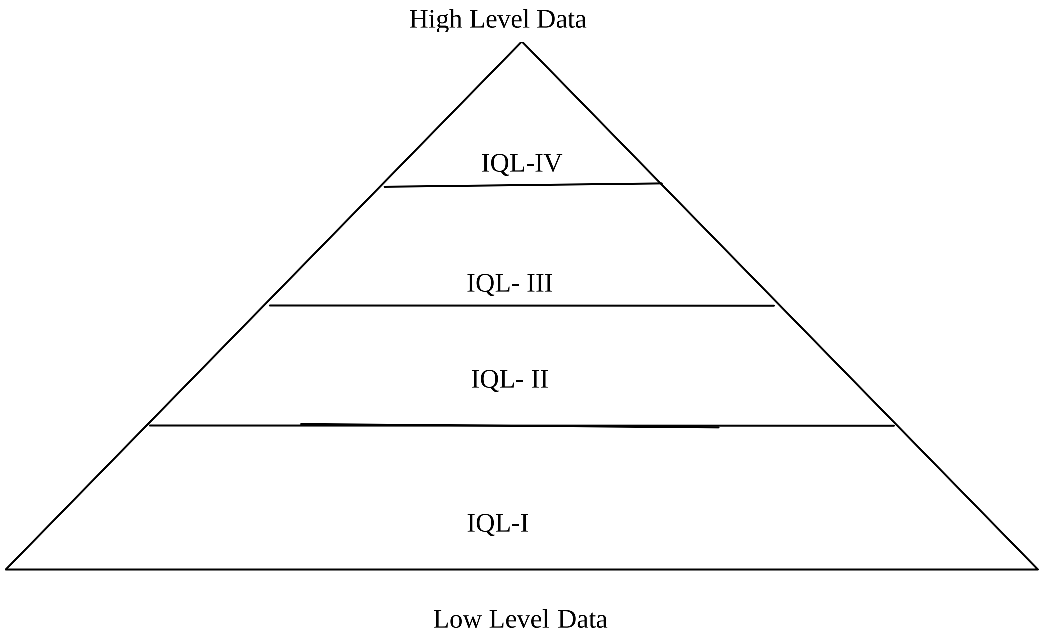


Figure 5.2 Information Quality Level Concept

The data quality level for this research was defined at IQL-1II and IQL-IV levels and the details are given in Appendix 5.2.

5.2.1.3 Data Collection and Processing for HDM-4 Analysis

The detail of the data collection and processing methods for the HDM-4 analysis in this study is described in the following paragraphs.

1. Road Network Characteristics

(i) Road Length: The length of roads used for the HDM-4 analysis included the entire maintainable road network in Ghana for trunk, urban and feeder roads. The trunk and feeder road network data were obtained from aggregated descriptors within the Maintenance Management Programme (PMMP) and the Maintenance Performance Budgeting System (MPBS) respectively. The urban road network data was extracted from records of rapid network screens by two local consultancy firms; (M/s Associated consultants and Comptran

Engineering and Planning consultants 2000). The consultancy data was deemed to be authentic since they were collected by well-recognized consultants and research based institutions which provide services to the MRT and the donor community affiliated with the road sector. The data was aggregated and converted into HDM-4 object file format. Appendix 5.3 provides a sample of the data on urban roads used. The total length of roads collated was 39,669 Km of which 12,436 Km (31.4 percent) were Trunk roads, 7,376 (18.6 Percent) were Urban and 19,864km (50 Percent) were feeder roads.

(ii) Functional Classification: The trunk roads are classified by function as; National (N) where it links the national capital to regional capitals; Inter Regional (IR) where it links various regions and; Regional ® where it links district capitals to their respective regional capitals. Urban roads are classified as major arterials where it serves intercity trips; minor arterials which augment the major arterials; distributors/collectors which primarily carry traffic within individual urbanized areas; and access/local roads which provide access to residence. Feeder roads are classified as inter district where it links more than one district; connectors where it links a trunk road and access where it terminates in a community.

(iii) Pavement Class: Road pavement in Ghana is classified as paved and unpaved. Paved roads are categorised into (1) Asphalt Mix on Granular Base (AMGB); (2) Asphalt Mix on Asphalt Stabilised Base (AMSB; (3) Asphalt Mix on Asphalt Pavement (AMAP); (4) Surface Treatment on Granular Base (STGB); and Surface Treatment on Asphalt Pavement (STAP). The unpaved roads are categorised as gravel and earth roads. The distribution of the paved road class is presented in Table 5.2.

Table 5.2: Distribution of Pavement Type

Pavement Type	Percentage (%)
AMGB and AMSB	11.0
AMAP	4.0
STGB/STSB	75.0
STAP Resealing or Double Surface Dressing	10.0

Source: MRT (2000)

(iv) Pavement Condition: The pavement condition is determined on the basis of the roughness level which is measured by the International Roughness Index (IRI). The condition is rated as good, fair and poor. The criterion for the pavement condition rating is presented in Table. 5.3.

(v) Traffic levels: The Average Annual Daily Traffic (AADT) for the trunk and feeder road sections were obtained from aggregated descriptors in the pavement management and maintenance programme for trunk roads and feeder roads. The traffic data on the urban road network was compiled from a consultancy report on an eight city traffic study by M/s Ablin Consult (2000) for the Department of Urban roads (DUR). The AADT levels for individual road links were merged for the representative road sections. The data reliability for each road section was tested on the basis of the coefficient of variation (CV) to determine the margin of reliability. Road links with CV's of ≤ 0.33 were accepted and those with CV's of > 0.33 were rejected, (Miller, 1991). Appendix 5.4 provides a sample of the analysis on the DUR traffic data. The data was further classified by traffic flow bands set by the MRT as high, medium and low. The details are presented in Table 5.3.

Table 5:3: Road Network Categorisation by Homogeneous Sections

Road Class	Surface Type	Road Condition (IRI)	Traffic Range	
National Regional	Asphaltic concrete or Surface Treated	1-6 Good 6-9 Fair > 9 Poor	>2,000 500 – 2000 <500	High Medium Low
Inter – Regional	Gravel	1-6 Good 6-9 Fair > 9 Poor	>500 250 – 500 <250	High Medium Low
Road Characteristics for Urban Roads				
Arterial	Asphaltic Concrete Surface Treated	1-6 Good 6-9 Fair > 9 Poor	> 2,000	High
Distributor/ Collector		1-6 Good 6-9 Fair > 9 Poor	800 – 2000,	Medium
Local/Access			<800	Low
Arterial	Gravel	1-8 Good 8-12 Fair > 12 Poor	> 250	High
Distributor/Collectors			50 -250	Medium
Local/Access			< 50	Low
Road Characteristics for Feeder Roads				
District Roads Connectors	Bitumen	1-6 Good 6-9 Fair > 9 Poor	>400	High
District Roads Connectors	Gravel	1-8 Good 8-12 Fair > 12 Poor	400-150	Medium
Access	Earth	1-8 Good 8-12 Fair > 12 Poor	>75	Low

(vi). Definition of Homogeneous Road Sections: Data on individual road links were aggregated into homogenous sections as described in section D4 2.3 of the HDM-4 documentation series volume 2. The elements for defining the homogenous road sections were based on road length; surface type, condition rating by IRI levels rated as good, fair and poor and AADT flow bands. Each homogenous section was identified by a code based on a combination of letters representing each of the parameters for each road type in a cell. Thus a cell with an urban road (U), with an Asphalt Concrete surface (A), a high traffic volume (HT), and Good Condition (GC) would have the code 'UAHTGC'. Cells with very low values of the total lengths were identified as 'minor' cells were merged with 'major' cells of most similar characteristic.

These were of the same road network, road class, surface type, aggregated AADT, and aggregated condition (IRI). The trunk road was further classified by function. The length of each representative section is the sum of the lengths of the constituent real sections. A total of 52 homogenous road sections were defined for the trunk roads, 26 for the urban roads and 27 for the feeder roads. A sample of the final road network matrix for the urban road network is presented in Table 5.4. The details of the Trunk and feeder road network are provided in Appendixes 5.5.

Table 5.4: Road Network Matrix for Urban Roads

Section Code	Homogeneous Section	Section Length
UAHTFC	Urban Asphalt-Concrete High Traffic Fair Condition	61.8
UAHTGC	Urban Asphalt-Concrete High Traffic Good Condition	301.2
UAHTPC	Urban Asphalt-Concrete High Traffic Poor Condition	14.7
UALTFC	Urban Asphalt-Concrete Low Traffic Fair Condition	1.4
UALTGC	Urban Asphalt-Concrete Low Traffic Good Condition	3
UALTPC	Urban Asphalt-Concrete Low Traffic Poor Condition	0.6
UAMTFC	Urban Asphalt-Concrete Medium Traffic Fair Condition	1.1
UAMTGC	Urban Asphalt-Concrete Medium Traffic Good Condition	30
UAMTPC	Urban Asphalt-Concrete Medium Traffic Poor Condition	3.18
UGHTFC	Urban Gravel High Traffic Fair Condition	380.2
UGHTGC	Urban Gravel High Traffic Good Condition	183.7
UGHTPC	Urban Gravel High Traffic Poor Condition	240
UGLTFC	Urban Gravel Low Traffic Fair Condition	113.7
UGLTGC	Urban Gravel Low Traffic Good Condition	78.6
UGLTPC	Urban Gravel Low Traffic Poor Condition	251.8
UGMTFC	Urban Gravel Medium Traffic Fair Condition	273.4
UGMTGC	Urban Gravel Medium Traffic Good Condition	238.1
UGMTPC	Urban Gravel Medium Traffic Poor Condition	207.4
USHTFC	Urban Surface-Treatment High Traffic Fair Condition	280.9
USHTGC	Urban Surface-Treatment High Traffic Good Condition	269.5
USHTSC	Urban Surface-Treatment High Traffic Poor Condition	4289
USLTFC	Urban Surface-Treatment Low Traffic Fair Condition	4.45
USLTGC	Urban Surface-Treatment Low Traffic Good Condition	37.8
USMTFC	Urban Surface-Treatment Medium Traffic Fair Condition	33.25
USMTGC	Urban Surface-Treatment Medium Traffic Good Condition	68.6
USMTSC	Urban Surface-Treatment Medium Traffic Poor Condition	8.9

(vii) Pavement Age: The pavement profile of Ghana exhibits three age categories. These are s young for those ≤ 3 years, middle for those between 4 to eight 8 years and old for those above > 8 years. The detail is presented in Table 5.5.

Table 5.5: Age Profile of Road Pavement in Ghana

Pavement	Age Range	Representative Age (years)
Young	0-3	2.0
Middle	4-8	6.0
Old	>8	15.0

Source: MRT Strategic Plan (2000)

(viii) Existing Road Features: Data on the physical characteristics of the aggregated road sections were obtained from MRT aggregated descriptors for trunk and feeder roads. The urban roads data were collated from reports on rapid screens by M/s Associated consultants and Comptran Engineering and Planning consultants in (2000). The data reliability was determined on the basis of test of correlation between selected variables such as pavement roughness and factors like potholes, rutting and deflection by regression analysis. The correlated variables with R^2 > 0 and a probability value of > 0.05 were accepted and those with R^2 < 0 and < 0.05 were rejected. Appendix 5.6 provides a sample of the correlation analysis between the existing road features for the urban road network. Appendix 5.7 also gives the summary of the existing features used for the HDM-4 analysis.

(ix) Pavement Strength: It is measured by the Adjusted Structural Number (SNP) (Parkman and Rolt, 1997). The SNP applies a weighting factor which reduces with increasing depth, to the subbase and subgrade contributions so that pavement strength for deep pavements are not over predicted. The mode of calculation is presented in section 3, Part C of the HDM-4 documentation series volume. 4. The calibrated (SNP) for Ghana by Odoki *et al* (2004) was adopted for this study. The calibrated HDM-4 indices were adopted because it is an extensive exercise which has been done over a 4 year period and is considered to be very authentic. The details are indicated in Table 5.6.

Table 5.6: Calibrated Pavement Strength Coefficient

Layer	Layer Thickness	Layer Strength Coefficient
Surfacing	40 mm	0.45
Roadbase	210 mm	0.32
Subbase	400 mm	0.23

Source: Draft Report on Calibrated HDM-4 Data Items for Ghana (2004)

(x) Road Distress Coefficient Factors: A summary of the calibrated coefficients on road deterioration works effect (RDWE) by Odoki *et al* (2004) was adopted for the HDM-4 analysis and the detail is presented in Table 5.7.

Table: 5.7: Summary of the RDWE Calibrated Coefficients

Calibration Factor	Code	STGB/STSB		AMAP	
		Value Adopted	Calibrated	Value Adopted	Calibrated
Cracking Initiation Factor	Kcia	2.65	2.53	2.53	2.53
Cracking Progression Factor	Kcip	0.38	0.40	0.40	0.40
Ravelling Initiation Factor	K_{vi}	1	0.65	0.65	0.65
Ravelling Progression Factor	K_{vp}	1	1.54	1.54	1.54
Rutting Initiation Factor	K_{rid}				
Rutting Progression Factor	K_{rst}		0.9723		1.182
Roughness Initiation	K_{ge}	1.1	1.0	1.1	1.0
Roughness Progression	K_{vp}	0.9	1.0	0.9	1.0
Potholes Initiation Factor	K_{pi}	0.3	-	1	-
Potholes Progression Factor	K_{pp}	1.0	-	1	-
Edge Break		1	-	1	-
Texture Depth		1		1	
Skid Resistance	K_{sfc}	1	1	1	

Source: HDM-4 Configuration and Calibration Report for MRT by UOB (2004)

2. Road Works Data:

(i) Pavement Treatment Interventions: The maintenance treatment interventions were set on the basis of the categories defined in section 2.1.4 of this literature.

(ii) Road Maintenance Standards: The road maintenance standards were adapted from the MRT's road maintenance standards and the principal decision levers were based on the following factors.

- The extent of work defect defined in terms of pavement roughness by IRI.
- Treatment intervention type.
- Intervention Interval, that is the maximum and minimum time limits for triggering interventions.
- Constraints on upper and lower limits set on the basis of NPV and capital costs.
- The traffic level categorised by the defined flow bands as high, medium and low. That is sections with low traffic were considered to have localised defect effect whilst those with high traffic were considered to be of prevalent defect effect.

Trial HDM-4 runs of different scenarios of maximum and lower limits of treatment options were performed for the specified defect types. The NPV and cost outputs for the test scenarios were then ranked in an ordinal order from the highest to the lowest value, Robinson *et al* (1998). The first four outputs with high NPV at minimum costs in a ranked order were selected to represent the prescribed maintenance standards for four alternative interventions and these are described in the following paragraphs.

1. Base Maintenance: This was the minimum maintenance intervention level considered. It included simple routine maintenance activities.

2. Basic Maintenance: The next level of intervention considered above the base level included scheduled activities such as resealing for paved roads and regravelling for unpaved roads.

3. Desired Maintenance: This level was aimed at preserving original investments to required levels and it included activities such as overlay and reconstruction.

4. Ideal Maintenance: This was the ultimate level required if all the needed resources were available including and it included activities such as reconstruction for paved roads and upgrading of unpaved roads to bituminous surface.

The details of the intervention levels defined for both unpaved and paved roads are presented in Tables 5.8 and 5.9 respectively.

Table 5.8: Works Standards for Unpaved Roads

S/No	Alternative	Activity	Intervention Criteria	Potholes	Units	Traffic		
						High	Medium	Low
1.	Base (Routine)	Grading Spot Gravelling	Scheduled	Roughness Gravel thickness	IRI mm	≥8 ≤100		
2.	Basic(Recurrent)	Grading Spot Gravelling Regravelling	Scheduled	Roughness Gravel thickness Gravel thickness	IRI Mm mm	≥8 ≤100 ≤50		
3	Desired (Periodic)	Grading Spot Gravelling Regravelling	Scheduled	Roughness Gravel thickness Gravel thickness	IRI Mm mm	≥8 ≤125 ≤75		
4	Ideal (Periodic)		Responsive					

Source: MRT Strategic Plan (2000)

Table 5.9: Works Standards for Paved Roads

S/No	Alternative	Activity	Potholes	Units	TRAFFIC		
					High	Medium	Low
1.	Base (Routine)	Drainage Edge repair Patching Crack Sealing	Potholes Wide Structural cracks	No./Km % / Km	Once a Year Once a year ≥10 ≥10	Once a Year Once a Year ≥20 ≥12	Once a Year Once a Year ≥30 ≥15
2.	Basic(Recurrent)	Drainage Edge Repair Patching Resealing	Potholes Total damaged area	No. /Km %	Once a Year Once a Year ≥10 ≥20	Once a Year Once a Year ≥20 ≥30	Once a Year Once a Year ≥30 ≥30
3	Desired (Periodic)	Drainage Edge Repair Patching Overlay Reconstruction	Drainage Edge Repair Potholes Roughness & Total damaged area Roughness	No./Km IRI % IRI	Once a Year Once a Year ≥10 ≥6 ≥5 ≥10	Once a Year Once a Year ≥20 ≥7 ≥5 ≥11	Once a Year Once a Year ≥30 ≥8 ≥5 ≥12
4	Ideal (Upgrading)	Drainage Edge Repair Patching Resealing Overlay Reconstruction	Potholes Total damaged area Roughness & Total damaged area Roughness	No./Km % IRI % IRI	Once a Year Once a Year ≥10 ≥20 ≥6 ≥5 ≥10	Once a Year Once a Year ≥20 ≥30 ≥7 ≥5 ≥11	Once a Year Once a Year ≥30 ≥40 ≥8 ≥5 ≥12

Source: MRT Strategic Plan (2000)

(iii) Maintenance Cost breakdown by Activity: Data on standard unit cost rates for different road maintenance interventions were obtained from the technical division of the Ministry of Roads and Transport (MRT). The rates were adjusted by a reduction of 7 percent tax margin and 6 percent general cost items to obtain the economic cost of works. A summary is given in Table 5.10.

Table 5.10:Unit Cost of Maintenance Activities

Item	Activity		Economic Unit cost US($)	Financial Unit Cost US ($)	Budget Heading
1	Crack sealing	M2	8.25	9.5	Recurrent
2	Patching	M2	10.07	11.58	Recurrent
3.	Edge repair	M2	7.06	8.12	Recurrent
4	Drainage	M2	8.50	9.78	Recurrent
5	Thin overlay	M2	62.86	72.29	Capital
6	Single surface dressing	M2	6.91	7.94	Capital
7	Double Surface dressing	M2	8.30	9.55	Capital
8	Overlay dense graded asphalt	M2	22.60	25.99	Capital
9.	Pavement reconstruction	Km	700,000.00	805,000.00	Capital
10	Spot regravelling	M3	6.5	7.47	Recurrent
11	Regravelling	M3	5.3	6.09	Capital
12	Grading	Km	215	247	Recurrent
13	Upgrading (Gravel to Bitumen surface)	Km	155,985	191,862	Capital

Source - MRT

The information was verified with sampled unit rates from tendered road maintenance contracts. A compilation of the contract costs from a total of 100 road maintenance contracts was made and a sample is given in Appendix 5.8. A ‘t’ statistical test analysis of the standard unit rates obtained from the MRT and the tendered unit rates was undertaken to determine the significant difference between the two data using Coolican's (1990) inference point of there being a significant difference at $\leq$ 0.05 probability value. The results indicated that there was no significant difference between the two data sets with a probability of 0.17 percent. However, higher CV's were recorded on the tendered contracts than the standard unit rates so the later was used for the analysis. Table 5.11 presents a sample output of the comparison.

Table 5.11: Assessment of Standard and Contract Unit Rates

ACTIVITY	Indicators on Standard Unit Rates			Indicators on Tendered Rates		
	Mean (US $)	Std	CV	Mean	Std	CV
Drainage	8.5	2.5	0.29	5.0	2.6	5.2
Reconstruction	700,000	119,736	0.17	416,829	107,705.8	0.25
Regravelling	5.3	1.72	0.32	35.0	1.33	0.38
Upgrading to Bitumen	155,985	30,000	0.19	132,621	52,690	0.27
't' test Results = 1.74 , Degrees of Freedom = 3, Critical 't' value = 2.3, P value = 0.174						

3. Traffic Data:

(i) Traffic Composition and Growth Rate: The average composition of representative vehicle types and traffic growth rates were estimated from records of traffic surveys conducted by local consultancy studies by M/s Ablin Consult (2000) and the Building and Road Research Institute (2004) on representative road sections. The projection of the traffic growth was based on Equation 5.1 which is expressed as;

$$P_n = P_o(1+r)^n \qquad \text{Equation 5.1}$$

Where,

P_n = Population at year (n).

P_o = Population at year zero (Initial Population)

n = no. of years

r = Growth rate

A sample of the detail estimates for the traffic growth is attached as Appendix 5.9 and a summary is presented in Table 5.12.

Table 5.12: Summary of Vehicle Composition and Growth rate by Road Type

Vehicle Number	Vehicle Type	Vehicle Composition			Traffic Growth Rate		
		Trunk	Urban	Feeder	Trunk	Urban	Feeder
01	Car	17.8	25.0	3.0	6.5	5.0	3.4
02	Taxi	11.8	27.0	5.0	6.5	5.0	3.4
03	Pick Up	19.4	6.0	20.0	6.5	5.0	3.4
04	Small Truck	3.4	5.0	15.0	5.0	5.0	5.0
05	Medium Truck	4.3	5.0	12.0	5.0	5.0	5.0
06	Heavy Truck	4.1	5.0	2.0	5.0	5.0	5.0
07	Articulated Truck	7.8	5.0	10.0	5.0	5.0	5.0
09	Small Bus	13.6	9.0	6.0	5.0	5.0	5.0
11	Medium Bus/Heavy Bus	10.0	8.0	6.0	5.0	5.0	5.0
12	Motorcycle	0.0	5.0	21.0	5.0	5.0	5.0
Total		100	100	100			

4. Vehicle Data

Data on vehicle characteristics was collected from field surveys and the details are discussed in the following paragraphs.

(i) Survey Locations: The surveys were conducted in three cities in Ghana and these are Accra, Kumasi and Takoradi. Appendix 5.10 presents the geographical locations of the three cities. The choice of the three cities was due to the fact that about 60 percent of all the vehicles in Ghana are located in them, (DVLA, 2004). This made it possible to obtain samples of all the vehicle classes which were required for the analysis.

(ii) Sampling Design for Data on Vehicle Characteristics

The sample frame on the vehicle characteristics was estimated to be 398,995.2 vehicles which is 60 percent of the total vehicle population of 664,992 vehicles in Ghana (DVLA, 2004). The HDM-4 documentation series is flexible on the selection of a sample size for the vehicle characteristics but emphasise on the need for the data quality to meet set study objectives. A maximum sample size of 350 that is about 1 percent of the sample frame was targeted. Then based on Utts’s (1976), concept of an acceptable margin of error (M.E.) at ≤ 0.05 based on the expression;

M.E. = $1/\sqrt{N}$ Equation 5.2

where

M.E. = the margin of error,

N = the sample size

The M.E. for the selected sample of 350 vehicles was tested as;

$1/\sqrt{350}$, which is;

$1/18.7 = 0.05034$.

The results indicated that the sample size had an M.E. of about 5 percent which gives a confidence level of 95 percent. Therefore the sample size of 350 was accepted to be representative of the vehicle population in Ghana. A description of each vehicle category, the proportion in the total vehicle distribution and the number of vehicles surveyed is given in Table 5.13.The types of sampling methods applied included the quota, stratified, random and convenience sampling. The vehicles were first classified into two broad categories as new and old vehicles. This is due to the predominance of used vehicles in Ghana.

The proportion of the vehicles in each category was estimated from DVLA records as 33 percent new and 67 percent old. Table 5.13 provides the details of the number of used and unused vehicles surveyed. The HDM-4 system models sixteen vehicle classes however for purposes of this study eleven (11) motorised vehicle classes were defined in accordance with the classification by the (DVLA) of Ghana. Each vehicle class was considered as a stratum from which representative samples were drawn. Appendix 5.11 provides a description of the vehicle classes. The sample size of 350 vehicles was prorated to correspond to the proportion of each vehicle class in the total distribution of vehicles within the sample frame. The individual vehicles in each stratum were randomly selected for the detail surveys at the stated locations. The selected vehicles included both commercial and non commercial vehicles. Some data categories on the vehicle data such as the resource costs were targeted at specific respondents for accuracy and the details are discussed under the relevant sections in this chapter.

Table 5.13: Sample Distribution of Selected Vehicles

Vehicle Class	Percentage	Number of Vehicles	Estimated Sample	Estimated Sample Size	
				New	Old
Car	15	59849.3	52.5	17.3	35.2
Taxi	14.5	57854.3	50.75	16.7	34.0
Pick up	11	43889.5	38.5	12.7	25.8
Small Truck	11.5	45884.4	40.25	13.3	27.0
Medium Truck	7.5	29924.6	26.25	8.7	17.6
Heavy Truck	8	31919.6	28	9.2	18.8
Articulated Truck	9	35909.6	31.5	10.4	21.1
Small Bus	12	47879.4	42	13.9	28.1
Medium/ heavy Bus	10	39899.5	35	11.6	23.5
Motorcycle	1.5	5984.9	5.25	1.7	3.5
Total	100	398995.2	350	117.0	233.0
Percentage				33	67

The response rate from the field studies on the vehicle characteristics was about 210 which constituted about 60 percent of the estimated sample size. The summary of the distribution is presented in Table 5.14.

Table 5.14 Response Rate

Vehicle Type		Response Rate		Total
Code	Vehicle Type	New	Old	
01	Car	10	20	30
02	Taxi	10	19	29
03	Pickups	6	16	22
04	Small Truck	7	16	23
05	Medium Truck	6	9	15
06	Heavy truck	6	11	17
07	4/5 Axle Articulator Truck	7	12	19
09	Small Bus	8	16	24
11	Medium/Heavy Bus	7	14	21
12	Motorcycle	5	5	
Total		72	183	210
Percentage		34	67	100

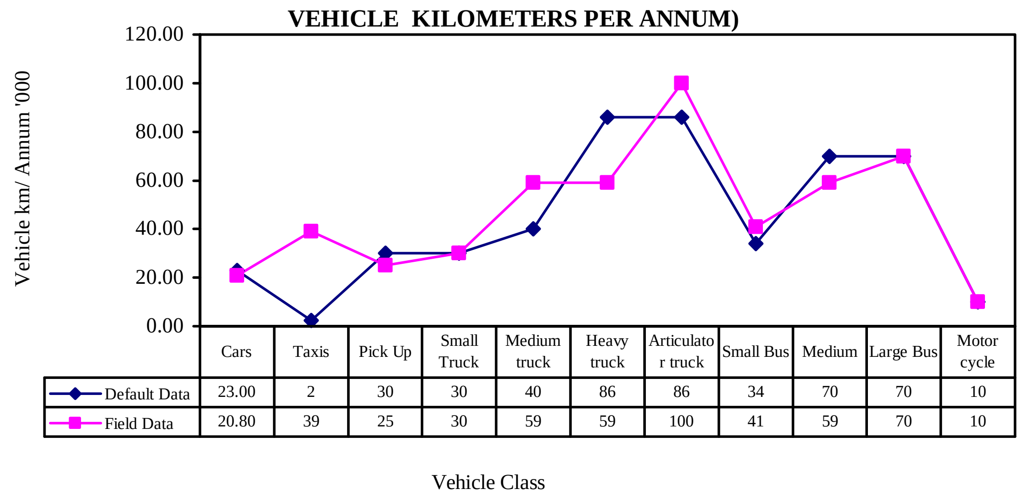
(iii) Annual Km (km/yr): The annual vehicle kilometers (km) were estimated by dividing the information on the distance traveled per annum for each vehicle type by the age of the vehicle, (Daniels, 1974, Bennet 1985). A sample of the detailed results is given in Appendix 5.12. A weighted average of the distance traveled by both used and brand new vehicles was used for the analysis. For example, if the new cars were 33 percent with an average mean of 40,576km and that of old cars were 67 percent with an average mean of 172,967km. Then the weighted average was estimated as;

(0.33 x 40,576km + 0.67 x 172967 = 129,376.84).

The result of the above example was divided by the average age of a car which is 6 years to obtain the average vehicle km per annum at 20,275.32km. A ‘t’ test comparison of HDM-4 default data on vehicle kilometers and the field data indicated that there were no significant differences between the two data sets at a probability value of 0.12. A summary of the results for all the vehicle categories are presented in Table 5.15 and illustrated with Figure 5.3.

Table 5.15: Average Vehicle Km Per Annum

Vehicle Type	Average Total Kilometres	Average Age	Average Vehicle –km / annum	Default Values
Car	129376.84	6	20,275.5	23,000
Taxi	241,055.9	6	39,334.1	0
Pick up	199,779.4	6.5	30,035.6	30,000
Small Truck	272,974.1	6.5	41,039.9	30,000
Medium Truck	398,006.9	6.5	59,805.7	40,000
Heavy Truck	417,923.00	7	59,692.8	86,000
Articulated Truck	721,911.5	7	102,539	86,000
Small Bus	266,605.1	6	41,474.79	34,000
Medium Bus/Heavy Bus	474,749.2	6.5	71,947.3	70,000
Motorcycle	20,000	5	10,000	10,000
t' test Results = 1.23 , Degrees of Freedom = 10, Critical 't' value = 1.8, P value = 0.12				



	Cars	Taxis	Pick Up	Small Truck	Medium truck	Heavy truck	Articulator truck	Small Bus	Medium	Large Bus	Motor cycle
Default Data	23.00	2	30	30	40	86	86	34	70	70	10
Field Data	20.80	39	25	30	59	59	100	41	59	70	10

Figure 5.3: Vehicle Km Per Annum

(iv) Service Life: This was estimated on assumption of a constant life. The double mean method by Daniels' (1974) and Bennett (1985) was used by squaring the age of the vehicle. A comparison of the field data with the HDM-4 default data indicated that the vehicle service life from the field data exhibited longer service life for all vehicle types with the exception of small buses. A statistical 't' test analysis indicated a very significant difference at an estimated probability of 0.0024. Table 5.16 provides the summary per vehicle type and Figure 5.5 presents an illustration. The field data was used for the analysis since vehicles are mostly kept beyond their specified service life in Ghana.

Table 5.16: Vehicle Service Life

Vehicle Type	Average age (age)	Service life (so^2)	Default
Car	6.0	12	10
Taxi	6.0	12	8
Pick up	6.5	13	8
Small Truck	6.5	13	8
Medium Truck	6.5	13	12
Heavy Truck	7.0	14	14
Articulated Truck	7.0	14	14
Small Bus	6.0	12	8
Medium Bus/Heavy bus	6.5	13	8
Motorcycle	5.0	10	10
t' test Results = 3.7 , Degrees of Freedom = 10, Critical 't' value = 1.8, P value = 0.0024			

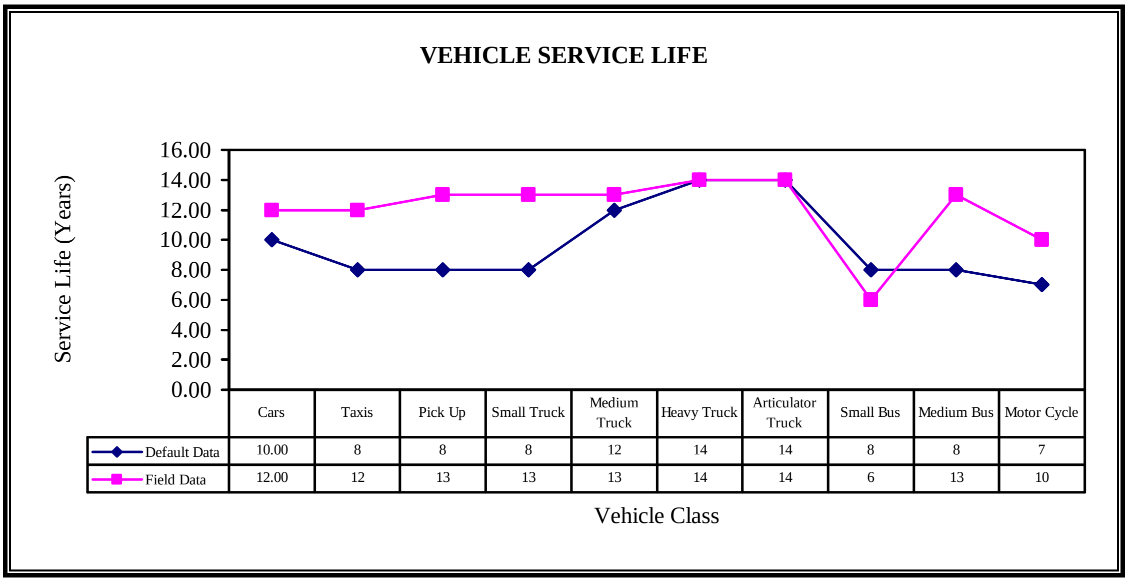
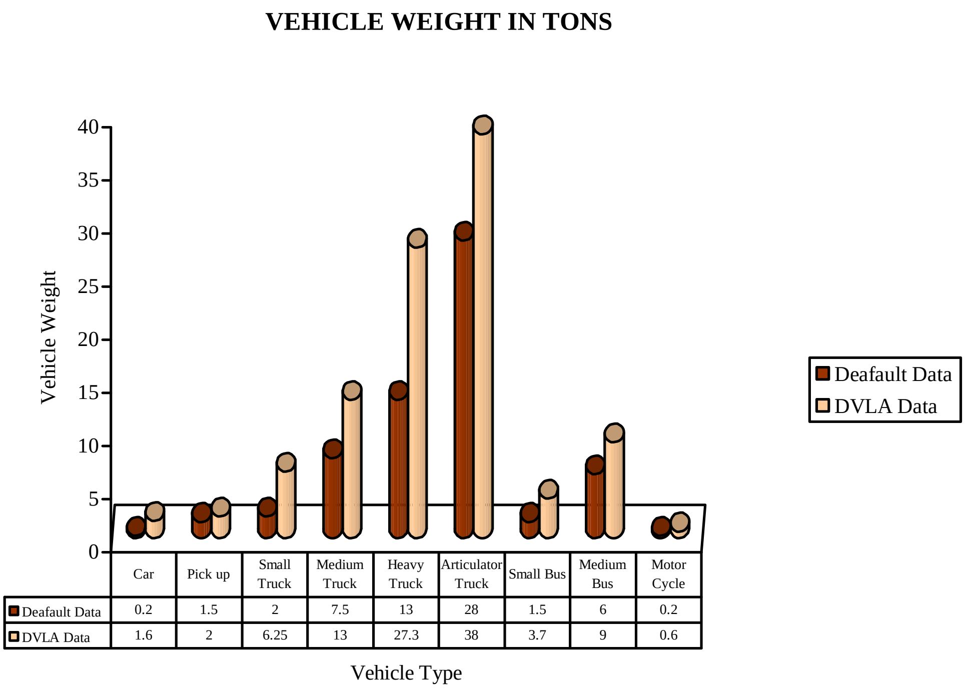


Figure 5.4: Vehicle Service Life

(v) Average Operating Weight (tons): The values used in the analysis were compiled from legal weight limit specifications for passenger and cargo vehicles by the DVLA. A statistical 't' test analysis of the DVLA standards and HDM-4 default data indicated a very high significant difference at a probability of 0.0077. This could be attributed to the general trend of overloading in Ghana. Table 5.17 gives the summary of results and Figure 5.6 presents an illustration of the data comparison.

Table: 5.17: Vehicle Weight

Vehicle Type	Default Vehicle Operating Weight	DVLA Standards
Car	0.2	1.6
Taxi	0.2	1.6
Pickups	1.5	2.0
Small Truck	2.0	6.25
Medium Truck	7.5	13.0
Heavy truck	13.0	27.35
4/5 Axle Articulator Truck	28.0	38.0
Small Bus	1.5	3.72
Medium / Heavy Bus	6.0	9.0
Motorcycle	0.2	0.6
'T' Value = -2.98 Critical 'T' = 1.83	P value = 0.0077	



	Car	Pick up	Small Truck	Medium Truck	Heavy Truck	Articulator Truck	Small Bus	Medium Bus	Motor Cycle
Deafault Data	0.2	1.5	2	7.5	13	28	1.5	6	0.2
DVLA Data	1.6	2	6.25	13	27.3	38	3.7	9	0.6

Figure 5.5: Vehicle Weight

(vi) ESALF: It was estimated with the specified formula in section 5.3 of the HDM-4 documentation series Vol. 4 as; ((vehicle weight / number of axles) / 8.2)) and the results are indicated in Table 5.18.

Table 5.18: Equivalent Standard Axle Load Factor

Vehicle Type	Number of Axles (A)	Operating Weight (B)	Operating Weight/ Number of Axles ©	ESALF = C/8.2
Car	2	1.6	0.8	0.1
Taxi	2	1.6	0.8	0.1
Pickups	2	2	1	0.1
Small Truck	2	6.35	3.2	0.4
Medium Truck	2	13	6.5	0.8
Heavy truck	3	27.35	9.12	1.1
4/5 Axle Articulator Truck	4	38	9.5	1.2
Small Bus	2	3.72	1.86	0.2
Medium/Heavy Bus	2	9	4.5	0.5
Motorcycle	2	0.2	0.1	0.0

(vii) New Vehicle Cost ($/vehicle): The "vehicle cost" is the financial cost of a new vehicle less the cost of tyres. This was determined from surveys on the retail prices of vehicles in Ghana. The price of each vehicle was converted to an economic cost by deducting the total percentage of import duty, the value added tax (VAT), the ECOWAS levy, EDIF tax as well as the examination and processing Fees. The summary is presented in Table 5.19.

Table: 5.19: Vehicle Costs

Vehicle Type	Financial Value (US $)	Duties and Taxes (Perecentage0	Value of Tax Margin (US $)	Economic Value (US $)	Standard Deviation	CV
Car	19,181	25	4,687	14,494	1604	0.083
Taxi	19,181	25	4,687	14,494	1604	0.083
Pickups	29,010	35	9,195	19,815	2581.9	0.089
Small Truck	25,117	20	4,747	20,370	2786	0.111
Medium Truck	41,100	20	7,767	33,333	3778.9	0.091
Heavy truck	71,242	20	13,464	57,778	6987	0.098
4/5 Axle Articulator 0.06Truck	92,477	20	17,477	75,000	4735	0.051
Small Bus	21,921	21	4,143	17,778	1160.5	0.053
Medium Bus/Heavy Bus	55,655	21	10,655	45,000	9086.5	0.11
Motor Cycle	1,985	15	285	1,700		

(viii) Vehicle Resource Costs

Since the study is on road maintenance funding, data was also collected for the cost related aspects of the vehicle characteristics Appendix 5.13 gives the details of the data on the vehicle resource costs.

5.2.2 Data Processing for RUCM Data

1. Road Maintenance Financing needs: This is classified as fixed and variable costs. HDM-4 costs estimates were run for two scenarios with and without traffic scenarios for each road class to determine each of these costs. The without traffic scenario costs were used as the fixed costs. Then the without traffic scenario costs was deducted from total maintenance cost estimates t obtain the with traffic or variable maintenance costs.

2. Road User Revenue: Data on the road user revenue from various sources were obtained from the Driver and vehicle licensing Authority and the National Road Fund secretariat. Since Ghana has a fixed vehicle registration fee that is paid at the time of licensing. The rate per vehicle type per year was estimated by dividing the fixed rate by an average life span of ten (10) years per vehicle. Also since the RUC specifies only a licensing fee, other user charges such as vehicle licensing fees and tolling charges were added to the licensing fees and averaged and the summary is as presented in table 5.20.

Table 5.20: Average User Charge by Vehicle Type

Vehicle class	Average User Charge
Cars and Pick ups (petrol)	4
Cars and Pick ups (diesel)	4
Motor cycle	0
Lorries and Buses	5
Heavy trucks (2-axle)	7
Heavy trucks (3-axle)	7
Farm tractors	18
Government vehicles (petrol)	0
Government vehicles (diesel)	0

3. Fleet Size: The number of Vehicles using the Network and the estimated vehicle kilometres for a two way travel is as summarised in Table 5.21.

Table 5.21: Size of Vehicle Fleet

Vehicle class	Vehicle Number	Vehicle Km
Cars and Pick ups (petrol)	175,000	26,090
Cars and Pick ups (diesel)	176,090	35,000
Motor cycle	14,462	11,300
Lorries and Buses	125,240	22,000
Heavy trucks (2-axle)	60,300	20,000
Heavy trucks (3-axle)	44,200	18,000
Farm tractors	800	1,200
Government vehicles (petrol)	45,000	20,000
Government vehicles (diesel)	42,000	20,000
Total	664,992	

Source: DVLA (2004)

4. Vehicle Kilometers: The data on vehicle kilometres was adapted from section 5.2.5.4 item 6 of this chapter and multiplied by 2 to reflect a two lane traffic movement.

5.2.3 Data on Income Levels

Data on income levels were compiled from the Ghana Living Standards Survey (GLSS) and the distribution is as presented in Table 5.22.

Table 5.22: Income Distribution by Road Type

Road Sector	Income Per Capita/Annum (US $)					
	2000	2001	2002	2003	2004	Average
Trunk	84.6	101.3	108.5	122	152	113.68
Urban	124	159	162	221	235	180.2
Feeder	72	91	102.4	115.4	128.9	101.9

Source: Records from Ghana Living Standards Survey (2004)

5.3 DATA COLLECTION AND PROCESSING FOR STATED PREFERENCE BASED MODEL (SPM)

The data on the SPM was derived on the basis of user expression of the benefits and costs of road maintenance impacts at three administrative levels. These are community or micro level, district or meso level and national or macro level. The data type was defined in terms of economic and social benefits and costs of road maintenance as set in the hierarchical order presented in Figure 4.2 for each road type. The framework of data collection at each administrative level on each criteria and sub criteria for each road type is illustrated in Figure: 5.6.

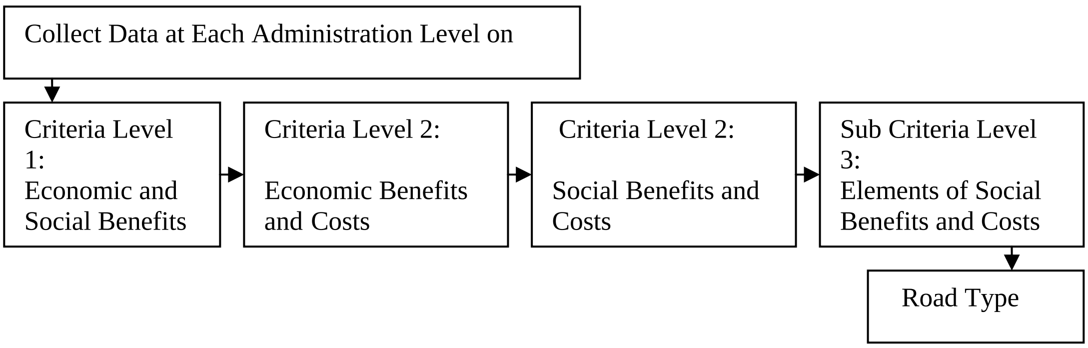


Figure 5.6: Set up on Data Collection for Stated Preference Based Method.

5.3.1. Data Collection at the Community or Micro Level

This was based on personal interviews with sampled members of selected communities through field surveys. The procedure is summarised in the following steps and described in the following paragraphs.

- Select Study Areas
- Define sample size
- Conduct Pre Interviews through field survey to select elements of social benefits and cost at sub criteria level based on a rating scale of 1 to 4.

- Conduct pairwise comparison of elements at criteria levels 1 and 2 and the sub criteria level 3 on a scale of 1-9 through field surveys.

1. Selection of Study Areas: The selection of the study locations involved first the selection of two districts and then the selection of two communities from within each district. The choice of districts was based on an inherent dimension of poverty status. There are ten regions in Ghana which are sub divided into 145, Metropolitan, Municipal and District Assemblies. This study was conducted in two districts rated as poor and non poor by the poverty stratification of the Ministry of Local Government (MLG). This was to meet the objective functions of ensuring both economic efficiency and social equity. The selected districts were the Dangme East District and the Ga West Municipal Assembly. The choice of district was also based on accessibility to all roads types. This was to provide a balanced view on the benefits and costs of road maintenance for all road types. The location of selected districts is indicated in Appendix 5.14. A brief profile of the selected districts and communities is described in the following paragraphs.

(i) Profile of the Dangme East District: The Dangme East is located in the eastern part of the Greater Accra Region of the south eastern part of Ghana. It covers a total land area of about 909 sq km with a density of 102.4 persons. (Ghana, Population Census, 2001). The major occupation is farming and it is rated as a poor district lacking in basic amenities such as good drinking water, health and educational facilities by the social investment f of Ghana und (SIF). The total length of the road network in the district is about 172 km, made up of primary road (28km), secondary roads (20.2 km), and feeder roads (123.3km). About 70 percent of the roads network, especially the feeder roads, is in very poor condition with most them becoming unmotorable during the wet season, (DFR Inventory Data, 2004). The major occupation is farming, fishing and salt mining. The main problems associated with the transport are; long waiting and long travel times due to the poor condition of the roads.

(ii) Profile of the Ga West Municipal: The Ga West Municipal is the second largest of the six Municipalities & Districts in the Greater Accra Region. It is rated as a non poor district. It has close proximity to Accra, the national capital and Tema which a port city with the country's largest harbour and an industrial hub. This enables the district to have access to utility services and employment opportunities. It also serves as a satellite sub urban settlement for city dwellers. It has good access to educational, health and other social infrastructure. It is accessed by trans national highways such as the Achimota-Nsawam and Mallam Junction-Winneba Highways.

(iii) Selected Communities: The communities in which the studies were conducted were also selected from the two districts. The choice of a community was determined on the basis of its ability to access all road types and the condition of the road leading to the community. A total of four communities were selected from the two districts with two communities selected per each district and one of the communities per district was with good access and the other was with poor access. The objective was to obtain a balanced perspective from each category. Amasaman the district capital with good access and Aiyikai Doblo which is about 25km from the district capital with poor access were selected from the Ga West Municipal Assembly. Sege an urban centre with good access and Toflokpo a 14km village with poor access were selected from the Dangbe East district. The location of the selected districts and the communities are given in Appendix 5.14.

2. Sampling Design

Representative samples of community members were selected for interviews within in each community. The sample frame was defined as the active population of each district. This was obtained from the Ghana population census (2001). The population was projected to the year 2004 using Equation 5.3 and the results are as summarised in Table 5.23.

$P_t = p_o\,(1+r)^t$ Equation 5.3

P_o = The present population

P_t = The population at the end of the planned period

r = the growth rate

t = the time period

Table 5.23: Projected Population by District

Name of District	2000 Population	Growth Rate ® in Percentage	Time Period	1+r	$(1+r)^t$	Projected Population (2204) (n)
Dangbe East	93,112	0.023	4	1.023	1.10	101,978.4
Ga West	96,809	0.021	4	1.021	1.09	105,2007

The sample size for the selection of the representative population for the surveys was developed on the basis of the following formula by Cochran, W.G (1963):

$$n = \frac{N}{1 + N(\mu)^2}$$ Equation 5.4

where;

N = Total Population for the two districts;

μ = Margin of error allowed in the sample size and

n = Estimated Sample Size

The sample size for each district was further reduced by the proportion of children within the age cohort of ≤16 years to determine the adult population eligible for the survey. The total sample size was estimated to be 213.5 for the two districts. Thus an average of 50 households was interviewed in each community. Different categories of people were randomly selected for questionnaire administration by field enumerators. The detail of the estimates on the sample size is presented in Table 5.24.

Table 5.24: Estimation of Sample Size

Total Population of Selected Districts (N)	μ	μ^2	$N(\mu^{2)}$	$1+ N(\mu^{2)}$	$\frac{N}{1+N(\mu)^2}$
207,179.1	0.05	0.0025	517.9	518.9	399.23
	Estimated Sample Size		Percentage of Children		Adjusted Sample size
Proportionate Allocation to Dangbe East	(101,978.40/207,179) = 195.34		48		101.5
Proportionate Allocation to Ga West	(105,200/207,179) = 203.5		45		111.9
Total Sample Size	213.5				

3. Pre- Interviews

Sudman (1976) suggests that a minimum of 100 elements is needed for each major group or subgroup in the sample and for each minor subgroup, a sample of 20 to 50 elements is necessary. Therefore an initial survey was conducted for the identification of the elements of the sub criteria using the 50 member sample size per each community. It involved interviews with passengers, transport operators and household members in the selected communities. Each community provided a list of social benefits and costs associated with road maintenance. The elements identified were ranked by order of importance over a scale of 1 to 4 by the respondents. The highest ranked social benefit or cost was awarded the highest score of 4, the next highest was awarded 3 points, the third highest was awarded 2 points and the lowest was awarded 1 point. Elements which scored below 1 were eliminated from further analysis. This is consistent with the theory of elimination by choice by Tversky, (1979). The types of social benefits defined at the community level on the elements at the sub criteria level 3 included increased access to employment, increased access to health, increased access to education and information as well as improved social interaction. The ranked distribution of social costs at the community level for both good and bad roads is presented in Table 5.25.

Table 5.25: Social Benefit Ranking at Sub Criterion Level (Community Level)

Social benefit Types	Ga East Municipal		Dangbme East District		Combined	
	Amasaman (Good Access)	Aikai Doblo (Poor Access)	Sege (Good Access)	Toflokpo (Poor Access)	Score	Overall Ranking
Increased access to Health facilities	N/A	√ (1)	√ (3)	√ (1)	14	2
Creation of employment opportunities	√ (1)	√ (1)	√ (1)	√ (1)	16	1
Increased Access to Education	√ (4)	N/A	√ (1)	√ (1)	9	3
Increased Access to Information	N/A	N/A	√ (2)	N/A	3	5
Increased Social Interaction	√ (4)	√ (2)	√ (2)	N/A	7	4

- Increased Access to Employment: All the communities ranked access to employment as the highest social benefit from road maintenance interventions. This was defined in terms of employment from construction works, access to other employment opportunities which hitherto were non existent in the communities as well as increased outputs from existing employment activities.

- Increased Access to Health Facilities: This was ranked as the second highest social benefit at the community level. Generally the communities with poor access rated this benefit higher than those with good access.
- Increased Access to Educational Facilities: This was considered to be important in both communities with good and bad access mostly in relation to higher levels of educational facilities which are non existent in low populated communities and for which students travel outside their communities to access.
- Increased Social Interaction: The ability to meet social obligation through interactions was considered to be the next important social benefit from road maintenance by most communities especially those communities with improved access. This is due to the ability to attend essential social functions and to meet social obligation.
- Increased access to information: This was eliminated since it is considered to be a function of social interaction. This satisfies Saaty's (1990), requirement to include enough relevant detail to represent a criteria in AHP analysis.

The types of social costs associated with road maintenance expressed at the community level included increased traffic accidents, pollution, negative cultural practices, increased spread of HIV and other diseases as well as increased crime and insecurity. The summary is provided in table 5.26.

Table 5.26: Social Costs Ranking at Sub Criterion Level (Community Level)

Social Costs	Ga East Municipal		Dangbme East District		Combined	
	Amasaman (Good Access)	Aikai Doblo (Poor Access)	Sege (Good Access)	Toflokpo (Poor Access)	Score	Overall Ranking
Increased road accidents	√ (1)	N/A	√ (1)	√ (2)	11	1
Increased insecurity and Crime	√ (1)	N/A	√ (4)	N/A	5	5
Increase in diseases (HIV/AIDS)	√ (2)	√(4)	√(3)	N/A	6	4
Water and dust pollution	N/A	√ (1)	√ (2)	√(4)	8	2
Negative cultural influence	√ (1)	N/A)	√ (2	√(3)	7	3

- Increased Accidents: Increased traffic accidents was considered to be the most important social cost related to road maintenance interventions especially for communities with good access. This is attributed to the high rate of accidents associated with improved roads due to over speeding from reduced road roughness.
- Pollution: Dust and water pollution was considered to be the next highest social cost to all communities. This is due to the fact that most communities are served by unpaved feeder roads which make them susceptible to dust pollution. The problem is also identified with pollution during construction works especially on urban and trunk roads.
- Negative Social Practices and Spread of HIV and AIDS: These are associated with exposure and increased interaction with others outside the communities due to increased in and out migration related to road maintenance.
- Insecurity and crime was considered to be a part of the exposure to negative cultural practices so was eliminated from the analysis

4. Pairwise Ranking by Community Surveys

A sample of 20 household members per each community who participated in the pre interviews were selected for the pairwise comparison of the elements set at the criteria levels 1, 2 and sub criteria level 3. The pairwise comparison involved a rating of each criterion or sub criterion according to their relative importance over the other. That is the following comparisons were made at each criteria level.

(i) Criteria Level 1: Economic benefits were compared with social benefits

(ii) Criteria Level 2: Economic benefits were compared to economic costs. However the elements of these parameters were obtained from HDM-4 outputs on NPV which represented economic benefit and road maintenance cost which represented economic cost.

(iii) Criteria Level 2: Social benefits were compared with social Costs.

(iv) Sub Criteria Level 3: Each element of social benefit was compared with each other and each element of social cost was compared with the other.

The comparison was done on the basis of a verbal scale of preference of one factor for the other on a numerical judgment scale of 1 and 9. The relative weightings scale is presented in Table 5.27. A value of 1 was assigned if both criteria were equally important, and a value of 9 if the criterion being compared was clearly more important than the other

Table 5.27 Relative Weightings for the Criteria

Intensity of importance	Definition
1	Equally preferred
2	Equal to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very strongly to extremely preferred
9	Extremely preferred

5.3.2 Data Collection at the Meso or District level

This was based on focus group survey method. Interviews were conducted with selected officials of the Metropolitan, Municipal and District Assemblies and representatives of two drivers union that is the Ghana Private Road Transport Union (GPRTU) and the Progressive Transport Drivers Union (PROTOA). Officials of two Non Governmental Organisations (NGOs) engaged in development work that is the World Vision and Adventist Development Aid (ADRA) as well as representatives of two Market Women's Associations were also included along with two representatives of the local traditional council. Initial visits were made to present the objectives of the study to the leadership of the respective organisations prior to the sessions. About 10 informants were composed for each session which lasted for two hours for each district. Pairwise comparisons on the factors defined at the criteria levels as well as on elements of sub criteria level defined were conducted at the sessions.

5.3.3 Data Collection at the Macro levels

The key informant survey method was adopted for the surveys at this level. It involved interviews with top government officials from four Government Ministries affiliated with road works in Ghana. These were the Ministries of Roads and Transport (MRT); Finance and Economic Planning (MOF), Local Government (MLG) and the National Development Planning Commission (NDPC). Nominated officials of each agency were interviewed on scheduled appointment with each session lasting for up to an hour and a half time duration. A total of 16 officials were interviewed with 4 officials from each ministry or agency. Pairwise comparisons on the factors defined at the criteria levels as well as on elements of sub criteria level defined were conducted at the sessions.

5.3.4 Data Processing for Stated Preference Model

The outputs on the preference rating of one element over the other in the pairwise comparison on a scale of 1 to 9 at the each criteria level was compiled by road type for each administrative level and the details are presented in the following paragraphs.

5.3.4.1 Data Processing at the Criteria Levels 1 and 2 for all Administrative Levels by Road Type

The factors on economic benefits and social benefit in criteria level 1 and the economic benefit and costs in criteria level two and social benefits cost also at criteria level 2 were predefined on the basis of Ghana development objectives. The completed questionnaires with the defined rating on a scale of 1 to 9 were compiled on the basis of the output at each administrative level by road type. A sample output is presented in Table 5.28 for the pair-wise comparison of the economic and social benefits for trunk road maintenance at the community level.

Table 5.28: Comparison of Economic and Social Benefits- Trunk Roads

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Scale of Economic Preference									Equal Preference	Scale of Social Preference								
High to Low Preference										Low to High Preference								

The data processing was conducted such that if economic benefit was ranked as 4 as compared with social benefit for trunk roads at the criteria level 1, then 4 was recorded for economic benefit and 0 for social benefit. The average of all the entries per each category that is either economic or social benefit for the number of questionnaires per each locality was estimated as the representative score for that component for that particular road type. The value of the component with the highest average score is reduced by the margin of score of the component with the lowest score to obtain the representative sample which was used for further analysis.

For example if the average score for all community members per one locality on economic and social benefits were 4.75 and 0.7 respectively for trunk roads, then the lowest score which the score for social benefits is subtracted from the value of the component with the highest score which economic benefits as 4.75 – 0.7 to obtain a represented score of 4.05. This is then used to represent the preference scale on economic efficiency for trunk roads at the community level. A sample of the summary of scores by road type at criteria level 1 on economic and social benefits for each administration level is given in Appendix 6.16. The same procedure was repeated for the summary of scores by road type at criteria level 2 on social benefits and costs for each administration level and the result is given in Appendix 5.17.

5.3.4.2 Data Processing at Sub Criteria Level 3 for all Administrative Levels by Road Type

A compilation of the elements of the social benefits and costs identified at all administration levels at the sub criteria level 3 is given Appendix 5.18. The results of the first four highly ranked elements on social benefits and costs at the sub criteria level 3 for each administrative level is presented in Table 5.29.

Table 5.29: Selected Elements of Benefits and Costs at Different Levels

Item	Investigation Levels		
	Micro Community	Meso (District)	Macro (National)
Social benefits			
Creation Of Employment	√	√	√
Access to Health	√		
Access to Education	√		
Increased Social Interaction	√		
Access to Amenities		√	√
Induced Housing		√	
Increased Access to Land		√	√
Increased Access to Information			√
Social Costs			
Increased Road Accidents	√	√	√
Negative Cultural Values	√		
Dust Pollution	√	√	√
Spread of HIV/AIDS	√		√
Disruption of Services		√	
Increased Crime			√
Increased Land Prices		√	

The results indicated that there were similarities and differences in the elements on social benefits and costs identified at the three administrative levels. Social benefits such as employment creation and access to social services were common at all levels. Others such as increased access to land and induced housing were of higher priority at the district level whilst increased social interaction was mentioned only at the community level. Similarly the elements of social costs that were common to all three administrative levels were increased accidents and dust pollution. However, the spread of HIV/AIDs was mentioned at the community level, increased crime was mentioned at the national level and disruption of utilities and increased land prices were mentioned only at the district level. The summary of pairwise comparison of these elements on a scale of 1-9 generated at the community, district and national are given in Appendix 5.19 for social benefits and 5.20 for social costs.

5.4 DATA FOR TESTING MODEL SENSITIVITY

A new data set on road length, condition and traffic characteristics based on 2005 to 2009 data was used to validate the deterministic model. The new data set was based on changes in the length of the road network, road condition, traffic growth, unit rates and vehicle costs. There was an average of over 30 percent increase in the length of feeder roads between 2004 and 2007. The highest increase involved feeder roads at an average of almost 50 percent. The road condition mix also changed within the period. Even though, the road length increased, the length of roads in good condition reduced by 7 percent, those in fair condition reduced by an average of 6 percent, whilst those in poor condition increased by 28 percent. There was an average of about 12 percent increase in the unit rates. Vehicle price increased by an average of about 200 percent A summary is of the 2004 and 2007 is provided in Appendix 5.21.

5.5 ESTIMATION OF AVAILABLE BUDGET

The threshold of available road fund was estimated from records of allocated roads fund threshold to the three road agencies in Ghana for the period 2000 to 2004 by the Ministry of Roads and Transport (MRT). The details are presented in Table 5.30.

Table: 5.30: Road Fund Allocation by Road Sector (2000-2004)

Road Type	Amount Allocated by Year (US $M)					
	2000	2001	2002	2003	2004	Total
Trunk	17.1	16.7	24.4	28.6	40.9	127.7
Urban	29.81	22.7	32.8	31.5	30.0	146.31
Feeder	7.90	15.0	18.0	23.00	25.0	89.3
Total	54.8	53.9	75.2	83.1	96.3	363.29
Average	18.7	17.92	25.07	27.7	32.1	121.1

Source: Statistical and Analytical Report - Transport Indicators Data Base (2000-2004)

5.6 SUMMARY

This chapter has presented the data collection methods and the results of the processed data used for the HDM-4 and RUC analysis. It has also presented the methods used for deriving the data for the stated preference based approach by pairwise comparison of selected elements at the criteria and sub criteria levels at three administrative levels for each road type. The data has been presented in frequency tables and figures. A description of the mode by which each data set was used to develop the DM and the SPM are presented in chapters six and seven respectively.

CHAPTER SIX DEVELOPMENT OF A MODEL WITH DETERMINISTIC APPROACH

6.1 INTRODUCTION

This chapter presents the development of the model with deterministic approach for road fund Allocation. It is in four parts. The first part presents the specified functional form of the model with deterministic approach. The second part presents the procedure for the estimation of the values of the model parameters. The third part presents the model validation and the fourth part presents a worked example. Figure 6.1 illustrates the framework of the chapter presentation and the steps involved are summarised as follows.

1. Specification of model functional form.
2. Estimation of input parameters.
3. Model validation
4. Worked Example

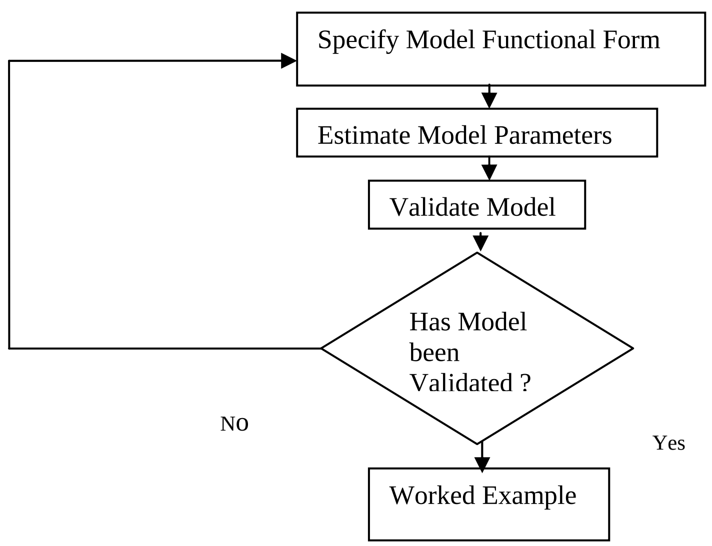


Figure 6.1: Framework of Chapter Presentation

6.2 MODEL SPECIFICATION

Conceptually, it is proposed in this model that the total road fund budget available will be allocated for the maintenance of the different road types on the assumption that road maintenance does not generate wider social impacts. Then the proportion of the road funds allocated for the maintenance of each road type will be internally sub divided on the basis of two criteria, namely economic efficiency and egalitarian equity. The model structure proposed for allocating the road maintenance funds by each road type is illustrated in Figure 6.2 and expressed by Equation 6.1

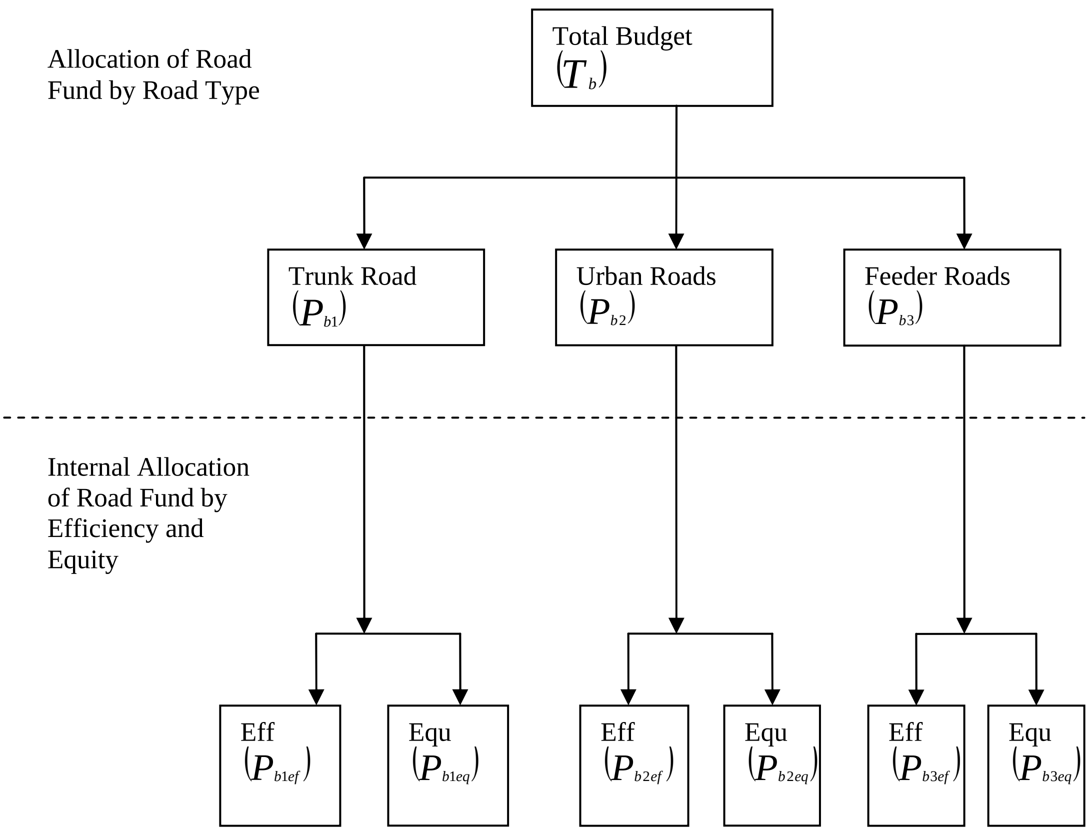


Figure 6.2: Framework for Road Fund Allocation by a Model with Deterministic Approach

(i) $P_{bi} = T_b \left[\alpha_i r_{bief} + \beta_i (1 - r_{bief}) \right]$ Equation 6.1

Where;

P_{bi} = Proportion of total budget allocated to the i^{th} road type.

T_b = Total budget to be allocated

α_i = The coefficients for the internal division of funds allocated to the i^{th} sector for efficiency.

β_i = The coefficients for the internal division of funds allocated to the ith sector for equity

r_{bief} = The proportion of the internal allocation for efficiency and it is expressed as;

$$r_{bief} = \frac{1}{(\alpha_i - \beta_i)}\left(\frac{P_{bi} - \beta_i T_b}{T_b}\right) \qquad \text{Equation 6.2}$$

then

(ii) $P_{bief} = r_{bief} \cdot P_{bi}$ Equation 6.3

and

$$P_{bieq} = P_{bi} - P_{bief} \qquad \text{Equation 6.4}$$

$(i = 1,2,3)$

Where;

P_{bief} =The portion of the proportion of the road fund allocated by road type which is sub divided for efficiency.

P_{bieq} =The portion of the proportion of the road fund allocated by road type which is sub divided for equity.

6.3 ESTIMATION OF MODEL PARAMETERS

The procedure for estimating the input parameters for the model with deterministic approach (DM) was in three parts. The first part involved the estimation of the proportion of the road fund allocated for the maintenance of each road type using the value function model (VFM). The second part involved the determination of total budget available for road maintenance. The third part involved the use of the concept of efficiency frontier to estimate model coefficients for the internal allocation of the proportion of the road fund allocated to each road agency into efficiency and equity components. The steps are summarised below and the details are discussed in the following chapters.

1. Estimate the proportion for the allocation of road fund by each road type with the value function model (VFM).
2. Estimate the total available road maintenance budget.
3. Estimate coefficients for the allocation of proportion of fund allocated by road type into efficiency and equity components using the concept of efficiency frontier

6.3.1 Estimation of Input Parameters for the Proportionate Allocation of Road Fund by Road Type by the Value Function Model.

The use of the value function model (VFM) for the proportionate allocation of the road fund for the maintenance involved the estimation of a ratio scale for each road type. The ratio scale was generated from a value score on a set of attributes with assigned weights. The procedure for estimating input variables with of the VFM is illustrated in Figure 6.3.

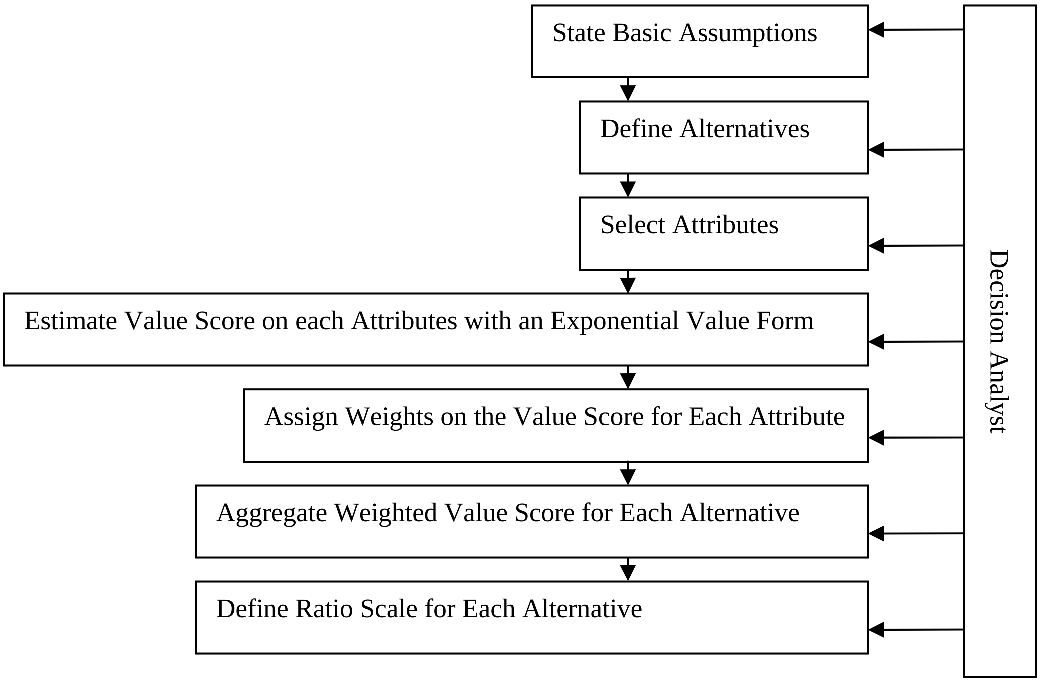


Figure 6.3: Procedure for Estimating Input Variables with VFM

6.3.1.1 Statement of Basic Assumptions

The application of the value function model (VFM) was based on the assumptions indicated in the following paragraphs.

1. A value function (VFM) can be based on the formalization of subjective preference or known values, (Keeney, 1976). The approach adopted in this research was based on known values. This was to satisfy the requirement for certainty of values in a model with a deterministic approach.

2. The VFM involves decision alternatives which are candidate factors from which a choice is made. It was assumed that each of the alternatives determined to be eligible for road fund allocation in this study can be evaluated on the basis of defined attributes.

3. Attributes are evaluators used as reference points for assessing the alternatives, (Tversky and Kahneman, 1991). Each attribute was evaluated as a need of an aspect of a road maintenance system which should justify fund allocation and not as a benefit to be gained if funds are allocated.
4. The selection of attributes was not exhaustive in this analysis. Factors such as environmental effects, accidents and political concerns were not considered for lack of accurate data.
5. The value score was estimated with a weighting interval scale of preference between [1, 0], (Keeney and Raiffa, 1993).
6. An exponential value form based on the standard equation for an ‘s’ shaped function was used. This is on the basis of the inherent nature of life cycle assessment associated with an ‘s’ shaped function. It assumes that the product of each attribute can have both gains (concave function) and losses (convex), (Clemen, 1991). This is such that the low range of the attribute need increases slowly where the curve is almost flat; then gets into a range of concern and increases rapidly where the curve has a steeper slope; but reaches some critical level in the need beyond which the level is minimal and the curve flattens out, (Kalyanaram and Winer, 1995). The function was applied to address the problems associated with forecasting of long term impacts of road investment.
7. Even though weighting in MCA’s are often assessed subjectively, (Stewart, 1992), an objective weighting method was used in this study due to the need for certainty of values in a model with a deterministic approach.
8. The selected attributes and the preferences stated in the model are not static and could be subject to continual revision.

6.3.1.2 Definition of Alternatives: The choice of alternatives in MCA analysis are usually thought of as either ‘given’ in the sense that they are a prior and strictly defined. They may also result from systematic exploration of the objectives pursued. For purposes of this research the alternatives were prior defined as the three road types who are recipients of the road fund in Ghana. These are Trunk, Urban and Feeder roads.

6.3.1.3 Selection of Attributes

The attributes were selected on the basis of the following conditions, (Roy, 1996).

1. Completeness: That is shared commonality by all alternatives, availability of information, ease of access, ease of understanding to policy makers and the commonality of the scale of measurement.
2. Objectivity: That is the ability for an attribute to be numerically judged against another.
3. Avoidance of Double Counting: Each attribute presented a separate point of view with a threshold of acceptable performance. Sub functions were not considered in the analysis to avoid double counting.
4. Dominance: All attributes were assessed on equal basis with none being considered to be more desirable than the other, (Howard, 1966).
5. Dynamically Changing and Imprecise Preference: The attributes selected and the preferences stated in the model are not static and could be subject to continual revision.
6. The number of attributes was more than three as suggested by Debreu, (1960) for accuracy;

The selected attributes consisted of three basic physical characteristics of a road network system and one operational factor and these are presented as follows.

(i) Road Length: This was to determine the physical quantity of the road network by road type measured in terms of kilometers. It was assessed as a monotonically increasing attribute such that the higher the value the higher the associated need for maintenance.

(ii) Traffic (AADT): Traffic was defined as need in terms of its contribution to road deterioration and the related effects on travel delays and safety. It was also considered to be a monotonically increasing measure.

(iii) Condition (IRI): This was defined as a need in terms of loss of investments in road improvement and VOC effects. It was applied as a monotonically increasing function such that higher the IRI, then the higher the need for maintenance.

(iv) Percentage of Work Achievement: It reflects the capacity of road each agency. It was defined as monotonically increasing such that the higher percentage of work achieved the higher the need for more funds. The goal for the selection of each attribute is summarized in Table 6.1.

Table 6.1: Description of Selected Attributes

Attributes	Justification for Selection	Performance Measure
Length	To maximize the total length of the maintainable road network	Kilometers
Traffic	To minimize vehicle operating cost	Average Annual Daily Traffic
Condition	To minimize the proportion of roads in poor condition	IRI
Percentage of Work Achievement	To determine the ability of each agency to meet set targets	Percentage

The hierarchical relationship between the objectives of study, the alternatives and the selected attributes is represented in Figure 6.4.

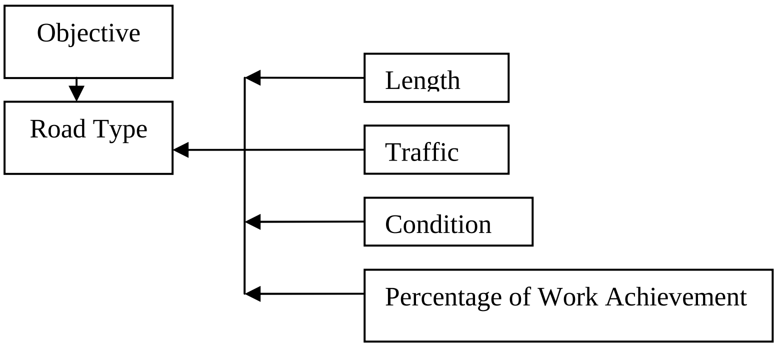


Figure 6.4: Hierarchical Relationship between Objective, Alternatives and Attributes

The correlation between the selected attributes and required conditions on an attribute is summarised in Table 6.2.

Table 6.2: Conditions on Selected Attributes

Condition for Selection of Attributes	Margin of Satisfaction
Completeness	All selected attributes are common to the three road types
Objectivity	All the selected attributes are nuerically quantifiable
Avoidance of Double Counting	Each attribute represents a separate point of view
Dominance	None of the road types dominated all others on all attributes. (Refer to Section 6.3.1.4 Step 3)
Number of attributes	The number attributes selected are more than three

6.3.1.4 Estimation of Value Scores on Each Attribute

The main steps adopted for estimating the value score for each attribute is presented in the following paragraphs;

Step 1 Determination of Values for Selected Attributes: The values on road length, traffic and road condition were determined by road type for each representative road section. They were derived from the road representative matrix used for the HDM-4. The information on the percentage of work achievement was estimated from trends of maintenance performance by road type in Ghana from 2000 to 2004. A summary of the maximum and minimum values as well as the arithmetic mean for each attribute for the representative road sections is presented in Table 6.3.

Table 6.3: Value of Attributes for a Road Section

Value of Attributes	Road Type		
	Trunk	Urban	Feeder
Road Length			
Maximum	605.60	4189.0	3,974.00
Minimum	36.10	0.60	13.30
Average	205.90	283.70	735.80
Traffic (AADT)			
Maximum	13,781.00	16,612.00	1,310.00
Minimum	662.00	126.00	65.00
Average	5063.90	5175.10	515.10
Road Condition by (IRI)			
Maximum	18.80	18.60	13.90
Minimum	3.40	4.20	4.50
Average	10.75	8.9	8.20
Percentage of Work Achieved			
Maximum	89.00	120.00	193.00
Minimum	65.00	20.00	44.00
Average	75.00	68.00	59.00

Step 2 Determination of Additivity: All the attributes were determined to be mutually independent since logically changes in any paired set will not effect changes in other pairs if the other pairs are held constant.

Step 3 Test of Dominance in all Attributes by Road Type: A test of dominance was undertaken to determine whether an alternative or a road type dominated the others on all attributes. Using the attribute values given in Table 6.6, a value path of the attribute values was displayed as indicated in Figure 6.5, (Keeney and Raiffa, 1980). The results indicated that no single road type dominated the others on all attributes.

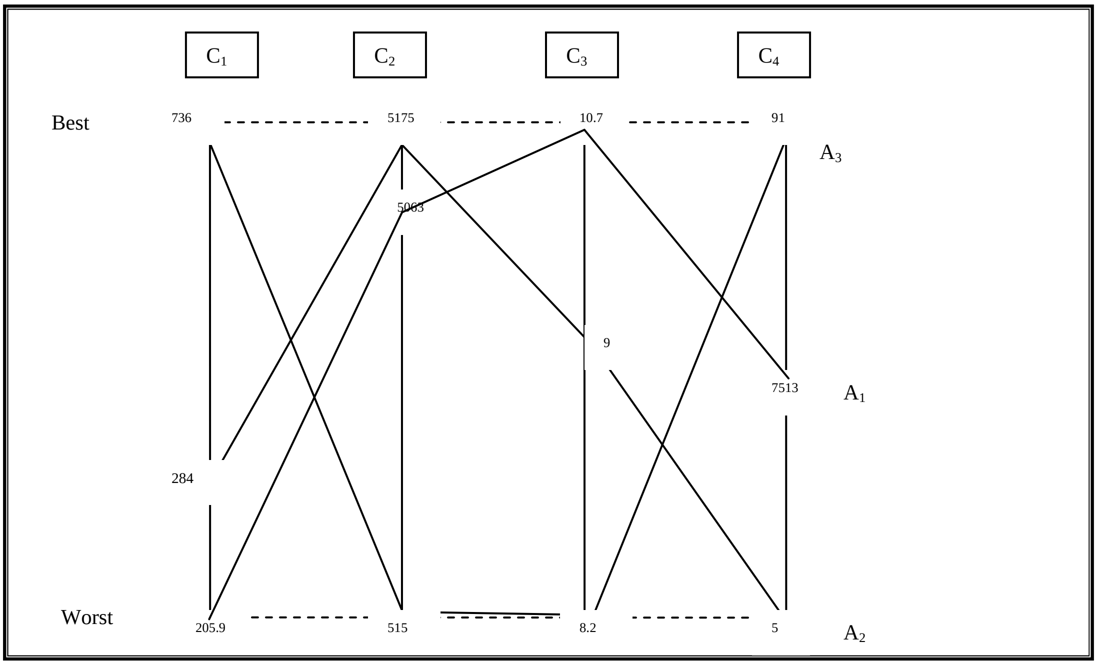


Figure 6.5: Display of Value Path for Each Attribute

Step 4 Estimation of Value Score: The value score was estimated on the basis of an ‘s’ shaped exponential value form as applied in the context of a need score by Kulkarni *et al*, (2004) using the expression:

$$v_j(x_j) = 1 - \exp\left[-\frac{3(x_j - x_{j\min})^2}{(x_{j\max} - x_{j\min})^2}\right] \qquad \text{Equation 6.1}$$

Where;

$v_j(x_j)$ = The need Score

x_j = is value of an attribute for a road section defined as a proportion to the maximum level of an attribute.

$x_{j\min}$ = minimum level of attribute x which is equated to zero.

$x_{j\max}$ = maximum level of attribute x which is equated to 1.

and $(j = 1,2,3,4)$

A need score on each attribute for each road type by the representative section in the road matrix was estimated. For example, from Table 6.6;

Let;

the length of the longest section in the matrix of representative road sections for trunk roads = 605.6km

and

the length of the shortest section in the matrix of representative road sections for trunk roads = 36.1km

then let the length of a selected trunk road section in the representative road matrix be = 416.5km

If the maximum and the minimum values of the trunk road length are rescaled as;

$x_{j\max}$ for Trunk Road Length = 1

$x_{j\min}$ for Trunk Road Length =0

and

x_j is estimated as; $\frac{416.5}{605.6} = 0.687$

the need score for trunk the road section with length 416.5km was estimated as;

$$\text{Need Score} = 1 - \exp\left[-\frac{3(0.687-0)^2}{(1-0)^2} = 0.758\right] \qquad \text{Equation 6.2}$$

A graphical representation of the need score for the select road section in the above example is given in Figure 6.6. The distribution points of the need score estimated by rescaling the minimum and maximum values of the trunk road length to 0 and 1is represented on the horizontal axis. The values of the lengths of the road sections in the representative matrix are represented on the vertical x axis. The need score for the road section of length 416.5km can then be determined from the value of the need score to be about 0.758 on the graph.

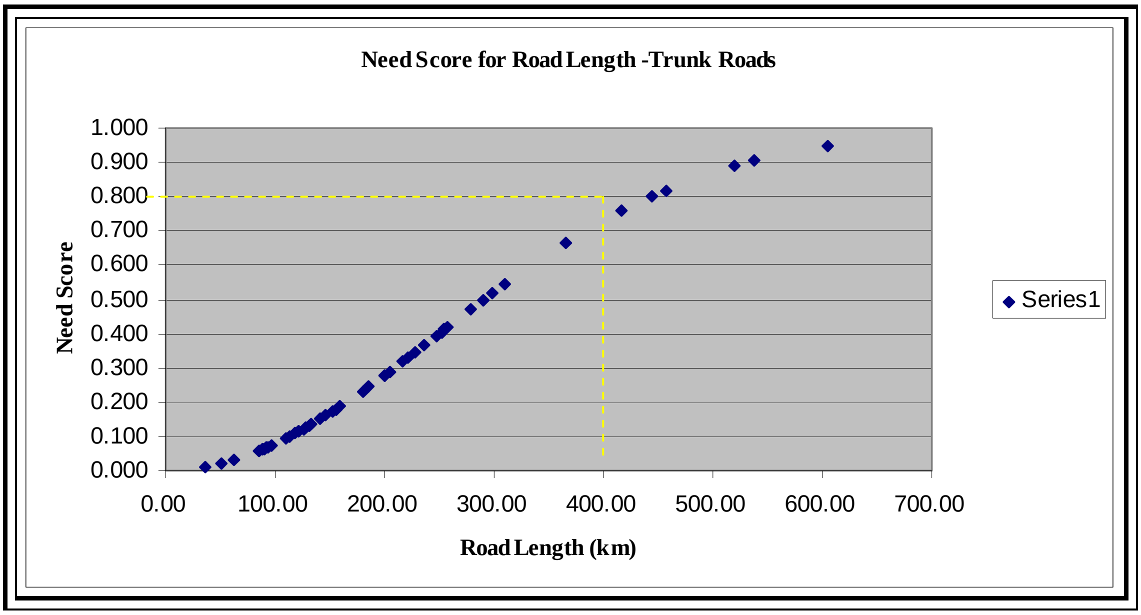


Figure 6.6: Estimated Need Scores for Trunk Road Length

The same procedure was applied to generate the need scores for all attributes, for all road sections, for all road types that is trunk, urban and feeder. Samples of the details of the estimated need scores for trunk road, urban and feeder roads are given in Appendix 6.1, 6.2 and 6.3 respectively.

Step 5 Assessment of the Performance of Each Attribute: The performance of each attribute for each road type was assessed on the basis of the need score estimated for the arithmetic mean of an attribute. The arithmetic mean was used as reference point. The margin by which a mean value of an attribute was considered to be representative was tested with a test of the margin of standard error (SE). The inference was that if three times the standard error was larger than the mean then the error margin was significant so the mean value should be rejected. Table 6.4 presents the summary of the estimated standard errors for each attribute for each road type using the mean value of each attribute for each road type presented in Table 6.3.

Table 6.4: Test of Standard Error for Mean Attributes

Statistical Description	Attributes			
	Length (km)	Traffic (AADT)	Condition (IRI)	Percentage of Work Achievement
Trunk Roads				
Mean	205.95	5,063.98	10.75	74.9
Sample Size	52	52	5.2	5
Standard Error (S.E)	18.7	640.26	0.8	5.3
(S.E x 3)	54.7	1920.8	2.3	16.0
Inference	Not Significant	Not Significant	Not Significant	Not Significant
Urban Roads				
Mean	283.7	5175.1	8.9	68.0
Sample Size	26	26	26	0.37
Standard Error (S.E)	161.9	974.1	0.88	0.165
(S.E x 3)	485.8	2922.5	2.6	0.497
Inference	Significant	Not Significant	Not Significant	Not Significant
Feeder Roads				
Mean	735	515.1	8.2	59.0
Sample Size	27	27	27	5
Standard Error (S.E)	210.3	89.1	0.65	0.273
(S.E x 3)	630.9	267.2	1.94	0.819
Inference	Not Significant	Not Significant	Not Significant	Significant

From the result of the analysis, it was realized that the error margins of the mean values of the road length for the urban roads and the percentage of work achievement for feeder roads were significant. The extreme values of the attributes causing the significance of the error margins were assessed by the Nairs' method of rejection of outliers using the formula:

$$\left| \frac{T_m - \overline{T}}{\sigma} \right| \qquad \text{Equation 6.2}$$

Where;

T_m = is the greatest or the smallest value of T that can be expected in a sample size n at a significance (probability) level of 5 percent.

$\overline{T}$ = is the mean of the distribution and

σ = is the standard deviation of the distribution.

The values of the extreme deviates were the maximum value of 4289km for urban roads and the value for the percentage of work achieved for feeder roads was 193 percent. A test for extreme deviation was applied to these values. A summary of the results is presented in Table 6.5.

Table 6.5: Estimation of Critical Levels of Extreme Deviates

Statistical Description	Urban Roads Length	Feeder Roads Percentage of Work Achievement
Mean	283.7	0.59
Standard Deviation	825.84	0.61
Greatest Value	4289	1.93
Sample Size	26	5
Level of Significance	5%	5%
Estimated Deviation	4.85	2.18
Not to be rejected value of Deviation at 5%	2.59	2.49

From the results, the ‘not to be rejected’ value for the percentage of work achievement for feeder roads maintenance indicated in Table 6.6 at a degree of freedom v was larger than the estimated deviation. Therefore the value was accepted. However the ‘not to rejected; value for the urban road length was smaller than the estimated deviation. Therefore the value was rejected.

Table 6.6: Values of Extreme Deviate 'Not to be Rejected' as Outliers

5 Percent Level of Confidence							
	n						
V (Degree of Freedom)	3	4	5	6	7	8	9
10	2.02	2.29	2.49	2.63	2.75	2.85	2.93
11	1.99	2.26	2.44	2.58	2.70	2.79	2.87
12	1.97	2.22	2.40	2.54	2.65	2.75	2.83
13	1.95	2.20	2.38	2.51	2.62	2.71	2.79
14	1.93	2.18	2.35	2.48	2.59	2.68	2.76
15	1.92	2.16	2.33	2.46	2.56	2.65	2.73
16	1.90	2.14	2.31	2.44	2.54	2.63	2.70
17	1.89	2.13	2.30	2.42	2.52	2.61	2.68
18	1.88	2.12	2.28	2.41	2.51	2.59	2.66
19	1.87	2.11	2.27	2.39	2.49	2.58	2.65
20	1.87	2.10	2.26	2.38	2.48	2.56	2.63
24	1.84	2.07	2.23	2.35	2.44	2.52	2.59
30	1.82	2.04	2.20	2.31	2.40	2.48	2.55
40	1.80	2.02	2.17	2.28	2.37	2.44	2.51
60	1.78	1.99	2.14	2.25	2.33	2.41	2.47
120	1.76	1.97	2.11	2.21	2.30	2.37	2.43
∞	1.74	1.94	2.08	2.18	2.27	2.33	2.39

Source: K. R. Nair, Biometrika, Vol 39, 1952, pp. 189-191.

With the rejection of the extreme deviate a new mean and standard deviation were derived without the extreme values for urban road length. A test of the margin of error on the new mean is indicated in Table 6.7. The new mean was accepted since three times the value of the recalculated standard error was lower than the mean.

Table 6.7: Test of Errors Without Extreme Values

Verification of Standard Error	
New Mean	123.49
New Standard Deviation	123.52
New Standard Error	24.22
New S.E * 3	72.65

The values of the attributes used for estimating the needs scores with the replaced mean for urban road length are summarized in Table 6.8.

Table 6.8: Revised Attributes Values

Value of Attributes	Road Type		
	Trunk	Urban	Feeder
Road Length			
Maximum	605.6	380.6	3,974.0
Minimum	36.1	0.6	13.3
Average	205.9	283.7	735.8
Traffic (AADT)			
Maximum	13,781.0	16,612.0	1,310.0
Minimum	662.0	126.0	65.0
Average	5063.9	5175.1	515.1
Road Condition by (IRI)			
Maximum	18.8	18.6	13.9
Minimum	3.4	4.2	4.5
Average	10.7	8.9	8.2
Percentage of Work Achieved			
Maximum	89.0	120.0	193.0
Minimum	65.0	20.0	44.0
Average	75.0	68.0	59.0

On the basis of the corrected means, the need score on each attribute for each road type is summarised in Table 6.9 and illustrated in Figure 6.7.

Table 6.9: Estimated Need Score on Each Attribute by Road Type

Alternatives	Attributes			
	Length	AADT	Condition	Percentage of Work Achievement
Trunk	0.29	0.33	0.62	0.89
Urban	0.27	0.25	0.50	0.77
Feeder	0.098	0.37	0.697	0.834

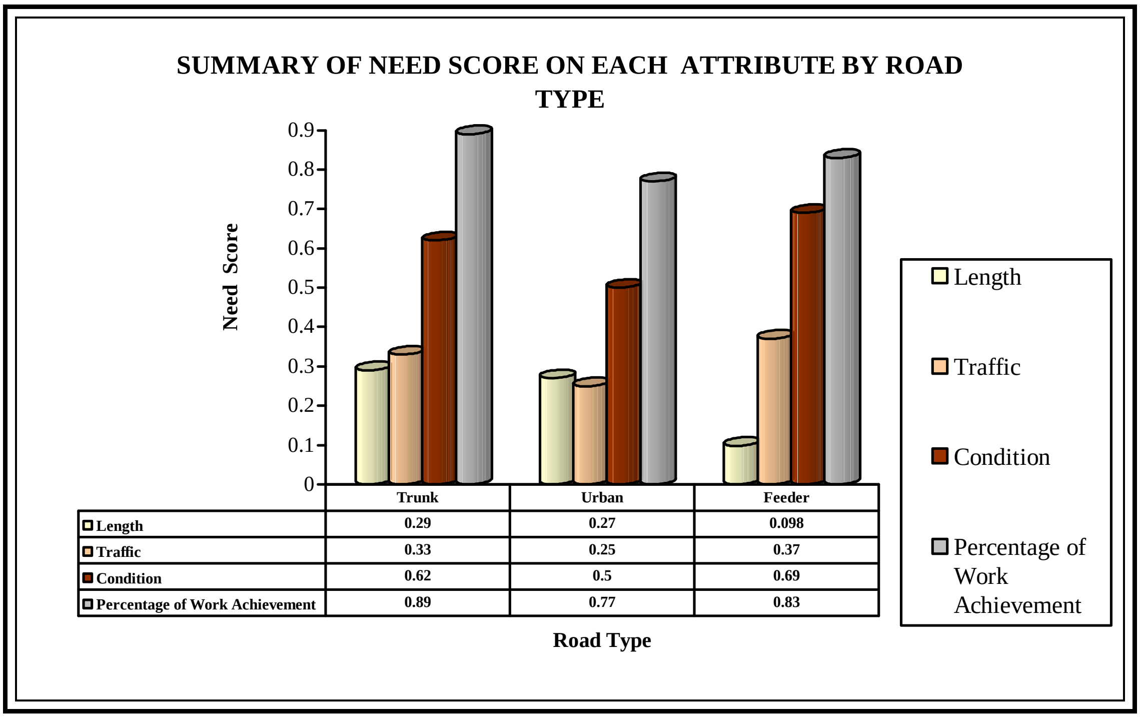


Figure 6.7: Summary of Need Score by Attribute for Each Road Type

6.3.1.4 Assignment of Weights on Needs Score for Each Attribute: The methods used for assigning weights were based on two weighting functions. The first was based on a weighting formula and the other by equivalent lotteries. The details are described in the following paragraphs.

(i) The Rank Order Centroid (ROC) Weighting Method: The ROC weighting method by Edwards and Barron (1994) was adopted for the assignment of weights on the estimated need scores for each attribute by road type. This was based on equation 6.4. The ROC was used because of its objectivity, ease of understanding and the precision of the outcomes. The details are presented as follows.

$$k'_j = \left(\frac{1}{n}\right)\sum_{j=1}^{n}\left(\frac{1}{v_j(x_j)}\right) \qquad \text{Equation 6.4}$$

and

k'_j = Estimated Weight on the need score for attribute i

n =the number of attributes considered

For example from Table 6.12, let the need score for trunk roads length = 0.29

and $\frac{1}{v_j(x_j)} = \frac{1}{0.29}$

which is;

=3.45.

If n = 4

then

$\frac{1}{n}$ = is 0.25.

If $\sum \frac{1}{v_j(x_j)}$ = 17.36

then

(k'_j) = 4.34

The estimated (k'_j) for each attribute based on the ROC are indicated in Table 6.10.

The estimated weights were normalised by Equation 6.5 as

$$k_j = \frac{k'_j}{\sum_{i=1}^{n} k'_j} \qquad \text{Equation 6.5}$$

Where;

(k_j)= Is the assigned weight on attribute j

Therefore from Table 6.10 the assigned weight for road length was estimated as;

$(k_j) = \frac{4.34}{8.89}$ which is 0.49

The procedure was applied to generate the assigned weights for the other attributes including traffic, road condition and the percentage of work achievement

Table 6.10: Calculation of Weights by ROC Method

Attributes	Alternatives			$\sum \frac{1}{v_j(x_j)}$	$\frac{1}{n}$	$(k_j^{'})$ $\frac{1}{n}\sum \frac{1}{v_j(x_j)}$	(k_j) $\frac{k_j^{'}}{\sum k_j^{'}}$
	Trunk	Urban	Feeder				
Road Length $\left(\frac{1}{v_1(x_1)}\right)$	3.45	3.70	10.2	17.36	0.25	4.34	0.49
Traffic $\left(\frac{1}{v_2(x_2)}\right)$	3.03	4.00	2.7	9.73	0.25	2.43	0.27
Condition $\left(\frac{1}{v_3(x_3)}\right)$	1.61	2.00	1.30	4.91	0.25	1.23	0.14
Percentage of Work Achieved $\left(\frac{1}{v_4(x_4)}\right)$	1.12	1.12	1.2	3.55	0.25	0.89	0.10

The result of the application of the estimated weights on the need scores of the individual attributes for each road type is given in Table 6.11.

Table 6.11: Summary of Weighted Need Score by ROC Weighting Method

Weighted Value Function by Alternative	Alternative		
	Trunk	Urban	Feeder
Road Length	0.49(0.29)	0.49(0.27)	0.49(0.098)
Traffic	0.27 (0.33)	0.27(0.25)	0.27(0.37)
Condition	0.14(0.62)	0.14(0.50)	0.14(0.70)
Percentage of work Achieved	0.10(0.89)	0.1(0.77)	0.10(0.83)

(ii) Weighting by Equivalent Lotteries - A second weighting criteria was also applied on the need scores using the equivalent probability function expressed in Equation 6.6. The assumption was that the weight of each attribute is determined by the probability of either 50 percent of its best outcome or 50 percent of its worse outcome on a need score. The concept is illustrated in Figure 6.8. The detail estimates are also presented in Table 6.12.

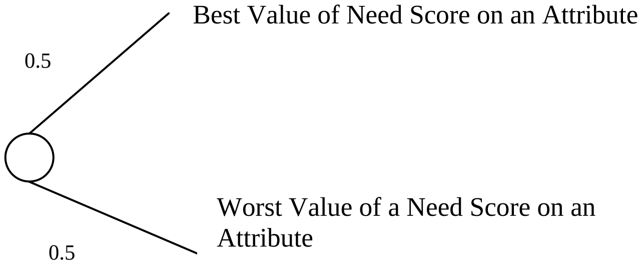


Figure 6.8: An illustration of Equivalent Lotteries

$$k_j = P * b + (1 - P)w \qquad \text{Equation 6.6}$$

Where;

k_j = Assigned Weight

P = is the equivalent probability at 0.05

b = is the best outcome of a need score on an attribute

w = the value of the worst outcome of a need score on an attribute

The summary of weights generated by the equivalent probability is presented in Table 6.12.

Table 6.12: Calculation of Weights by Equivalent Probability

Attributes	b	w	P	Pxb	$1-P$	$(Pxb)+(1-P)$	Weight ((k_j) (ii) x (vi)
Road Length	0.29	0.098	0.5	0.15	0.5	0.65	0.07
Traffic	0.37	0.25	0.5	0.19	0.5	0.69	0.17
Condition	0.69	0.50	0.5	0.35	0.5	0.85	0.42
Percentage of work Achieved	0.89	0.77	0.5	0.45	0.5	0.95	0.73

The result of the estimated weights by the equivalent probability method is presented in Table 6.13 below;

Table 6.13: Summary of Weighted Need Scores with Equivalent Probability Method

Attributes	Weighted Need Score by Value Function		
	Trunk	Urban	Feeder
Road Length	0.042(0.29)	0.042 (0.27)	0.042(0.098)
Traffic	0.16(0.33)	0.16(0.25)	0.16(0.37)
Condition	0.76(0.62)	0.76(0.50)	0.76(0.70)
Percentage of work Achieved	1.82 (0.89)	1.82(0.77)	1.82(0.83)

6.3.1.5 Aggregation of Weighted Need Scores by Linear Additive Function The aggregation of the weighted need score for each alternative was based on the multi linear additive value function as presented in Equation 3.2; which can be expanded as;

$$a_i = k_1 v_1(x_1) + k_2 v_2(x_2) + k_3 v_3(x_3) + k_4 v_4(x_4) \qquad \text{Equation 6.7}$$

Where;

a_i = the road type

(i) Aggregation of Weighted Need Scores based on ROC Weighting Method: Using the results of the estimated weights in Table 6.13 the aggregated score of each alternative from the combined weighted value function was obtained as follows;

Trunk = 0.49(0.29) +0.27 (0.33) +0.14(0.62) +0.10(0.89) = 0.41

Urban = 0.49(0.27) +0.27(0.26) +0.14(0.5) +0.10(0.77) = 0.35

Feeder = 0.49(0.0.98) +0.27(0.37) +0.14(0.697) +0.10(0.83) = 0.34

These can be normalised such that; $a_1 + a_2 + a_3 = 1.0$

Thus a_1 = 0.37, a_2 = 0.32 and a_3 = 0.31

(ii) Aggregation of Weighted Need Scores Based on Equivalent Probability Weighting Method - From Table 6.15 the summary of aggregated score was estimated as follows;

Trunk = 0.042(0.29) + 0.163(0.33) + 0.765(0.62) +1.812 (0.89) =0.98

Urban = 0.0042(0.27) + 0.163(0.25) + 0.765(0.50) +1.812 (0.77) =0.56

Feeder =0.042(0.098) + 0.163(0.37) + 0.765(0.69) +1.812 (0.83) =0.97

These can be normalised as; $a_1 + a_2 + a_3 = 1.0$

Thus

$a_1 = 0.35$, $a_2 = 0.30$, and $a_3 = 0.35$

6.3.1.6 Definition of Ratio Scale

The proportionate allocation of the road fund by the value function method and the ROC weighting method was therefore estimated to be 37 percent for trunk roads, 32 percent for urban roads and 31 percent for feeder roads. The result of the weighting method by equivalent proportion was 35 percent for trunk roads, 30 percent for urban roads and 35 percent for feeder roads. The result indicates that the ROC method differentiates between the different road types, whilst the equivalent proportion method gives a more equal allocation of funds between the road types.

A tolerance interval which contains the upper and lower limits of the mean values of the attributes used at 95 percent degree of confidence was estimated. This was to determine the possible effects of changes in the values of the attributes used on the model. The analysis was based on the excel function for estimating upper and lower limits by Sheskin (2002) which is expressed as;

Lower limit: =SD*SQRT((N-1)/CHIINV((alpha/2), N-1))

Upper limit: =SD*SQRT((N-1)/CHIINV(1-(alpha/2), N-1))

where ;

SD = an excel function of a standard deviation

SQRT = an excel function of a square root

CHIIN= an excel function of Chi square test

N = the sample size that was used to estimate the mean and standard deviation.

Alpha = 95 percent confidence level

The summary of upper and lower estimated are presented in Table 6.14

Table 6.14: Summary of Estimated Tolerance Intervals on attributes

Road Type	Attribute							
	Length		AADT		Condition		Percentage of Work Achievement	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Trunk	180.3	103.6	6327.3	3635.9	4.5	7.8	34.3	7.15
Urban	170.5	96.9	6856.31	3895.3	3.5	6.2	104.1	21.7
Feeder	1497.7	860.6	634.3	364.48	2.6	4.6	325.86	67.9

6.3.2 Estimation of Total Budgets Available for Road Maintenance in Ghana

The available road maintenance budget for Ghana was estimated from the trend of road maintenance funding allocation between 2000 and 2004. A summary of the allocated funds is presented in Table 5.29 and the average annual funding threshold available for road maintenance for the entire road network of Ghana is estimated at about US$121.1.

6.3.3 Definition of Model Parameters for Coefficients on Efficiency and Equity

The procedure for estimating the model parameters for the internal division of the proportion of the road fund allocated to each road type by efficiency and equity components with the concept of efficiency frontier is illustrated in Figure 6.9 and details are presented in the following paragraphs.

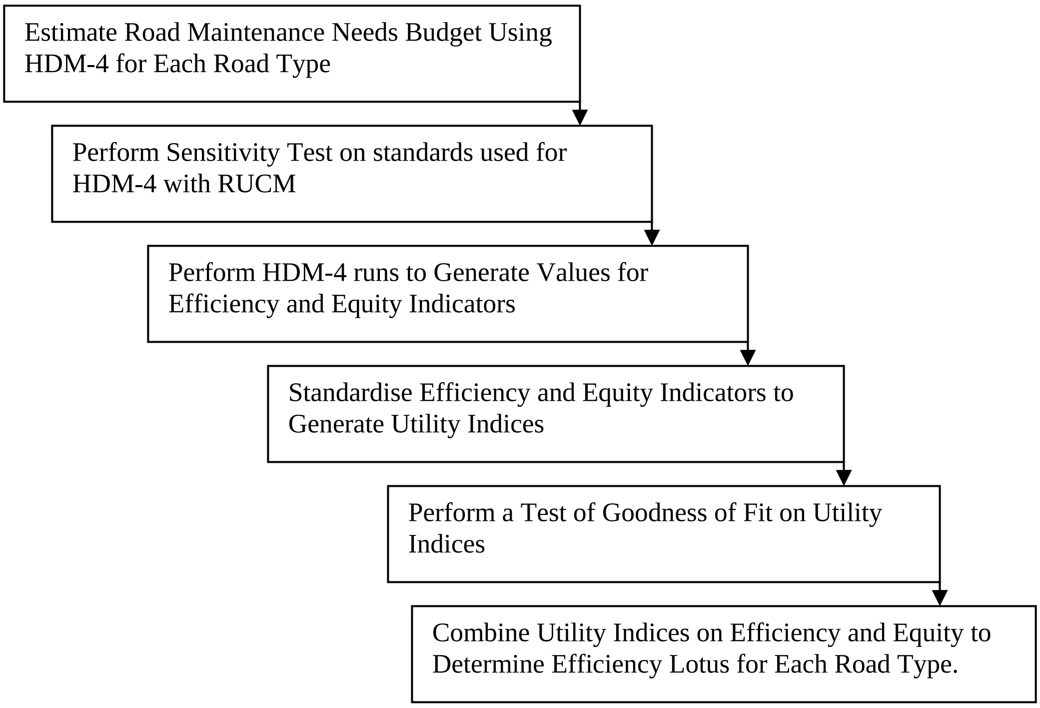


Figure 1Figure 6.9: Procedure Estimating Coefficients for Efficiency and Equity Components

6.3.3.1 Estimation of Road Maintenance Needs

The HDM-4 strategic analysis was used to estimate the maintenance needs of the entire road network in Ghana and the procedure can be summarised in the following steps.

- Structure data outputs into HDM-4 object file format.
- Select representative road sections
- Select representative vehicles
- Define traffic composition and growth rates
- Assign maintenance alternatives

- Set start year and analysis period,
- Define currency
- Run HDM-4 Analysis
- Generate reports on routine and periodic budget estimates
- Conduct sensitivity test with RUCM

The data items specified in section 5.2.1 was used for the HDM-4 as well as the maintenance standards specified in section 5.2.1.3 item 2. The road maintenance financing needs were estimated for each road type over a period of 20 years. A Sample output from the HDM-4 analysis is given in Appendix. 6.4. A summary of the selected treatment options from the HDM-4 analysis at different levels of traffic and the initial road condition is summarised in Table 6.15

Table 6.15: Summary of Selected Treatment Options by HDM-4 Analysis

Initial Pavement Condition		Traffic Level		
		High Traffic	Medium Traffic	Low Traffic
Good	IRI ≤ 4	Routine Maintenance + Reseal + Overlay		
Fair	4< IRI ≤ 8	Overlay + Reconstruction		Reconstruction
Poor	IRI > 8	Reconstruction		

The estimated maintenance needs using the HDM-4 indicated that an average maintenance costs per annum for all road types was higher than the current MRT estimates as shown in Table 6.16. This could be attributed to the use of historic data for MRT strategic budgets which does not reflect actual maintenance needs. The road maintenance cost estimates for routine maintenance using the HDM-4 were higher for feeder roads whilst periodic maintenance costs were higher for urban and trunk roads.

Table 6.16: Road Maintenance Needs Estimated Using HDM-4

Road Type	Recurrent Cost (US $M)	Capital Cost (US $M)	Total Cost (US $M)	Cost per Annum (US $M)
Trunk Roads	57.2	1539.9	1597.1	79.85
Urban Roads	45.6	2229.8	2275.4	113.77
Feeder Roads	139.7	459.9	599.2	29.98
Total	242.5	4229.9	4472.1	223.61

Source – HDM-4 Strategic Analysis Output on Cost Estimates for Unconstrained Budgets (2004)

6.3.3.2 Sensitivity Analysis with Road User Charges Modelling (RUCM)

A sensitivity analysis was undertaken to test the margin of accuracy of the standards used for the HDM-4 with the RUCM. This was due to the reclassification of the MRT's road maintenance standards into four categories in this study as described in section 5.2.1.3 item 2 (ii). The RUCM was used to estimate an optimised road user charge to match the estimated maintenance budgets with HDM-4 for all road types.The ratio of the MRT's available budget per annum for road maintenance to the estimated total road maintenance budget per annum with HDM-4 was compared with the ratio of the current MRT road user charge to the optimised user charge estimated with the RUCM.

The decision criterion for determining whether the standards used in the HDM-4 were acceptable or not was based on the MRT's contingency provision of 15 percent allowed on road contracts. The rational was that if the difference in the two ratios was > 15 percent then the standards used would be rejected. Appendix 6.5 provides a sample output of the results of the RUCM. The results indicated that the two ratios recorded a difference of 11 percent thus the standards used were accepted to be reliable. Table 6.17 presents the summary of results.

Table 6.17: Results of Sensitivity Test on Road Maintenance Standards

Item	Value
Road Maintenance Budget Estimate/ Annum (US $M) With HDM-4	223.6
Available MRT Budget / Annum (US $ M)	121.1
Ratio of Available MRT Budget per Annum to HDM-4 Budget Estimates per Annum	1:0.54
Current Road User Charge per Annum (US $ M)	101.0
Estimated Road User Charge/ Annum with RUCM (US $ M)	156.0
Ratio of Current Road User Charge to Optimised Road User Charge	1:0.65
Percentage Difference in Ratios	11%

6.3.3.3 Generation of values on Efficiency and Equity Indicators

1. Estimation of values for Efficiency Indicator: The maintenance budgets estimated for each road type from the HDM -4 was constrained into decile proportions on a scale of 10 to 90 percent. Each level of constrained budget was used as an investment level for HDM-4 runs. Corresponding NPV values at each level of constrained budget for the representative road sections for each road type were generated to represent the efficiency indicator. For purposes of uniformity the estimated NPV's at constrained and unconstrained budget levels for each road section were divided by the corresponding capital costs to obtain the NPV/capital ratio (NPV/cap).

2. Estimation of Values for Equity Indicator: The affordability factor was estimated by deducting VOC/km per annum for each road section from the average annual per capita income spent per a km of travel for that road type. HDM-4 runs at the constrained and unconstrained budgets were used to generate the average VOC for each representative road section by road type. The average VOC for all vehicle types for the 20 year analytical period was generated for each road section. This was divided by 20 to obtain the average annual VOC for each road section. The VOC per annum for each representative road section was divided by the length of that road

section to obtain the VOC/km per annum for that road section. Using feeder roads as an example the affordability factor was estimated as;

Let;

Feeder Road Length	= 191.04
Average VOC per Vehicle for 20 years US ($)	= 101,855.00
Average VOC per Vehicle per Annum US ($)	=5092.75
VOC per Vehicle per month at 10 months/year US ($)	=5.09
VOC/km per Vehicle per month US ($)	=0.026658
Average Income /Capita /Month on a feeder road US $	=102.00
Proportion of Income spent on transport	=0.24
Income per capita spent on transport	=20.4

An equivalent distance of travel at the specified income proportion spent on transport was estimated as;

the amount spent on transport divided by VOC/km	20.4/0.026658
Income per capita /km was then estimated as	= 102/765.2
And income per capita/km - VOC/km	= 0.13329-0.026658
$\therefore$ Affordability factor	= 0.106632

6.3.3.4 Standardization of Variables

The generated values on the efficiency and equity indicators were further standardised to obtain dimensionless values in the form of utility indices (UI's) for uniformity. The standardisation was based on the Interval Scale Properties formula by Voogd (1983). The interval scale formula was used because it provided the least differential effect from the test of correlation between the standardised and non standardised data. It was also based on the need to maintain the interval between the highest and lowest values of the distribution of non standardised data to avoid skewness. Equation 6.8 was used for the standardisation of the efficiency indicators and Equation 6.9 was used for the standardisation of equity indicators. The details are presented in Equations 6.8 and 6.9 as;

(i) $$ui_{sei} = \frac{s_{ei} - \min s_{ei}}{\max s_{ei} - \min s_{ei}}$$ Equation 6.8

Where;

ui_{sei} = The derived utility index for the NPV/cap variable at the defined decile rank

s_{ei} = NPV/Cap at the specified constrained budget level.

$\min s_{ei}$ = Lowest NPV/Cap value for all road sections by road type

$\max s_{ei}$ = Highest NPV/Cap value for all road sections by road type

(ii) $$ui_{smj} = \frac{s_{mj} - \min s_{mj}}{\max s_{mj} - \min s_{mj}}$$ Equation 6.9

where

ui_{mj} = The derived utility index for the affordability factor at the defined decile rank

s_{smj} = affordability factor at the specified constrained budget level.

$\min s_{mj}$ = Lowest value of affordability factor for all road sections by road type.

$\max s_{mj}$ = Highest value of affordability factor for all road sections by road type.

Samples of the standardised efficiency variables at constrained and unconstrained budget levels are given in Appendix 6.6 for trunk roads, Appendix 6.7 for urban roads and Appendix 6.8 for feeder roads. Sample of the standardised equity variables at the constrained and unconstrained budget proportions are also given in Appendix 6.9 for trunk roads, Appendix 6.10 for urban roads and Appendix 6.11 for feeder roads respectively.

6.3.3.5 Test of Goodness of Fit

A test of goodness of fit between the Utility Indices (UI's) and actual values of the efficiency and equity indicators was undertaken to determine the effect of the standardisation on the distribution. This was done by comparing the estimated UI's of the two variables with the actual values of the two variables by a linear regression analysis. The test was based on a test of direct (''a α b'') and indirect (''a α 1/b'') relationships between the standardised and the non standardised variables.

1. The test of the relationship between ui_{sei} and the actual NPV/cap values was based on the direct relationship where NPV/cap increases with higher budgets.The results indicated similar trends for the UI's and the actual NPV/cap values. Table 6.18 provides a summary of the utility indices estimated on NPV/Cap for trunk roads Figures 6.10 and 6.11 indicate the trend of distribution between ui_{sei} and the actual NPV/cap for trunk roads were acceptable.

Table 6.18: Summary of Utility Indices for NPV/cap – Trunk Roads

Item	Proportion of Constrained Budget in Percentage	Total NPV/Cap	Summary of ui_{sei}
10	50.50	0.97	0.08
20	88.80	1.70	0.15
25	128.40	2.47	0.21
30	153.70	2.95	0.25
40	200.70	3.85	0.33
50	205.40	3.95	0.34
60	209.90	4.03	0.34
70	213.70	3.95	0.35
75	216.20	4.57	0.35
80	217.30	4.10	0.36
90	209.40	4.02	0.35
100	209.30	3.95	0.35

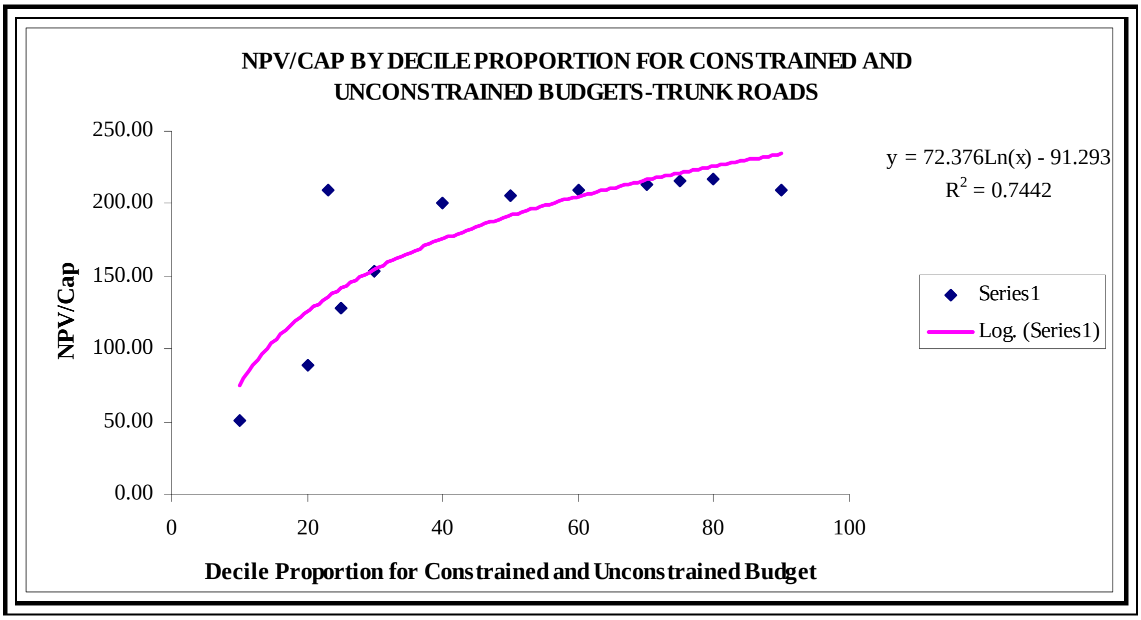


Figure 6.10: Distribution of NPV/cap by Proportion of Budget

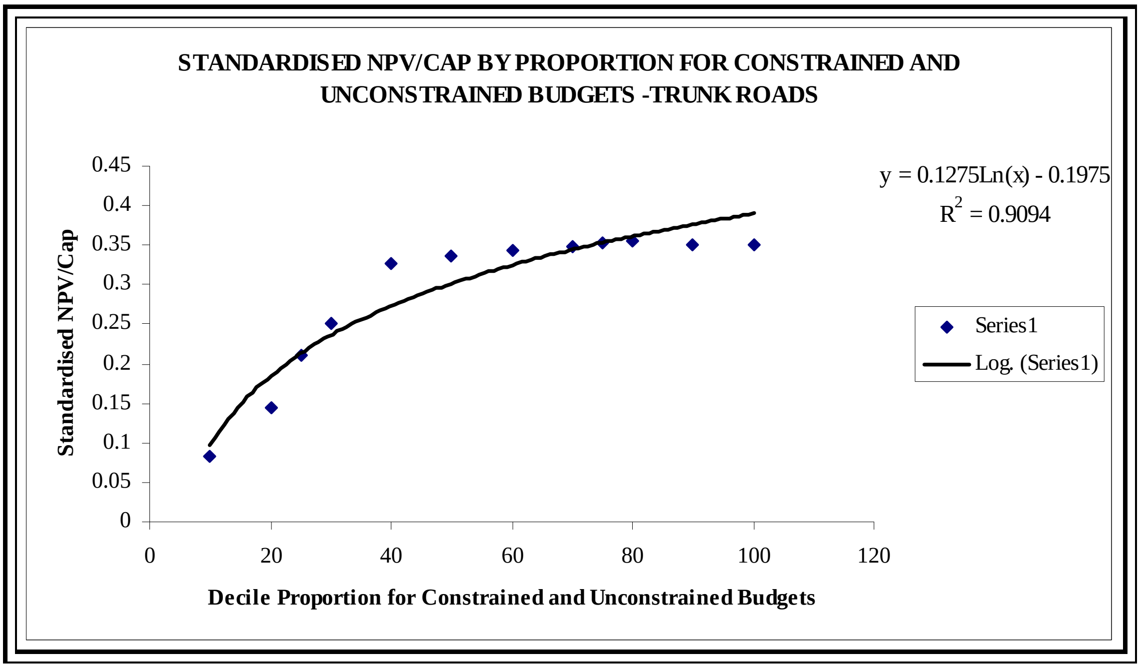


Figure 6.11: Distribution of UI's for NPV/cap by Proportion of Budget

2. The test of the relationship between the ui_{mj} and the actual value on the affordability factor was based on the indirect relationship where VOC/km reduces with higher budget levels. The summary of the UI's estimated for the affordability factor and VOC/km for the trunk roads are also presented in Table 6.19. The relationship between the distribution of VOC/km and the constrained budget levels for trunk roads is presented in Figure 6.12. The relationship between the distribution of the ui_{mj} and the constrained budget levels for trunk roads is also presented in Figure 6.13. Since the relationship between ui_{sei} and the constrained budget level is such that there are savings in the affordability factor when VOC levels are reduced, the output from the analysis was considered to be acceptable. Appendix 6.12 and 6.13 provides the details of the analysis for the urban and feeder road sectors respectively.

Table 6 .19: Summary of Utility Indices for Adjusted VOC/km - Trunk Roads

Proportion of Constrained Budget in Percentage	VOC/km (US $)	Affordability Factor	Summary of ui_{smj}
10	0.125	1.009	0.316
20	0.123	0.994	0.319
25	0.123	0.992	0.319
30	0.121	0.975	0.312
40	0.119	0.960	0.307
50	0.116	0.940	0.299
60	0.114	0.920	0.293
70	0.113	0.917	0.292
75	0.113	0.917	0.292
80	0.112	0.908	0.289
90	0.111	0.898	0.285
100	0.111	0.894	0.284

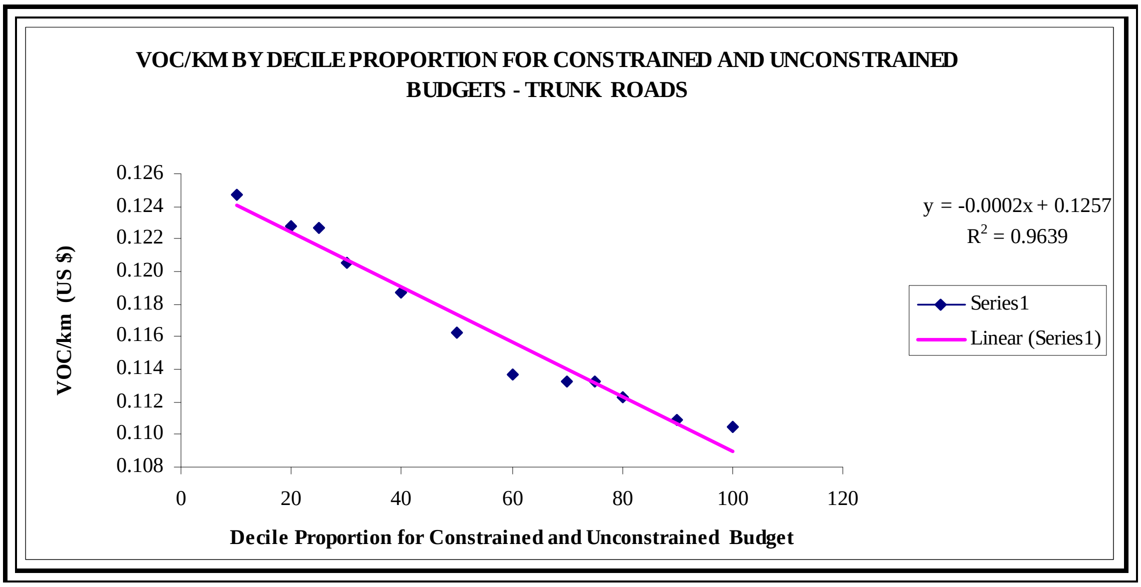


Figure 6.12: Distribution of Affordability Factor by Proportion of Budget

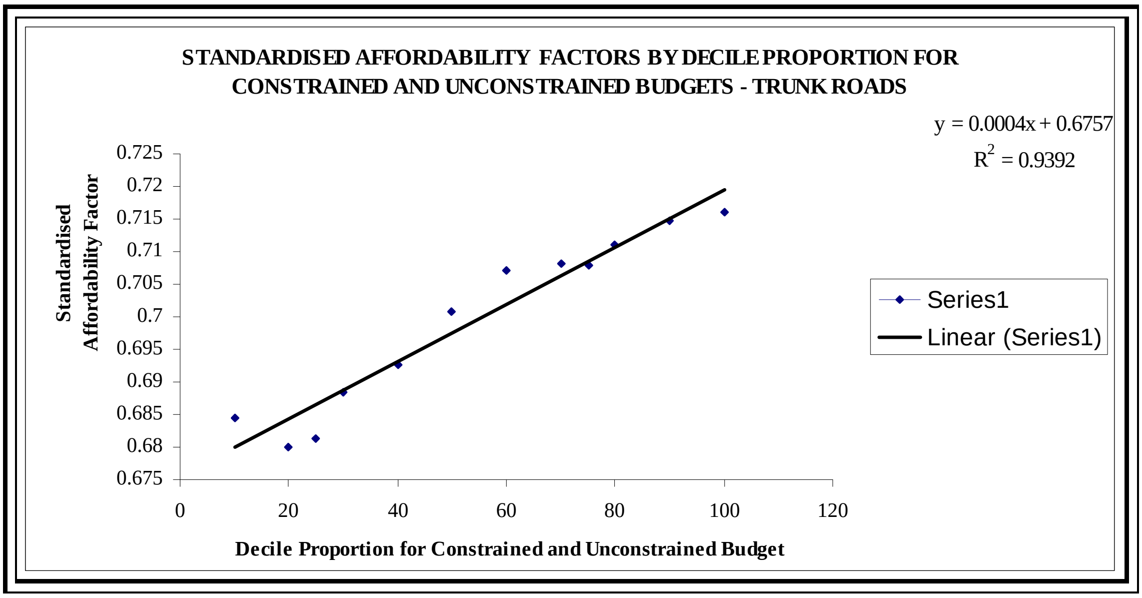


Figure 6.13: Distribution of UI's of Affordability Factors by Proportion of Budget

3. Test of correlation between the utility indices and actual values: The R^2 values of the distribution of the raw scores and the distribution of UI's were used to determine the margin of consistency between the two distributions. A comparison of the relation between the actual NPV/cap values and the ui_{sei} in Figures 6.10 and 6.11 indicated R^2 values 0.74 and 0.93 respectively which were considered to be acceptable. The R^2 score of the correlation between the ui_{sei} and the actual values of on the affordability factors in Figures 6.12 and 6.13 also indicated good correlation at R^2 values of 0.96 and 0.93 respectively. Appendixes 6.12 and 6.13 provide the details of the analysis for the urban and feeder road sectors respectively

6.3.3.6 Combination of Efficiency and Equity Indicators

The mean of the estimated ui_{sie} and ui_{smj} for all representative road sections at the constrained budget levels were summed. The result of the ui_{sie} was arranged in an ordinal order to correspond with the proportion of constrained budget. The results of the ui_{smj} was arranged a reversed ordinal order to correspond with the proportion of constrained budget. This was undertaken such that the ui_{sie} at a specified percent of constrained budget level was added to the ui_{smj} at a specified percent of constrained budget level to sum the budget proportions at which the values were estimated to 100. For example the ui_{sie} at 10 percent constrained budget level was added to ui_{smj} at 90 percent constrained budget level. Table 6.20 provides the results of the summation of ui_{sei} and ui_{smj} at the corresponding budget proportions at which they were added. The details of the estimates for Urban and Feeder Roads are attached as Appendixes 6.12 and 6. 13.

6.3.3.7 Determination of Efficiency Lotus

The efficiency lotus was determined as the proportion of the constrained budgets for the combined ui_{smj} and ui_{sei} closest to the combined UI's of the unconstrained budget. The results for trunk roads are presented in Table 6.20 and illustrated in Figure 3.7. From Figure 3.7 the highest combination of UI value is 0.674 which corresponds to ui_{sei} at 80 percent budget proportion and ui_{smj} at 20 percent. This was interpreted to represent the efficiency lotus for the combined values of economic efficiency and equity functions as 80 percent efficiency and 20 percent Equity. The details for the urban and feeder roads are presented in Appendixes 6.14 and 6.15.

Table 6.20: Efficiency Lotus for Combined UI's for Trunk Roads

Proportion of Budget for ui_{sei}	UI's of NPV/cap (ui_{sei})	Proportion of Budgets in Reversed Order (ui_{smj})	UI's of Ω-VOC/km (ui_{smj})	Combined UI's	Rank
	A		B	A+B	
10	0.08	90	0.29	0.367	12
20	0.15	80	0.29	0.434	11
25	0.21	75	0.29	0.502	10
30	0.25	70	0.29	0.543	9
40	0.33	60	0.29	0.621	8
50	0.34	50	0.30	0.635	6
60	0.34	40	0.31	0.650	5
70	0.35	30	0.31	0.661	4
75	0.35	25	0.32	0.669	3
80	0.36	20	0.32	0.674	1
90	0.35	10	0.32	0.670	2
100	0.35	100	0.28	0.634	7

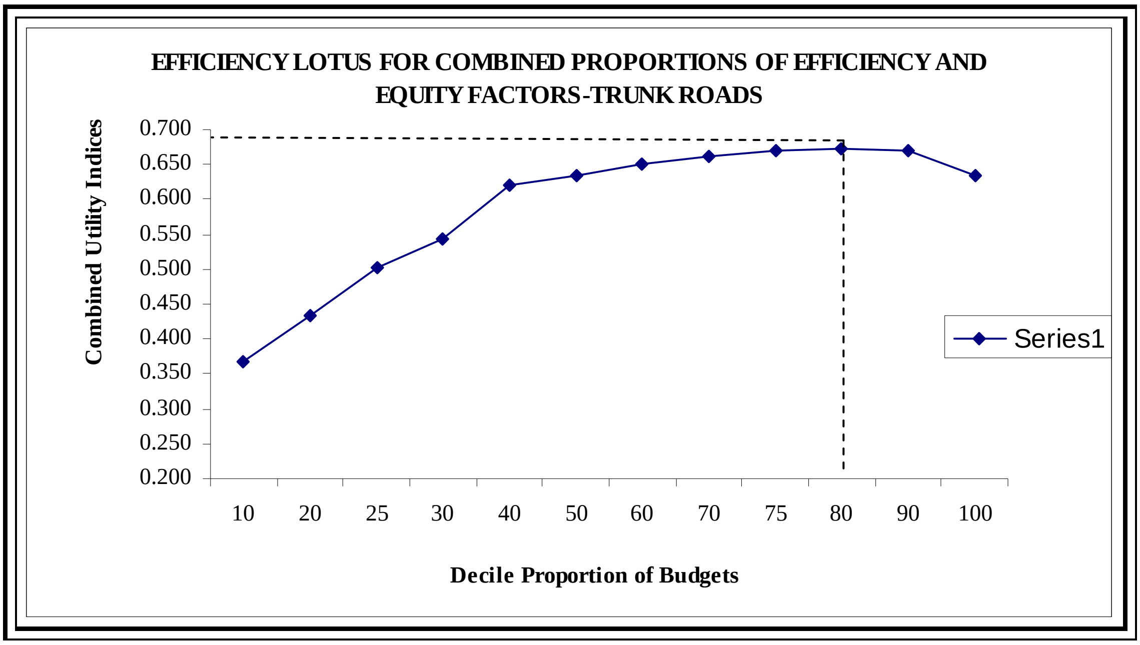


Figure 6.14: Efficiency Lotus of Economic Efficiency and Equity for Trunk Roads

Table 6.21 presents the summary of efficiency and equity coefficients estimated for each road type.

Table 6.21 Road Fund Allocation by Economic Efficiency for Each Road Sector

Road Sector	Proportionate Distribution of Road Fund Allocation by Defined Principle	
	Efficiency	Equity
Trunk	0.80	0.20
Urban	0.75	0.25
Feeder	0.90	0.10

6.4 SENSITIVITY TEST

The output of the model with deterministic approach based on 2000-2004 data sets was tested with a new data set from 2005 to 2007 as defined in section 5.4. The summary of the outputs from the analysis are presented in the following paragraphs and the detail outputs are presented in Appendix 6.16.

6.4.1 Summary of Estimated Maintenance Needs

The summary of the estimated maintenance needs by HDM -4 for the two study periods of study are presented in Table 6.22.

Table 6.22: Estimated Maintenance Budgets – Sensitivity Test

Maintenance Cost estimates	Road Type						Total	
	Trunk		Urban		Feeder			
	2000-2004	2005-2007	2000-2004	2005-2007	2000-2004	2005-2007	2000-2004	2005-2007
Recurrent Costs	57.2	261	45.6	129.9	139.7	707.8	242.5	1098.7
Capital Costs	1539.9	2506.2	2229.8	3339.9	459.9	931.2	4229.9	6777.3
Total Costs	1597.1	2767.2	227.5	3469.8	599.7	1639	4472.1	7876.1
Estimated Budget per Annum	79.9	230.6	113.8	289.2	30.0	136.6	223.6	656.3

The cost of maintenance works increased from 2004 to 2007 for all road types mostly due to increased lengths. Feeder roads recorded the highest increase at 2.7 percent, followed by Trunk roads at 1.7 percent and urban roads at 1.5 percent.

6.4.2 Values of Attributes Used for Sensitivity Test

The summary of the values of the attributes used for the value function modelling for 2000-2004 and 2005-2007 are summarized in Table 6.23.

Table 6.23: Value of Attributes Used for Two Study Periods

Value of Attributes	Road Type					
	Trunk		Urban		Feeder	
	2000-2004	2005-2007	2000-2004	2005-2007	2000-2004	2005-2007
Road Length						
Maximum	605.6	731.4	380.2	487.5	3,974.0	6,014.0
Minimum	36.1	247.2	0.6	0.78	13.3	20.2
Average	205.9	43.6	283.7	487.5	735.8	1089.9
Traffic (AADT)						
Maximum	13,781.0	19,915.0	16,612.0	19,268	1,310	1,706.0
Minimum	662.0	956.0	126.0	177.0	65.0	1,720.0
Average	5063.9	7734.5	5175.1	6061.6	515.1	683.2
Road Condition by (IRI)						
Maximum	18.8	18.4.0	18.6	18.1	13.9	12.4
Minimum	3.4	3.5	4.2	3.6	4.5	0.5
Average	10.7	9.4	8.9	7.9	8.2	5.6
Percentage of Work Achieved						
Maximum	89.0	82.0	120.0	28.0	193.0	59.9
Minimum	65.0	42.0	20.0	40	44.0	61.0
Average	75.0	60.0	68.0	160.0	59.0	53.0

The values of road lengths and ADT levels increased for all road types whilst values of road condition improved for all road types. The value of work achieved however reduced for trunk roads but increased for urban and feeder roads with urban roads recording a highest.

6.4.3 Summary of Estimated Need Scores

The values of the need scores per attribute by road type for the two periods of study are presented in Table 6.24.

Table 6.24: Need Score for Sensitivity Test

Value of Attributes	Road Type					
	Trunk		Urban		Feeder	
	2000-2004	2005-2007	2000-2004	2005-2007	2000-2004	2005-2007
Road Length	0.29	0.29	0.27	0.28	0.097	0.094
AADT	0.33	0.33	0.25	0.26	0.37	0.38
Condition	0.62	0.54	0.50	0.45	0.70	0.46
Percentage of work achieved	0.89	0.80	0.77	0.69	0.83	0.92

6.4.4 Summary of Proportionate Allocation of Funds for Sensitivity Test

The summary of the results of the proportionate allocation of road fund for the two study periods are presented in Table 6.25 and illustrated in Figure 6.18.

Table 6.25: Proportionate of Fund Allocation by Weighting Method- Sensitivity Test

Value of Attributes	Road Type					
	Trunk		Urban		Feeder	
	2000-2004	2005-2007	2000-2004	2005-2007	2000-2004	2005-2007
ROC Method						
Road Length	0.14	0.14	0.13	0.13	0.05	0.04
AADT	0.09	0.08	0.07	0.07	0.10	0.10
Condition	0.09	0.09	0.07	0.08	0.11	0.08
Percentage of Work Achieved	0.09	0.08	0.08	0.07	0.08	0.09
Total	0.41	0.394	0.35	0.345	0.34	0.313
Percentage Allocation	37	37	32	33	31	30
Probability Method						
Road Length	0.02	0.02	0.017	0.017	0.006	0.006
AADT	0.06	0.02	0.043	0.027	0.063	0.039
Condition	0.26	0.19	0.211	0.156	0.292	0.159
Percentage of Work Achieved	0.65	0.53	0.560	0.457	0.604	0.609
Total	0.984	0.50	0.831	0.657	0.965	0.814
Percentage Allocation	35	33	30	30	35	37

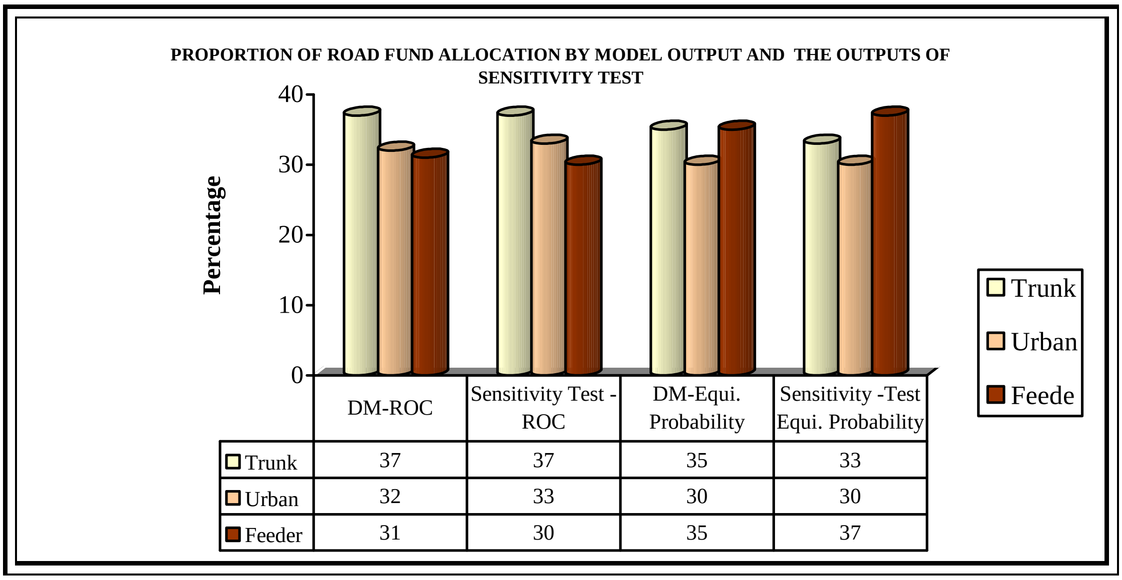


Figure 6.15: Proportion of Road Fund Allocated by Sector

The ROC weighting method presented a more consistent results of the proportionate allocation of the road fund with data from (2000-2004) and the data based on (2005-2007) as compared with the equivalent probability weighting method. The proportion of road fund allocated to the urban road sector, increased by 1 percent and that of feeder roads sector reduced by 1 percent. The equivalent probability method however presented a reduction of 2 percent in the allocation to trunk roads, and a 2 percent increment in the allocation funds feeder roads.

The results of a 't' test comparison between the outputs of the model based on the (2000-2004) data and the outputs based on (2005-2007) indicated no significant differences in the results at a probability of 0.05. However the ROC result was more consistent as compared with the results of the equivalent probability. Therefore it was adopted for the subsequent analysis. For purposes of consistency only the aspects of the model with deterministic approach based on the ROC weighting method was used for further analysis. This is due to the inconsistencies observed in the application of the equivalent probability method from the case study. Also it is assumed that it is unlikely for all road types to be accorded equivalent weights in an analysis.

6.4.5 Summary of Subdivision of Funds by Efficiency and Equity for Sensitivity Test

The summary of the subdivision of road fund by economic efficiency and equity based on the case study for the deterministic model for both the ROC method and the equivalent proportion method are presented in Table 6.26.

Table 6.26: Road Fund Allocation by Efficiency and Equity – Sensitivity Test

Road Type	Proportionate Distribution of Road Fund Allocation by Objective Function			
	Model Output Based on (2000-2004)		Model Outputs Based on (2004-2007) Data	
	Efficiency	Equity	Efficiency	Equity
Trunk	0.80	0.20	0.80	0.20
Urban	0.75	0.25	0.80	0.20
Feeder	0.90	0.20	0.20	0.80

The results indicated a significant difference in the proportion of fund allocation by efficiency and equity components for feeder roads. This is attributed to the fact that the feeder road length increased by about 50 percent between the two study periods.

6.5 MODEL VALIDATION

The results of the deterministic based model was validated by comparing the outcome of the proportion of road fund allocation by road type to the results of road fund allocation using conventional CBA analysis with a decision criteria based on the IRR generated by HDM-4 analysis. This is due to the fact the CBA methods are based on quantifiable indicators as with the deterministic based approach. It is also because the results are also generated form HDM-4 analysis which provides a working logic for the model validation. The outputs of the results of the weighted average of estimated IRR's for selected trunk, urban and feeder road links as indicated in Table 6.27 were normalised to generate the proportion of fund allocation by road type using the CBA method.

Table 6.27: Model Validation With Case Study

Road Type	Proportionate of Road Fund Allocation by Deterministic Based Method and CBA Method			
	Road Fund Allocation by Deterministic Based Method		Road Fund Allocation by CBA Method	
	Proportion of Road Fund Allocation by ROC Method	Proportion of Road Fund Allocation by Equivalent Method	Estimated Average IRR's for Representative Road Links	Proportion of Road Fund Allocation
Trunk	37	35	15	39
Urban	32	30	17	45
Feeder	31	35	6	16

The results of the model validation with the case study indicates that if funds are allocated on the basis of conventional CBA methods using a decision criteria based on only economic analysis which tends to favour roads with high traffic levels then trunk and urban roads will receive higher proportions of funds as compared with feeder roads. However, the application of the deterministic based model developed in this study will allocate a higher proportion of funds to feeder roads due to the inclusion of equity indicators.

6.6 WORKED EXAMPLE

6.6.1 Worked Example with the Results Based on 2000-2004 Data

The worked example explains the use of the model structure specified in 6.2. It considers the proportion of the road fund (T_b) allocated to each road sector (P_{bi}) and proportion of the (P_{bi}) allocated by efficiency (P_{bief}) and equity (P_{bieq}) to each road sector. The threshold of road fund to be allocated (T_b) was based on the average of the estimated road fund allocated between 2000 and 2004 to the three road sectors presented in 6.3.2 as US $ 121.1. The proportion (T_b) allocated as (P_{bi}) to each sector defined is as in equations 6.1. The inputs for equation 6.1 are also derived from the outputs of equation 6.2 and the coefficients on efficiency and equity indicators presented in Table 6.20. From section 6.3.1 items 7 (i) and 7 (ii) the summary of the weighted need scores used for generating the proportions for estimating (P_{bi}) using both the two weighting methods that is the ROC and the equivalent proportions method can be summarized as;

Proportion of Fund Allocation to ith Road Based on ROC Weighting Method (Percentage)			Proportion of Fund Allocation to ith Based on Equivalent Weighting Method (Percentage)		
Road Sector 1	Road Sector 2	Road Sector 3	Road Sector 1	Road Sector 2	Road Sector 3
0.37			0.35		
	0.32			0.30	
		0.31			0.35

6.6.1.1 Worked Example Based on ROC Method

Based on the estimated proportions using the ROC weighting method, (T_b) and (P_{bi}) can be estimated from equation as;

(P_{b1}) = US $ 44.81,

(P_{b2}) = US $ 38.75 and

(P_{b3}) = US \$ 37.54

which can also be summarized as ($T_b = \sum_{i=1}^{3} P_{bi}$)

= US \$ 44.81 +US \$ 38.75 + US \$ 37.54

From Table 6.20 the values of α_i and β_i which are defined as the coefficients for the subdivision of the allocated fund to the *ith* road type into economic efficiency and equity and the estimated values of (P_{bi}) and (T_b) can be used to generate r_{bief} using in Equation 6.2 as;

Model Components	Road Sector 1	Road Sector 2	Road Sector 3
α_i	0.8	0.75	0.90
β_i	0.2	0.25	0.10
$\frac{1}{\alpha_i - \beta_i}$	1.67	2.0	1.25
$\beta_i T_b$	24.22	30.28	12.11
$(p_{bi} - \beta_i T_b)$	0.17	0.07	0.25
r_{bief}	0.28	0.14	0.26
$1 - r_{bief}$	0.72	0.86	0.74

Using the estimated values for r_{bief} and r_{bieq}, P_{bief} and P_{bieq} are estimated as;

Model Components	Subdivision of Road Fund to the ith Sector for	Efficiency and Equity	
	Road Sector 1	Road Sector 2	Road Sector 3
(P_{bi})	44.81	38.75	37.53
r_{bief}	0.28	0.14	0.26
P_{bief}	12.7	5.4	9.9
P_{bieq}	32.1	33.3	27.7

Therefore $P_{bi} = P_{bief} + P_{bieq}$ can be estimated as;

(P_{b1}) = US \$ 44.81,

(P_{b2}) = US \$ 38.75 and

(P_{b3}) = US \$ 37.54

and

$$T_b = \sum_{i=1}^{3} \left(P_{bief} + P_{bieq}\right)$$

= US $ 44.81 +US $ 38.75 + US $ 37.54

6.6.1.2 Worked Example Based on Equivalent Probability Method

Using the proportions defined for road fund allocation with the equivalent probability method and the specified value of (T_b), (p_{bi}) can be estimated as;

(p_{b1}) = US $ 42.4,

(p_{b2}) = US $ 36.3 (p_{b3}) = US $ 42.4

which can be summarized as; $T_b = \sum_{i=1}^{3} P_{bi}$

= US $ 42.4 +US $ 36.3 + US $ 42.4

Based on estimated values of α_i and β_i from Table 6.20 r_{bief} can be estimated from Equation 2 as;

Model Components	Road Sector 1	Road Sector 2	Road Sector 3
$\frac{1}{\alpha_i - \beta_i}$	1.67	2.0	1.25
$\beta_i T_b$	24.22	30.28	12.11
$(P_{bi} - \beta_i T_b)$	0.15	0.05	0.25
r_{bief}	0.25	0.10	0.31
1-r_{bief}	0.75	0.90	0.69

Based on the value of r_{bief} P_{bief} and P_{bieq} are estimated from equations 6.3 and 6.4 as;

Model Components	Road Sector 1	Road Sector 2	Road Sector 3
(P_{bi})	42.4	36.3	42.4
r_{bief}	0.25	0.10	0.31
r_{bieq}	0.75	0.90	0.90

$P_{bief} = r_{bief}\, x\, P_{bi}$	10.6	3.6	13.2
P_{bieq}	31.8	32.7	29.1

The results of the worked example indicated that the deterministic model allocated a higher proportion of funds to trunk roads, followed by the feeder road and the urban road. It also indicated that the approach allocated higher proportions of funds on the basis of equity considerations as compared with efficiency consideration. It was therefore concluded that road fund allocation on the basis of a deterministic approach can have positive benefits for equity.

6.6.2 Worked Example with the Results of the 2005-2007 Data

A summary of the worked examples with the input parameters defined on the basis of the 2005 -2007 data for the case are presented as follows;

6.6.2.1 ROC Weighting Method

Model Components	Subdivision of Road Fund to the ith Sector for Efficiency and Equity		
	Road Sector 1	Road Sector 2	Road Sector 3
Proportion of Fund Allocation (P_{bi})	0.37 US $ 44.8	0.32 US $ 40.3	0.31 US $.40.0.
α_i	0.80	0.80	0.20
β_i	0.20	0.20	0.80
$\frac{1}{\alpha_i - \beta_i}$	1.6	1.67	-1.67
$\beta_i T_b$	24.22	24.22	96.80
$(p_{bi} - \beta_i T_b)$	0.17	0.13	-0.47
r_{bief}	0.28	0.22	0.78
$1 - r_{bief}$	0.72	0.77	0.22
$P_{bief} = r_{bief}\, x\, P_{bi}$	US $12.7	US $8.9	US $31.3
P_{bieq}	US $32.1	US $31.34	US $8.7

6.6.2.2 Equivalent Probability Method

Model Components	Subdivision of Road Fund to the ith Sector for Efficiency and Equity		
	Road Sector 1	Road Sector 2	Road Sector 3

Proportion of Fund Allocation	0.34	0.30	
(P_{bi})	US $ 41.2	US $36.3	US $.44.8
α_i	0.80	0.80	0.20
β_i	0.20	0.20	0.80
$\frac{1}{\alpha_i - \beta_i}$	1.67	1.82	-1.67
$\beta_i T_b$	24.22	30.28	96.88
$(p_{bi} - \beta_i T_b)$	0.14	0.05	-0.43
r_{bief}	0.23	0.09	0.72
$1 - r_{bief}$	0.77	0.91	0.28
$P_{bief} = r_{bief} x P_{bi}$	US $9.6	US $3.3	US $32.1
$P_{bieq} = r_{bieq} x P_{bi}$	US $31.6	US $33.0	US $12.7

The result of the subdivision by efficiency and equity principles for the case study as compared with the initial results indicates consistent results for trunk and urban roads. The results of the feeder road however indicated a wide variation. This could be attributed to the high increase in the length of the feeder road and the unit costs of works.

6.7 SUMMARY

This chapter has presented the functional structure of the model with deterministic approach. The procedures used in deriving the input parameters used for developing the deterministic model have also been described. This involved the application of VFM and efficiency frontier analysis. The results indicated that the model accorded trunk roads the highest proportion of the road fund, followed by the urban and the feeder roads. The subdivision of funds efficiency and equity also indicated that the model outcome allocated more funds on the basis of the equity principle than the efficiency principle. A case study on the model validated the model outputs.

CHAPTER SEVEN   ROAD FUND ALLOCATION BY STATED PREFERENCE MODEL

7.1 INTRODUCTION

This chapter presents the development of a second model for allocating road maintenance with a stated preference based method (SPM) as an alternative to the model based on a deterministic approach. The chapter is divided into four major parts. The first part presents the model specification. The second part presents the estimation of model parameters using the Analytical Hierarchy Process. The third part describes the validation of the model and the fourth part presents a worked example to show how the model developed can be applied. The procedure for developing the SPM is illustrated by Figure 7.1 and can be summarised by the following steps.

1. Specification of the model structure
2. Determination of model parameters
3. Model Validation
4. Worked Example

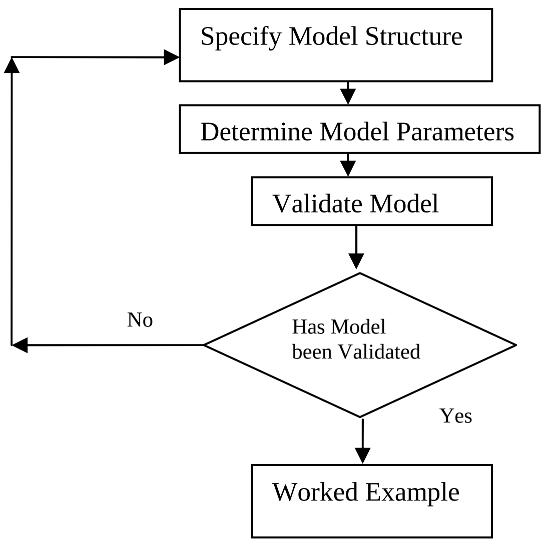


Figure7.1: Chapter Presentation

7.2 MODEL SPECIFICATION

The proposed model structure for the stated preference based method (SPM) considers two tiers of road maintenance fund allocation. The first tier is based on efficiency and equity principles to ensure that road fund allocation for the entire Ghana road network is balanced between economic and social considerations. It effects the allocation of road fund by efficiency and equity components by each road type. The second tier sums the allocation by efficiency and equity for each road type to determine the proportion of road fund allocation to each road type. An illustration of the model structure of the SPM is presented in Figure 7.2 and the details are provided in Equations 7.1, 7.2 and 7.3.

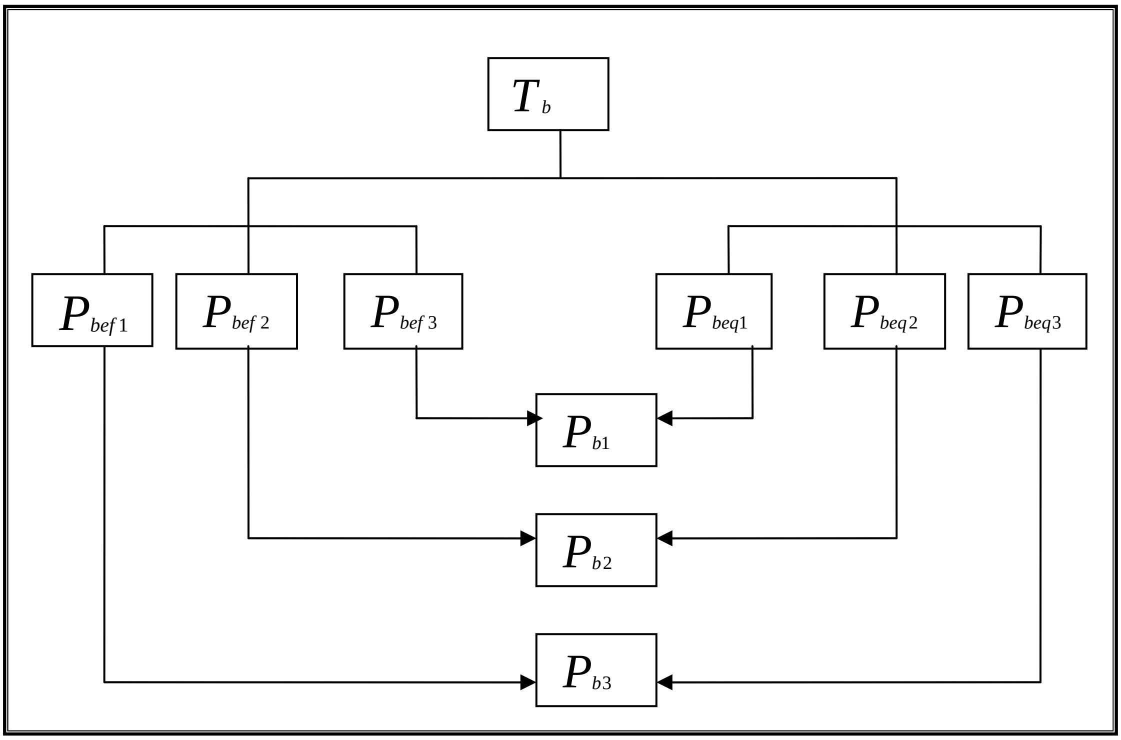


Figure: 7. 2: Framework for Stated Preference Model

(i) $P_{befi} = T_b \cdot r_{befi}$ Equation 7.1

and

$P_{beqi} = T_b \cdot r_{beqi}$ Equation 7.2

Where;

P_{befi} = Amount of total budget allocated by economic efficiency by the ith road type.

r_{befi} = Proportion of total budget allocated by economic efficiency by the ith road type.

T_b =Total Road Maintenance Budget Available

P_{beqi} = Amount of total budget allocation by social equity by the ith road type.

r_{beqi} = Proportion of total budget allocated by social equity by the ith road type.

and

(ii) $P_{bi} = P_{befi} + P_{beqi}$ Equation 7.3

P_{bi} = Amount of total budget allocation by road type

Where $(i = 1,2,3)$

7.3 DEVELOPMENT OF MODEL PARAMETERS

The parameters for modelling the stated preference based model (SPM) were developed from Analytical Hierarchy Process (AHP) as discussed in section 3.8.2. The data items specified in section 5.3.2 was used for the AHP. A generic procedure of the AHP was applied to generate priority vectors which were used to determine the model parameters required at the two tiers of the model structure. The generic procedure for the application of the AHP and the procedure for estimating the input parameters for each tier within the model structure are presented in the following paragraphs.

7.3.1 Description Procedure for the Analytical Hierarchy Process

The generic the AHP is illustrated in Figure 7.3 and the details are described in the following paragraphs.

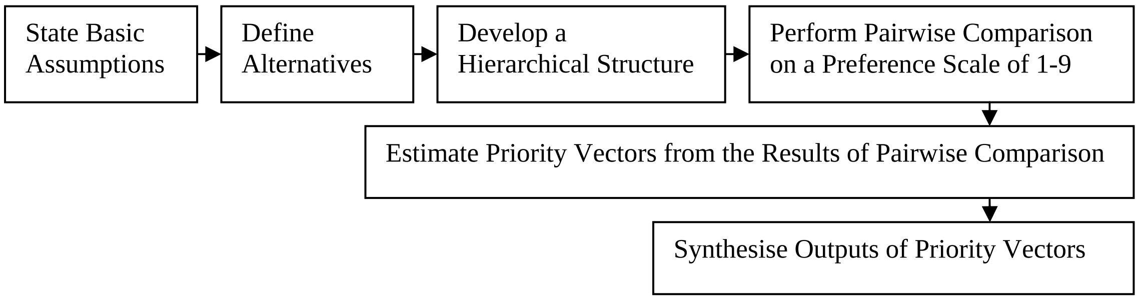


Figure7.3: Procedure for AHP Analysis

7.3.1.1 Basic Assumptions

The following assumptions were made in the application of the AHP.

1. Criteria: The criteria defined at levels 1 and 2 of the hierarchical structure illustrated in Figure 4.2 were pre-determined on the basis of the development goals of Ghana. This was to ensure economic efficiency and social equity. The elements of the sub criteria were determined by stakeholder preference. The priorities assigned on all the elements at all criteria level were also based on stake holder preference.
2. Scale of Measurement: The elements generated on social factors did not have a standard scale of measurement.
3. The elements of the sub criteria are subject to change since the information input on stakeholder priorities could change.

7.3.1.2 Definition of Alternatives

The alternative for which the preference options were determined are the three road types in Ghana which are the beneficiaries of the road fund and these are the trunk, urban and feeder roads.

7.3.1.3 Development of a Hierarchical Structure

The hierarchical structure used is as presented in Figure 4.2.

7.3.1.4 Pairwise comparisons

This involved a rating of the importance of an element of a criterion over the other on a scale of 1-9 as presented in section 5.3.1.4 item (3iii) and summarised in the sample in Appendix 5.15.

7.3.1.5 Determination of the Priority of Requirements

This involved the assignment of priority vectors to outputs of the pairwise comparisons at the criteria and sub criteria levels at each administrative level for all road types. The approach to the development of the priority vector was in the context applied by Odoki and Kerali (2002). The steps involved are summarised below and the details are presented in the subsequent paragraphs.

(i) Estimate the intensity of preference of one element over the other

(ii) Assign Weights

(iii) Calculate Priority Vectors

(iv) Check for Consistency

Step 1: The assigned numerical values on the scale of preference from 1-9 was used to develop a matrix cell denoted as w_{ij} . The intensity of preference of an element over the other from the pairwise comparison were denoted as i and j in the matrix cell. For example if a pairwise comparison of economic benefits and social benefits on a scale of 1 to 9 resulted on good roads for trunk roads indicated a preference rank of 4 for economic benefits (See Appendix 5.16) at the community level, then the value of the matrix cells w_{ij} of a comparison between economic benefit on row $1(w_i)$ and economic benefit in column $1(w_j)$ was estimated as; $w_{ij} = \frac{1_j}{1_i}$.

Then the comparison between economic benefit on row $1(w_i)$ and social benefit in column 2 (w_j) will be estimated as;

$$w_{ij} = \frac{4_j}{1_i}.$$

The reciprocal w_{ji} on the second row is then estimated as presented as in Figure 7.4.

Good Road

Criteria	Economic	Social
Economic	1	4/1
Social	1/4	1

=

Criteria	Economic	Social
Economic	1	4
Social	0.25	1
Total	1.25	5.0

Figure 7.4: Pair-wise Comparison of Economic and social benefits on Good Road

Similarly if the preference for economic benefits over economic benefit was rated as 3 on a bad road at the community level for trunk roads as compared to social benefits then the matrix analysis will be as indicated in Figure 7.5

Bad Road

Criteria	Economic	Social
Economic	1	3/1
Social	1/3	1

=

Criteria	Economic	Social
Economic	1	3
Social	0.33	1
Total	1.33	4.0

Figure 7.5: Pair-wise Comparison of Economic and social benefits Bad Road

Step 2: Assignment of Weights: The value generated for each matrix cell by the pairwise construction of elements i and j was normalized by dividing each cell value with the sum of the corresponding column as;

$$AW = \frac{w_{ij}}{\sum_{i=1}^{n} w_{ij}} \qquad \text{Equation 7.1}$$

Where;

AW = the weighted matrix cell value

For example using the results from Figures 7.2 and 7.3 the estimated AW for good and bad roads can be presented in Figure 7.6.

Good Road

Criteria	Economic	Social
Economic	0.8	0.8
Social	0.2	0.2

Bad Road

Criteria	Economic	Social
Economic	0.25	0.25
Social	0.75	0.75

Figure 7.6: Assignment of Weights

Step 3: Calculation of Priority Vector: The priority vector (PV) is the principal eigenvector. It is a column matrix obtained by dividing the sum of the row of the weighted matrix AW by the number of elements in the row using the expression

$$x = \frac{\sum_{j=1}^{n} AW_{ij}}{n} \qquad \text{Equation 7.2}$$

Where

x = the priority vector

The elements of the estimated x based on Figures 7.4 for good and bad roads are presented in Figure 7.7.

Good Road		Priority Vector
Economic	1.6/2 = 0.8	0.8
Social	0.4/0.2 =0.2	0.2

Bad Road		Priority Vector
Economic	0.5/2=0.25	0.25
Social	1.5/2 = 0.75	0.75

Figure 7.7: Estimation of Priority Vector

The priority vector for the community score was then obtained for both good and bad roads as;

[Economic = [0.8 +0.25 = 1.05/2 = 0.525] and Social = [0.2+0.75 = 0.95/2 = 0.475]

Step 4: Consistency Check: The Eigen Vector ($\lambda_{\max}$) is estimated by defining another vector Y . Y is obtained by first dividing the priority vector x with the sum of the weighted matrix AW in a row using the expression;

$$Y_i = \frac{x_i}{\sum AW_i} \qquad \text{Equation 7.3}$$

Using the results of the priority vectors estimated for good and bad roads in Figure 7.8 the result of the estimated $Y's$ is presented in Figure 7.9.

Good Road		Y
Economic	1.6/.08 = 2	2
Social	0.4/0.2 = 2	2

Bad Road		Y
Economic	0.5/0.25= 2	2
Social	1.5/0.75 = 2	2

Figure 7.8: Estimation of Eigen Vector

Then the parameter $\lambda_{\max}$ is estimated by the arithmetic mean of the elements of vector Y_i as:

$$\lambda_{\max} = \frac{\sum_i Y_i}{N}, \qquad \text{Equation 7.4}$$

That is ($\lambda_{\max}$) = (2+2)/2
= 2

($\lambda_{\max}$) = (2+2)/2
= 2

Figure 7.9: Estimation of Eigen Vector

The Consistency Index CI is then estimated as;

$$CI = \frac{\lambda_{\max} - n}{n-1} \qquad \text{Equation 7.5}$$

Using the output in Figure 7.7 the CI for both good and bad roads was estimated as;

$$CI = \frac{2-2}{2-1}$$

$$= \frac{0}{1}$$

$$= 0$$

The Consistency Ratio (CR) was also estimated on the basis of the expression;

$$CR = \frac{CI}{RI} \qquad \text{Equation 7.6}$$

The Random Index parameter (RI) was derived from Wiston’s Table of values of Random Index Wistons (1993) given in Appendix 7.1.

Table 7.1: Random Index

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

From the results of the example on the good and bad roads the appropriate value of RI for a matrix size 2 is equal to 0 therefore CR was estimated as:

$$CR = \frac{0}{0}$$

which is;

$$= \infty$$

Since the value of CR was less than 0.1 the comparison of the pair wise matrix was considered to be consistent and satisfactory. The procedure was applied on the data on the elements defined at the criteria and sub criteria levels for all the three road types at the different levels of administration where the studies were conducted. The outputs of the priority vectors estimated at the criteria and sub criteria levels for all road types at the micro, meso and macro levels were used to generate weighted scores which determined the input parameters for the model structure and the details are discussed as follows.

7.3.2 Estimation of Input Parameters for Efficiency and Equity Factors.

This involved the determination of the proportion of the road fund allocated on the basis of economic efficiency and social equity for each road type. Priority vectors were developed at each of the defined criteria levels within each of the three administrative levels for each road type. The average of the priority vectors of the three administrative levels at each criteria level for each road type was further subjected to a Pairwise comparison. This generated a weighted score based on a comparison of the priority score of one road type over the other at the criterion and sub criterion level. The process is illustrated in Figure 7.10 and the details are also presented in the following paragraphs.

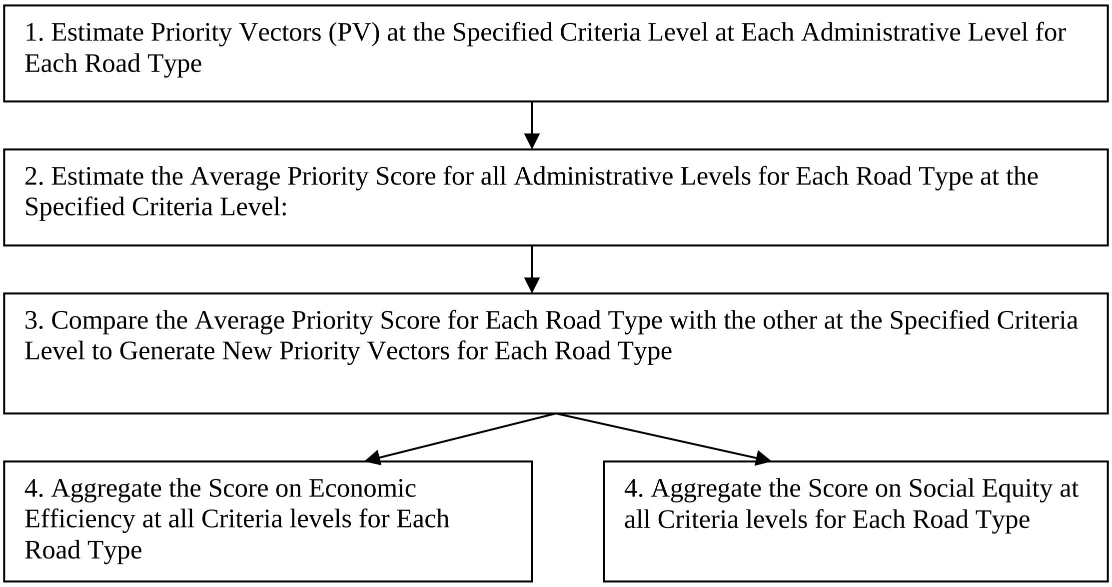


Figure 7.10: Procedure for Estimating Inputs Parameters for Efficiency and Equity

7.3.2.1 Summary of Estimated Priority Vectors (PV) for Criteria on Economic and Social Benefits (Criteria Level 1)

1. PV for Criteria level 1 on Economic and Social Benefits- Community (Micro) Level

The detail of the priority vectors on economic and social benefits at the community level for good and bad roads are attached as Appendixes 7.1 and 7.2 respectively and the summaries are also presented in Tables 7.2 and 7.3 respectively.

Table 7.2: PV for Criteria Level 1on Economic and Social Benefits (Good Roads)

Benefits and Cost Categories	Type of Road		
	Trunk	Urban	Feeder
Economic	0.80	0.88	0.077
Social	0.20	0.11	0.923

Table 7.3: PV for Criteria Level 1on Economic and Social Benefits (Bad Roads)

Benefits and Cost Categories	Type of Road		
	Trunk	Urban	Feeder
Economic	0.25	0.75	0.053
Social	0.75	0.25	0.947

The average of the results of the priority vectors at the community level 1 on economic and social benefits for good and bad roads is presented in Table 7.4. The output indicated a higher rating for social benefits as compared to economic benefit for trunk and urban roads whilst social benefits were rated higher on the feeder roads.

Table 7.4: Average PV for Criteria 1 on Economic and Social Benefits (Micro Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Economic	0.525	0.815	0.065	0.47
Social	0.475	0.180	0.935	0.53

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

2. PV for Criteria Level on Economic and Social Benefits -District (Meso) Level

Economic benefits were rated higher than social benefits at the district level. A higher economic rating was assigned on the trunk and urban roads as compared to feeder roads. Feeder roads were assigned the highest social benefits. Table 7.5 presents a summary of the economic and social weights assigned at the district level and Appendix 7.3 provides the detail analysis.

Table 7.5: PV for Criteria Level 1 on Economic and Social Benefits (Meso Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Economic	0.833	0.75	0.20	0.594
Social	0.166	0.25	0.80	0.405

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

3. PV for Criteria Level 1on Economic and Social Benefits-National (Macro) Level

Economic benefits were rated higher at the national level as compared to the district and community levels. Trunk and urban roads were rated higher on economic benefits as compared with feeder roads. However feeder roads were assigned the highest social benefits at the national level as compared with the district and community levels. Table 7.6 presents a summary of the priority vectors for economic and social benefits assigned at the national level and Appendix 7.4 provides the detail analysis.

Table 7.6: PV for Criteria Level 1on Economic Benefits-Costs (Macro Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Economic	0.875	0.833	0.111	0.606
Social	0.125	0.166	0.888	0.393

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

4. Average PV for Criteria Level 1on Economic and Social Benefits at the Micro, Meso and Macro Levels.

The average of the priority vectors estimated at each administrative level is summarized in Table 7.7. The results indicated that economic benefits were rated higher than social benefits at the national and district levels than social benefits. Social benefits were rated higher at the community level than economic benefits.

Table 7.7: Average PV for Criteria Level 1on Econ and Social Benefits (All Administrative Levels)

Criteria	Investigation level			
	Micro (Community)	Meso (District)	Macro (National)	Average
Economic	0.47	0.59	0.61	0.56
Social	0.53	0.41	0.39	0.44

5. Summary of Weighted Score for Criteria on Economic and Social Benefits for Each Road Type

The average of the priority vectors on criteria Level 1 for the pairwise comparison of economic and social benefits at all the three administrative levels for each road type was further analysed by pairwise comparison of the results of one road type with the other to determine the weighted score for each road sector on economic and social benefits. A summary of the results is summarized Table 7.8. The detail analysis on economic benefits is given in Appendixes 7.5 and that of social benefits is in Appendix 7.6.

Table 7.8: Weighted Score at Criteria Level 1 Economic and Social Benefits by Road Type

Road Type	Economic		Social Benefit	
	Average of Combined Score	Weighted Score	Average of Combined Score	Weighted Score
Trunk	0.74	0.44	0.26	0.20
Urban	0.80	0.48	0.22	0.15
Feeder	0.56	0.08	0.87	0.65

7.3.2.2 Summary of Weighted Score for Criteria Level 2 on Economic Benefits and Costs by Road Type

The values of the criteria on economic benefits and costs were estimated with HDM-4 for each road type over twenty years. The economic benefits were based on the average of estimated NPV/cap for each road type. The economic costs were defined in terms of road maintenance costs for each road type. The output on NPV/cap for each road type was subjected to a pairwise comparison of the results of one road type with the other. The same was repeated for the economic costs of each road type. The summary of the weighted scores for criteria on economic benefits and costs are summarized in Table 7.9. The details of the pairwise comparison on economic benefits and costs are given in Appendixes 7.7 and 7.8 respectively.

Table 7.9: Summary of Weighted Scores for Criteria Level 2 on Economic Benefits and Costs by Road type

Alternative	Economic Benefits		Economic Costs	
Road	Average NPV/Cost	Weighted Score	Economic Costs US $m	Weighted Score
Trunk	4.02	0.55	1539.9	0.38
Urban	2.9	0.39	2143.2	0.53
Feeder	0.431	0.06	391	0.10

7.3.2.3 Summary of Estimated Priority Vectors for Criteria on Social Benefits and Costs (Level 2)

1. PV for Criteria Level 2 on Social Benefits and Costs –Community (Micro) Level

The result of the analysis for good roads is presented in Table 7.10. The detail analysis on the social benefits and costs for good roads is attached as Appendix 7.9.

Table 7.10: PV for Criteria Level 2 on Social Benefits and Social Costs (Good Roads)

Benefits and Cost Categories	Type of Road		
	Trunk	Urban	Feeder
Social Benefits	0.857	0.889	0.857
Social Costs	0.143	0.111	0.143

The result of the analysis for bad roads on social benefits and costs at the criteria level 2 is presented in Table 7.11 and the detail analysis is attached as Appendix 7.10.

Table 7.11: PV for Criteria Level 2on Social Benefits and Social Costs (Bad Roads)

Benefits and Cost Categories	Type of Road		
	Trunk	Urban	Feeder
Social Benefits	0.889	0.889	0.857
Social Costs	0.111	0.111	0.143

The average of the priorities assigned on social benefits and costs at the community level for good and bad roads indicated that all communities rated social benefits to be higher than social costs for all road types. The result is presented in Table 7.12.

Table 7.12: Average PV for Criteria Level 2 on Social Benefits and Costs (Micro Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Social Benefits	0.873	0.889	0.857	0.873
Social Costs	0.127	0.111	0.143	0.127

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

2. PV for Criteria Level 2 on Social Benefits and Costs -District (Meso) Level

The priority vectors assigned to social benefits and costs indicated that social benefits were rated higher for all road types than social costs. Trunk roads recorded the highest social benefit and urban roads recorded the lowest. The result is summarized in Table 7.13 and the details are presented in Appendix 7.11.

Table 7.13: P V for Criteria Level 2 on Social Benefits and Costs (Meso Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Social Benefits	0.833	0.750	0.800	0.794
Social Costs	0.167	0.250	0.200	0.206

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

3. PV for Criteria Level 2 on Social Benefits and Costs -National (Macro) Level

Social benefits were also rated higher at the national level than social costs. Trunk and urban roads were had an equal rating on social benefits whilst feeder roads were rated as highest in terms of social benefits. The result is summarized in Table 7.14 and the details are given in Appendix 7.12.

Table 7.14: PV for Criteria Level 2 on Social Benefits and Costs (Macro Level)

Benefits and Cost Categories	Type of Road			Overall
	Trunk	Urban	Feeder	
Social Benefits	0.875	0.875	0.900	0.883
Social Costs	0.125	0.125	0.100	0.116

λ_{max} = 2, CI = 0, RI = 0, CR = 0 < 0.1 (Acceptable)

4. Average PV for Criteria on Social benefits and Social Costs at Micro, Meso and Macro Levels: Social benefits were rated higher at all the administrative levels than social costs. This indicated that the positive impacts of road maintenance were considered to outweigh the negative impacts. The national level assigned the highest rating on social benefits followed by the community level. The district level assigned the least weights to the social benefits. The details are summarized Table 7.15.

Table 7.15: Average PV for Criteria Level 2 on Social Benefits and Costs (All Administrative Levels)

Criteria	Investigation Level			
	Micro (Community)	Meso (District)	Macro (National)	Average
Social Benefits	0.873	0.794	0.883	0.85
Social Costs	0.127	0.206	0.116	0.15

5. Summary of Weighted Score for Criteria Level 2 on Social Benefits and Costs for Each Road Type: The average of the priority vectors on the criteria on social benefits and costs at all the three administrative levels for each road type was further analysed by the pairwise comparison of the results of one road type with the other to determine the weighted score for each road sector on social benefits and costs. The result is summarized in Table 7.16 and the details are attached as Appendixes 7.13 for social benefits and Appendix 7.14 for social costs.

Table 7.16: Summary of weighted Score for Social Benefits and Costs (Level 2)

	Social benefits		Social Costs	
Road	Combined Score	Weighted Score	Combined Score	Weighted Score
Trunk	0.86	0.34	0.14	0.31
Urban	0.84	0.33	0.16	0.36
Feeder	0.85	0.33	0.15	0.33

7.3.2.4 Summary of Estimated Priority Vectors for Social Benefits and Costs at Sub Criteria (level 3)

1. PV for Social Benefits and Costs at Sub Criteria Level 3 -Community (Micro) Level

The detail analysis of the priority analysis on social benefits at the sub criteria level for good roads is presented in Appendix 7.15 and that of social and costs is given in Appendix 7.16. The result of the analysis on social benefits and costs for good roads is presented in Table 7.17.

Table 7.17: PV at Sub Criteria Level 3 on Social Benefits and Costs (Good Roads)

Item	Road Type		
	Trunk	Urban	Feeder
Good Roads			
Creation Of Employment	0.592	0.532	0.544
Access to Health	0.170	0.238	0.252
Access to Education	0.170	0.187	0.065
Increased Social Interaction	0.065	0.041	0.137
Social Costs			
Increased Road Accidents	0.524	0.449	0.601
Negative Cultural Values	0.118	0.042	0.090
Dust Pollution	0.286	0.354	0.102
Spread of HIV/AIDS	0.70	0.152	0.205

The result of the analysis on social benefits and costs at the sub criteria level for bad roads is presented in Table 7.18. The detail of the analysis on social benefits is attached as Appendix 7.17 and that of social costs is given in Appendix 7.18.

Table 7.18: PV at the Sub Criteria Level 3 on Social Benefits and Costs (Bad Roads)

Item	Road Type		
	Trunk	Urban	Feeder
Social Benefits			
Creation Of Employment	0.448	0.618	0.363
Access to Health	0.252	0.167	0.402
Access to Education	0.205	0.153	0.085
Increased Social Interaction	0.094	0.060	0.148
Social Costs			
Increased Road Accidents	0.653	0.531	0.202
Negative Cultural Values	0.089	0.089	0.100
Dust Pollution	0.164	0.213	0.570
Spread of HIV/AIDS	0.093	0.165	0.125

The average of the results of the analysis on social benefits and costs at the sub criteria level 3 at the community level indicated that employment creation and access to health facilities were of high priority in terms of benefits whilst increased accidents and environmental pollution were considered as the most important social costs. The result is as presented in Table 7.19.

Table 7.19: Average PV at the Sub Criteria Level 3 Social on Benefits at (Micro Level)

Item	Road Type			Overall
	Trunk	Urban	Feeder	
Social Benefits				
Creation Of Employment	0.52	0.58	0.45	0.52
Access to Health	0.21	0.20	0.33	0.25
Access to Education	0.19	0.18	0.08	0.15
Increased Social Interaction	0.08	0.05	0.14	0.09
Social Costs				
Increased Road Accidents	0.59	0.49	0.40	0.49
Negative Cultural Values	0.10	0.07	0.10	0.09
Dust Pollution	0.23	0.28	0.34	0.28
Spread of HIV/AIDS	0.08	0.16	0.17	0.14

λ_{max} = 4, CI = 0, RI = 0.90, CR = 0 < 0.1 (Acceptable)

2. PV for Social Benefits and Costs at Sub Criteria Level 3 -District (Meso) Level

Access to employment was assigned the highest weight followed by access to social amenities at the district level. Increased access to land was weighted as the third highest and induced housing was weighted as the fourth highest. The social costs were increased traffic accidents, dust pollution, disruption of utility services and increased land prices. A summary of the weights is summarized in Table 7.20 and the details of the social benefits are presented in Appendix 7.19 and that of social costs is given in Appendix 7.20.

Table 7.20: PV at Sub Criteria Level 3 on Social Benefits and Costs (Meso Level)

Item	Road Type			Overall
	Trunk	Urban	Feeder	
Social Benefits				
Creation Of Employment	0.616	0.481	0.225	0.441
Access to Amenities	0.189	0.229	0.311	0.243
Induced Housing	0.133	0.149	-	0.094
Increased Access to land	0.061	0.139	0.464	0.221
Social Costs				
Increased Road Accidents	0.661	0.406	0.50	0.522
Dust Pollution	0.140	0.375	0.400	0.305
Disruption of services	0.116	0.063	-	0.060
Increased Land Prices	0.082	0.156	0.01	0.113

λ_{max} = 4, CI = 0, RI = 0.90, CR = 0 < 0.1 (Acceptable)

3. PV for Social Benefits and Costs at Sub Criteria Level 3 -National (Macro) Level

The types of social benefits identified at the national level were the same as that of the district level with the exception of increased access to information. Access to social amenities was given the highest weight followed by increased access to employment. Access to information was assigned the third highest weight whilst induced housing was assigned the lowest weight. Trunk roads were rated higher on employment generation, whilst feeder roads were rated higher for access to social amenities and access to information. The social costs identified at the national level also included increased accidents and pollution. However increased crime was identified in addition to the spread of HIV at the national level. A summary of the assigned weights are presented is presented in Table 7.21 and the details are presented in Appendix 7.21 for social benefits and Appendix 7.22 for social costs.

Table 7.21: PV at Sub Criteria Level on Social Benefits and Costs (Macro Level)

Item	Road Type			Overall
	Trunk	Urban	Feeder	
Social Benefits				
Creation Of Employment	0.440	0.436	0.129	0.335
Access to Amenities	0.224	0.340	0.568	0.337
Access to Information	0.181	0.154	0.212	0.182
Increased Access to Land	0.154	0.070	0.092	0.105
Social Costs				
Increased Road Accidents	0.600	0.600	0.428	0.543
Increased Crime	0.072	0.063	0.381	0.172
Dust Pollution	0.218	0.260	0.138	0.205
Spread of HIV/AIDS	0.110	0.077	0.053	0.080

λ_{max} = 4, CI = 0, RI = 0.90, CR = 0 $<$ 0.1 (Acceptable)

4. Average PV at the Sub Criteria Level 3 for All Administrative Levels: A of the priority score obtained on each element at the micro, meso and macro levels is presented in Table 7.22.

Table 7.22: Summary of PV at Sub Criteria Level 3 on Social Benefits and Costs (For All Administrative Levels)

Type of Sub Criteria	Priority Vector at Different Investigation Levels		
	Micro Community	Meso (District)	Macro (National)
Social benefits			
Creation Of Employment	0.52	0.44	0.34
Access to Health	0.25		
Access to Education	0.15		
Increased Social Interaction	0.09		
Access to Social Amenities		0.24	0.38
Access to information			0.18
Increased Access to Land		0.22	0.11
Induced Housing		0.14	
Social Costs			
Increased Road Accidents	0.49	0.500	0.54
Negative Cultural Values	0.09		
Dust Pollution	0.28	0.400	0.21
Spread of HIV/AIDS	0.14		0.08
Disruption of Services		-	
Increased Land Prices		0.100	
Increased Crime			0.17

Due to the differences in the elements of social benefits and costs identified at the three administration levels, the elements were normalised on a common preference scale for purposes of uniformity. The priority scores on the element representing social benefit or cost for the three administrative levels were rated from the highest to the lowest score in an ordinal order on a preference scale of 1 to 0.25. The element scoring the highest priority score had the highest rating of 1 and the element with the lowest priority score had the lowest rating of 0.25 as follows.

Highest Benefit or Cost = 1.0

2nd Highest Benefit or Costs = 0.75

3rd Highest Benefit or Cost = 0.50

and

4th Highest benefit or Cost = 0.25.

The priority scores were adjusted on the basis of the set preference scale by multiplying it with the preference rating using equation 7.7 to obtain a rated score as;

$$f = \sum w_i . t \qquad \text{Equation 7.7}$$

Where;

f = The adjusted priority score,

$\sum w_i$ = the sum of the priority score at the sub criteria level for a road sector

and

t = the preference scale.

The results of the adjusted priority scores are provided in Table 7.23 and the detail is given in Appendix 7.23.

Table7. 23: Summary of Adjusted PV

Road Type	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Trunk	0.53	0.16	0.09	0.03
Urban	0.50	0.20	0.08	0.02
Feeder	0.20	0.40	0.03	0.06
	Cost 1	Cost 2	Cost 3	Cost 4
Trunk	0.62	0.08	0.10	0.24
Urban	0.50	0.13	0.15	0.03
Feeder	0.45	0.06	0.09	0.04

5. Summary of Weighted Score for Sub Criteria level 3 on Social benefits and Costs for Each Road Sector: The average of the adjusted priority vectors on the sub criteria on social benefits and costs at all the three administrative levels for each road type was further analysed by the pairwise comparison of the results of one road type with the other to determine the weighted score for each road sector. The results are summarized in Table 7.24. The details of the priority scores and adjusted weighted scores for social benefits are given in Appendixes 7.24 and 7.25. The details of the priority scores and adjusted weighted scores for social costs are given in Appendixes 7.26 and 7.27.

Table 7. 24: Summary of Weighted Scores with Adjusted PV

Alternative	Benefit 1	Benefit 2	Benefit 3	Benefit 4
	Weighted Score	Weighted Score	Weighted Score	Weighted Score
Trunk	0.36	0.3	0.4	0.33
Urban	0.36	0.3	0.4	0.33
Feeder	0.27	0.4	0.2	0.33
	Cost 1	Cost 2	Cost 3	Cost 4
Trunk	0.33	0.43	0.29	0.6
Urban	0.33	0.43	0.43	0.2
Feeder	0.33	0.14	0.29	0.2

7.3.2.5 Aggregation of Overall Scores on Economic Efficiency and Social Equity: This was obtained by multiplying the weighted score on an element at one criteria level with the other. The details are described in the following paragraphs.

1. Estimated Total Score for Economic Efficiency by Road Type: The scores on the economic efficiency were obtained by multiplying the weighted score for criteria levels 1 and 2 for a each road type as;

$$b_i \cdot \left(\sum_{i=1}^{2} q_i h_i \right). \qquad \text{Equation 7.8}$$

where

b_i = the weighted score on economic benefits at criteria level 1 for each road type

q_i = the weighted score on economic benefits at criteria level 2 for each road type

h_i = the weighted score on economic costs at criteria level 2 for each road type

The estimated scores are summarized in Table 7.25. The results indicated that trunk and urban roads scored higher ratings on economic objectives than feeder roads.

Table: 7.25: Total Score for Economic Efficiency by Road Type

Level of Economic Factor	Alternatives		
	Trunk	Urban	Feeder
(A) Weighted Score at Level 1	0.56	0.56	0.56
(B) Weighted Score for Economic Benefit Based on NPV	0.55	0.39	0.06
Value of Economic Benefits (A x B)	0.31	0.22	0.03

2. Estimated Total Score for Social Benefits and Costs: The scores on the social objective was obtained by multiplying the combined weighted score for social benefits and costs at criteria level 1with the combined scores on social benefits and costs at criteria levels 2 and 3using the expression;

$$d_i \cdot \left(\sum_{i=1}^{2} q_i h_i \right) \cdot \left(\sum_{i=1}^{n} l_i z_i \right) \qquad \text{Equation 7.9}$$

Where;

d_i = the weighted score on social benefits at criteria level 1 for each road type

q_i = the weighted score on social benefits at criteria level 2 for each road type

h_i = the weighted score on social costs at criteria level 2 for each road type

l_i = the weighted score on social benefits at sub criteria level 3 for each road type

z_i =the weighted score on social costs at sub criteria level 3 for each road type

The details of the aggregated score on social benefits are presented in Table 7.26.

Table: 7.26: Total Score for Social benefits by Alternative

Level of Social Factor		Alternatives		
		Trunk	Urban	Feeder
Weighted Score at Level 1		0.44	0.44	0.44
Weighted Score for Social benefit at Level 2		0.85	0.85	0.85
Weighted Score for Social benefit at Level 3				
Benefit 1	Average Weight	0.53	0.5	0.14
	Average Score	0.36	0.36	0.27
	Total	0.89	0.86	0.41
Benefit 2	Average Weight	0.20	0.20	0.40
	Average Score	0.30	0.3	0.40
	Total	0.50	0.50	0.80
Benefit 3	Average Weight	0.10	0.10	0.03
	Average Score	0.40	0.40	0.2
	Total	0.50	0.50	0.23
Benefit 4	Average Weight	0.03	0.02	0.06
	Average Score	0.33	0.33	0.33
	Total	0.36	0.35	0.39
Combined Score for Social Benefits at Level 3		2.24	2.18	1.82

The details of the aggregated scores for social costs are presented in 7.27.

Table: 7.27: Total Score for Social Costs

Level of Social Factor		Alternatives		
		Trunk	Urban	Feeder
Weighted Score at Level 1		0.44	0.44	0.44
Weighted Score for Social Cost at Level 2		0.15	0.15	0.15
Weighted Score for Social Cost at Level 3				
Cost 1	Average Weight	0.62	0.50	0.45
	Average Score	0.33	0.33	0.33
	Total	0.95	0.83	0.78
Cost 2	Average Weight	0.08	0.13	0.06
	Average Score	0.43	0.43	0.43
	Total	0.51	0.56	0.49
Cost 3	Average Weight	0.10	0.15	0.08
	Average Score	0.29	0.43	0.29
	Total	0.39	0.58	0.37
Cost 4	Average Weight	0.24	0.32	0.04
	Average Score	0.6	0.20	0.20
	Total	0.84	0.23	0.24
Combined Score for Social Benefits at Level 3		2.74	2.2	1.88

3. Summary of Aggregated Score on Social Equity: The total score for social equity is presented in Table 7.28.

Table 7.28: Total Score for Social Equity

Level of Social Factors	Alternatives		
	Trunk	Urban	Feeder
Weighted Score at Level 1	0.44	0.44	0.44
Weighted Score for Social benefit at Level 2	0.85	0.85	0.85
Sum of Weighted Score for Social benefits at Level 3	2.24	2.18	1.82
Total for Social benefits = f Levels (2 x 3)	1.90	1.86	1.54
Social Costs			
Weighted Score for Social Cost at Level 2	0.15	0.15	0.15
Sum of Weighted Score for Social benefits at Level 3	2.70	2.20	1.88
Total for Social cost = (2 x 3)	0.40	0.33	0.28
Total score for economic benefits and costs	2.3	2.19	1.82
Total Score for Social Factors= (Level 1 x totals for social benefits and Costs)	1.01	0.90	0.80

4. Summary of Scores for Economic Efficiency and Social Equity: The summary of scores on economic efficiency and social equity for each road types is illustrated in Figure 7.11 and the summarised in Table 7.29.

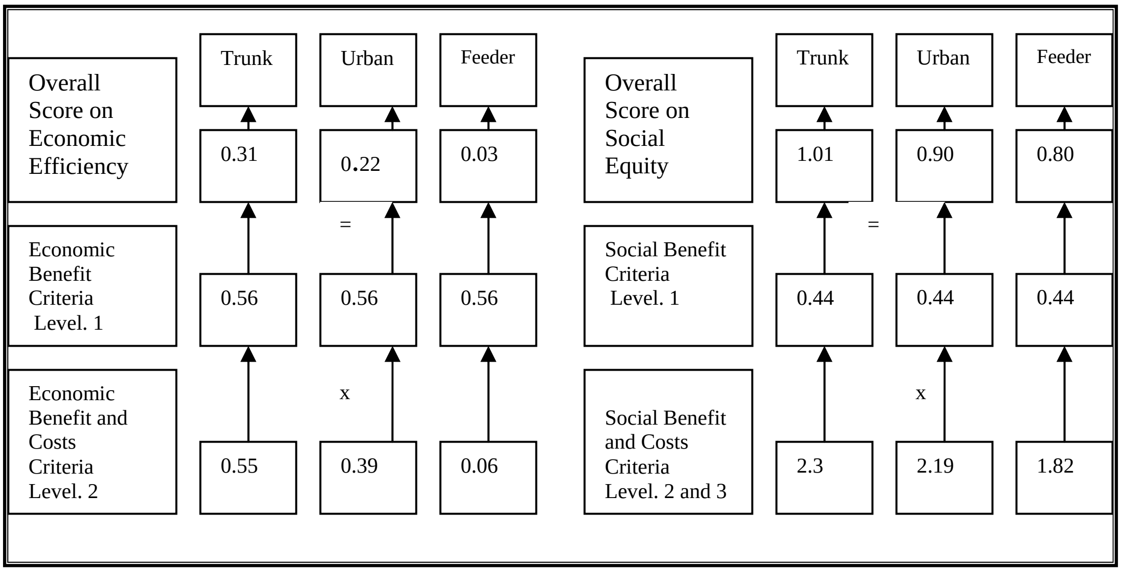


Figure 2Figure 7.11: Summary of Scores on Economic Efficiency and Social Equity

Table 7.29: Summary of Scores for Economic Efficiency and Social Equity

Total Score	Trunk	Urban	Feeder
Economic Objective	0.31	0.22	0.034
Social Objective	1.01	0.96	0.80
Total	1.32	1.18	0.84
Percentage Allocation by Economic Objective	23	18	4
Percentage Allocation by Social Objective	77	82	96
Percentage Allocation by Road Type	40	35	25

The results of the above analysis indicated that the average preference for road fund allocation to trunk, urban and feeder roads on the basis of economic efficiency and social equity is about 15 and 85 respectively for all road types. This indicates that higher emphasis is placed on social equity as compared to economic efficiency for all road types. Trunk and urban roads scored higher on economic considerations as than feeder roads. Feeder roads are considered to of higher social significance by stakeholder perception than economic considerations as compared to the other road types.

7.3.3 Estimation of Proportion of road Fund Allocation by Road Type

The proportion of funds allocated by each road type was estimated from the weighted scores on economic efficiency and social equity for each road type using the expression;

$$\sum_{i}^{n} f_i \cdot a_i + \sum_{i=1}^{n} f_i \cdot b_i \qquad \text{Equation 7.10}$$

Where;

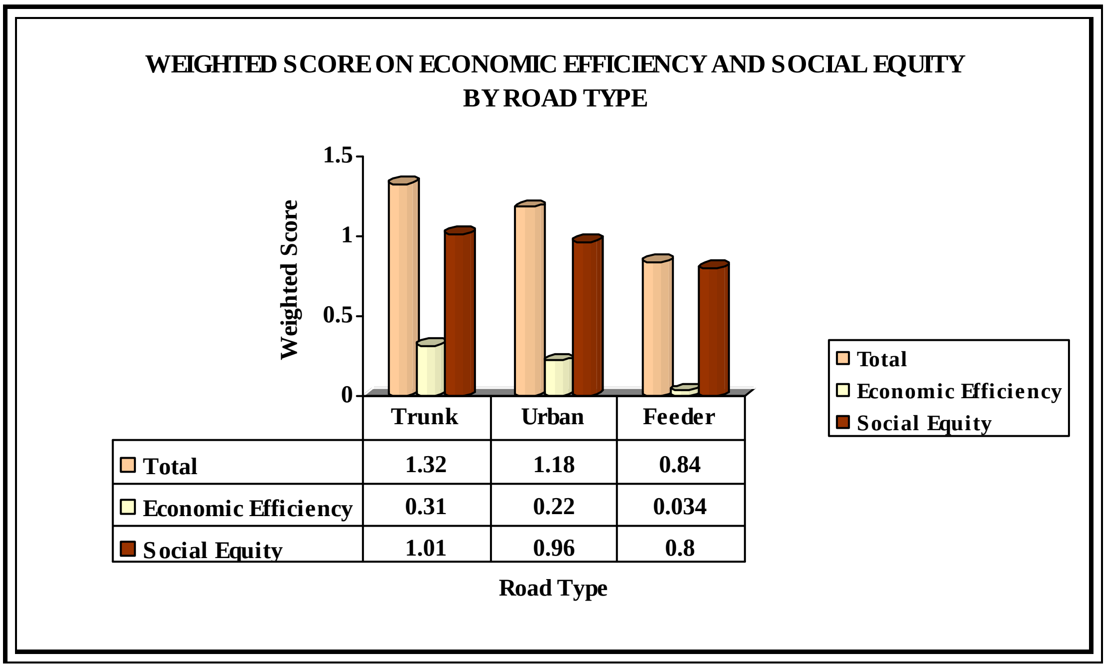
$\sum f_i a_i$ = The total score for each road type based on the intensity of the preference for economic efficiency.

$\sum f_i b_i$ = The total score for each road type based on the intensity of the preference for social equity.

The proportion of aggregated scores for each road sector was also estimated by the expression

$$P_{bi} = \frac{\sum_{i=1}^{2} fab}{\sum_{j=1}^{3}\sum_{i=1}^{2} fab} \qquad \text{Equation 7.11}$$

The results indicated that both trunk and urban roads scored higher than feeder road as indicated in Table 7.29. The proportionate allocation of the road fund to each agency also indicated a 40 percent allocation for trunk road maintenance, 35 percent for urban roads and 25 percent for feeder roads. Figure 7.12 illustrates the proportion of road fund allocation by road type.



	Trunk	Urban	Feeder
Total	1.32	1.18	0.84
Economic Efficiency	0.31	0.22	0.034
Social Equity	1.01	0.96	0.8

Figure 7.12: Road Fund allocation by Efficiency and Equity by Road Type

7.4 MODEL VALIDATION WITH CASE STUDY

The results the road fund allocation by efficiency and equity principles by the AHP model was validated with the results of a similar study conducted in Uganda (Odoki *et al*, 2008). The Ghanaian study was based on three road sectors whilst that of the Ugandan study was based only on rural roads therefore for purposes of effective comparison only the results on the feeder roads for the Ghanaian situation was compared with the Ugandan study. The outputs are as presented in Table 7.30.

Table 7.30: Comparison of AHP Application in Ghana and Uganda

Criteria	Investigation level					
	Ghana			Uganda		
	Micro	Meso	Macro	Micro	Meso	Macro
Economic	0.065	0.20	0.11	0.22	0.33	0.47
Social	0.935	0.80	0.89	0.79	0.67	0.53
‘t’ = 0.015 , P = 0.5, Critical ‘t’ = 2.0						

The outcome of the two studies indicated that higher priorities were placed on social equity than economic considerations at all levels for rural roads. A ‘t’ test statistics of the distribution of outcomes indicated that there was no significant difference between the outcomes of the two results.

7.5 WORKED EXAMPLE

The worked example is based on the threshold of available road fund disbursed to each road sector between the years 2000-2004 as indicated in Table 5.29. The results of the input parameters on the proportions on economic efficiency and social equity (r_{befi} and r_{beqi}) presented in Table 7.29 is summarised as follows.;

Proportion	Trunk (1)	Urban (2)	Feeder (3)
r_{befi}	0.23	0.19	0.04
r_{beqi}	0.77	0.81	0.96

From Table 5.29, let (T_b) = US $ 121.1, and then based on the estimated proportions for, r_{befi} and r_{beqi}, p_{befi}, p_{beqi} and p_{bi} can be estimated as;

Proportion	*ith* Trunk (1)	Urban (2)	Feeder (3)
p_{befi}	11.14	8.05	1.21
p_{beqi}	37.3	42.39	30.28
p_{bi}	48.44	42.39	30.28

7.6 SUMMARY

The chapter has presented the modelling process for the stated preference model. The model structure has been specified. The approach for estimating the input parameters with AHP analysis has been described. The aggregation of the outputs from each administrative level for each road sector on the basis of the criteria and sub criteria to arrive at the proportionate allocation of funds for each sector and the subdivision has also been indicated. A worked example on the basis of the available road has been undertaken to further explain the model. The model output has been compared with similar studies to verify the results.

CHAPTER EIGHT: MODEL COMPARISON

8.1 INTRODUCTION

This study developed two sets of models for road fund allocation. One model is presented in chapter six and the other model is presented in chapter seven. This chapter compares the results of the two models on the basis of the outcome of the impact on pavement roughness performance. The model comparison was in two parts. The first part involved a comparison of the impact of the proportionate allocation of fund to each road sector on the basis of pavement roughness performance. The second part involved a comparison of the impact of the outcome of each model on the value of the backlog of poor roads generated by the application of each model.

8.2. COMPARISON OF MODEL OUTCOME ON PAVEMENT ROUGHNESS PERFORMANCE

The purpose of the model comparison was to determine the model which resulted in a better pavement roughness performance than the other. It was also to determine whether the application of a model to road fund allocation was better than the ad hoc approach which is currently practiced in Ghana. The current approach to road fund allocation was defined as a 'base case scenario'. The proportion at which the road fund is allocated by this approach by road type was estimated from the mean of the past rerecords of road fund allocation by the MRT. The summary of estimated proportion for road fund allocation by models developed in this study and the 'base case' (BC) scenario and the proportions for road fund allocation estimated with the two models is illustrated in Figure 8.1.

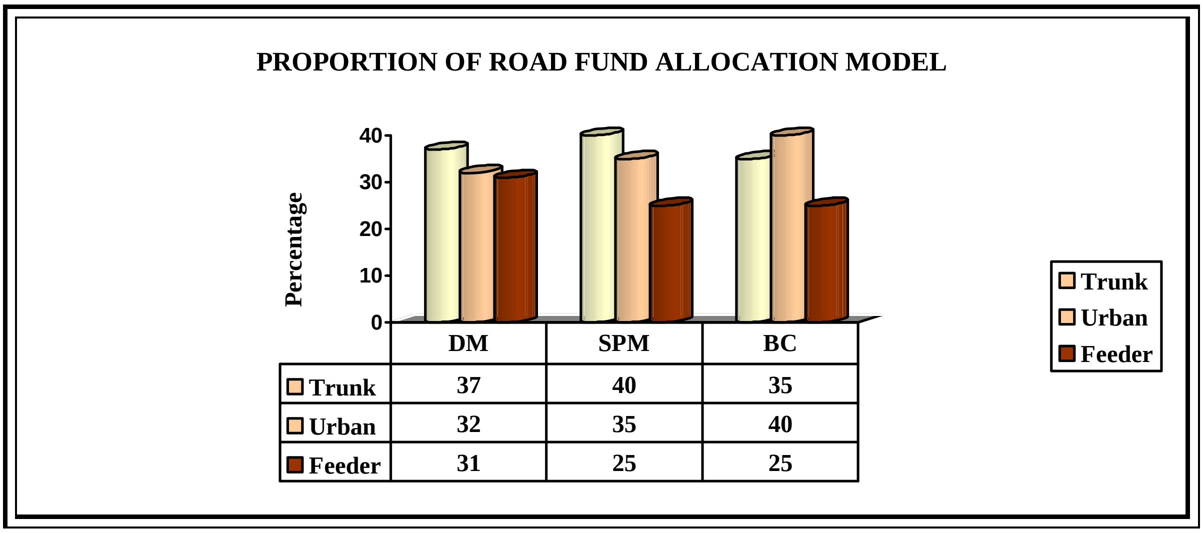


Figure 8.1: Proportion of Road Fund Allocation by Model Type

The impact of the model with deterministic approach (DM), the stated preference based model (SPM) and the 'base case' scenario on pavement roughness performance was assessed at optimal budget levels and with the current MRT's available road maintenance budget levels.

8.2.1 Trends in Pavement Roughness Progression at Optimal Budget Levels

The data on road network, traffic and vehicle characteristics used for the period 2005 to 2007 were used to perform HDM-4 runs at optimal budget levels. The HDM runs were performed for each road type at the proportions for road fund allocation estimated with the DM, the SPM and the 'base case' scenario (BC). The output reports on the impact on pavement roughness progression by IRI for a twenty year analytical for each road type by model type are presented in the following paragraphs.

8.2.1.1 Trend in Pavement Roughness Progression at Optimal Budget levels by Model Type

1. Pavement Roughness Progression at Optimal Budget levels: The trend in pavement roughness progression based on road fund allocation by the DM, the SPM and the BC at optimal budget level indicated that road fund allocation based on the SPM has better impact on pavement roughness progression at an initial minimum of about 3 IRI and a maximum of 9 IRI than the DM at a minimum of 3 IRI and a maximum of 10. However, the DM had better impact on pavement roughness performance than the BC which had a minimum of about 3 IRI and a maximum of about 12 IRI's. The results indicated that the range of IRI levels will be between a minimum of 4 and a maximum of 11 IRI for a twenty year analytical period if funds are at optimal thresholds. Figure 8.2 provides an illustration of the trend in pavement roughness progression for all roads by each model type at optimal budget level.

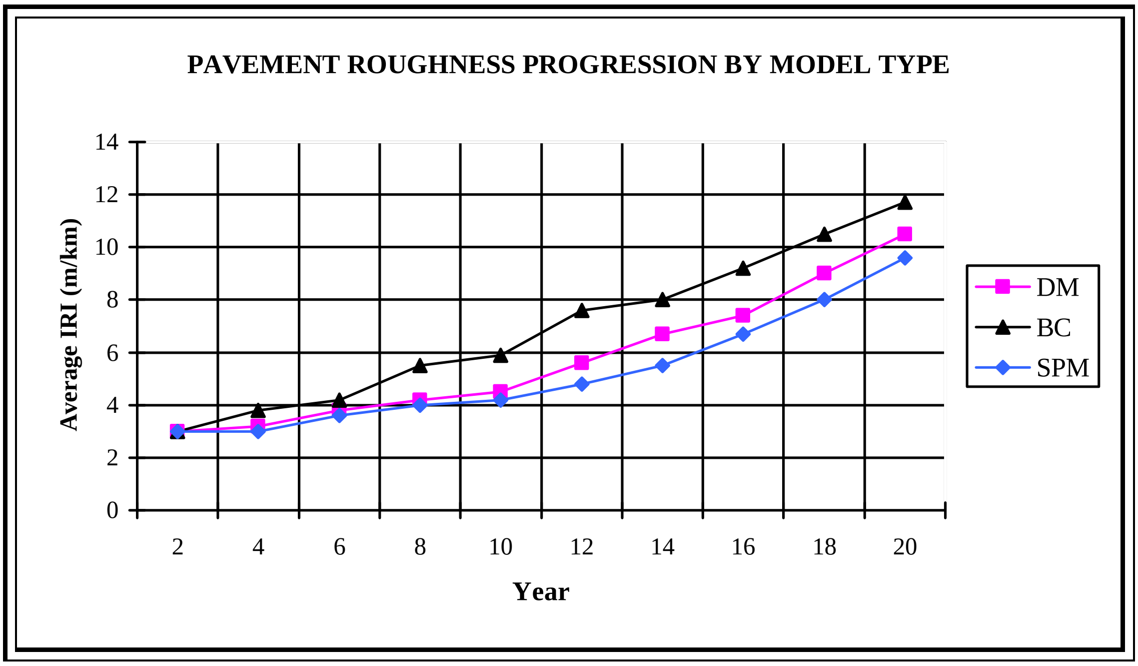


Figure 8.2: Trend in Pavement Roughness Progression at Optimal Budget

8.2.12. Trends in Pavement Roughness Progression at 75 percent Optimal Budget Level: The trend in pavement roughness performance at 75 percent optimal budget level by model also indicated the SPM will have better results than the DM and the DM will in turn have better results than the BC. The range of IRI levels for the twenty year period will be between a minimum of 4 and a maximum of 15 IRI Level. Figure 8.3 present an illustration of the pavement roughness progression at 75 percent optimal budget level by Model type

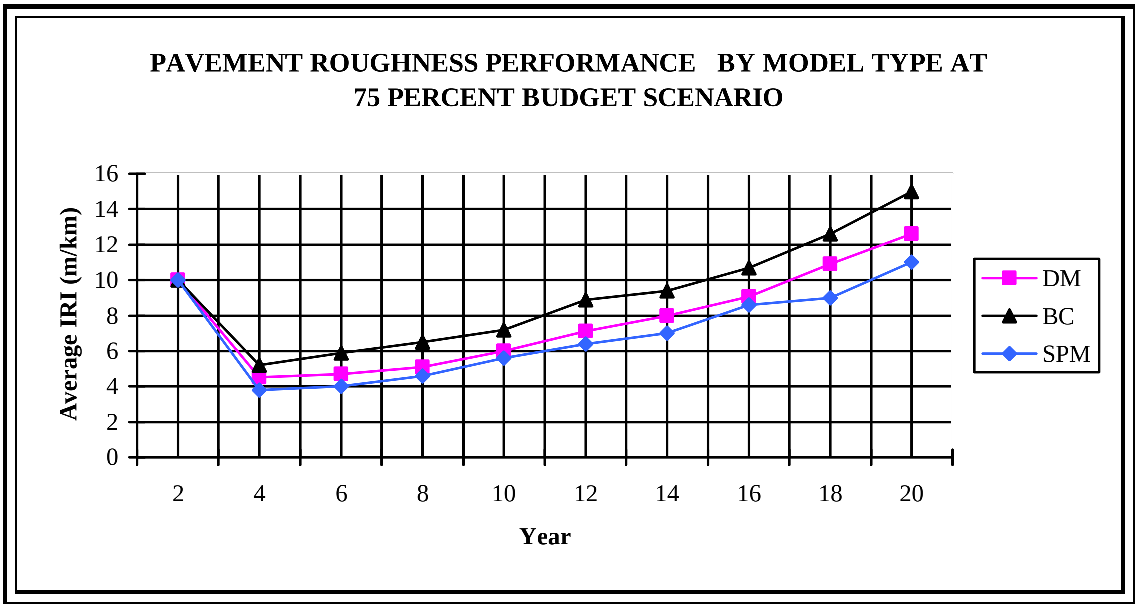


Figure 8.3: Trends in Pavement Roughness Progression at 75 Percent Budget Scenario

8.2.1.3 Trends in Pavement Roughness Progression at 50 percent Optimal Budget Level: The trend in pavement roughness progression at 50 percent optimal budget level by model type indicated the gap between the roughness progression of all the three models will become shorter. However the pavement roughness progression between the SPM and the DM will be almost at the same level but both will have better results than the results of the BC. The range of IRI levels for the twenty year period will be between 4 and 19. Figure 8.4 present an illustration of the pavement roughness progression at 50 percent optimal budget level by Model type

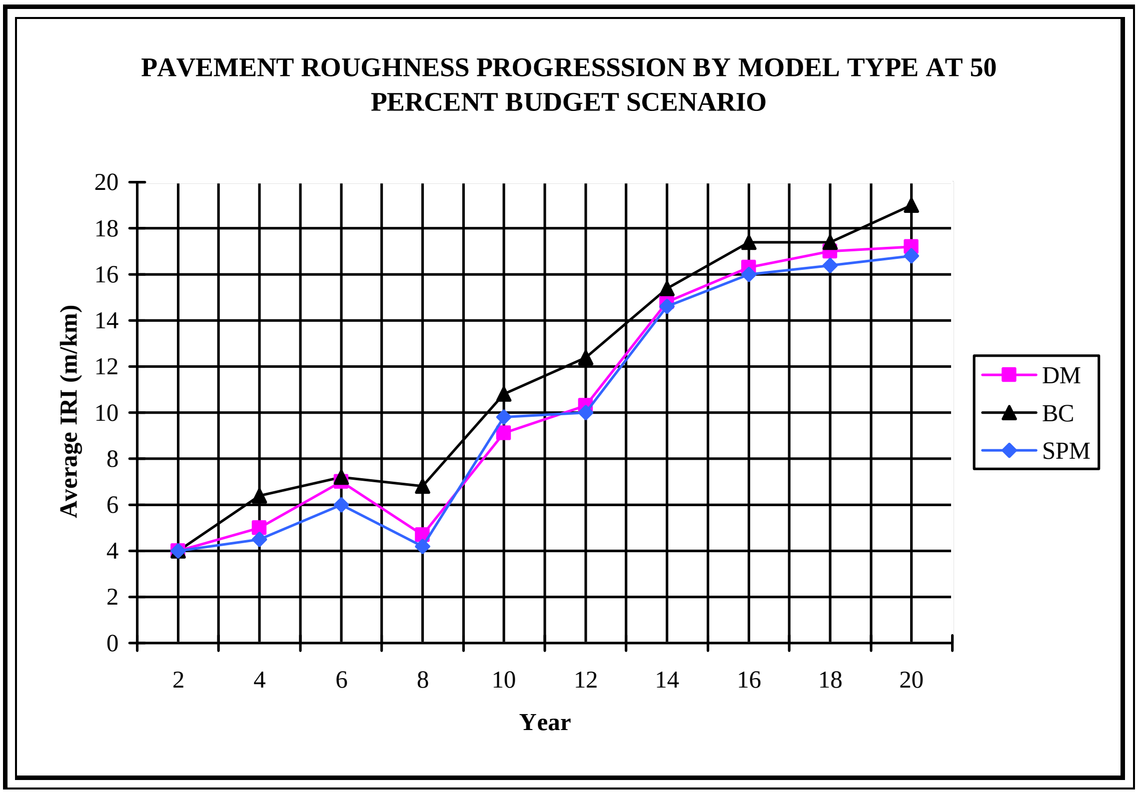


Figure 8.4: Trends in Pavement Roughness Progression at 50 Percent Budget Scenario

8.2.2 Assessment of Pavement Roughness Performance by Model Type with Available funds.

The available road fund was estimated from the average road fund allocation for road maintenance in Ghana from 2005 to 2007. It was assumed that all the funds were allocated for road maintenance and a summary of the available funds is provided in Table 8.1.

Table 8.1: Available Road Fund

Item	Year			Total	Average Per Annum	Estimated Total for 20 years
	2005	2006	2007			
Amount of road fund Available (US $)	115.20	118.13	123.37	356.70	118.90	2378.00

Source: Statistical Analysis on Transport Sector Programme Support Phase II (Ghana),2007

The fund was projected for a twenty year analytical period and allocated by road types with the proportions for road fund allocation estimated by model type. A summary of the constrained budget level estimated for each road type based on the DM, the SPM and the base case scenario is provided in Table 8.2. The proportion of the available road fund estimated by road type using the proportions estimated by model type was used as constrained budget to for HDM-4 runs to generate corresponding IRI levels.

Table 8.2: Proportion of Constrained Budgets

Road Type	DM		SPM		BC	
	Proportion for Fund Allocation	Constrained Budget Level (US $)	Proportion for Fund Allocation (US $)	Constrained Budget Level (US $)	Proportion for Fund Allocation (US $)	Constrained Budget Level (US $)
Trunk	0.37	879.90	0.40	951.2	0.35	832.3
Urban	0.32	761.00	0.35	832.3	0.40	951.2
Feeder	0.31	737.20	0.25	594.5	0.25	594.5

The output report on pavement roughness level by IRI for a twenty year analytical period from the HDM-4 runs were used for the following categories of comparisons by model type.

(ii) Comparison of the impact of the proportionate allocation of road fund by model type on pavement condition rating by model type.

(iii) Comparison of the impact of the proportionate allocation of road fund by trends in pavement roughness progression by road type.

(iv) Comparison of pavement roughness performance on the basis of road fund allocation by efficiency and equity components by model type.

8.2.2.1 Impact of Proportionate Allocation of Funds on Pavement Condition Rating

1. Pavement Condition Rating By Model Type: The outputs of the HDM-4 report on pavement roughness performance at constrained budgets were used to rate the pavement condition of each road type as good, fair and poor based on the criteria defined in Table 5.3. Figure: 8.5 presents the results of the pavement condition rating for by model type. The results indicated that road fund allocation by the SPM has better results on road condition rating than the DM and the BC. It also indicated that the DM had better condition rating than the BC. From this result it can be inferred that the application of a model for road fund allocation gives better outcomes on pavement roughness performance than road fund allocation on ad hoc basis.

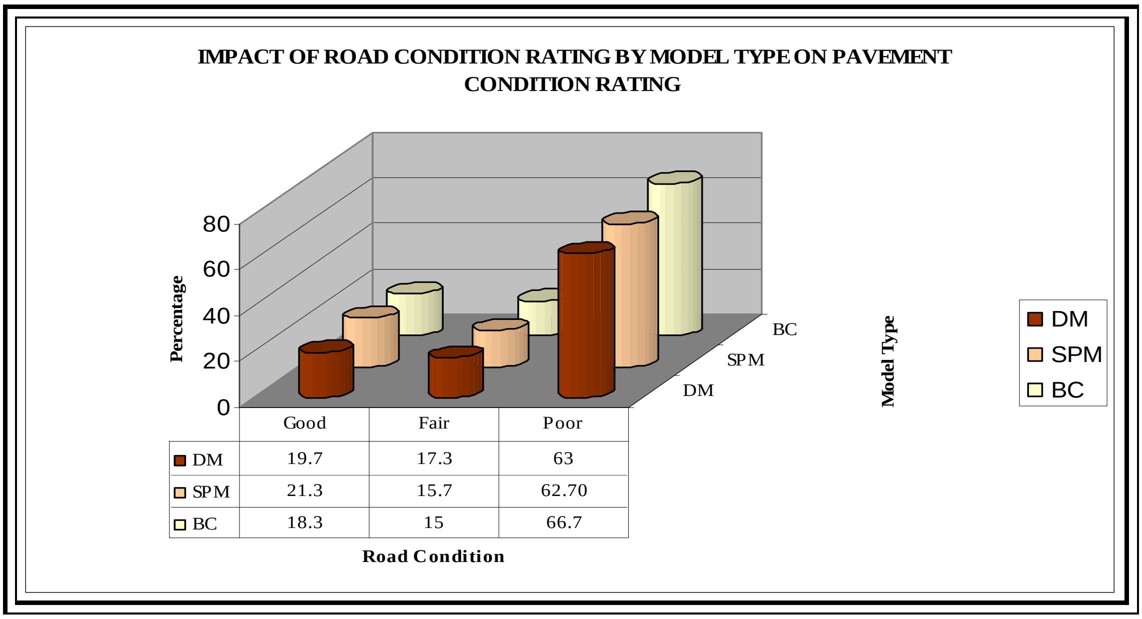


Figure 8.5: Road Condition Rating By Model Type

2. Pavement Condition Rating Based on DM: The results of the proportionate allocation of road fund by the DM at current available funding levels indicated that

the DM presents a more equitable approach to road fund allocation than the SPM and the BC. The DM gives better roughness performance for feeder roads than the other methods. However the DM results in urban roads accumulating the highest proportion of poor roads. Figure 8.6 gives the results of the road condition rating by the deterministic approach to road fund allocation. Appendixes 8.1 to 8.3 give the details of the road condition for trunk, urban and feeder roads respectively.

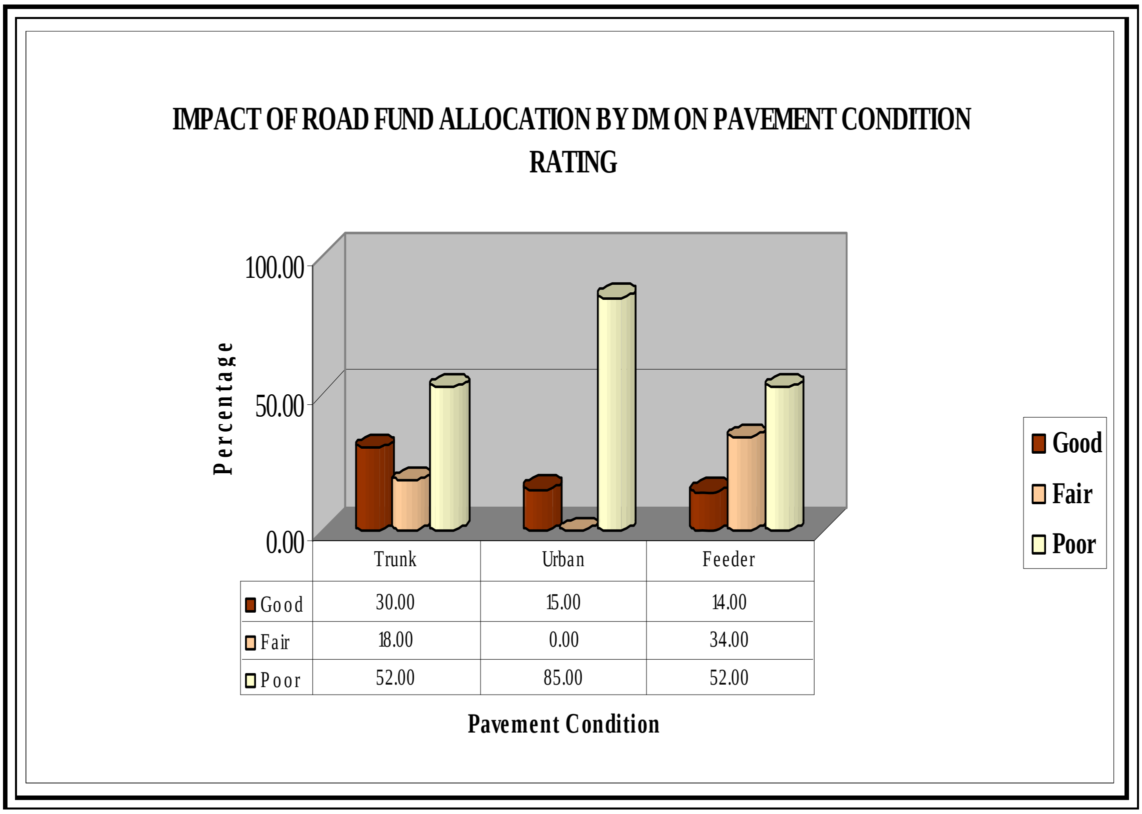


Figure 8.6: Road Condition Rating By DM

3. Pavement Condition Rating Based on SPM: Road fund allocation based on the SPM allocates a higher proportion of funds to the trunk road network than the other roads. Since the SPM gives the best result on pavement roughness performance as compared with the other models, it is concluded that a higher allocation of funds to the trunk road network results in a better performance of the entire road network as compared with the other methods. A summary of the condition rating from road fund

allocation with the SPM is illustrated in Figure 8.7. Appendixes 8.4 to 8.6 give the details of the road condition for trunk, urban and feeder roads respectively.

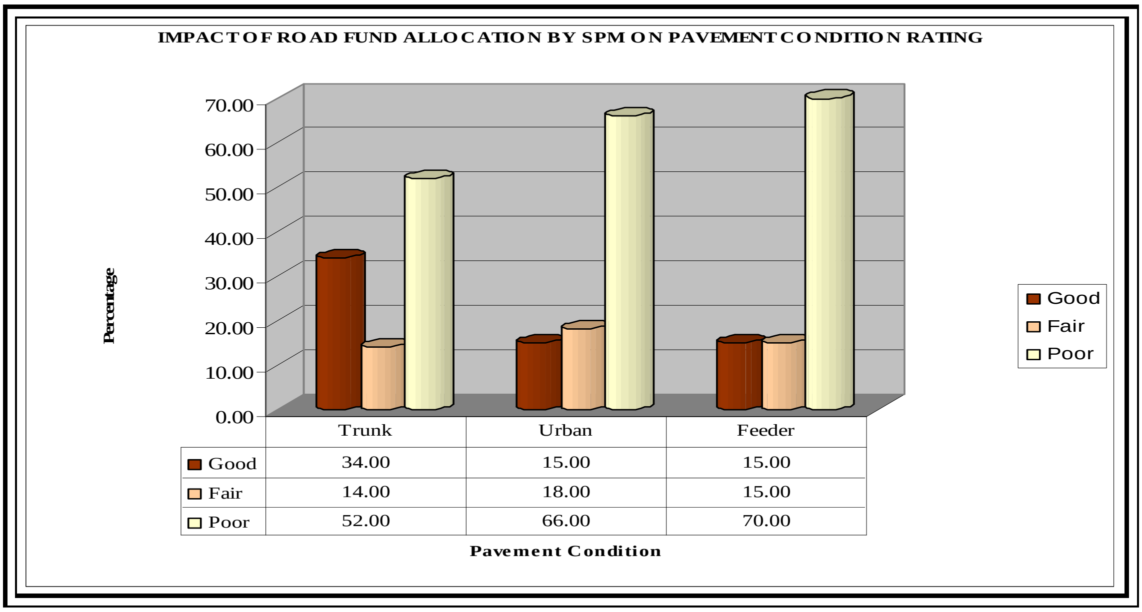
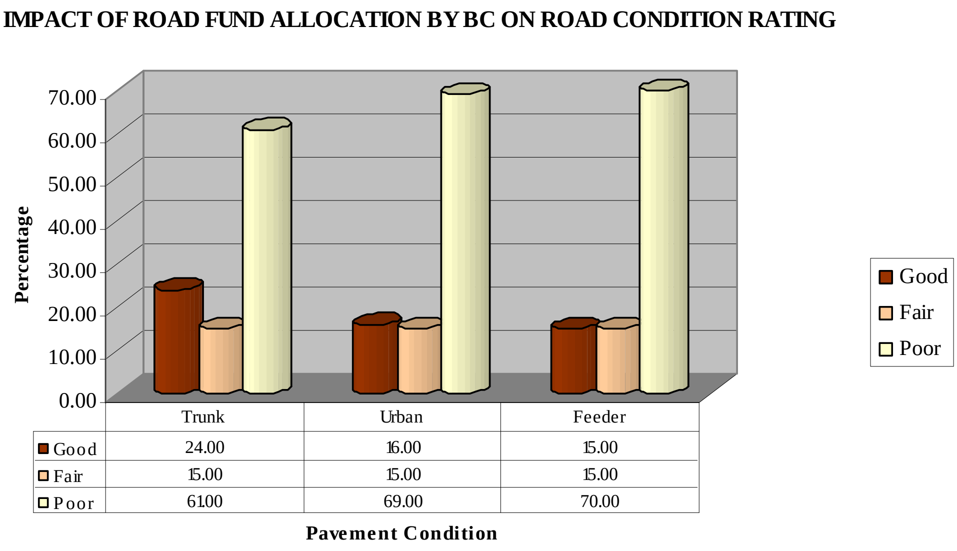


Figure 8.7: Road Condition Rating By SPM

4. Pavement Condition Rating Based on BC: Road fund allocation based on the BC approach results in a higher allocation for the maintenance of urban roads than the other road types. It also gives the worst pavement condition rating for the entire road network. It can therefore be inferred that a higher allocation of road fund to urban roads does not ensure a better performance of the entire road network. Figure 8.8 gives an illustration of the pavement condition rating with the BC approach. Appendixes 8.7 to 8.9 give the details of the road condition for trunk, urban and feeder roads respectively.



	Trunk	Urban	Feeder
Good	24.00	16.00	15.00
Fair	15.00	15.00	15.00
Poor	61.00	69.00	70.00

Figure 8.8: Road Condition Rating By BC

8.2.2.2 Trends in Pavement Roughness progression by Road Type with Available Budgets.

1. Pavement Roughness Performance by Model Type for Trunk Roads: The pavement roughness performance of the trunk road network will give better results if funds are allocated with the SPM as compared with the DM and BC. The pavement roughness performance of the trunk road network will be lower with allocation based on the BC. Figure 8.9 presents the trend in the pavement roughness performance of the trunk road network by model type.

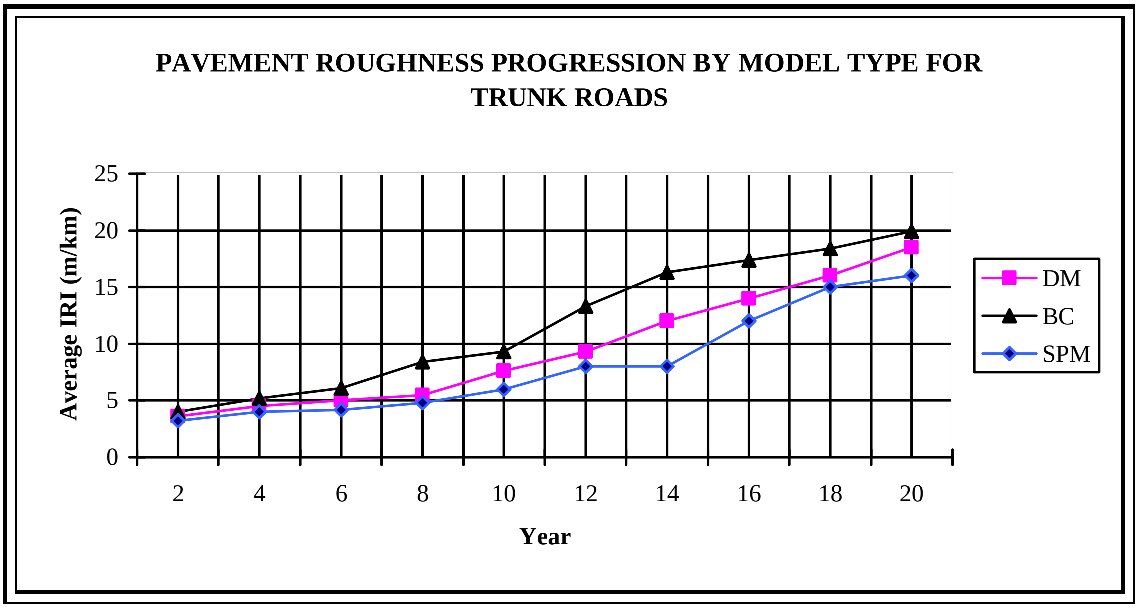


Figure 8.9: Trends in Pavement Roughness Progression for Trunk Roads

2. Pavement Roughness Performance by Model Type for Urban Roads: The trend in the pavement roughness performance of the urban road network will be better with road fund allocation by the BC and SPM as compared to the DM. However the difference in impact is minimal. This is because the cost of an urban road is higher as compared to the other road types such that it would require a very high proportionate of fund allocation to reflect a significant difference in pavement condition. Figure 8.10 gives an illustration of the trend in pavement allocation of funds by model type for urban roads.

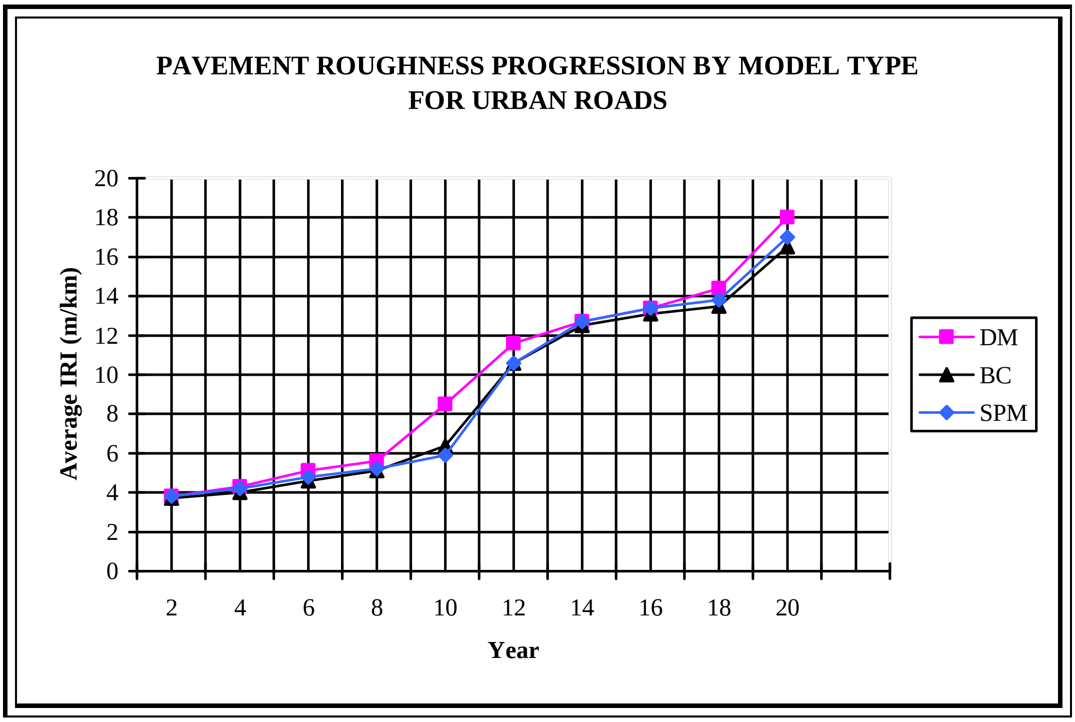


Figure 8.10: Trends in Pavement Roughness Progression for Urban Roads

3. Pavement Roughness Performance by Model Type for Feeder Roads: The trend in pavement performance of the feeder road network is better with road fund allocation using the DM as compared with the SPM and the BC. However the cost of a feeder road is lower as compared to the other road types. Therefore a lower proportion of fund allocation might not make a significant impact. Figure 8.11 gives an illustration of the trend in pavement allocation of funds by model type for feeder roads.

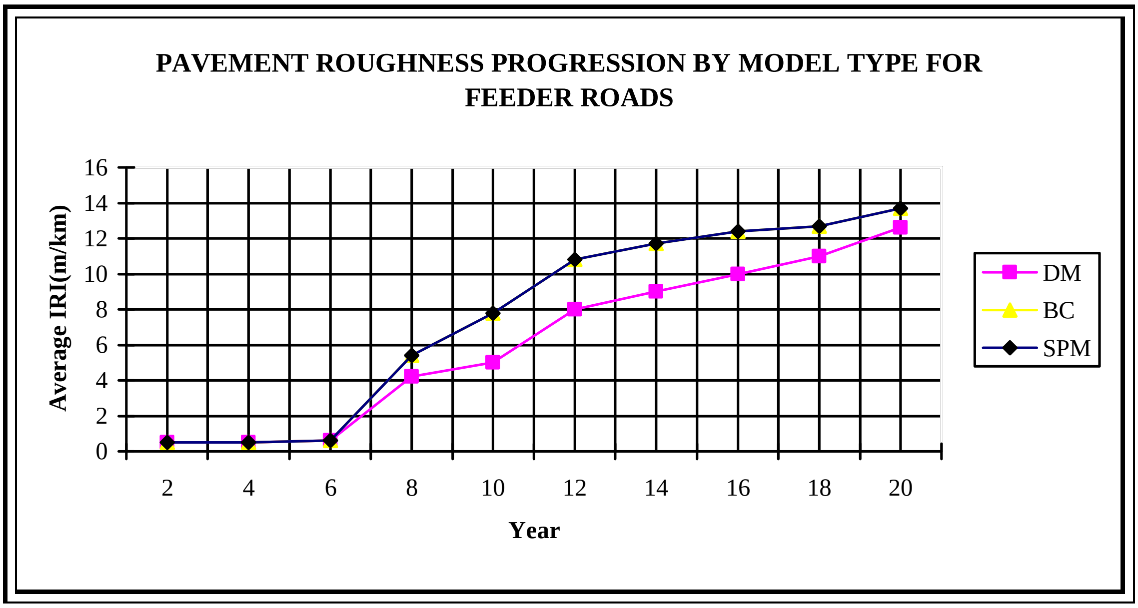


Figure 8.11: Trends in Pavement Roughness Progression for Feeder Roads

8.2.2.3 Pavement Roughness Performance Based on Road Fund Allocation by Efficiency and Equity.

The comparison of the pavement roughness performance by efficiency and equity by model type was based on the DM and the SPM. This is because the road fund allocation with the base case scenario does not consider economic efficiency and equity factors. The available budget indicated in Table 8.1 was constrained to correspond with economic efficiency and equity proportions for each road type based on the estimated proportions for efficiency and equity allocations with the DM and the SPM. This was used to run HDM-4 to determine the corresponding road condition for road fund allocation in terms of efficiency and equity proportions. The comparison of the impact of road fund allocation 'with' and 'without' efficiency and equity considerations on road condition rating was done at three levels. The summary is presented in the following steps and the details are presented in the following paragraphs.

(i) Road Condition Rating for Road Fund Allocation ‘With’ and ‘Without’ Efficiency and Equity Considerations for all Road and Model Types.

(ii) Road Condition Rating for Road Fund Allocation ‘With’ and ‘Without’ Efficiency and Equity Considerations by Model Types.

(iii) Road Condition Rating for Road Fund Allocation ‘With’ and ‘Without’ Efficiency and Equity Considerations by Road Type.

1. Road Condition Rating for Road Fund Allocation ‘With’ and ‘Without’ Efficiency Considerations for all Road and Model Types

The summary of the results of road fund allocation with and without efficiency considerations for all road and model types is provided in Table 8.3.

Table 8.3: Road Condition Rating ‘With’ and ‘Without’ Efficiency and Equity

Road Condition Rating	Road Fund ‘Without’ Efficiency and Equity Inputs	Road Fund ‘With’ Efficiency and Equity Inputs
Good	20.5	18.5
Fair	16.5	20.5
Poor	62.8	61.

The results of the comparison of the impact of road fund allocation ‘with’ and ‘without’ considerations for economic efficiency and equity factors indicated that the proportion of good roads will be higher for the ‘without’ economic efficiency and equity scenario. However, the proportion of poor roads for the situation with consideration for economic efficiency and equity is lower than the ‘without’ consideration for economic efficiency and equity scenario. This is attributed to the inclusion of equity which provides some form of leverage on the pavement condition. Figure 8.12 presents an illustration of the results of the two scenarios.

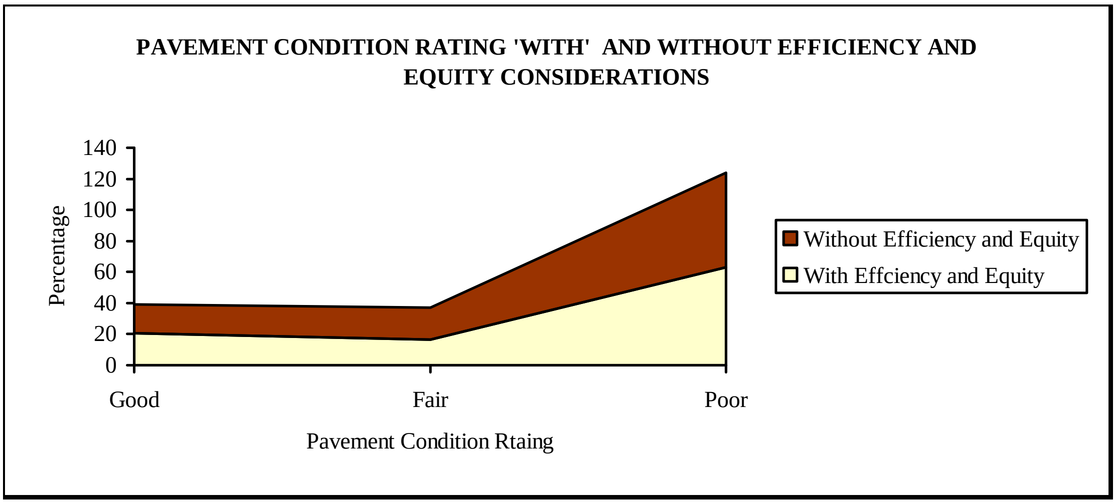


Figure 8.12: Pavement Condition Rating ‘With’ and ‘Without’ Efficiency and Equity

A ‘t’ statistic test result of the outcome of the two scenarios indicated that there is no significant difference between the two scenarios at a probability of 0.48. A summary of the statistical output is presented in Table 8.4.

Table 8.4: Statistical Output of ‘With’ and ‘Without’ Efficiency and Equity by Model Type

Statistical Outputs	
‘t’ Statistic	-0.05
Critical ‘t’	2.35
Probability Value	0.48

2. Summary of Road Fund Allocation ‘With’ and ‘Without’ Efficiency Considerations by Model Types

The results indicated that the road fund allocation using the SPM ‘without’ consideration for efficiency and equity principles had better road condition rating than that of the DM. It also indicated that the ‘without’ efficiency and equity scenario gives a higher proportion of good roads for both models. However, the impact is balanced with a low proportion of roads in poor condition as compared with the 'without' economic efficiency and equity scenarios. A test of statistical significance of the difference in the results of the 'with' economic efficiency and equity considerations for the two models indicated that there was no significant difference and the details of 't' statistic test is summarised in Table 8.5. It can be inferred that road fund allocation based on equity consideration does not result in a waste of funds.

Table 8.5: Road condition Rating 'With' and 'Without' Economic Efficiency and Equity by Model Type

Road Condition Ration	Model Type			
	DM		SPM	
	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs
Good	19.7	19.7	21.3	17.3
Fair	17.3	12.0	15.7	29.0
Poor	63	68.3	62.7	53.7

3. Summary of Road Fund Allocation 'With' and 'Without' Efficiency Considerations by Road Types

(i) Trunk roads: The results of the comparison of pavement roughness performance based on road fund allocation 'With' and 'Without' efficiency and equity considerations for trunk roads by model type is provided in Table 8.6 and illustrated in Figures 8.13 and 8.14 for the two scenarios. A 't' statistic test of the with and without efficiency scenarios indicated that there was no significant difference at a probability of 0.5.

Table 8.6: Road Condition Rating 'With' and 'Without' Economic Efficiency -Trunk Roads

Road Condition Ration	Model Type			
	DM		SPM	
	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs
Good	30	30	34	23
Fair	18	17	14	28
Poor	52	53	52	49
't' statistic: -2.6E-16, Critical 't' : 2.92 P = 0.5				

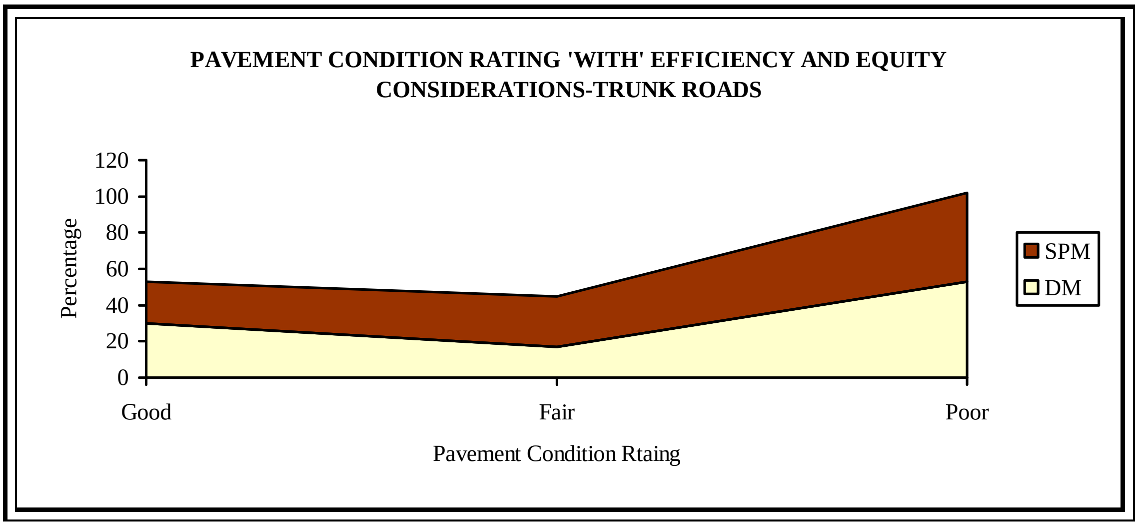


Figure 8.13: Pavement Condition Rating 'With' Efficiency and Equity-Trunk Roads

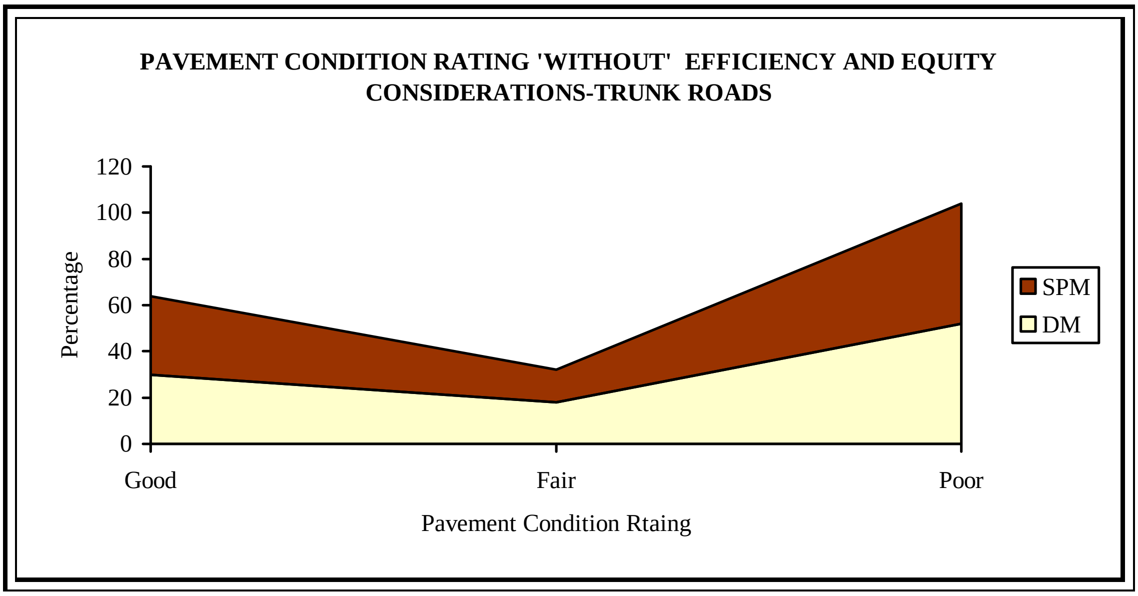


Figure 8.14: Pavement Condition Rating 'Without' Efficiency and Equity-Trunk Roads

2. Urban Roads: The results of the comparison of pavement roughness performance based on road fund allocation 'With' and 'Without' Efficiency and Equity principles for urban roads by model type is provided in Table 8.7 and illustrated in Figures 8.15 and 8.16 for the two scenarios. A 't' A 't' statistic test of the with and without efficiency scenarios indicated that there was no significant difference at a probability of 0.21.

Table 8.7: Road Condition Rating 'With' and 'Without' Economic Efficiency -Urban Roads

Road Condition Ration	Model Type			
	DM		SPM	
	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs
Good	15	15	15	15
Fair	5	5	18	5
Poor	85	85	66	80
't' statistic: 1, Critical 't' : 2.92 P = 0.21				

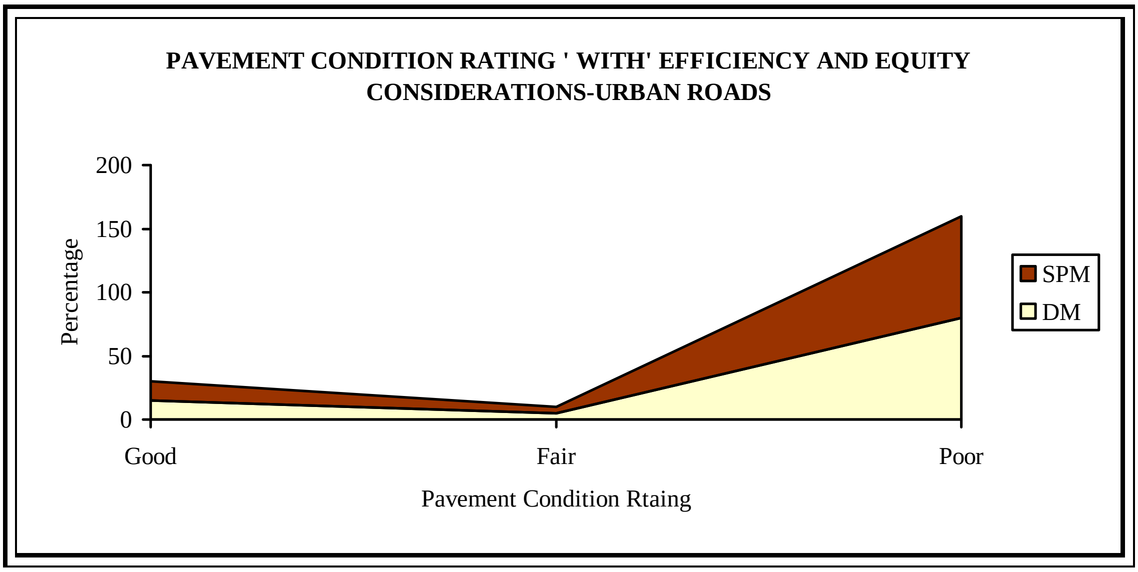


Figure 8.15: Pavement Condition Rating 'With' Efficiency and Equity- Urban Roads

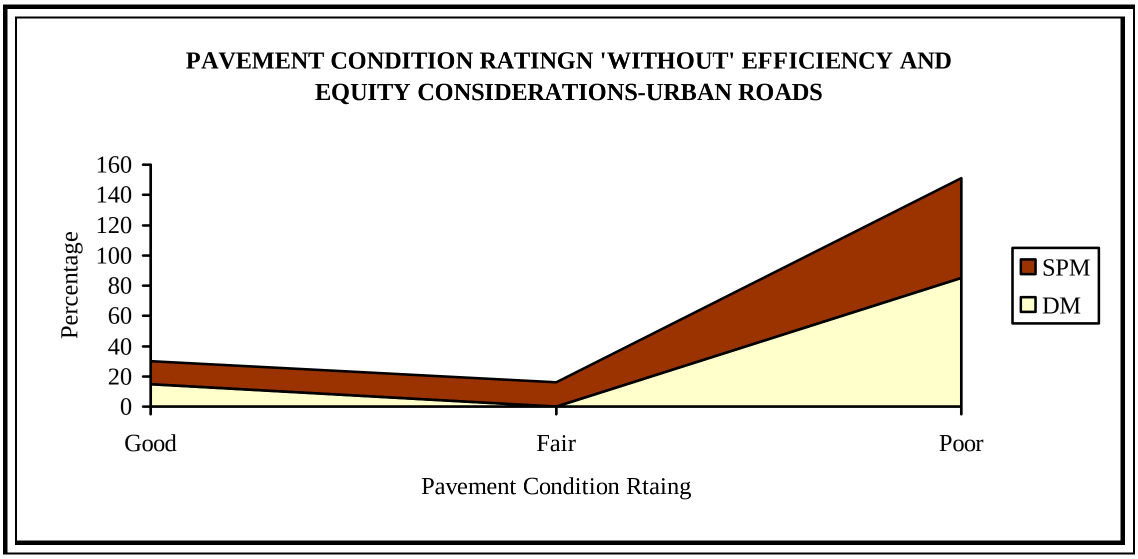


Figure 8.16: Pavement Condition Rating Without' Efficiency and Equity-Urban Roads

3. Feeder Roads: The results of the comparison of pavement roughness performance based on road fund allocation 'With' and 'Without' Efficiency and Equity considerations for feeder roads by model type is provided in Table 8.8 and illustrated in Figures 8.17 and 8.18 for the two scenarios. A 't' statistic test of the 'with' and 'without' efficiency scenarios indicated that there was no significant difference at a probability of 0.5.

Table 8.8: Road condition Rating 'With' and 'Without' Economic Efficiency and for Feeder Roads

Road Condition Ration	Model Type			
	DM		SPM	
	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs	Without Efficiency and Equity Inputs	With Efficiency and Equity Inputs
Good	14	14	15	14
Fair	34	14	15	54
Poor	52	72	70	32
't' statistic: 0, Critical 't' : 2.92 P = 0.5				

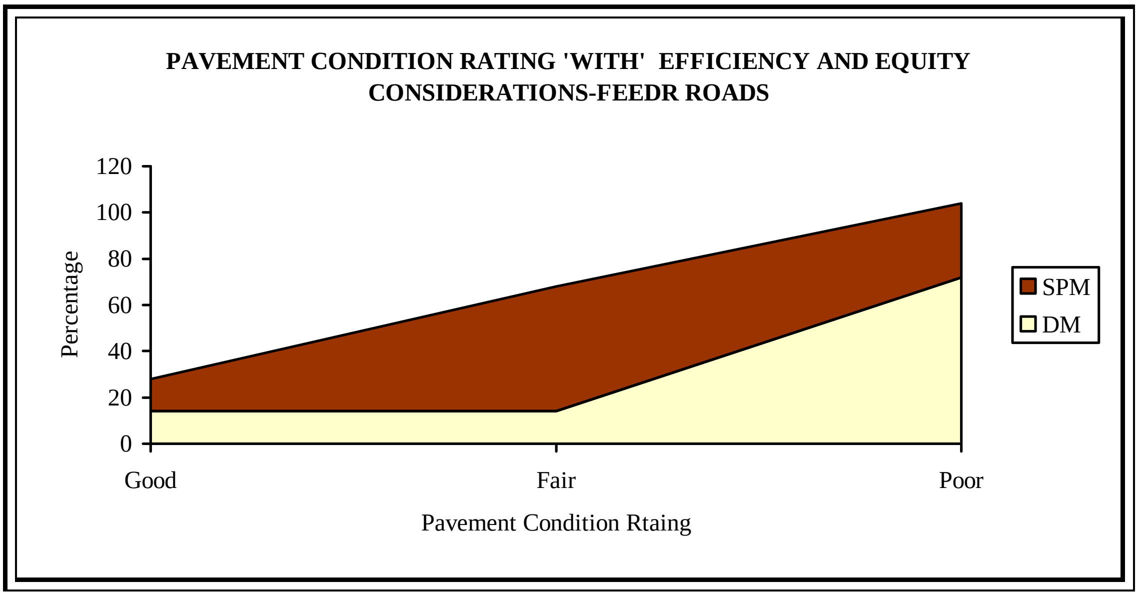


Figure 8.17: Pavement Condition Rating 'With' Efficiency and Equity-Feeder Roads

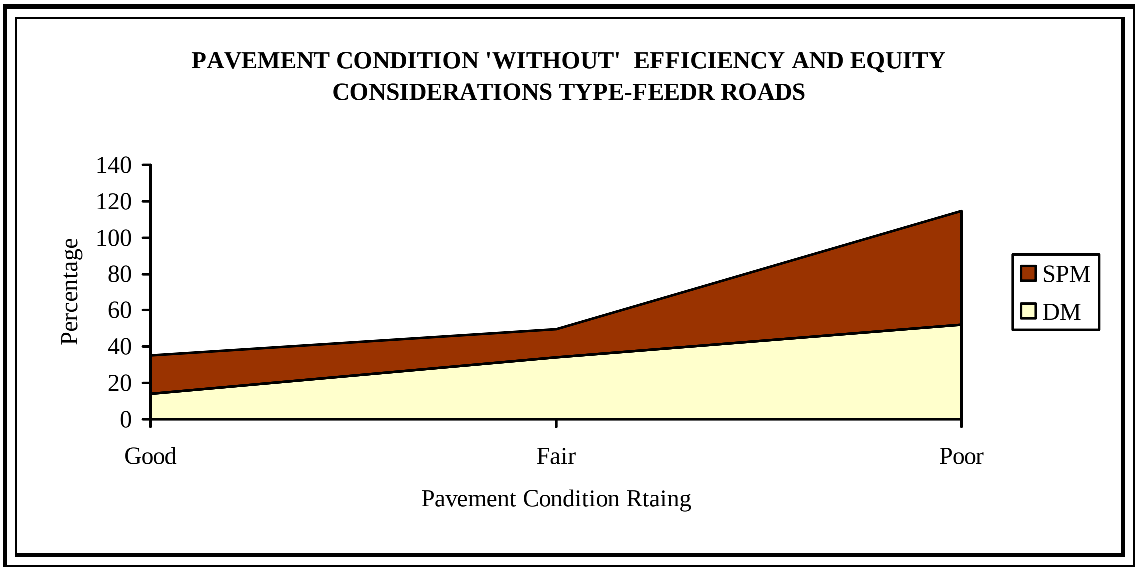


Figure 8.18: Pavement Condition Rating 'Without' Efficiency and Equity-Feeder Roads

From the results of the comparison of pavement condition rating based on road fund allocation with efficiency and equity principles indicates that the inclusion of equity consideration does not result in significant loss of value of the road network.

8.3 ESTIMATION OF THE VALUE OF THE BACKLOG OF POOR ROADS BY MODEL TYPE

The backlog of poor road maintenance was estimated by multiplying the unit cost of road maintenance per kilometre for each road type with the proportion of road length in poor condition for each road type by model type. The procedure is summarised in the following steps

Step 1 From Table 6.21 the total cost of road maintenance needs estimated with HDM-4 for Ghana is about U$7876.1 for a period of 20 years and the budget per annum is estimated as;

Maintenance Cost estimates	Road Type			Total
	Trunk	Urban	Feeder	
Recurrent Costs (US $,000)	261	129.9	707.8	1098.7
Capital Costs (US $,000)	2506.2	3339.9	931.2	6777.3
Total Costs (US $,000)	2767.2	3469.8	1639	7876.1
Estimated Budget per Annum (US $,000)	230.6	289.2	136.6	656.3

Step 2. The current length of each road type based on 2000-2007 data can be summarised as;

Road Type	Length (km)	Proportion of Road Type
Trunk	12,856.52	0.25
Urban	9547.07	0.18
Feeder	29,429.44	0.57
Total	51,833	

Step 3: The proportion of roads in poor condition by model type was then estimated as;

Model Type	Proportion of Roads in Poor Condition	Total Length of Roads in Poor Condition
DM	63.0	32,654.8
SPM	62.7	32,499.31
BC	66.7	34,572.6

At a corresponding road length as indicated below

Model Type	Length of Roads in Poor Condition by Road Type		
	Trunk	Urban	Feeder
DM	8099.6	6014.7	18540.5
SPM	8061.0	5986.0	18452.3
BC	8575.3	6367.9	19629.4

And a current unit cost of road maintenance as;

Road Type	Unit Cost of Road/km (US $)
Trunk	215.2
Urban	363.1
Feeder	55.7

The Value of the backlog of poor roads by model type was estimated by multiplying the unit cost for a road length with the total length in poor condition and the results were as follows.

Model Type	Cost of Backlog of Poor Roads by Road Type (US $)				
	Trunk	Urban	Feeder	Total	
DM	1,743,336.00	2,185,974.00	1,032,570.0	4,961,880.00	0.327443
SPM	1,735,034.40	2,175,564.60	1,027,653.0	4,938,252.00	0.325884
BC	1,845,722.40	2,314,356.60	1,093,213.0	5,253,292.00	0.346674
				15,153,424.00	

The results of the estimated value of the backlog of poor roads by model type indicated that the SPM provides the best value in terms of the backlog of poor road condition as compared with the DM and the BC. However, the DM also recorded better conditions than the BC. The BC scenario resulted in higher costs in terms of poor roads than the other two models and it can be concluded a model based road fund allocation is better than an ad hoc approach.

The average of the proportion of the backlog of poor roads for the DM and the SPM was tested against that of the BC by a chi-squared test. This was the basis of a null hypothesis that there is no difference between the results of the value of the backlog of poor roads for a ‘with model and ‘without model situation. The average of the value of the backlog of poor roads estimated from the results of DM and SPM was considered as ‘with model’ situation and that of the base case scenario was considered as ‘without model’ This purpose was to determine the importance of model application in road fund allocation. The result of the BC was assumed to be the observed situation whilst the average of the DM and the SPM were used as the predicted situation. The results of the chi squared test indicated that the calculated χ^2 is larger than the tabulated χ^2. It also indicated a low probability at 0.004. Therefore it was concluded that there is a significant difference between the impacts of the ‘with’ model scenario for road fund allocation and the ‘without’ model situations. Table 8.9 gives a summary of chi test results.

Table 8.9: Output of statistical test on ‘with Model’ and ‘without’ Model Scenarios

Calculated χ^2 = 1
Tabulated χ^2 at 0.05 probability = 0.00393 at 1 degree of freedom

8.4 SUMMARY

This chapter has analysed the margin of optimality of the two models developed in this study on the basis of the possible impacts of the outcome on pavement roughness performance. The significance of the differences observed in the level of impacts have also been analysed on the basis of appropriate statistical applications. The results indicated that the issue of the inclusion of stakeholder analysis as compared with not including stakeholder analysis is of relevant consideration in road fund allocation. It has also established that road fund allocation on the basis of a logical analysis is better than the arbitrary allocation of funds. The import of the significance of these findings in relation to the set objective for this study is as presented in the findings and conclusions in the next chapter.

CHAPTER NINE: CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

9.1.1 Optimality in Road Fund Allocation

1. Adequate funding is essential to sustainable road maintenance regimes because road deterioration is a continuous process after an initial investment. However road maintenance is characterised with funding shortfalls. Due to the problem of limited funding optimal utilisation of limited funds is essential. The theoretical perspectives of road investment analysis are either based on ensuring economic efficiency or equity. As of now the key challenge is how to effectively achieve both objectives for road fund allocation.

2. The quest for optimal road fund allocation is defined in terms of ensuring economic efficiency for maximum returns and accountability to the contributors of the fund. Therefore Multi criteria analysis (MCA), are perceived as the decision paradigm for addressing this problem.

3. MCA application in transportation is limited and there are no principles. There is also a perspective in road investment analysis that road maintenance does not generate wider social impacts but the issue is not verified in Literature. The comparison of a deterministic approach to road fund allocation with no consideration for wider social perspectives and a stated preference based

method with the inclusion of wider social has afforded this study to make the following observations.

(i) That a comparison of more than one MCA application in the same decision can determine the best outcome if there are resources to achieve this.

(ii) That the inclusion of wider social impacts in road investment analysis for road maintenance fund allocation is relevant. The details are discussed in the following paragraphs.

9.1.2 Outcome of Model with Deterministic Approach

The model with a deterministic approach to road fund allocation was applied with the road as a product of its status. It was based on quantitative data determined from the physical attributes of a road and the capacity of responsible agencies to achieve set targets. It also included considerations for market mechanisms and equality on the basis of transport affordability. The observed outcomes of a road fund allocation in this context include the following.

1. The result of the study indicated that the deterministic approach to road fund allocation resulted in the allocation of higher proportions of the road fund on equity basis for all road types. (see section 6.4.1). It is therefore concluded that it is possible to allocate higher proportions of the road fund on the basis of equity than efficiency considerations with a road fund allocation method based on quantitative analysis.

2. It can also be concluded that road fund allocation based on the deterministic approach results in a more equitable allocation of funds between the competing sectors than an approach based on stakeholder preference.

3. The results of the deterministic approach to road fund allocation also gave a higher proportion of the fund to feeder roads which are generally associated with methods based on subjective judgments. Thus it was concluded that a deterministic approach can result in higher road fund allocation to rural roads. This is contrary to the general perception that a deterministic approach allocates higher proportions of funds to other road sectors than rural roads.

4. The results of the case study indicated that if the value of an attribute exceeds a tolerance interval of about 50 percent, there could be significant changes in the proportion of fund allocation by efficiency and equity proportions for feeder roads. This is due to the reversal of the results of the subdivision of the fund allocation to feeder roads on the basis of efficiency and equity by the DM and the case study. Thus it is concluded that road fund allocation purely on the basis of technical and strategic considerations though might ensure objectivity and transparency could also result in some distortions as with methods based on value judgement.

9.1.3 Outcome of Stated Preference Based Model

The results of the study indicated that road maintenance fund allocation with considerations for road user interest can have the following outcomes.

1. The comparison of the impact of the stated preference based approach for road fund allocation and the deterministic approach indicated that road fund allocation with the stated preference based approach allocated a higher proportion of funds to trunk roads, followed by urban roads and feeder. The proportion of fund allocation to equity was also higher than the proportion allocated to efficiency. Thus it was concluded that investment analysis on the basis of stakeholder preference does not necessarily allocate a higher proportion of funds to rural roads. This therefore discounts the view that road fund allocation by stakeholder analysis with no technical considerations will results in higher proportion of funds to rural roads with consequent wastage.

2. It was observed that considerations for wider social perspectives in road maintenance investment could result in better results outcome on pavement roughness performance. This is a deviation from the general perception that efficiency is only attained on the basis of market based systems in road investment analysis.

9.1.4 Outcome of Road Fund Allocation with the DM Compared to the SPM

1. The comparison two MCA applications in the same decision revealed that each method has its strengths and weakness. It can be said that no single MCA method is totally conclusive.

2. The results of the comparison of the outcome of the impact of the two models indicated that the impact of road fund allocation on pavement roughness

performance with the stated preference based approach indicated better outcome than the deterministic model. This was achieved irrespective of the allocation of higher proportions of funds to trunk and urban roads as compared with feeder roads. The reason is due to the differences in cost margins. That is at a certain funding threshold the feeder road condition can be maintained in good condition due to lower costs. On the other hand allocating more money to feeder roads past that threshold might not make much difference to the condition of the feeder network but might affect the condition of the other road types which could have utilised the excess funds. This is because of the application of only engineering attributes with no cost considerations in the case of the DM. This indicates that human judgement in investment analysis can have some advantage where a factor that is not directly included in an investment analysis has to be considered.

3. It was also observed in situations where the funding threshold is extremely limited the outcome of the DM and the SPM do not exhibit significant differences.

9.1.5 Road Fund Allocation 'With Model' and 'Without' Model

1. The outcome of the impact of the approach to road fund allocation with the current method gave a lower return in terms of the impact on pavement roughness performance. This is because a higher proportion is given to urban roads. Urban road present the highest cost components due to higher standards but has a shorter road length. Therefore a higher proportion of funds to urban

roads do not have a good effect on the entire road network in terms of pavement roughness performance.

9.2 RECOMMENDATIONS

1. This research has determined that road fund allocation outside a structured analytical framework might not give good returns. It is recommended that road fund allocation should be based on the application of formalised approach rather than an ad hoc approach for better outcomes.

2. It is observed that road maintenance allocation based on subjective judgment can have good results if the procedure is logically structured with quantitative analysis. Therefore it is recommended that road fund allocation for road maintenance should include stakeholder preferences to ensure accountability to the stakeholders. However the approach should be based on the application of logical assessment and quantitative analysis of the value judgment expressed by can be said to be the best approach to road fund.

3. The limitations of this research are that the analysis of the DM method did not include cost consideration. This was to avoid the problem of double counting, since all the engineering products which were applied determine the cost needs of the investment. However, the effect was that rural roads could receive more funds than is needed in situations where there is adequate funding. Also the case study for the deterministic model was based on a data set collected at different time duration and the physical changes in the road condition affected the outcome of the results. Therefore it could not be totally established that

the deviations in the result of the feeder roads with the case study was as a result of the significant changes in the feeder road network or a limitation of the deterministic model itself. It is therefore recommended that future research should take these factors into consideration.

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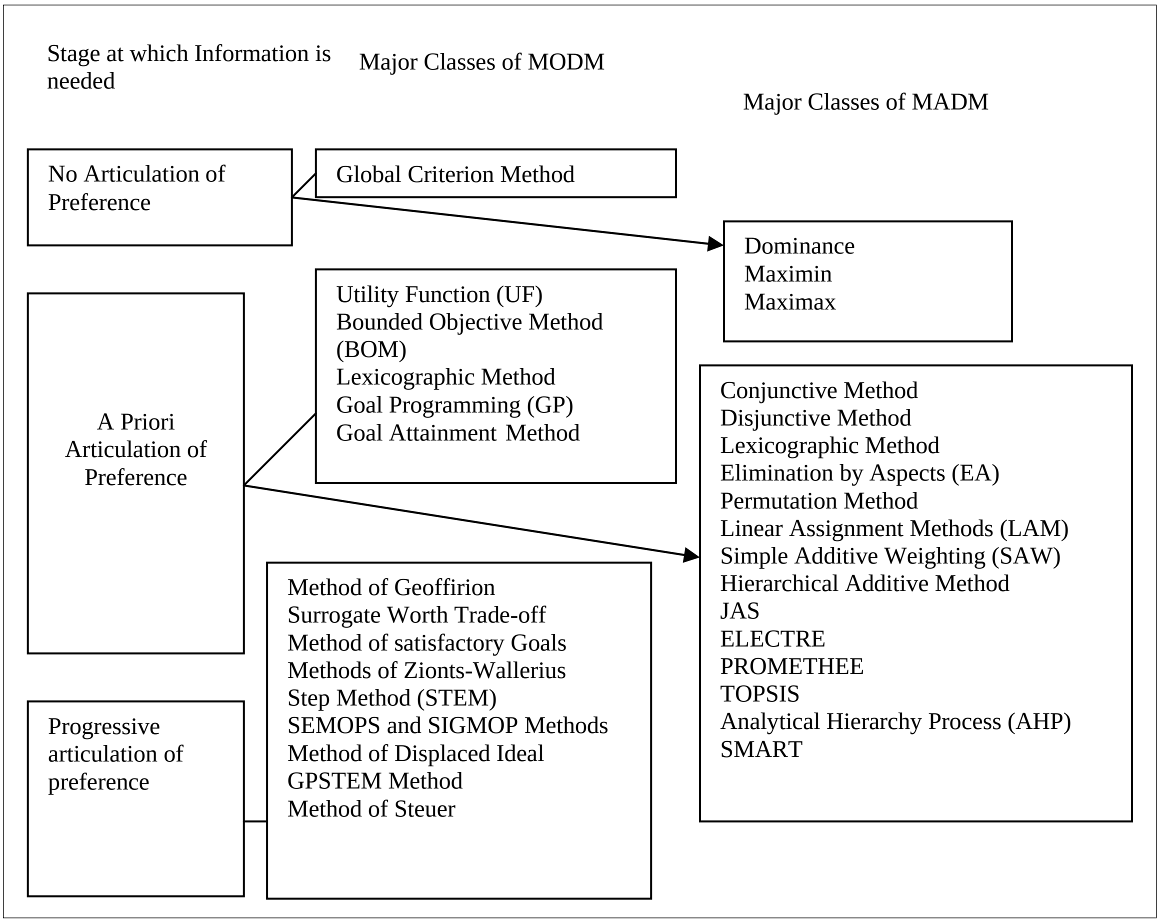
APPENDIXES

APPENDIX 2.1: CONDITIONS OF SUCCESS FOR BOT PROJECTS IN THE DEVELOPING WORLD

Requirement	Comments
Project financially sound, feasible and affordable	This must be demonstrated in the project feasibility study, and charges made to users must be affordable. Risk analyses of the project assumptions must be made, and supported by historical and comparative data.
Country risks manageable	A stable political and economic environment is required.
Strong government support	Government must demonstrate its support for such projects by promoting public-private partnerships etc.
High government priority for project	This must be demonstrated by the host government.
Stable legal framework	Enforceability of the various BOT contracts is *sine qua non*
Efficient administrative framework	Lengthy bureaucratic procedures create uncertainty for sponsors thus having a negative impact on such projects.
Fair and transparent bidding procedure	Bid evaluation criteria must be clearly defined and bids must be evaluated in a public and objective manner.
Transactions can be concluded within reasonable time/cost	Procurement procedures should be quick and transparent, to reduce the risk of forecasting for tenderers.
Experienced and reliable sponsors with sufficient financial strength	Award to the lowest bid is not a sufficient selection criterion as bidders must also be experienced and demonstrate financial strength.
Construction contractor experienced and properly resourced	The prime contractor should be capable of the work.
Rational risk allocation	Risks must be identified, allocated to the party best able to bear them and managed in a rational way.
Security for lenders	Various guarantees, insurance and trust arrangements must be established to allow lenders the right of the sponsors well in advance of any defaults on the loan agreements.
Currency/foreign exchange and inflation issues solved	Foreign currency must be available in the host country, the host government must allow conversions to such currencies, and the contractual arrangements must account for exchange rate fluctuation and inflation.
Contractual frameworks reflect economics of project	The contractual framework is complex and will require qualified legal counsel. Fair contracts which avoid surprises must be developed
Co-operation on a win-win basis	Experience shows that successful BOT projects are regarded as such by all parties to the contracts.

Source: UNIDO (1996)

APPENDIX 3.1: TAXONOMY OF MCA TECHNIQUES

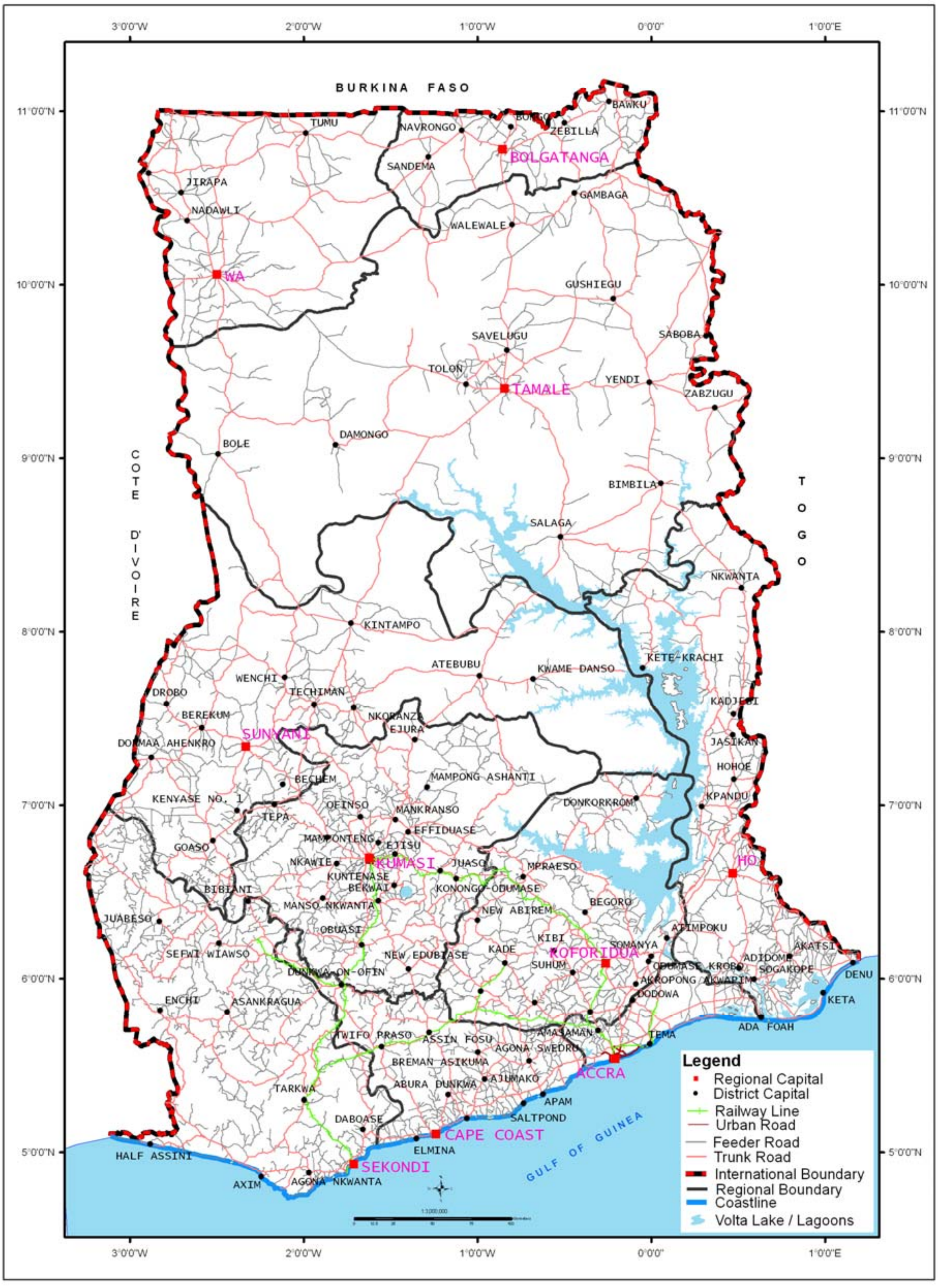


APPENDIX 3.2 SUMMARY OF DIMENSION APPRAISAL SCHEMES USED FOR RURAL ROADS IN GHANA

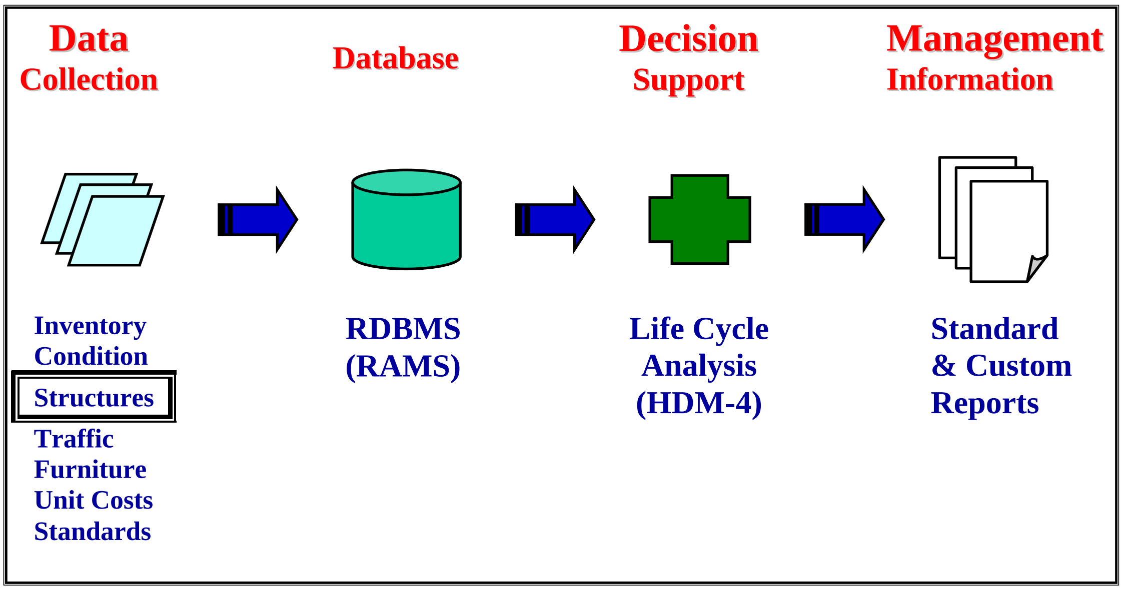
Appraisal Scheme	Formula	Author	Advantages	Disadvantages
Accessibility Improvement Index	$PI = \frac{P * \Delta I}{L * C}$ where PI = Priority Index P=Population L=Length I=Accessibility Improvement Index	Clive Daniels (1990)	Relatively Simple Minimum Cost Involved Objective and Transparent	Population data was not structured to suit need
Road Area Prioritisation Model	F=0.4G+0.3T+0.2P +0.1A F=Priority Score G=Farm Produce T=Haulage Rate P=Population Density A=Accessibility	K. Adarkwa (1989)	Considers a wide range of variables	Factors measured in quantifiable units were subject to errors Data difficult and expensive to obtain Formula was Mathematically wrong Formula was Mathematically wrong
Road Maintenance Priortisation Model.	It is Systems Based It is based on traffic and road condition but incorporates access to health and education		Suited to rural roads. Included community participation	Quantification of social factors was subjective Expensive due to data requirement

APPENDIX 3.3: DISTRIBUTION OF ROAD NETWORK IN GHANA

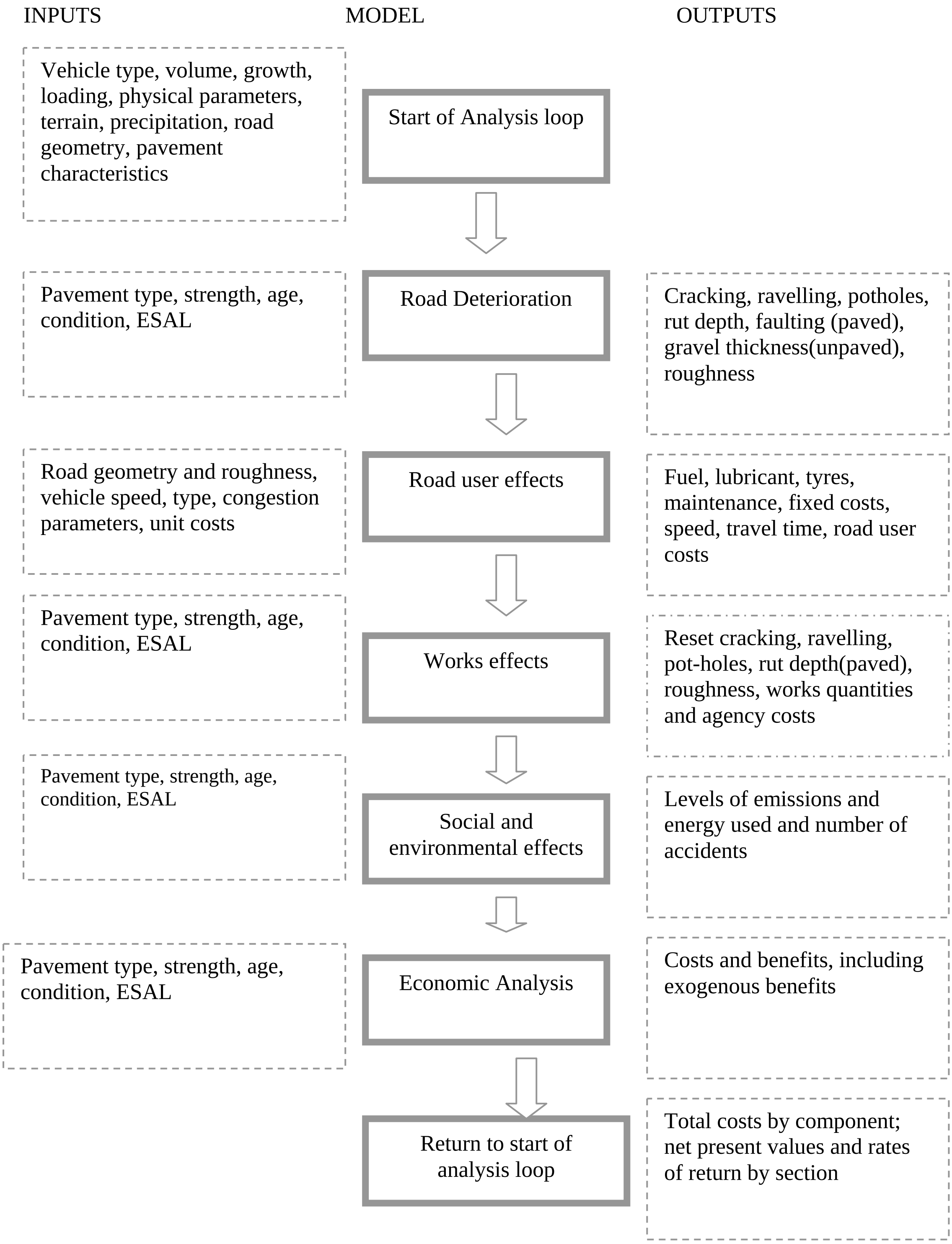
ROAD MAP OF GHANA



APPENDIX 4.1 COMPONENTS OF THE HDM-4 ANALYTICAL TOOL



APPENDIX 4.2: INPUT OUTPUT STRUCTURE OF THE HDM-4 SYSTEM



Source:HDM-4 Documentation Series

APPENDIXES 4.3: VEHICLE OPERATOR QUESTIONNAIRE

Name of Interviewer: …………………………………………………………………………
Name of Driver/Vehicle Operator: ………………………………………………………….
Station / Terminal / Road Link: …………………………………………………………
Road Name: ……………………………………………………………………………..
Date of Interview: ………………………… Time of Interview: ……………………………

A. TYPE AND CAPACITY OF VEHICLE

1. What type of vehicle are you using?…………………………………………………

2. What is the make or model of your vehicle?…………………………………………

3. Indicate the following physical characteristics of the vehicle.

No. of Axles	**No. of Wheels**	**Max. Passenger Occupancy**	**Max. Vehicle Load**	**Gross Weight**	**Net Weight**	**Age**

B. TRIP CHARACTERISTICS

4. Indicate on the table below your major destinations.

Destination	**Distance**	**Trip Freq/Week**	**Travel Time**

C.VEHICLE OPERATION AND MAINTENANCE COST

5. How many kilometres do you cover per day?……………………………………….

6. How often do you service (oil and filter change, etc) your vehicle?………………

7. Excluding tyres how much do you pay on vehicles maintenance in a year?……….

8. How many gallons of fuel do you use per week?……………………………………

9. How often do you change your tyres?……………………………………………….

10. How much do you spend each time you change a tyre?…………………………….

11. Which year was the vehicle manufactured?..…………………………………………

12. When did you buy the vehicle?………………………………………………………

13. How much was it then?……………………………………………………………….

14. What is the value of your vehicle today?………………………………………………

APPENDIX 4.4: QUESTIONNAIRE FOR COMMUNITY LEVEL SURVEYS

Questionnaire for Community Level Surveys

Survey Number: Date: Name of Settlement:
Enumerator:

1a. What are the benefits that you derive from this road

Social Benefits	Tick	Rank	Social Benefits	Tick	Rank
Increased GDP			Access to Health care		

1b. What are the What are Disadvantages (Costs) of this Road

Social Costs	Tick	Rank	Social Benefits	Tick	Rank
Others					

2.0. Conduct a Pairwise Ranking of Economic and Social Benefits of Road Maintenance by circling the appropriate level of preference.

2a. Comparison of Economic and Social Benefits of Trunk Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Scale of Economic Preference									Equal Preference	Scale of Economic Preference								
High to Low Preference										Low to High Preference								

2b Comparison of Economic and Social Benefits of Urban Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Scale of Economic Preference									Equal Preference	Scale of Economic Preference								
High to Low Preference										Low to High Preference								

2c Comparison of Economic and Social Benefits of Feeder Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Scale of Economic Preference									Equal Preference	Scale of Economic Preference								
High to Low Preference										Low to High Preference								

3a. Comparison of Economic Benefits of Trunk Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																		Benefit 2
Benefit 1																		Benefit 3
Benefit 1																		Benefit 4
Benefit 2																		Benefit 3
Benefit 2																		Benefit 4
Benefit 3																		Benefit 4

3b. Comparison of Economic Benefits of Urban Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																		Benefit 2
Benefit 1																		Benefit 3
Benefit 1																		Benefit 4
Benefit 2																		Benefit 3
Benefit 2																		Benefit 4
Benefit 3																		Benefit 4

3c. Comparison of Economic Benefits of Feeder Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																		Benefit 2
Benefit 1																		Benefit 3
Benefit 1																		Benefit 4
Benefit 2																		Benefit 3
Benefit 2																		Benefit 4
Benefit 3																		Benefit 4

4a. Comparison of Economic Costs of Trunk Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																		Cost 2
Cost 1																		Cost 3
Cost1																		Cost 4
Cost 2																		Cost 3
Cost 2																		Cost 4
Cost 3																		Cost 4

4b. Comparison of Economic Costs of Urban Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																		Cost 2
Cost 1																		Cost 3
Cost1																		Cost 4
Cost 2																		Cost 3
Cost 2																		Cost 4
Cost 3																		Cost 4

4c. Comparison of Economic Costs of Feeder Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																		Cost 2
Cost 1																		Cost 3
Cost1																		Cost 4
Cost 2																		Cost 3
Cost 2																		Cost 4
Cost 3																		Cost 4

5a. Comparison of Social Benefits of Trunk Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																		Benefit 2
Benefit 1																		Benefit 3
Benefit 1																		Benefit 4
Benefit 2																		Benefit 3
Benefit 2																		Benefit 4
Benefit 3																		Benefit 4

5b. Comparison of Social Benefits of Urban Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																			Benefit 2
Benefit 1																			Benefit 3
Benefit 1																			Benefit 4
Benefit 2																			Benefit 3
Benefit 2																			Benefit 4
Benefit 3																			Benefit 4

5c. Comparison of Social Benefits of Feeder Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	Social Benefits
Benefit 1																			Benefit 2
Benefit 1																			Benefit 3
Benefit 1																			Benefit 4
Benefit 2																			Benefit 3
Benefit 2																			Benefit 4
Benefit 3																			Benefit 4

6a. Comparison of Social Costs of Trunk Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																			Cost 2
Cost 1																			Cost 3
Cost1																			Cost 4
Cost 2																			Cost 3
Cost 2																			Cost 4
Cost 3																			Cost 4

6b. Comparison of Social Costs of Urban Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																			Cost 2
Cost 1																			Cost 3
Cost1																			Cost 4
Cost 2																			Cost 3
Cost 2																			Cost 4
Cost 3																			Cost 4

6c. Comparison of Social Costs of Feeder Road Maintenance

Economic Benefits	9	8	7	6	5	4	3	2		1	2	3	4	5	6	7	8	9	Social Benefits
Cost1																			Cost 2
Cost 1																			Cost 3
Cost1																			Cost 4
Cost 2																			Cost 3
Cost 2																			Cost 4
Cost 3																			Cost 4

APENDIX 4.5: SUMMARY OF SECONDARY DATA SOURCES

Road Network Characteristics			
Type of Data	Sources	Agency	Survey Instrument
Road Network and Sectional Descriptions	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Functional Classification	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Pavement Type	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Condition	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Pavement Age	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	
Carriageway Width	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Shoulder Width	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Geometry	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Number of Lanes	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Length	MRT Aggregated Descriptors MRT Strategic plan (2000-2004. M/s Associated Ltd and Comptran engineering and Planning associated	MRT DUR	Check list
Traffic Characteristics			
AADT for Trunk and Feeder roads	MRT Aggregated Descriptors	MRT	Check list
AADT for Urban Roads	Eight city traffic surveys by M/s Ablin Consult	DUR	Check list
Traffic Flow Pattern	MRT Aggregated Descriptors	MRT	Check list
Traffic Flow Type	MRT Aggregated Descriptors	MRT	Check list
Traffic Loading	MRT Records	MRT	Check list
Speed Flow Direction	MRT Aggregated Descriptors	MRT	Check list
Speed Flow Type		MRT	
Road Maintenance Treatment -	MRT Documentations	MRT	Check list
Road Maintenance Standards -	MRT Documentations	MRT	Check list
Unit Rates For Standard Maintenance Interventions	Past Expenditures by Road Intervention Type	Respective Agencies	Check list
Other Data Sources			
Data Type by Source for Road User Charges Analysis			
Fuel Levy – Rate per litre, Fuel volume in Litre	Documented Records	GRFC	Checklist
Build up of Fuel Prices	Documented Records	NPB	
Factors Influencing the Fixing of Fuel Levies	Documented Records	NPB	Checklist
Vehicle Registration Fees -	Documented Records	DVLA	Checklist
Tolling – Road, Bridge and Ferry Tolls	Documented Records	DVLA	Checklist
Road (Vehicle Use Fee)	Documented Records	DVLA	Checklist
International Transit Fees – By vehicle category	Documented Records	DVLA	Checklist
Data for Institutional Analysis	MRT Documentations		
Threshold of MRT Expenditures from Approved Budgets	MRT Documentations		
Data for Case Study	MRT Documentations		

APPENDIX 5.1: HDM-4 SENSITIVITY CLASSES

Impact	Sensitivity Class	Impact Elasticity	Data Type		
			RDWE	RUE – VOC and VOC Savings	RUE – VOC savings
High	S-1	>0.50	Structural Number Modified Structural Number Deflection Traffic Volume Roughness	kp- Parts Model exponent -New Vehicle Price	kp- Parts Model exponent -New Vehicle Price -CSPQI – Parts model roughness term -C0SP – parts model constant term
Moderate	S-II	0.20 – 0.50	Annual Loading Age All Cracking Area Wide Cracking Area Roughness – Environment Factor Cracking Initiation Factor Cracking Projection Factor	-Roughness -E0-Speed Bias Correction -Average Service Life -Average Annual Utilisation -Vehicle Weight	-E0-Speed Bias Correction -ARVMAX- max. rectified velocity -CLPC – Labour model exponent
Vehicle Resource costs					
All other data					

APPENDIX 5.2: IQL LEVEL FOR ROAD AND TRAFFIC DATA

IQL Level	Road Network data	Traffic Data	
IQL-III	Gradient Class Curvature Class Speed Environment class Ride quality Surface distress Index Pavement type class Construction Quality Previous Intervention class Gravel standards Earth Passing Load rating Class	Traffic Volume Percentage of Heavy Vehicles Growth Rate Volume Capacity Ratio	
IQL-IV	Gradient Class Pavement Condition Class Pavement Type Class Remaining service life Climate Classification	Traffic Class Congestion Class	

APPENDIX 5.3: SAMPLE OF DATA ON URBAN ROADS NETWORK

Link No.	Segment No.	Chainage (m)		Lane Count	Width	Surface Class	Pavement Type	Length (m)	Functional class
		Start	End						
AHINSAN ML1	1	0	201.0	2	7	Bituminous	Surface Dressed	201.0	
KN-SN-D-1596-001	1	0.00	20.70	2	7.00	Bituminous	Surface Dressed	20.7	local/access
KN-SN-D-1596-002	1	20.70	27.70	2	7.00	Bituminous	Surface Dressed	7.0	local/access
KU-AA-A-0005-001	1	0	80.1	2	9	Bituminous	Surface Dressed	80.1	major arterial
KU-AA-A-0005-001	1	3500	3675	2	11	Unsealed	Gravel	175.0	major arterial
KU-AA-A-0005-002	1	80.1	375.1	2	9	Bituminous	Surface Dressed	295.0	major arterial
KU-AA-A-0005-002	1	3675	3899	2	11	Unsealed	Gravel	224.0	major arterial
KU-AA-A-0005-003	1	375.1	1002.2	2	9	Bituminous	Surface Dressed	627.1	major arterial
KU-AA-A-0005-003	1	3899	4074	2	11	Unsealed	Gravel	175.0	major arterial
KU-AA-A-0005-004	1	1002.2	1176.1	2	9	Bituminous	Surface Dressed	173.9	major arterial
KU-AA-A-0005-004	1	4074	4123	2	11	Unsealed	Gravel	49.0	major arterial
KU-AA-A-0005-005	1	1176.1	2461.8	2	9	Bituminous	Surface Dressed	1285.7	major arterial
KU-AA-A-0005-005	2	4402	4423	2	7.5	Bituminous	Asphalt Mix	21.0	major arterial
KU-AA-A-0005-005	1	4123	4402	2	11	Unsealed	Gravel	279.0	major arterial
KU-AA-A-0005-006	1	2461.8	2469.6	2	9	Bituminous	Surface Dressed	7.8	major arterial
KU-AA-A-0005-006	1	4423	4766	2	7.5	Bituminous	Asphalt Mix	343.0	major arterial
KU-AA-A-0005-007	1	4766	4827	2	7.5	Bituminous	Asphalt Mix	61.0	major arterial
KU-AA-A-0005-008	1	2469.6	2705.8	2	11.1	Bituminous	Surface Dressed	236.2	major arterial
KU-AA-A-0005-008	1	4827	5035	2	7.5	Bituminous	Asphalt Mix	208.0	major arterial
KU-AA-A-0005-009	1	2705	3519	2	11.1	Bituminous	Surface Dressed	814.0	major arterial
KU-AA-A-0005-009	1	5035	5159	2	7.5	Bituminous	Asphalt Mix	124.0	major arterial
KU-AA-A-0005-010	1	5159	5467	2	7.5	Bituminous	Asphalt Mix	308.0	major arterial
KU-AA-A-0005-011	1	5467	5707	2	7.5	Bituminous	Asphalt Mix	240.0	major arterial
KU-AA-A-0005-012	1	5707	6094	2	7.5	Bituminous	Asphalt Mix	387.0	major arterial
KU-AA-A-0005-013	1	6094	6569	2	7.5	Bituminous	Asphalt Mix	475.0	major arterial
KU-AA-A-0005-042	1	0.00	90.70	2.00	8.20	Bituminous	Surface Dressed	90.7	major arterial
KU-AA-A-0005-043	1	90.70	268.10	2.00	8.20	Bituminous	Surface Dressed	177.4	major arterial
KU-AA-A-0005-044	1	268.10	413.10	2.00	8.20	Bituminous	Surface Dressed	145.0	major arterial

APPENDIX 5.4: SAMPLE OF TRAFFIC DATA ON URBAN ROADS

LINK	01-143	01-144	01-145	01-146	01-147	01-148	01-149	01-150	01-151	01-152	01-153	01-154	01-155
Veh Class													
Cars	84	104	144	210	210	145	2150	1031	1216	1570	726	1333	1196
Taxis	143	176	176	179	135	106	183	717	1508	434	139	562	188
Pick Ups	35	1	1	4	2	8	17	2	2	5	0	6	2
Small buses	84	91	168	85	103	111	1058	24	1608	2831	315	1517	706
Large buses	85	101	91	112	102	99	71	58	115	193	44	212	54
Small Trucks	46	56	92	83	104	85	157	74	264	51	66	84	47
Medium trucks	42	58	69	51	44	93	115	56	169	56	155	90	49
Heavy trucks	53	27	25	53	52	29	41	11	34	41	39	28	43
Articulators	162	163	184	204	166	72	75	65	136	61	47	51	52
Total (AADT)	697	776	916	977	869	720	3850	2036	5050	5549	1531	3890	2343
Average	113.8	122.6	146.4	154.4	139.5	110.0	556.6	295.6	731.3	775.1	222.1	558.9	338.0
STD	43.7	53.2	61.9	66.8	62.9	46.6	621.3	323.4	606.0	844.3	201.8	521.8	358.0
CV	0.38	0.43	0.42	0.43	0.45	0.42	1.12	1.09	0.83	1.09	0.91	0.93	1.06

APPENDIX 5.5: HOMOGENEOUS ROAD SECTIONS FOR TRUNK AND FEEDER ROADS

ROAD NETWORK MATRIX FOR TRUNK		
SECT_ID	SECT_NAME	LENGTH
TIAHTGC	Trunk Inter-regional Asphalt-Concrete High Traffic Good Condition	88.4
TIALTGC	Trunk Inter-regional Asphalt-Concrete Low Traffic Good Condition	112.5
TIGHTFC	Trunk Inter-regional Gravel High Traffic Fair Condition	88.5
TIGHTPC	Trunk Inter-regional Gravel High Traffic Poor Condition	62.4
TIGLTFC	Trunk Inter-regional Gravel Low Traffic Fair Condition	216.7
TIGLTGC	Trunk Inter-regional Gravel Low Traffic Good Condition	96.1
TIGLTPC	Trunk Inter-regional Gravel Low Traffic Poor Condition	519.2
TIGMTFC	Trunk Inter-regional Gravel Medium Traffic Fair Condition	158.8
TIGMTPC	Trunk Inter-regional Gravel Medium Traffic Poor Condition	235.8
TISHTFC	Trunk Inter-regional Surface-Treatment High Traffic Fair Condition	51.6
TISHTGC	Trunk Inter-regional Surface-Treatment High Traffic Good Condition	141.3
TISHTPC	Trunk Inter-regional Surface-Treatment High Traffic Poor Condition	89.7
TISLTFC	Trunk Inter-regional Surface-Treatment Low Traffic Fair Condition	88.7
TISLTGC	Trunk Inter-regional Surface-Treatment Low Traffic Good Condition	91.4
TISLTPC	Trunk Inter-regional Surface-Treatment Low Traffic Poor Condition	84.8
TISMTFC	Trunk Inter-regional Surface-Treatment Medium Traffic Fair Condition	200.2
TISMTGC	Trunk Inter-regional Surface-Treatment Medium Traffic Good Condition	220.9
TNAHTFC	Trunk National Asphalt-Concrete High Traffic Fair Condition	310.6
TNAHTGC	Trunk National Asphalt-Concrete High Traffic Good Condition	456.9
TNAHTPC	Trunk National Asphalt-Concrete High Traffic Poor Condition	118.7
TNALTGC	Trunk National Asphalt-Concrete Low Traffic Good Condition	132.4
TNAMTGC	Trunk National Asphalt-Concrete Medium Traffic Good Condition	254.8
TNGHTPC	Trunk National Gravel High Traffic Poor Condition	179.7
TNGLTFC	Trunk National Gravel Low Traffic Fair Condition	444.4
TNGLTPC	Trunk National Gravel Low Traffic Poor Condition	605.6
TNGMTFC	Trunk National Gravel Medium Traffic Fair Condition	93.9
TNGMTPC	Trunk National Gravel Medium Traffic Poor Condition	227.7
TNSHTFC	Trunk National Surface-Treatment High Traffic Fair Condition	247.9
TNSHTGC	Trunk National Surface-Treatment High Traffic Good Condition	84.6
TNSHTPC	Trunk National Surface-Treatment High Traffic Poor Condition	278.2
TNSLTFC	Trunk National Surface-Treatment Low Traffic Fair Condition	146.4
TNSLTGC	Trunk National Surface-Treatment Low Traffic Good Condition	290.4
TNSMTFC	Trunk National Surface-Treatment Medium Traffic Fair Condition	130.9
TNSMTPC	Trunk National Surface-Treatment Medium Traffic Poor Condition	122.1
TRAHTGC	Trunk Regional Asphalt-Concrete High Traffic Good Condition	36.1
TRGHTFC	Trunk Regional Gravel High Traffic Fair Condition	204.5
TRGHTGC	Trunk Regional Gravel High Traffic Good Condition	126.2
TRGHTPC	Trunk Regional Gravel High Traffic Poor Condition	258.1
TRGLTFC	Trunk Regional Gravel Low Traffic Fair Condition	538
TRGLTGC	Trunk Regional Gravel Low Traffic Good Condition	121.7
TRGLTPC	Trunk Regional Gravel Low Traffic Poor Condition	1528.2
TRGMTFC	Trunk Regional Gravel Medium Traffic Fair Condition	298.4
TRGMTGC	Trunk Regional Gravel Medium Traffic Good Condition	155.1
TRGMTPC	Trunk Regional Gravel Medium Traffic Poor Condition	598.7
TRSHTFC	Trunk Regional Surface-Treatment High Traffic Fair Condition	109.9
TRSHTGC	Trunk Regional Surface-Treatment High Traffic Good Condition	184.9
TRSLTFC	Trunk Regional Surface-Treatment Low Traffic Fair Condition	127.1

TRSLTGC	Trunk Regional Surface-Treatment Low Traffic Good Condition	290.3
TRSLTPC	Trunk Regional Surface-Treatment Low Traffic Poor Condition	151.9
TRSMTFC	Trunk Regional Surface-Treatment Medium Traffic Fair Condition	366.2
TRSMTGC	Trunk Regional Surface-Treatment Medium Traffic Good Condition	416.5
TRSMTPC	Trunk Regional Surface-Treatment Medium Traffic Poor Condition	252.1

ROAD NETWORK MATRIX FOR FEEDER ROADS

SECT_ID	SECT_NAME	LENGTH
FBHTFC	Feeder Bituminous High Traffic Fair Condition	191.04
FBHTGC	Feeder Bituminous High Traffic Good Condition	408.83
FBHTPC	Feeder Bituminous High Traffic Poor Condition	92.67
FBLTFC	Feeder Bituminous Low Traffic Fair Condition	47.76
FBLTGC	Feeder Bituminous Low Traffic Good Condition	58.41
FBLTPC	Feeder Bituminous Low Traffic Poor Condition	37.07
FBMTFC	Feeder Bituminous Medium Traffic Fair Condition	79.60
FBMTGC	Feeder Bituminous Medium Traffic Good Condition	116.81
FBMTPC	Feeder Bituminous Medium Traffic Poor Condition	55.60
FEHTFC	Feeder Earth High Traffic Fair Condition	25.20
FGHTFC	Feeder Gravel High Traffic Fair Condition	2121.50
FEHTGC	Feeder Earth High Traffic Good Condition	13.34
FGHTGC	Feeder Gravel High Traffic Good Condition	3974.00
FEHTPC	Feeder Earth High Traffic Poor Condition	141.80
FGHTPC	Feeder Gravel High Traffic Poor Condition	402.70
FELTFC	Feeder Earth Low Traffic Fair Condition	341.11
FGLTFC	Feeder Gravel Low Traffic Fair Condition	1062.00
FELTGC	Feeder Earth Low Traffic Good Condition	80.04
FGLTGC	Feeder Gravel Low Traffic Good Condition	2782.00
FELTPC	Feeder Earth Low Traffic Poor Condition	708.90
FGLTPC	Feeder Gravel Low Traffic Poor Condition	536.94
FEMTFC	Feeder Earth Medium Traffic Fair Condition	279.09
FGMTFC	Feeder Gravel Medium Traffic Fair Condition	2121.50
FEMTGC	Feeder Earth Medium Traffic Good Condition	40.02
FGMTGC	Feeder Gravel Medium Traffic Good Condition	3179.00
FEMTPC	Feeder Earth Medium Traffic Poor Condition	567.10
FGMTPC	Feeder Gravel Medium Traffic Poor Condition	402.70

APPENDIX 5.6: SAMPLE OF CORRELATION ANALYSIS FOR EXISTING ROAD FEATURES

Segment No.	Start	End	Lane Count	Width (m)	Surface Class	Pavement Type	length (m)	FILTER	Rut Depth (m)	Roughness
1	0.00	90.70	2.00	8.20	Bituminous	Surface Dressed	90.7	MAJOR ARTERIAL	3.08	2.06
1	375.1	1002.2	2	9	Bituminous	Surface Dressed	627.1	MAJOR ARTERIAL	2.13	1.87
1	621.80	636.70	2.00	8.20	Bituminous	Surface Dressed	14.9	MAJOR ARTERIAL	2.43	1.73
1	1030.40	1171.10	2.00	8.20	Bituminous	Surface Dressed	140.7	MAJOR ARTERIAL	2.5	1.2
1	636.70	671.60	2.00	8.20	Bituminous	Surface Dressed	34.9	MAJOR ARTERIAL	2.57	1.49
1	1846.50	1984.20	2.00	8.20	Bituminous	Surface Dressed	137.7	MAJOR ARTERIAL	2.6	1.1
1	671.60	853.40	2.00	8.20	Bituminous	Surface Dressed	181.8	MAJOR ARTERIAL	2.9	1.6
1	268.10	413.10	2.00	8.20	Bituminous	Surface Dressed	145.0	MAJOR ARTERIAL	3.01	1.97
1	1415.50	1425.40	2.00	8.20	Bituminous	Surface Dressed	9.9	MAJOR ARTERIAL	3.1	2.4
1	0.00	20.70	2	7.00	Bituminous	Surface Dressed	20.7	LOCAL/ACCESS	3.11	1.92
1	90.70	268.10	2.00	8.20	Bituminous	Surface Dressed	177.4	MAJOR ARTERIAL	3.13	1.98
1	1002.2	1176.1	2	9	Bituminous	Surface Dressed	173.9	MAJOR ARTERIAL	3.13	2.16
1	80.1	375.1	2	9	Bituminous	Surface Dressed	295.0	MAJOR ARTERIAL	3.17	1.84
1	853.40	1012.20	2.00	8.20	Bituminous	Surface Dressed	158.8	MAJOR ARTERIAL	3.2	2
1	0	201.0	2	7	Bituminous	Surface Dressed	201.0	LOCAL/ACCESS	3.39	2.19
1	1176.1	2461.8	2	9	Bituminous	Surface Dressed	1285.7	MAJOR ARTERIAL	3.55	3.35
1	413.10	489.00	2.00	8.20	Bituminous	Surface Dressed	75.9	MAJOR ARTERIAL	3.69	1.82
1	1669.80	1846.50	2.00	8.20	Bituminous	Surface Dressed	176.7	MAJOR ARTERIAL	4.1	2.7
1	2461.8	2469.6	2	9	Bituminous	Surface Dressed	7.8	MAJOR ARTERIAL	4.18	2.2
1	2469.6	2705.8	2	11.1	Bituminous	Surface Dressed	236.2	MAJOR ARTERIAL	4.46	2.74
1	1171.10	1415.50	2.00	8.20	Bituminous	Surface Dressed	244.4	MAJOR ARTERIAL	4.8	3
1	489.00	577.10	2.00	8.20	Bituminous	Surface Dressed	88.1	MAJOR ARTERIAL	4.98	2.36
1	1425.40	1669.80	2.00	8.20	Bituminous	Surface Dressed	244.4	MAJOR ARTERIAL	5	3.6
1	609.00	621.80	2.00	8.20	Bituminous	Surface Dressed	12.8	MAJOR ARTERIAL	5.6	2.74
1	601.40	609.00	2.00	8.20	Bituminous	Surface Dressed	7.6	MAJOR ARTERIAL	5.75	2.47
1	1012.20	1030.40	2.00	8.20	Bituminous	Surface Dressed	18.2	MAJOR ARTERIAL	5.8	3
1	2705	3519	2	11.1	Bituminous	Surface Dressed	814.0	MAJOR ARTERIAL	5.85	3.02
1	0	80.1	2	9	Bituminous	Surface Dressed	80.1	MAJOR ARTERIAL	6.05	2.53
1	577.10	601.40	2.00	8.20	Bituminous	Surface Dressed	24.3	MAJOR ARTERIAL	6.42	3.01

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.74336
R Square	0.552584
Adjusted R Square	0.536013
Standard Error	0.867187
Probability	0.49

APPENDIX 5.7: SUMMARY OF EXISTING ROAD FEATURES

ROAD CHARACTERISTICS	UNIT OF MEASUREMENT	BITUMINOUS SURFACE	ASPHALT SURFACE
1. Geometry class			
Rise + Fall	m/km	20	10
Average Horizontal Curvature	Deg/km	150	100
Speed Limit	Km/hr	100	100
Altitude	M	250	150
Drain Type			
2. Pavement			
Material Type		Double Bituminous Surface Dressing	Asphaltic Concrete
Most recent Surface Thickness	Mm	15	15
Previous/old Surfacing Thickness	Mm	25	100
3. Pavement Strength			
Adjusted Structural Number	SNP	2.85	3.04
Deflection	DEF	1.22	0.60
Base Material Thickness	Mm	25	200
4. Pavement Distressed Condition			
Condition at the end of Year	Year	1999	1998
Roughness	IRIm/km	6.00	2.5
Total Area of cracking	%	5.0	1
Ravelled Area	%	8.0	1
Number of Potholes	No/km	5.0	0.00
Edge Break	m^2/km	5.0	0.00
Mean Rut Depth	Mm	5.0	2.00
Texture Depth	Mm	3.00	3.00
Skid Resistance	SCRIM 50km/hr	0.5	0.60
Number of Lanes		2	2
Construction Year	Year		
Year of Most Recent Overlay	Year		

APPENDIX 5.8: SAMPLE OF DATA ON TENDERED CONTRACT RATES FOR UPGRADING

Record	Work Activity	Length	Cost/km in US $
GHAA0008	Upgrading Gravel to Bituminous Surface road	5.00	92,982
GHAA0009	Upgrading Gravel to Bituminous Surface road	15.00	114,929
GHAA0010	Upgrading Gravel to Bituminous Surface road	3.00	90,243.92
GHAA0012	Upgrading Gravel to Bituminous Surface road	5.00	174,762.45
GHAA0016	Upgrading Gravel to Bituminous Surface road	7.30	143,413
GHAA0017	Upgrading Gravel to Bituminous Surface road	3.00	203,243
GHAA0019	Upgrading Gravel to Bituminous Surface road	4.30	88,266
GHAA0023	Upgrading Gravel to Bituminous Surface road	2.50	150,276
GHAA0024	Upgrading Gravel to Bituminous Surface road	10.10	163,075
GHAA0025	Upgrading Gravel to Bituminous Surface road	19.13	82,431
GHAA0026	Upgrading Gravel to Bituminous Surface road	2.00	180,820
GHAA0027	Upgrading Gravel to Bituminous Surface road	2.00	180,692
GHAA0028	Upgrading Gravel to Bituminous Surface road	7.00	120,840
GHAA0029	Upgrading Gravel to Bituminous Surface road	4.20	141,888
GHAA0030	Upgrading Gravel to Bituminous Surface road	2.00	100,921
GHAA0031	Upgrading Gravel to Bituminous Surface road	39.70	81,594
GHAA0034	Upgrading Gravel to Bituminous Surface road	5.00	87,702
GHAA0038	Upgrading Gravel to Bituminous Surface road	5.00	135,097
GHAA0042	Upgrading Gravel to Bituminous Surface road	4.50	121,733
GHAA0043	Upgrading Gravel to Bituminous Surface road	5.00	128,437
GHAA0044	Upgrading Gravel to Bituminous Surface road	5.00	55,200
GHAA0049	Upgrading Gravel to Bituminous Surface road	10.00	69,957
GHAA0050	Upgrading Gravel to Bituminous Surface road	5.00	154,016
GHAA0051	Upgrading Gravel to Bituminous Surface road	4.00	108,492
GHAA0052	Upgrading Gravel to Bituminous Surface road	5.00	198,028
GHAA0053	Upgrading Gravel to Bituminous Surface road	7.50	187,851
GHAA0054	Upgrading Gravel to Bituminous Surface road	5.00	213,445
GHAA0055	Upgrading Gravel to Bituminous Surface road	10.00	130,086
GHAA0057	Upgrading Gravel to Bituminous Surface road	4.00	89,356
GHAA0058	Upgrading Gravel to Bituminous Surface road	7.50	206,455
GHAA0059	Upgrading Gravel to Bituminous Surface road	5.00	154,833
GHAA0061	Upgrading Gravel to Bituminous Surface road	20.00	60,831
GHAA0063	Upgrading Gravel to Bituminous Surface road	4.00	126,367
GHAA0064	Upgrading Gravel to Bituminous Surface road	5.00	143,067
GHAA0069	Upgrading Gravel to Bituminous Surface road	8.00	97,511
GHAA0073	Upgrading Gravel to Bituminous Surface road	9.00	126,338
GHAA0075	Upgrading Gravel to Bituminous Surface road	12.00	126,537
GHAA0076	Upgrading Gravel to Bituminous Surface road	5.00	121,373
GHAA0077	Upgrading Gravel to Bituminous Surface road	5.00	144,303
GHAA0078	Upgrading Gravel to Bituminous Surface road	5.00	153,954
GHAA0079	Upgrading Gravel to Bituminous Surface road	3.00	148,900
GHAA0080	Upgrading Gravel to Bituminous Surface road	3.00	196,205
GHAA0084	Upgrading Gravel to Bituminous Surface road	10.00	111,664
GHAA0085	Upgrading Gravel to Bituminous Surface road	5.00	185,147
GHAA0088	Upgrading Gravel to Bituminous Surface road	11.00	98,933
GHAA0089	Upgrading Gravel to Bituminous Surface road	5.50	96,333
Average			132,359
Standard Deviation			41,323

CV	0.312

APPENDIX 5.9 TRAFFIC GROWTH RATE PROJECTIONS FOR FEEDER ROADS

Vehicle Class	AADT 2001	AADT 2004	po	pn	n	1/n	(pn/po)	In(pn/po)	1/nIn(pn/po)	**e**	**e**1/nIn(pn/po)	**e**1/nIn(pn/po) - 1	r
Cars	211	311	211	311	4	0.25	1.474	0.167	0.042	2.272	1.035	0.035	3.5
Cars	332	488	332	488	4	0.25	1.470	0.164	0.041	2.272	1.034	0.034	3.4
Average													3.45
Light Trucks	447	767	447	767	4	0.25	1.716	0.233	0.058	2.272	1.049	0.049	4.9
Medium Trucks	213	371	213	371	4	0.25	1.742	0.241	0.060	2.272	1.051	0.051	5
Heavy Trucks	123	215	123	215	4	0.25	1.748	0.241	0.060	2.272	1.051	0.051	5
Articulated Trucks	121	190	121	190	4	0.25	1.570	0.196	0.049	2.272	1.041	0.041	4.1
Small Bus	201	209	201	209	4	0.25	1.040	0.121	0.030	2.272	1.025	0.025	2.5
Large/Medium Bus	112	257	112	257	4	0.25	2.295	0.360	0.090	2.272	1.077	0.077	7.6
Motorcycle	149	218	149	218	4	0.25	1.463	0.164	0.041	2.272	1.034	0.034	3.4
Average													4.52

APPENDIX 5.10: LOCATION OF SELECTED CITIES FOR VEHICLE SURVEYS

APPENDIX 5.11: PHYSICAL CHARACTERISTICS OF VEHICLES

VEHICLE CLASS	DESCRIPTION
Cars and Pick Ups or Station Wagons	These are vehicles with a wheelbase of 3.2 meters or less
Light Vehicles (LCV	These include vans, 4 wheel drive sports utility vehicles, vans/mini-buses, utilities and light trucks up to 3.5 tonnes gross laden weight. LCVs mainly have single rear tyres, but include some small trucks with dual tyres4
Medium Commercial Vehicles (MCV)	These are two-axle heavy trucks without a trailer, over 3.5 tonnes gross laden weight;
Heavy Commercial Vehicles (HCV-I)	These are rigid trucks with or without trailers or articulated vehicle with three or four axles in total;
Heavy Commercial Vehicles (HCV-II)	These are trucks and trailers and articulated vehicles with or without trailers with five or more axles in total
Buses	These are Buses, excluding mini-buses (which are included with LCV).

APPENDIX 5.12: VEHICLE KM/ANNUM BY AGE OF VEHICLES

	Classification by Age	Km	Year of Make	Age	km/annum
1	Old	164,800	1996	8	20600
2	Old	154,000	1996	8	19250
3	Old	102,000	1997	7	14571.4
4	Old	130,000	1998	6	21666.7
5	Old	199,060	1997	7	28437.1
6	Old	112,926	1996	8	14115.75
7	Old	206,840	1995	9	22982.2
8	Old	222,200	1995	9	24688.9
9	Old	94,920	1997	7	13560
10	Old	197,200	1996	8	24650
11	Old	183,880	1995	9	20431.1
12	Old	184,684	1997	7	26383.4
13	Old	179,060	1997	7	25580
14	Old	192,926	1995	9	21436.2
15	Old	166,840	1997	7	23834.3
16	Old	197,200	1996	8	24650
17	Old	194,920	1996	8	24365
18	Old	197,200	1996	8	24650
19	Old	193,880	1997	7	27697.1
20	Old	184,800	1995	9	20533.3
21	New	63,400	1999	5	12680
22	New	43920	2000	4	10980
23	New	23,020	2002	2	11510
24	New	33,020	2001	3	11006.7
25	New	36,000	2001	3	12000
26	New	43,200	2000	4	10800
27	New	64,800	1999	5	12960
28	New	34,400	2001	3	11466.7
29	New	33,800	2001	3	11266.7
30	New	33,200	2001	3	11066.7
	Service Life			12.7	
	Average New	40,876		4	11,574
	Average Old	172,967		8	22,204
	Average Both	106,921		6	16,889
	Weighted Average New	13489.1		1.155	3819.31
	Weighted Average Old	115887.8		5.226	14876.8
	Weighted Average Both	129376.8		6.381	18696.1
	Ave km/yr (both)	20275.3			
	Std Deviation New	13538.5			
	CV New	0.3			
	Std Deviation Old	36,134			
	CV Old	0.21			
	Average CV	0.27			

APPENDIX 4.13 VEHICLE RESOURCE COSTS

Estimation of Fuel Cost

Component	Description	Fuel (US $)
A. Average Ex Refinery Price (2000-2004)/ Barrel	Financial Cost	38.92
B. Average Taxes (2000-2004)	Taxes	11.56
C. Average Transport Subsidy (2000-2004)	Subsidies	5.69
D. Ex Refinery Cost Less Taxes and Subsidies	Economic Cost	21.57
E. Average Number of Litres/ Barrel	89	
Average Cost / Litre (Economic Cost /89 litres)	0.24	

Maintenance Labour Cost

Vehicle Type	Labour Cost (Informal Operators)	Labour Cost (Formal Operators)
Car	0.4	1.6
Taxi	0.5	1
Pickups	0.3	1
Small Truck	1.3	1
Medium Truck	1.8	1
Heavy truck	1.7	1
4/5 Axle Articulator 0.06Truck	1.9	1.4
Small Bus	0.3	1
Medium/Heavy bus	1.5	1
Motorcycle	0.2	1
CV	0.71	0.2

T' Value = 0.471, Degrees of Freedom = 9, Critical 'T' = 1.83P value = 0.32

ESTIMATES ON CREW COSTS FROM FIELD SURVEYS

Vehicle Type	Cost/Month	No of Working days	Cost /Day	No hrs/day	Calibrated Crew Cost/hr	Crew Cost/hr
Car	27.2	0.25	0.23	3.68	0.06	0.08
Taxi	27.2	0.75	0.68	19.74	0.03	0.3
Pickups	38.0	0.8	1.01	11.4	0.09	0.38
Small Truck	38.0	0.5	0.63	6.2	0.10	0.75
Medium Truck	48.9	0.7	1.14	18.9	0.06	0.83
Heavy truck	59.8	0.9	1.79	23.1	0.08	0.9
4/5 Axle Articulator 0.06Truck	59.8	0.9	1.79	23.7	0.08	0.95
Small Bus	27.2	0.7	0.63	8.75	0.07	0.45
Medium/Heavy Bus	38.0	0.7	0.89	13.2	0.07	0.68

Crew Cost

Vehicle Type	Formal Rates (US $/Hr)	Informal Rates (US $/Hr)
Car	0.06	0.08
Taxi	0.03	0.3
Pickups	0.09	0.38
Small Truck	0.10	0.75
Medium Truck	0.06	0.83
Heavy truck	0.08	0.90
Axle Articulator Truck	0.08	0.95
Small Bus	0.07	0.45
Medium/Heavy Bus	0.07	0.68
Motorcycle	0	0
CV	0.29	0.51

T' Value = 4.61 Critical 'T' = 1.83, P value = 0.000638

ESTIMATION OF TIME VALUE BASED ON GROSS DOMESTIC PRODUCT (GDP)

1	GDP-2004	8,595,000,000		
2	Total Population	20,000,000		
3	Productive Population (50%)	10,000,000		
4	Number of Working Hours	1800		
5	GDP/Productive Population	859.5		
6	Cost per hr (5/4)	0.4775		
7	Less 25% Adjustment for non Work	0.119375		
	Vehicle Class	Percentage of Work Related Trips	Cost/Hr Adjusted by Wk Related Trips	Cost/hr Adjustment by Non Work Time
	Car	70%	0.334	0.084
	Taxis	52%	0.248	0.062
	Pick ups	60%	0.287	0.072
	Small Trucks	50%	0.239	0.060
	Medium Trucks	40%	0.191	0.048
	Heavy Trucks	40%	0.191	0.048
	Articulators	40%	0.191	0.048
	Small Bus	53%	0.253	0.063
	Medium/Heavy Bus	53%	0.253	0.063
	Motorcycle	0	0	0

CALIBRATED RESIDUAL VALUE

Residual value = RVPLTPCT = Max[a2,a3 - Max(0,(Rlav - a4))]

RVPLTPCT = Residual vehicle value less tyres at the end of service life

a2 = minimum residual value of the vehicle (%) default value =2

a3 = maximum residual value of the vehicle (%) default value is 15

a4 average roughness IRI below which the maximum value arises , default value = 5

Rlav = Average Road Roughness

i	ii	iv	v	vi	vii		ix	x	
	a2	a3	Rlav	a4	Rlav-a4	Max	a2 x a3	ix-viii	RVP LTPC T)
Car	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Taxi	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Pickups	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Small Truck	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Medium Truck	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Heavy truck	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Axle Articulator	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Small Bus	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Medium/	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Heavy Bus	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01
Motorcycle	0.05	0.2	6	7.5	-1.5	0	0.01	0.01	0.01

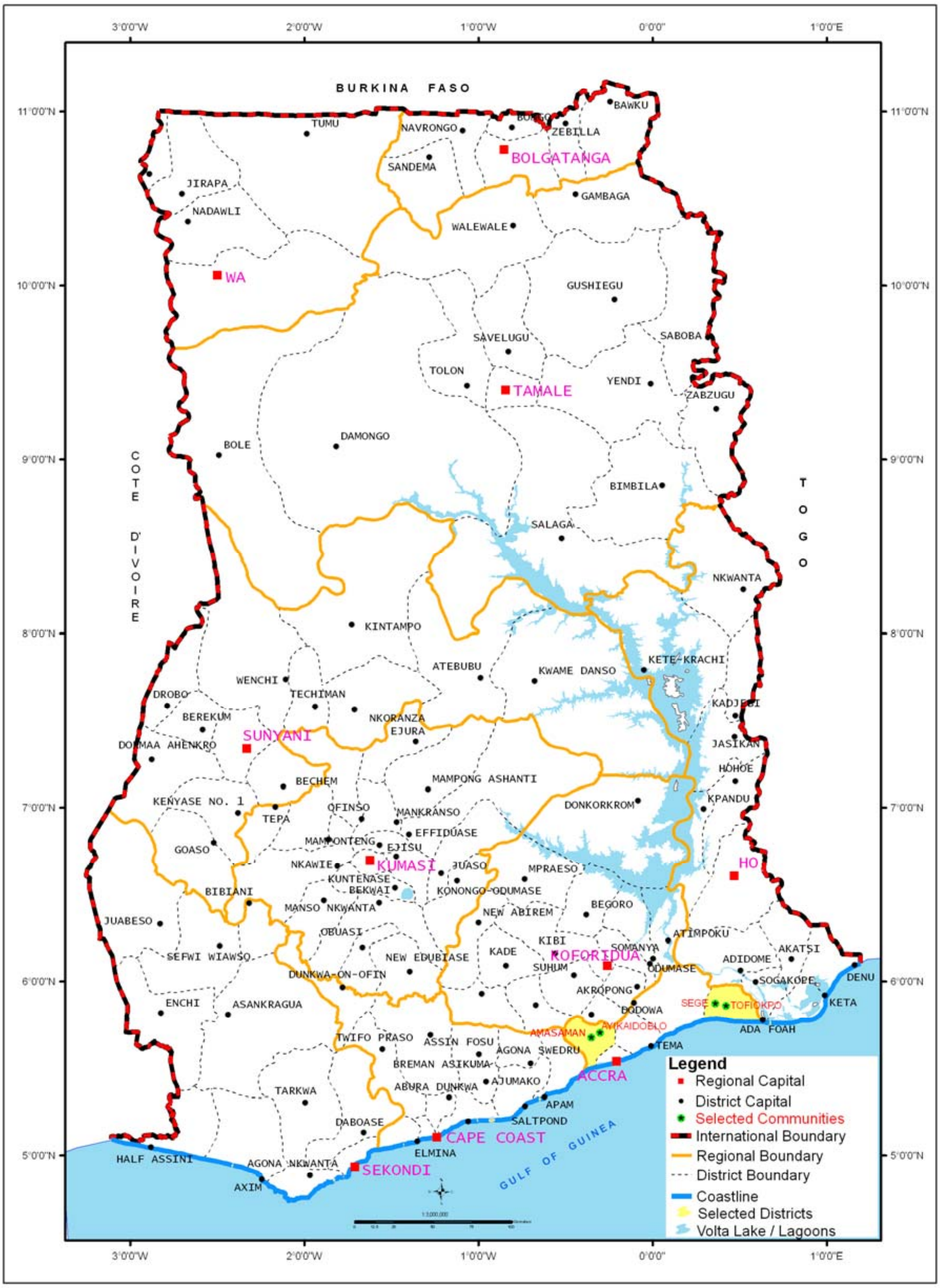
Annual Overhead Cost

Vehicle Type	Formal Sector	Informal Sector
Car	182.6	400
Taxi	340.5	500
Pickups	493.6	200
Small Truck	259.9	700
Medium Truck	618.6	700
Heavy truck	1025.3	800
Axle Articulator	934.8	800
Small Bus	566.7	500
Medium/Heavy Bus	566.7	700
Motorcycle	159	170

T' Value = 0.461 , Critical 'T' = 1.83 P value = 0.33

APPENDIX 5.14 LOCATION OF SELECTED DISTRICTS AND COMMUNITIES

DISTRICT MAP OF GHANA MAP OF GHANA



APPENDIX 5.15: AGGREGATED DATA ON PAIRWISE COMPARISON AT THE COMMUNITY LEVEL

Level 1	Pairwise Comparison of Economic and Social Benefit						Level 2 Pairwise Comparison of Social Benefits and Costs						
Number	Trunk Road		Urban Road		Feeder Road		Number	Trunk Road		Urban Road		Feeder Road	
	Economic Benefit	Social Benefit	Economic Benefit	Social Benefit	Economic Benefit	Social Benefit		Social Benefit	Social Cost	Social Benefit	Social Cost	Social Benefit	Social Cost
1	4	1	9	0	1	0	1	9	0	4	0	0	9
2	7	0	7	0	0	9	2	5	0	7	0	0	4
3	8	0	8	0	0	6	3	9	0	8	0	0	2
4	2	0	9	0	0	8	4	0	1	9	0	0	9
5	3	0	9	0	0	9	5	0	2	9	0	0	9
6	7	0	9	0	3	0	6	9	0	9	0	0	9
7	0	1	9	0	0	9	7	9	0	9	0	0	9
8	1	0	9	0	0	8	8	9	0	6	0	0	7
9	0	3	9	0	0	6	9	9	0	9	0	0	3
10	9	0	8	0	2	0	10	0	1	8	0	0	9
11	9	0	9	0	1	0	11	9	0	9	0	0	9
12	4	0	9	0	0	9	12	0	4	9	0	0	9
13	2	0	9	0	0	9	13	8	0	9	0	1	0
14	6	0	9	0	0	9	14	6	0	9	0	0	6
15	5	0	0	3	0	7	15	9	0	8	0	0	8
16	8	0	9	0	0	6	16	8	0	0	1	1	0
17	9	0	7	0	0	8	17	9	0	7	0	1	0
18	2	0	9	0	0	8	18	6	1	9	0	0	9
19	0	9	6	0	0	9	19	0	0	6	0	0	9
20	9	0	9	0	0	6	20	9	0	9	0	0	9
Average	4.75	0.7	8.1	0.15	0.35	6.3		6.15	0.45	7.65	0.05	0.15	6.45
	4.75 – 0.7=4.05		8.1-0.15=7.95		6.3-0.35=5.95			6.15-0.45=5.7		7.65-0.05=7.6		6.5-0.15=6.3	

APPENDIX 5.16 SUMMARY OF ECONOMIC AND SOCIAL BENEFITS AT CRITERIA LEVEL 1

Average Score at Criteria Level for Economic and Social Benefits (Good Road)

Type of Road	Economic Benefits	Social Benefits
Trunk	4	
Urban	4	
Feeder		6

Average Score at Criteria Level for Economic and Social Benefits (Bad Road)

Type of Road	Economic Benefits	Social Benefits
Trunk	3	
Urban	3	
Feeder		9

Average Score at Criteria Level for Economic and Social Benefits (District Level)

Type of Road	Economic Benefits	Social Benefits
Trunk	5	
Urban	3	
Feeder	4	

Average Score at Criteria Level for Economic and Social Benefits (National Level)

Type of Road	Economic Benefits	Social Benefits
Trunk	7	
Urban	5	
Feeder		7

APPENDIX 5.17 SUMMARY OF SOCIAL AND COSTS BENEFITS AT CRITERIA LEVEL 2

Average Score at Criteria Level for Social Benefits and Costs (Good Road)

Type of Road	Social Benefits	Social Costs
Trunk	6	
Urban	8	
Feeder	8	

Average Score at Criteria Level for Social Benefits and Costs (Bad Road)

Type of Road	Social Benefits	Social Costs
Trunk	8	
Urban	8	
Feeder	6	

Average Score at Criteria Level for Social Benefits and Costs (District Level)

Type of Road	Social Benefits	Social Costs
Trunk	5	
Urban	6	
Feeder	8	

Average Score at Criteria Level for Social Benefits and Costs (National Level)

Type of Road	Social Benefits	Social Costs
Trunk	7	
Urban	7	
Feeder		9

APPENDIX 5.18: A COMPILATION OF ELEMENTS OF SOCIAL BENEFITS AND COSTS AT CRITERIA LEVEL 3

	Social. Benefits	Social Costs
1	Increased Access to Health Facilities	Increased Road Accidents
2	Creation of Employment	Increased Crime and Insecurity
3	Attraction of teachers	Spread of HIV/AIDS
4	Increased Access to Information	Water and Dust Pollution
5	Increased Social Interaction	Negative Cultural Influences
6	Increase in Income Levels	Increase in Land Prices
7	Increased Production	Increased Competition
9	Access to Markets	Influx of Poor Quality Goods
8	Decreased Transport Costs	Difficulty in Accessing Land
10	Increased Access to Inputs	Increased Accidents
11	Increased Access to Employment	Increased Crime
12	Access to Markets	Dust pollution
13	Increased Revenue to Assemblies	Operation of quack medical Practitioners
14	Increased Income Levels	Migration to cities
15	Increased Production	Increased accidents
16	Increased Access to Employment Opportunities	Increased stealing activities
17	Access to raw Materials	Spread of STDs
18	Increased Exports	Increased rent
19	Visits to Friends and Relatives	Increased Accidents
20	Increased Economic Activities	Migration to cities
21	Reduction in Travel time	Negative Cultural Influences
22	Reduced Transport fares	Dust pollution
23	Reduction in Post Harvest Losses	Increase in Teenage Pregnancy
24	Increased Access to Social Amenities	Increased Truancy Amongst Children
25	Induced Housing Development	Increased dust pollution
26	Improved Safety	Increased land prices
27	Improved Environmental conditions	Increased Accidents
28	Link to other communities	Spread of HIV/AIDS
29	Funeral	Scarcity in land availability
30	Visit Friends	High death rate from accidents
31	Access to Health	Increased access to alcohol
32	Access to Bank	Negative Cultural Influences
33	Go to School	Increased Accidents
34	Extension visits	High land prices
35	Increased Activities of Itinerary Traders	High Accident rates
36	Access to Maternal health care	Destruction of vegetation
37	Immunisation of Children	Increased rent
38	Increased Access to Information on credit facilities	Competition for land
39	Access to Hospitals	
40	Improved Income	
41	Access to Education	
42	Increased Trading Activities	
43	Increased Farming Activities	
44	Reduced Travel Time	
46	Transport Availability	
47	Increased Cost of Lands	
48	Access to credit facilities	
49	Ability to Vote	

APPENDIX 5.19: SUMMARY OF SOCIAL BENEFITS AT SUB CRITERIA LEVEL 3

Average Score at Sub Criteria Level for Social Benefits (Good Roads)

Sub Criteria												
Type of Road	Ben 1	Ben 2	Ben 1	Ben 3	Ben 1	Ben 4	Ben 2	Ben 3	Ben 2	Ben 4	Ben 3	Ben 4
Trunk	4		4		8		1		4		4	
Urban	4		3		8			2	7		7	
Feeder	4		5		5		4		4			4

Average Score at Sub Criteria Level for Social Benefits (Bad Roads)

Sub Criteria												
	Ben 1	Ben 2	Ben 1	Ben 3	Ben 1	Ben 4	Ben 2	Ben 3	Ben 2	Ben 4	Ben 3	Ben 4
Trunk	6		2		2		2		5		4	
Urban	7		5		7		3		2		5	
Feeder	1		3		4		5		4			7

Average Score at Sub Criteria Level for Social Benefits (District Level)

Sub Criteria												
	Ben 1	Ben 2	Ben 1	Ben 3	Ben 1	Ben 4	Ben 2	Ben 3	Ben 2	Ben 4	Ben 3	Ben 4
Trunk	7		6		7		5		2			5
Urban	7		5		1		2		6		4	
Feeder	2		0		0		3		0		6	

Average Score at Sub Criteria Level for Social Benefits (National Level)

	Ben 1	Ben 2	Ben 1	Ben 3	Ben 1	Ben 4	Ben 2	Ben 3	Ben 2	Ben 4	Ben 3	Ben 4
Trunk	4		2			2		I		3	2	
Urban	1		4			7		3		3	4	
Feeder		7		4		3		4		4		2

APPENDIX 5.20: SUMMARY OF SOCIAL COSTS AT SUB CRITERIA LEVEL 3

Average Score at Sub Criteria Level for Social Costs (Good Roads)

Sub Criteria												
Type of Road	Cost 1	Cost 2	Cost 1	Cost 3	Cost 1	Cost 4	Cost 2	Cost 3	Cost 2	Cost 4	Cost 3	Cost 3
Trunk	5		4		4			4	3		6	
Urban	8		2		3			7		6	5	
Feeder	6		5		4		1			3		2

Average Score at Sub Criteria Level for Social Costs (Bad Roads)

Sub Criteria												
	Cost 1	Cost 2	Cost 1	Cost 3	Cost 1	Cost 4	Cost 2	Cost 3	Cost 2	Cost 4	Cost 3	Cost 3
Trunk	7		5		6		2		1			2
Urban	7		6		2			7	1		1	
Feeder	3			6	2			5	1		3	

Average Score at Sub Criteria Level for Social Costs (District Level)

Sub Criteria												
	Cost 1	Cost 2	Cost 1	Cost 3	Cost 1	Cost 4	Cost 2	Cost 3	Cost 2	Cost 4	Cost 3	Cost 3
Trunk	8		7		6		2		4		1	
Urban	6		1		4		4		4		5	
Feeder	1		0		5		0		4		0	

Average Score at Sub Criteria Level for Social Costs (National Level)

	Cost 1	Cost 2	Cost 1	Cost 3	Cost 1	Cost 4	Cost 2	Cost 3	Cost 2	Cost 4	Cost 3	Cost 3
Trunk												
Urban												
Feeder												

APPENDIX 5.21: SUMMARY OF DATA FOR CASE STUDY

ROAD LENGTH (2005-2007)

Road Type	Length	Percentage Change
Trunk	12,864.9	20
Urban	9648	31
Feeder	21,902	47.5

ROAD CONDITION MIX (2005-2007)

	2000-2004			2005-2007		
	Good	Fair	Poor	Good	Fair	Poor
Trunk	0.38	0.40	0.22	49	29	32
Urban	0.32	0.37	0.31	32	37	31
Feeder	0.53	0.32	0.15	33	36	31
Percentage Change	**Good =7 Percent, Fair = 6 Percent, Poor = 28 Percent**					

UNIT RATES (2005-2007)

	Activity	Unit	Economic Unit Cost($)	Financial Unit Cost ($)	Budget Heading
6	Single surface dressing	M^2	8.88	9.21	Capital
7	Double Surface dressing	M^2	15.89	16.48	Capital
8	Overlay dense graded asphalt	M^2	25.0	29.0	Capital
10	Spot regravelling	M^3	14.00	14.58	Recurrent
11	Regravelling	M^3	11.44	11.87	Capital
12	Grading	Km	468	538	Recurrent
13	Upgrading (Gravel to Bitumen surface)	Km	177,848	203,332	Capital

VEHICLE COSTS (2005-2007)

Vehicle Type	Amount in US $
Car	40,583.2
Taxi	40,583.2
Pickups	47,556
Small Truck	53,573
Medium Truck	90,573.1
Heavy truck	149,067.2
4/5 Axle Articulator 0.06 Truck	185,250
Small Bus	47,111.7
Medium Bus/Heavy Bus	115,650
Motor Cycle	3,111.0

APPENDIX 6.1 SAMPLE OF ESTIMATED NEED SCORE FOR ROAD LENGTH – TRUNK ROADS

Road Section	Length	Need Score	Normalised Length	Equivalent to 1
TIAHTGC	88.40	0.062	0.025	0.146
TIALTGC	112.50	0.098	0.053	0.186
TIGHTFC	88.50	0.062	0.025	0.146
TIGHTPC	62.40	0.031	0.006	0.103
TIGLTFC	216.70	0.319	0.260	0.358
TIGLTGC	96.10	0.073	0.033	0.159
TIGLTPC	519.20	0.890	0.885	0.857
TIGMTFC	158.80	0.186	0.130	0.262
TIGMTPC	235.80	0.365	0.308	0.389
TISHTFC	51.60	0.022	0.002	0.085
TISHTGC	141.30	0.151	0.097	0.233
TISHTPC	89.70	0.064	0.026	0.148
TISLTFC	88.70	0.062	0.025	0.146
TISLTGC	91.40	0.066	0.028	0.151
TISLTPC	84.80	0.057	0.022	0.140
TISMTFC	200.20	0.280	0.220	0.331
TISMTGC	220.90	0.329	0.271	0.365
TNAHTFC	310.60	0.546	0.502	0.513
TNAHTGC	456.90	0.819	0.806	0.754
TNAHTPC	118.70	0.109	0.061	0.196
TNALTGC	132.40	0.134	0.082	0.219
TNAMTGC	254.80	0.412	0.358	0.421
TNGHTPC	179.70	0.232	0.174	0.297
TNGLTFC	444.40	0.801	0.786	0.734
TNGLTPC	605.60	0.950	0.950	1.000
TNGMTFC	93.90	0.070	0.030	0.155
TNGMTPC	227.70	0.346	0.288	0.376
TNSHTFC	247.90	0.395	0.340	0.409
TNSHTGC	84.60	0.057	0.022	0.140
TNSHTPC	278.20	0.469	0.419	0.459
TNSLTFC	146.40	0.161	0.106	0.242
TNSLTGC	290.40	0.498	0.450	0.480
TNSMTFC	130.90	0.131	0.080	0.216
TNSMTPC	122.10	0.115	0.066	0.202
TRAHTGC	36.10	0.011	0.000	0.060
TRGHTFC	204.50	0.290	0.231	0.338
TRGHTGC	126.20	0.122	0.072	0.208
TRGHTPC	258.10	0.420	0.366	0.426
TRGLTFC	538.00	0.906	0.903	0.888
TRGLTGC	121.70	0.114	0.066	0.201
TRGLTPC	200.00	0.279	0.220	0.330
TRGMTFC	298.40	0.517	0.471	0.493
TRGMTGC	155.10	0.179	0.123	0.256
TRGMTPC	200.00	0.279	0.220	0.330
TRSHTFC	109.90	0.094	0.049	0.181
TRSHTGC	184.90	0.244	0.185	0.305
TRSLTFC	127.10	0.124	0.074	0.210
TRSLTGC	290.30	0.498	0.450	0.479

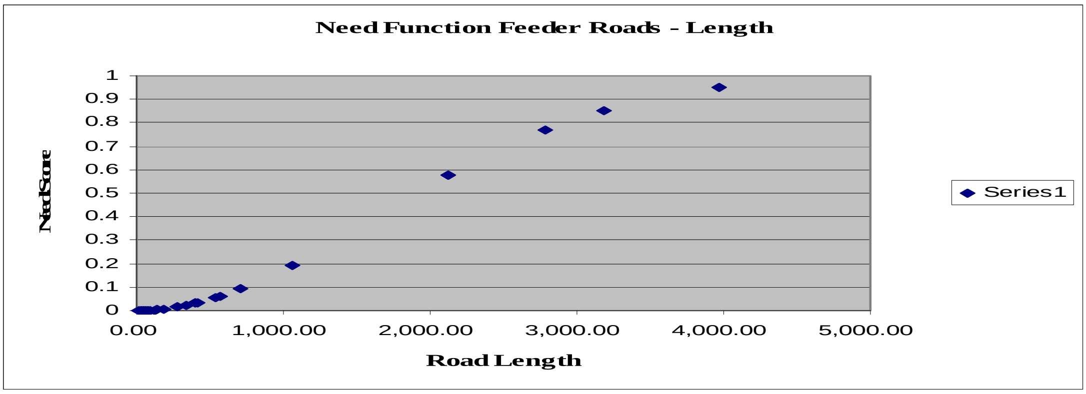
TRSLTPC	151.90		0.172	0.117	0.251
TRSMTFC	366.20		0.666	0.635	0.605
TRSMTGC	416.50		0.758	0.738	0.688
TRSMTPC	252.10		0.405	0.351	0.416
Mean	205.9462		0.2931537	0.2342017	0.3400696
min	36.10				
max	605.60				
Average	205.9				
Standard Deviation	131.6				
SQRT	5.2				
STD Error	25.3				
Significance level	0.1	1.96			
Sample Size	27.0				
Confidence Int	49.6				
	255.6				

APPENDIX 6.2: SAMPLE OF ESTIMATED NEED SCORE FOR TRAFFIC LEVELS – URBAN ROADS

Road Section	AADT	Need	Normalised	Equ
UAHTFC	14344	0.893	0.893	0.863
UAHTGC	9860	0.652	0.649	0.594
UAHTPC	10107	0.671	0.667	0.608
UALTFC	1187	0.015	0.012	0.071
UALTGC	1233	0.016	0.013	0.074
UALTPC	1263	0.017	0.014	0.076
UAMTFC	3032	0.095	0.089	0.183
UAMTGC	5053	0.242	0.235	0.304
UAMTPC	5053	0.242	0.235	0.304
UGHTFC	8111	0.511	0.505	0.488
UGHTGC	7583	0.465	0.459	0.456
UGHTPC	7833	0.487	0.481	0.472
UGLTFC	126	0.000	0.000	0.008
UGLTGC	126	0.000	0.000	0.008
UGLTPC	126	0.000	0.000	0.008
UGMTFC	581	0.004	0.002	0.035
UGMTGC	654	0.005	0.003	0.039
UGMTPC	668	0.005	0.003	0.040
USHTFC	13693	0.870	0.869	0.824
USHTGC	16612	0.950	0.950	1.000
USHTSC	11143	0.741	0.738	0.671
USLTFC	1068	0.012	0.010	0.064
USLTGC	1149	0.014	0.011	0.069
USMTFC	5053	0.242	0.235	0.304
USMTGC	5468	0.278	0.270	0.329
USMTSC	3426	0.119795	0.11326	0.206236
min	126.0			
max	16,612.0			
Average	5,175.1			
Standard Deviation	4,966.9			
SQRT	0.22			
STD Error	22212.5			
Significance level	0.05	1.96		
Sample Size	26			
Confidence Int	1909.2			
3265.91	7084.2			

APPENDIX 6.3: SAMPLE OF ESTIMATED NEED SCORE FOR ROAD LENGTH - FEEDER ROADS

Road Section	Length (km)	Need Score	Normalised Length	Equivalent to 1
FBHTFC	191.04	0.00690891	0.006020746	0.048072
FBHTGC	408.83	0.031251779	0.029469845	0.102876
FBHTPC	92.67	0.001630008	0.001202817	0.023319
FBLTFC	47.76	0.000433212	0.000226547	0.012018
FBLTGC	58.41	0.000647887	0.000388398	0.014698
FBLTPC	37.07	0.000261008	0.000107686	0.009328
FBMTFC	79.60	0.001202902	0.00083928	0.02003
FBMTGC	116.81	0.002588588	0.002045364	0.029394
FBMTPC	55.60	0.000587067	0.000341484	0.013991
FEHTFC	25.20	0.000120626	2.68998E-05	0.006341
FGHTFC	13.34	3.38041E-05	0	0.003357
FEHTGC	141.80	0.003812316	0.003150916	0.035682
FGHTGC	341.11	0.021860678	0.020336242	0.085835
FEHTPC	80.04	0.001216229	0.000850458	0.020141
FGHTPC	708.90	0.091048088	0.088372849	0.178384
FELTFC	279.09	0.014687405	0.013415385	0.070229
FGLTFC	40.02	0.000304196	0.000136122	0.01007
FELTGC	567.10	0.059263376	0.056958294	0.142703
FGLTGC	2,121.50	0.574704658	0.572563604	0.533845
FELTPC	3,974.00	0.950212932	0.950212932	1
FGLTPC	402.70	0.030335882	0.028576453	0.101334
FEMTFC	1,062.00	0.192850931	0.189665274	0.267237
FGMTFC	2,782.00	0.770123112	0.769146279	0.70005
FEMTGC	536.94	0.053294068	0.051079892	0.135113
FGMTGC	2,121.50	0.574704658	0.572563604	0.533845
FEMTPC	3,179.00	0.853357619	0.852882808	0.79995
FGMTPC	402.70	0.030335882	0.028576453	0.101334
Mean	735.8048	0.097734809	0.095000106	0.185155
min	13.34			
max	3,974.00			
Average	735.80			
Standard Deviation	1092.84			
SQRT	5.20			
STD Error	210.32			
Significance level	0.05	1.96		
Sample Size	27			
Confidence Int	412.21			
323.59	1148.02			


Need Function Feeder Roads - Length
Need Score
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00
1,000.00
2,000.00
3,000.00
4,000.00
5,000.00
Road Length
Series1

APPENDIX 6.4: SAMPLE OUTPUT ON WORKS DESCRIPTION FROM HDM -4 ANALYSIS

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Study Name: **DFR Strategy Analysis 1**
Run Date: **15-06-2007**

Section	Road Class	Length (km)	AADT	Surface Class	Year	Work Description	NPV/CAP	Financial Costs	Cumulative Costs
Feeder Bituminous High Traffic Fair Condition	Feeder	191.0	734	Bituminous	2007	Overlay	-0.024	34.756	34.756
Feeder Bituminous High Traffic Fair Condition	Feeder	191.0	734	Bituminous	2007	Overlay	-0.024	34.756	34.756
Feeder Bituminous High Traffic Good Condition	Feeder	408.8	891	Bituminous	2011	Overlay	-0.366	74.378	109.134
Feeder Bituminous High Traffic Good Condition	Feeder	408.8	891	Bituminous	2011	Overlay	-0.366	74.378	109.134
Feeder Bituminous High Traffic Poor Condition	Feeder	92.7	734	Bituminous	2007	Reconstruction AMGB	0.772	25.364	134.498
Feeder Bituminous High Traffic Poor Condition	Feeder	92.7	734	Bituminous	2007	Reconstruction AMGB	0.772	25.364	134.498
Feeder Bituminous Low Traffic Fair Condition	Feeder	47.8	440	Bituminous	2007	Overlay	-0.161	8.689	143.187
Feeder Bituminous Low Traffic Fair Condition	Feeder	47.8	440	Bituminous	2007	Overlay	-0.161	8.689	143.187
Feeder Bituminous Low Traffic Good Condition	Feeder	58.4	440	Bituminous	2007	Resealing	-0.578	3.905	147.092
Feeder Bituminous Low Traffic Good Condition	Feeder	58.4	440	Bituminous	2007	Resealing	-0.578	3.905	147.092
Feeder Bituminous Low Traffic Poor Condition	Feeder	37.1	440	Bituminous	2007	Reconstruction STGB	0.061	8.952	156.044
Feeder Bituminous Low Traffic Poor Condition	Feeder	37.1	440	Bituminous	2007	Reconstruction STGB	0.061	8.952	156.044
Feeder Bituminous Medium Traffic Fair Condition	Feeder	79.6	587	Bituminous	2007	Overlay	-0.203	14.482	173.004
Feeder Bituminous Medium Traffic Fair Condition	Feeder	79.6	587	Bituminous	2007	Overlay	-0.203	14.482	173.004
Feeder Bituminous Medium Traffic Good Condition	Feeder	116.8	587	Bituminous	2007	Resealing	-0.706	7.809	180.813
Feeder Bituminous Medium Traffic Good Condition	Feeder	116.8	1100	Bituminous	2020	Overlay	-0.706	21.251	202.064
Feeder Bituminous Medium Traffic Poor Condition	Feeder	55.6	587	Bituminous	2007	Reconstruction STGB	0.075	13.427	215.491
Feeder Bituminous Medium Traffic Poor Condition	Feeder	55.6	1048	Bituminous	2019	Overlay	0.075	10.115	225.607

APPENDIX 6. 5: SAMPLE OUTPUT FROM RUC ANALYSIS ON USER REVENUES

Vehicle Characteristics				Current Total Road User Revenues				Proposed User Revenues		
Vehicle Type	Number of Vehicles (veh)	Vehicle Utilization veh-km/yr (million)	Loading Impact ESA-km/yr (million)	Fuel Levy (M$/yr)	Standard License Fee (M$/yr)	Axle Loading License Fee (M$/Yr)	Total (M$/yr)	Fuel Levy (M$/yr)	Standard License Fee (M$/yr)	Total (M$/yr)
Cars, pickups (petrol)	175,000	4,566	46	8.45	0.64	0.00	9.09	22.83	0.64	23.47
Cars, pickups (diesel)	176,000	6,160	62	11.40	0.64	0.00	12.04	57.68	0.64	58.32
Motor cycle	14,462	163	2	0.24	0.00	0.00	0.24	0.65	0.00	0.65
Lorries & Buses (2-axle)	125,240	2,755	551	6.12	0.68	2.76	9.55	30.96	0.68	31.64
Heavy Trucks (3-axle)	60,300	1,206	4,076	4.02	0.44	20.38	24.83	20.33	0.44	20.76
Heavy Trucks (multi-axle)	44,200	796	8,179	4.12	0.32	40.89	45.33	20.86	0.32	21.18
Articulators	800	1	18	0.00	0.01	0.00	0.02	0.03	0.01	0.04
Government vehicles (petrol)	45,000	900	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Government vehicles (diesel)	42,000	840	504	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	683,002	17,387	13,464	34.34	2.74	64.03	101.11	153.32	2.74	156.06

APPENDIX 6.6: STANDADISATION OF NPV/CAP UNCONSTRAINED BUDGET –TRUNK ROADS

Section -Road Class	Financial Capital Costs	Financial Recurrent Costs	NPV	NPV/cap S_{ei}	$\frac{S_{ei} - \min S_{ei}}{\max S_{ei} - \min S_{ei}}$ $S_{ei} - \min S_{ei}$	$\max S_{ei} - \min S_{ei}$
Trunk Inter-regional Asphalt-Concrete High Traffic Good Condition	5.07	0.03	5.47	1.080252	1.080251569	11.491483
Trunk Inter-regional Asphalt-Concrete Low Traffic Good Condition	4.82	0.01	0.23	0.047973	0.047973091	11.491483
Trunk Inter-regional Gravel High Traffic Fair Condition	2.25	0.32	18.13	8.062946	8.062946241	11.491483
Trunk Inter-regional Gravel High Traffic Poor Condition	1.25	0.21	13.52	10.79697	10.79696979	11.491483
Trunk Inter-regional Gravel Low Traffic Fair Condition	0.00	0.37	0.76	0.76	0.75884231	11.491483
Trunk Inter-regional Gravel Low Traffic Good Condition	0.00	0.19	0.30	0.30	0.29629697	11.491483
Trunk Inter-regional Gravel Low Traffic Poor Condition	0.00	0.84	1.53	1.53	1.52582838	11.491483
Trunk Inter-regional Gravel Medium Traffic Fair Condition	1.76	0.61	12.78	7.27843	7.278430435	11.491483
Trunk Inter-regional Gravel Medium Traffic Poor Condition	2.06	0.80	19.58	9.521457	9.521456984	11.491483
Trunk Inter-regional Surface-Treatment High Traffic Fair Condition	8.83	0.00	69.30	7.847117	7.847116732	11.491483
Trunk Inter-regional Surface-Treatment High Traffic Good Condition	22.05	0.00	171.86	7.792287	7.792286576	11.491483
Trunk Inter-regional Surface-Treatment High Traffic Poor Condition	13.90	0.00	130.45	9.381851	9.381851401	11.491483
Trunk Inter-regional Surface-Treatment Low Traffic Fair Condition	3.62	0.01	0.33	0.092275	0.092275426	11.491483
Trunk Inter-regional Surface-Treatment Low Traffic Good Condition	0.00	0.02	0.00	0.00	0	11.491483
Trunk Inter-regional Surface-Treatment Low Traffic Poor Condition	0.00	0.02	0.00	0.00	0	11.491483
Trunk Inter-regional Surface-Treatment Medium Traffic Fair Condition	30.94	0.01	72.03	2.328128	2.328127669	11.491483
Trunk Inter-regional Surface-Treatment Medium Traffic Good Condition	19.24	0.01	64.30	3.341139	3.341138526	11.491483
Trunk National Asphalt-Concrete High Traffic Fair Condition	50.89	0.01	458.98	9.019502	9.01950197	11.491483
Trunk National Asphalt-Concrete High Traffic Good Condition	38.57	0.01	50.81	1.317417	1.317417053	11.491483
Trunk National Asphalt-Concrete High Traffic Poor Condition	19.47	0.00	182.21	9.357354	9.357353781	11.491483
Trunk National Asphalt-Concrete Low Traffic Good Condition	0.00	0.85	0.00	0.00	0	11.491483
Trunk National Asphalt-Concrete Medium Traffic Good Condition	22.83	0.01	23.48	1.028534	1.028534171	11.491483
Trunk National Gravel High Traffic Poor Condition	4.05	0.63	36.72	9.071341	9.071341238	11.491483
Trunk National Gravel Low Traffic Fair Condition	0.00	0.88	1.43	1.43	1.42829963	11.491483
Trunk National Gravel Low Traffic Poor Condition	0.00	1.14	1.42	1.42	1.41993325	11.491483
Trunk National Gravel Medium Traffic Fair Condition	1.50	0.39	6.79	4.529871	4.529870542	11.491483
Trunk National Gravel Medium Traffic Poor Condition	2.58	0.81	17.26	6.701452	6.701452008	11.491483
Trunk National Surface-Treatment High Traffic Fair Condition	39.17	0.01	270.13	6.89564	6.895640237	11.491483
Trunk National Surface-Treatment High Traffic Good Condition	12.93	0.02	89.43	6.915457	6.915457015	11.491483
Trunk National Surface-Treatment High Traffic Poor Condition	39.35	0.45	340.25	8.646798	8.646797603	11.491483
Trunk National Surface-Treatment Low Traffic Fair Condition	12.74	0.01	1.58	0.123945	0.123945361	11.491483
Trunk National Surface-Treatment Low Traffic Good Condition	0.00	0.08	0.00	0.00	0	11.491483
Trunk National Surface-Treatment Medium Traffic Fair Condition	11.37	0.01	17.01	1.495788	1.495788297	11.491483
Trunk National Surface-Treatment Medium Traffic Poor Condition	15.87	0.00	36.16	2.278933	2.278933378	11.491483
Trunk Regional Asphalt-Concrete High Traffic Good Condition	0.00	0.36	0.00	0.00	0	11.491483
Trunk Regional Gravel High Traffic Fair Condition	3.83	0.66	44.03	11.49148	11.49148279	11.491483
Trunk Regional Gravel High Traffic Good Condition	2.77	0.47	27.14	9.783096	9.783095531	11.491483
Trunk Regional Gravel High Traffic Poor Condition	5.49	0.84	52.41	9.555554	9.555553651	11.491483
Trunk Regional Gravel Low Traffic Fair Condition	0.00	1.08	2.59	2.59	2.59264025	11.491483

Trunk Regional Gravel Low Traffic Good Condition	0.00	0.21	0.44	0.44	0.44440791	11.491483
Trunk Regional Gravel Low Traffic Poor Condition	0.00	0.34	0.59	0.59	0.593176	11.491483
Trunk Regional Gravel Medium Traffic Fair Condition	2.61	1.01	23.82	9.136722	9.136722231	11.491483
Trunk Regional Gravel Medium Traffic Good Condition	1.79	0.51	11.63	6.502789	6.502789413	11.491483
Trunk Regional Gravel Medium Traffic Poor Condition	1.61	0.58	15.73	9.774881	9.774880881	11.491483
Trunk Regional Surface-Treatment High Traffic Fair Condition	17.06	0.00	93.88	5.503445	5.5034451	11.491483
Trunk Regional Surface-Treatment High Traffic Good Condition	29.58	0.01	191.07	6.460128	6.460127995	11.491483
Trunk Regional Surface-Treatment Low Traffic Fair Condition	4.93	0.01	1.33	0.269664	0.269663697	11.491483
Trunk Regional Surface-Treatment Low Traffic Good Condition	0.00	0.08	0.00	0.00	0	11.491483
Trunk Regional Surface-Treatment Low Traffic Poor Condition	0.00	0.03	0.00	0.00	0	11.491483
Trunk Regional Surface-Treatment Medium Traffic Fair Condition	45.75	0.01	99.43	2.173365	2.173365087	11.491483
Trunk Regional Surface-Treatment Medium Traffic Good Condition	35.60	0.01	46.49	1.306082	1.306081713	11.491483
Trunk Regional Surface-Treatment Medium Traffic Poor Condition	30.32	0.01	74.39	2.45306	2.453060025	11.491483
			2799.183	218.4225	218.4225499	597.55711
	10.93136	0.288486	53.83043	4.200434	4.200433652	11.491483
						0.3655258
	u_{ei}					0.3655258

APPENDIX 6.7: STANDADISATION OF NPV/CAP AT 50 PERCENT CONSTRAINED BUDGET –URBAN ROADS

	Financial Capital	Financial Recurrent		NPV/cap	$\frac{s_{ei}-\min s_{ei}}{\max s_{ei}-\min s_{ei}}$	
Section -Road Class	Costs	Costs	NPV	s_{ei}	$s_{ei}-\min s_{ei}$	$\max s_{ei}-\min s_{ei}$
Urban Asphalt-Concrete High Traffic Fair Condition	5.09	0.05	31.85	6.262064466	6.262064	9.81855474
Urban Asphalt-Concrete High Traffic Good Condition	24.79	0.12	129.58	5.227449521	5.22745	9.81855474
Urban Asphalt-Concrete High Traffic Poor Condition	2.17	0.01	12.61	5.801315915	5.801316	9.81855474
Urban Asphalt-Concrete Low Traffic Fair Condition	0.00	0.00	0.00	0.00	0	9.81855474
Urban Asphalt-Concrete Low Traffic Good Condition	0.00	0.01	0.00	0.00	0	9.81855474
Urban Asphalt-Concrete Low Traffic Poor Condition	0.07	0.00	0.01	0.203883415	0.203883	9.81855474
Urban Asphalt-Concrete Medium Traffic Fair Condition	0.09	0.00	0.06	0.667683066	0.667683	9.81855474
Urban Asphalt-Concrete Medium Traffic Good Condition	0.00	0.12	0.00	0.00	0	9.81855474
Urban Asphalt-Concrete Medium Traffic Poor Condition	0.00	0.01	0.00	0.00	0	9.81855474
Urban Gravel High Traffic Fair Condition	0.00	2.32	0.00	0.00	0	9.81855474
Urban Gravel High Traffic Good Condition	4.46	0.67	30.34	6.810268153	6.810268	9.81855474
Urban Gravel High Traffic Poor Condition	5.82	0.78	34.54	5.933791842	5.933792	9.81855474
Urban Gravel Low Traffic Fair Condition	0.00	0.08	0.00	0.00	0	9.81855474
Urban Gravel Low Traffic Good Condition	0.00	0.05	0.00	0.00	0	9.81855474
Urban Gravel Low Traffic Poor Condition	0.00	0.17	0.00	0.00	0	9.81855474
Urban Gravel Medium Traffic Fair Condition	1.69	0.79	6.51	3.844234463	3.844234	9.81855474
Urban Gravel Medium Traffic Good Condition	1.66	0.66	6.68	4.024428911	4.024429	9.81855474
Urban Gravel Medium Traffic Poor Condition	1.44	0.57	6.35	4.416239196	4.416239	9.81855474
Urban Surface-Treatment High Traffic Fair Condition	23.12	0.44	208.30	9.010606086	9.010606	9.81855474
Urban Surface-Treatment High Traffic Good Condition	41.48	0.49	407.32	9.818554744	9.818555	9.81855474
Urban Surface-Treatment High Traffic Poor Condition	352.97	3.57	2,785.13	7.890621956	7.890622	9.81855474
Urban Surface-Treatment Low Traffic Fair Condition	0.00	0.00	0.00	0.00	0	9.81855474
Urban Surface-Treatment Low Traffic Good Condition	0.00	0.01	0.00	0.00	0	9.81855474
Urban Surface-Treatment Medium Traffic Fair Condition	0.00	0.06	0.00	0.00	0	9.81855474
Urban Surface-Treatment Medium Traffic Good Condition	0.00	0.13	0.00	0.00	0	9.81855474
Urban Surface-Treatment Medium Traffic Poor Condition	0.00	0.05	0.00	0.00	0	9.81855474
			sum	69.91114173	69.91114	255.282423
			average	2.688890067	2.68889	9.81855474
						0.27385803
		u_{ei}				0.27385803

APPENDIX 6.8: STANDADISATION OF NPV/CAP AT 90 PERCENT CONSTRAINED BUDGET –FEEDER ROADS

Section -Road Class	Financial Capital Costs	Financial Recurrent Costs	NPV	NPV/cap s_{ei}	$\frac{s_{ei} - \min s_{ei}}{\max s_{ei} - \min s_{ei}}$ $s_{ei} - \min s_{ei}$	$\max s_{ei} - \min s_{ei}$
Feeder Bituminous High Traffic Fair Condition	23.65	0.01	6.68	0.282544418	0.282544418	2.373075887
Feeder Bituminous High Traffic Good Condition	12.36	0.01	6.82	0.55184924	0.55184924	2.373075887
Feeder Bituminous High Traffic Poor Condition	11.47	0.00	5.91	0.515068746	0.515068746	2.373075887
Feeder Bituminous Low Traffic Fair Condition	0.00	0.00	0.00	0.00	0	2.373075887
Feeder Bituminous Low Traffic Good Condition	0.00	0.00	0.00	0.00	0	2.373075887
Feeder Bituminous Low Traffic Poor Condition	0.00	0.01	0.00	0.00	0	2.373075887
Feeder Bituminous Medium Traffic Fair Condition	0.00	0.02	0.00	0.00	0	2.373075887
Feeder Bituminous Medium Traffic Good Condition	3.53	0.00	0.85	0.240108041	0.240108041	2.373075887
Feeder Bituminous Medium Traffic Poor Condition	0.00	0.02	0.00	0.00	0	2.373075887
Feeder Earth High Traffic Fair Condition	0.00	0.02	0.00	0.00	0	2.373075887
Feeder Earth High Traffic Good Condition	0.00	0.01	0.00	0.00	0	2.373075887
Feeder Earth High Traffic Poor Condition	0.00	0.10	0.00	0.00	0	2.373075887
Feeder Earth Low Traffic Fair Condition	0.00	0.26	1.90	1.90	1.897126	2.373075887
Feeder Earth Low Traffic Good Condition	0.00	0.06	0.44	0.44	0.43947869	2.373075887
Feeder Earth Low Traffic Poor Condition	0.00	0.53	3.95	3.95	3.94780775	2.373075887
Feeder Earth Medium Traffic Fair Condition	0.00	0.20	0.00	0.00	0	2.373075887
Feeder Earth Medium Traffic Good Condition	0.00	0.03	0.00	0.00	0	2.373075887
Feeder Earth Medium Traffic Poor Condition	0.00	0.40	0.00	0.00	0	2.373075887
Feeder Gravel High Traffic Fair Condition	13.32	5.26	31.61	2.373075786	2.373075786	2.373075887
Feeder Gravel High Traffic Good Condition	24.95	9.86	59.22	2.373075461	2.373075461	2.373075887
Feeder Gravel High Traffic Poor Condition	2.53	1.00	6.00	2.373075887	2.373075887	2.373075887
Feeder Gravel Low Traffic Fair Condition	0.00	0.72	0.00	0.00	0	2.373075887
Feeder Gravel Low Traffic Good Condition	0.00	1.87	0.00	0.00	0	2.373075887
Feeder Gravel Low Traffic Poor Condition	0.00	0.36	0.00	0.00	0	2.373075887
Feeder Gravel Medium Traffic Fair Condition	9.26	3.78	8.21	0.886193672	0.886193672	2.373075887
Feeder Gravel Medium Traffic Good Condition	13.88	5.67	12.29	0.885393113	0.885393113	2.373075887
Feeder Gravel Medium Traffic Poor Condition	1.76	0.72	1.56	0.887034504	0.887034504	2.373075887
		sum		17.65183131	17.65183131	64.07304896
					0.65377153	2.373075887
						0.275495417
				u_{ei}		0.275495417

APPENDIX 6.9: STANDADISATION OF AFFORDABILITY FACTOR AT 10 PERCENT CONSTRAINED BUDGET –TRUNK ROADS

Section Road Class	VOC	VOC/annum	VOC/km	Income	Proportion used for Transport	Amount spent on Transport	Equivalent Distance Travelled / annum	Income/km	Income-VOC/km S_{mj}	Interval Scale Properties $\frac{S_{mj}-\min S_{mj}}{\max S_{mj}-\min S_{mj}}$	$S_{mj}-\min S_{mj}$ $\max S_{mj}-\min S_{mj}$
Trunk Inter-regional Asphalt-Concrete High Traffic Good Condition	251.395	12.56975	0.1421917	114	0.11	12.54	88.1908	1.292652	1.15	1.051965342	2.886272366
Trunk Inter-regional Asphalt-Concrete Low Traffic Good Condition	55.995	2.79975	0.0248867	114	0.11	12.54	503.884	0.226242	0.201	0.102860641	2.886272366
Trunk Inter-regional Gravel High Traffic Fair Condition	534.944	26.7472	0.3022282	114	0.11	12.54	41.4918	2.74753	2.445	2.346806168	2.886272366
Trunk Inter-regional Gravel High Traffic Poor Condition	460.392	23.0196	0.3689038	114	0.11	12.54	33.9926	3.353671	2.985	2.886272366	2.886272366
Trunk Inter-regional Gravel Low Traffic Fair Condition	92.485	4.62425	0.0213394	114	0.11	12.54	587.645	0.193995	0.173	0.074160104	2.886272366
Trunk Inter-regional Gravel Low Traffic Good Condition	41.022	2.0511	0.0213434	114	0.11	12.54	587.535	0.194031	0.173	0.07419233	2.886272366
Trunk Inter-regional Gravel Low Traffic Poor Condition	226.702	11.3351	0.0218319	114	0.11	12.54	574.39	0.198471	0.177	0.078144451	2.886272366
Trunk Inter-regional Gravel Medium Traffic Fair Condition	134.371	6.71855	0.0423082	114	0.11	12.54	296.396	0.38462	0.342	0.243817083	2.886272366
Trunk Inter-regional Gravel Medium Traffic Poor Condition	199.82	9.991	0.0423707	114	0.11	12.54	295.96	0.385188	0.343	0.244321986	2.886272366
Trunk Inter-regional Surface-Treatment High Traffic Fair Condition	309.699	15.48495	0.3000959	114	0.11	12.54	41.7866	2.728145	2.428	2.329553774	2.886272366
Trunk Inter-regional Surface-Treatment High Traffic Good Condition	721.93	36.0965	0.25546	114	0.11	12.54	49.0879	2.322364	2.067	1.968408634	2.886272366
Trunk Inter-regional Surface-Treatment High Traffic Poor Condition	551.324	27.5662	0.3073155	114	0.11	12.54	40.805	2.793777	2.486	2.387966625	2.886272366
Trunk Inter-regional Surface-Treatment Low Traffic Fair Condition	27.567	1.37835	0.0155395	114	0.11	12.54	806.978	0.141268	0.126	0.027233232	2.886272366
Trunk Inter-regional Surface-Treatment Low Traffic Good Condition	33.731	1.68655	0.0184524	114	0.11	12.54	679.586	0.167749	0.149	0.050801631	2.886272366
Trunk Inter-regional Surface-Treatment Low Traffic Poor Condition	29.992	1.4996	0.017684	114	0.11	12.54	709.117	0.160763	0.143	0.044584215	2.886272366
Trunk Inter-regional Surface-Treatment Medium Traffic Fair Condition	380.212	19.0106	0.094958	114	0.11	12.54	132.058	0.863255	0.768	0.669801768	2.886272366
Trunk Inter-regional Surface-Treatment Medium Traffic Good Condition	480.055	24.00275	0.1086589	114	0.11	12.54	115.407	0.987808	0.879	0.780654128	2.886272366

Trunk National Asphalt-Concrete High Traffic Fair Condition	1818.969	90.94845	0.2928154	114	0.11	12.54	42.8256	2.661958	2.369	2.27064732	2.886272366
Trunk National Asphalt-Concrete High Traffic Good Condition	2011.734	100.5867	0.2201504	114	0.11	12.54	56.9611	2.001367	1.781	1.682721442	2.886272366
Trunk National Asphalt-Concrete High Traffic Poor Condition	766.707	38.33535	0.32296	114	0.11	12.54	38.8283	2.936	2.613	2.514544747	2.886272366
Trunk National Asphalt-Concrete Low Traffic Good Condition	58.576	2.9288	0.0221208	114	0.11	12.54	566.886	0.201099	0.179	0.080482637	2.886272366
Trunk National Asphalt-Concrete Medium Traffic Good Condition	495.051	24.75255	0.097145	114	0.11	12.54	129.085	0.883137	0.786	0.687496374	2.886272366
Trunk National Gravel High Traffic Poor Condition	1039.174	51.9587	0.2891413	114	0.11	12.54	43.3698	2.628558	2.339	2.240921234	2.886272366
Trunk National Gravel Low Traffic Fair Condition	194.651	9.73255	0.0219004	114	0.11	12.54	572.592	0.199095	0.177	0.078699252	2.886272366
Trunk National Gravel Low Traffic Poor Condition	261.396	13.0698	0.0215816	114	0.11	12.54	581.051	0.196196	0.175	0.076119421	2.886272366
Trunk National Gravel Medium Traffic Fair Condition	77.691	3.88455	0.041369	114	0.11	12.54	303.125	0.376082	0.335	0.236217779	2.886272366
Trunk National Gravel Medium Traffic Poor Condition	187.575	9.37875	0.0411891	114	0.11	12.54	304.45	0.374446	0.333	0.23476186	2.886272366
Trunk National Surface-Treatment High Traffic Fair Condition	1210.548	60.5274	0.2441605	114	0.11	12.54	51.3596	2.219641	1.975	1.876985686	2.886272366
Trunk National Surface-Treatment High Traffic Good Condition	365.795	18.28975	0.2161909	114	0.11	12.54	58.0043	1.965372	1.749	1.650685788	2.886272366
Trunk National Surface-Treatment High Traffic Poor Condition	1574.82	78.741	0.2830374	114	0.11	12.54	44.3051	2.573067	2.29	2.19153462	2.886272366
Trunk National Surface-Treatment Low Traffic Fair Condition	61.863	3.09315	0.0211281	114	0.11	12.54	593.523	0.192073	0.171	0.072450208	2.886272366
Trunk National Surface-Treatment Low Traffic Good Condition	70.704	3.5352	0.0121736	114	0.11	12.54	1030.1	0.110669	0.098	0	2.886272366
Trunk National Surface-Treatment Medium Traffic Fair Condition	190.102	9.5051	0.0726134	114	0.11	12.54	172.695	0.660122	0.588	0.489013669	2.886272366
Trunk National Surface-Treatment Medium Traffic Poor Condition	233.175	11.65875	0.0954853	114	0.11	12.54	131.329	0.868048	0.773	0.674067425	2.886272366
Trunk Regional Asphalt-Concrete High Traffic Good Condition	128.461	6.42305	0.1779238	114	0.11	12.54	70.4796	1.617489	1.44	1.341070358	2.886272366
Trunk Regional Gravel High Traffic Fair Condition	1418.063	70.90315	0.3467147	114	0.11	12.54	36.1681	3.151952	2.805	2.706741758	2.886272366
Trunk Regional Gravel High Traffic Good Condition	887.579	44.37895	0.3516557	114	0.11	12.54	35.6599	3.19687	2.845	2.746719226	2.886272366
Trunk Regional Gravel High Traffic Poor Condition	1753.612	87.6806	0.3397156	114	0.11	12.54	36.9132	3.088324	2.749	2.650113034	2.886272366
Trunk Regional Gravel Low Traffic Fair Condition	236.047	11.80235	0.0219375	114	0.11	12.54	571.625	0.199431	0.177	0.078998826	2.886272366
Trunk Regional Gravel Low Traffic Good Condition	52.195	2.60975	0.0214441	114	0.11	12.54	584.776	0.194947	0.174	0.075007349	2.886272366
Trunk Regional Gravel Low Traffic Poor Condition	87.405	4.37025	0.0218513	114	0.11	12.54	573.88	0.198648	0.177	0.078301361	2.886272366
Trunk Regional Gravel Medium Traffic Fair Condition	248.236	12.4118	0.0415945	114	0.11	12.54	301.482	0.378132	0.337	0.238042234	2.886272366
Trunk Regional Gravel Medium Traffic Good	127.01	6.3506	0.0409	114	0.11	12.54	306.263	0.372229	0.331	0.232788747	2.886272366

Condition	2		452								
Trunk Regional Gravel Medium Traffic Poor Condition	164.806	8.2403	0.0412015	114	0.11	12.54	304.358	0.374559	0.333	0.234862474	2.886272366
Trunk Regional Surface-Treatment High Traffic Fair Condition	373.301	18.66505	0.1698367	114	0.11	12.54	73.8356	1.54397	1.374	1.275637938	2.886272366
Trunk Regional Surface-Treatment High Traffic Good Condition	789.974	39.4987	0.213622	114	0.11	12.54	58.7018	1.942018	1.728	1.629900724	2.886272366
Trunk Regional Surface-Treatment Low Traffic Fair Condition	44.102	2.2051	0.0173493	114	0.11	12.54	722.794	0.157721	0.14	0.041876745	2.886272366
Trunk Regional Surface-Treatment Low Traffic Good Condition	88.837	4.44185	0.0153009	114	0.11	12.54	819.56	0.139099	0.124	0.025303039	2.886272366
Trunk Regional Surface-Treatment Low Traffic Poor Condition	39.461	1.97305	0.0129891	114	0.11	12.54	965.422	0.118083	0.105	0.006598815	2.886272366
Trunk Regional Surface-Treatment Medium Traffic Fair Condition	559.525	27.97625	0.0763961	114	0.11	12.54	164.145	0.69451	0.618	0.519618743	2.886272366
Trunk Regional Surface-Treatment Medium Traffic Good Condition	557.869	27.89345	0.0669711	114	0.11	12.54	187.245	0.608828	0.542	0.44336171	2.886272366
Trunk Regional Surface-Treatment Medium Traffic Poor Condition	448.355	22.41775	0.088924	114	0.11	12.54	141.019	0.8084	0.719	0.620981192	2.886272366
All Sections											
	23155.01	1157.7504	6.4871034				16259.1	58.97367	52.49	47.36481822	150.086163
	445.2886	22.26443	0.124752				312.676	1.134109	1.009	0.910861889	2.886272366
											0.315584177
								u_{mj}			0.315584177

APPENDIX 6.10: STANDADISATION OF AFFORDABILITY FACTOR AT 10 PERCENT CONSTRAINED BUDGET –URBAN ROADS

Section	VOC	VOC/annum	VOC/km	Income	Proportion used for Transport	Amount spent on Transport	Equivalent Distance Travelled / annum	Income/km	Income-VOC/km	Interval Scale Properties $\frac{S_{mj}-\min S_{mj}}{\max S_{mj}-\min S_{mj}}$	
Road Class									S_{mj}	$S_{mj}-\min S_{mj}$	$\max S_{mj}-\min S_{mj}$
Urban Asphalt-Concrete High Traffic Fair Condition	277.277	13.86385	0.224334	180	0.07	12.6	56.1662	3.204773	2.98043932	2.940793464	4.523099784
Urban Asphalt-Concrete High Traffic Good Condition	923.557	46.17785	0.153313	180	0.07	12.6	82.1849	2.190185	2.03687159	1.997225729	4.523099784
Urban Asphalt-Concrete High Traffic Poor Condition	68.423	3.42115	0.232731	180	0.07	12.6	54.1397	3.324733	3.09200146	3.052355602	4.523099784
Urban Asphalt-Concrete Low Traffic Fair Condition	0.549	0.02745	0.019607	180	0.07	12.6	642.623	0.280102	0.2604949	0.220849042	4.523099784
Urban Asphalt-Concrete Low Traffic Good Condition	1.161	0.05805	0.01935	180	0.07	12.6	651.163	0.276429	0.25707857	0.217432715	4.523099784
Urban Asphalt-Concrete Low Traffic Poor Condition	0.277	0.01385	0.023083	180	0.07	12.6	545.848	0.329762	0.30667857	0.267032715	4.523099784
Urban Asphalt-Concrete Medium Traffic Fair Condition	1.102	0.0551	0.050091	180	0.07	12.6	251.543	0.715584	0.66549351	0.62584765	4.523099784
Urban Asphalt-Concrete Medium Traffic Good Condition	47.002	2.3501	0.078337	180	0.07	12.6	160.844	1.119095	1.04075857	1.001112715	4.523099784
Urban Asphalt-Concrete Medium Traffic Poor Condition	7.393	0.36965	0.116242	180	0.07	12.6	108.394	1.660602	1.54435984	1.504713982	4.523099784
Urban Gravel High Traffic Fair Condition	1420.997	71.04985	0.186875	180	0.07	12.6	67.4248	2.669642	2.48276698	2.443121127	4.523099784
Urban Gravel High Traffic Good Condition	852.054	42.6027	0.231915	180	0.07	12.6	54.3304	3.313065	3.08115024	3.041504389	4.523099784
Urban Gravel High Traffic Poor Condition	1134.701	56.73505	0.236396	180	0.07	12.6	53.3004	3.377086	3.14069027	3.101044412	4.523099784
Urban Gravel Low Traffic Fair Condition	6.92	0.346	0.003043	180	0.07	12.6	4140.52	0.043473	0.0404297	0.000783846	4.523099784
Urban Gravel Low Traffic Good Condition	4.691	0.23455	0.002984	180	0.07	12.6	4222.38	0.04263	0.03964586	0	4.523099784
Urban Gravel Low Traffic Poor Condition	16.017	0.80085	0.003181	180	0.07	12.6	3961.64	0.045436	0.04225522	0.002609364	4.523099784
Urban Gravel Medium Traffic Fair Condition	80.403	4.02015	0.014704	180	0.07	12.6	856.893	0.210061	0.19535686	0.155710999	4.523099784
Urban Gravel Medium Traffic Good Condition	78.652	3.9326	0.016517	180	0.07	12.6	762.869	0.235951	0.21943469	0.179788835	4.523099784
Urban Gravel Medium Traffic Poor Condition	72.738	3.6369	0.017536	180	0.07	12.6	718.535	0.25051	0.23297403	0.193328176	4.523099784

Urban Surface-Treatment High Traffic Fair Condition	1344.977	67.24885	0.239405	180	0.07	12.6	52.6305	3.420071	3.18066574	3.141019887	4.523099784
Urban Surface-Treatment High Traffic Good Condition	1851.101	92.55505	0.343432	180	0.07	12.6	36.6884	4.906178	4.56274564	4.523099784	4.523099784
Urban Surface-Treatment High Traffic Poor Condition	22627.78	1131.3892	0.263789	180	0.07	12.6	47.7655	3.768408	3.50461964	3.464973789	4.523099784
Urban Surface-Treatment Low Traffic Fair Condition	1.678	0.0839	0.018854	180	0.07	12.6	668.296	0.269342	0.25048796	0.210842105	4.523099784
Urban Surface-Treatment Low Traffic Good Condition	14.001	0.70005	0.01852	180	0.07	12.6	680.351	0.264569	0.24604932	0.206403464	4.523099784
Urban Surface-Treatment Medium Traffic Fair Condition	52.955	2.64775	0.079632	180	0.07	12.6	158.229	1.137594	1.05796241	1.01831655	4.523099784
Urban Surface-Treatment Medium Traffic Good Condition	129.442	6.4721	0.094345	180	0.07	12.6	133.552	1.347793	1.25344711	1.213801249	4.523099784
Urban Surface-Treatment Medium Traffic Poor Condition	14.207	0.71035	0.079815	180	0.07	12.6	157.866	1.140209	1.06039406	1.020748205	4.523099784
All Sections	31030.06	1551.50295	2.76803				19326.2	39.54328	36.7752521	35.7444598	117.6005944
	1193.464	59.6731904	0.106463				743.315	1.520895	1.41443277	1.374786915	4.523099784
											0.303947952
						u_{mj}					0.303947952

APPENDIX 6.11: STANDADISATION OF AFFORDABILITY FACTOR AT 20 PERCENT CONSTRAINED BUDGET –FEEDER ROADS

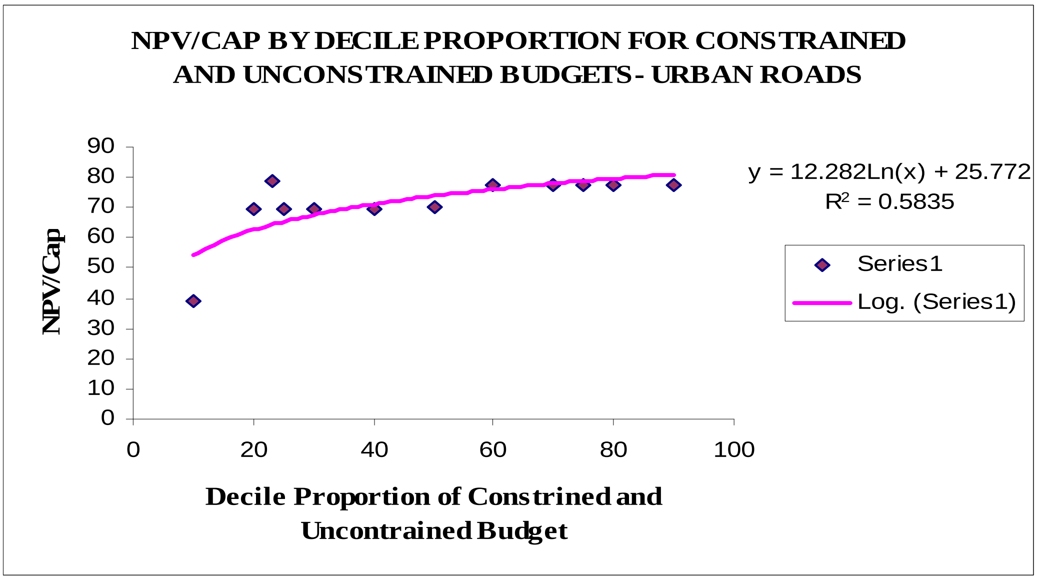
Section Road Class	VOC	VOC/annum	VOC/km	Income	Proportion used for Transport	Amount spent on Transport	Equivalent Distance Travelled / annum	Income/km	Income-VOC/km S_{mj}	Interval Scale Properties $\frac{S_{mj}-\min S_{mj}}{\max S_{mj}-\min S_{mj}}$ $S_{mj} - \min S_{mj}$	$\max S_{mj} - \min S_{mj}$
Feeder Bituminous High Traffic Fair Condition	127.539	6.37695	0.033380182	102	0.2	20.4	611.14106	0.166901	0.13352073	0.127306336	0.150973478
Feeder Bituminous High Traffic Good Condition	228.378	11.4189	0.02793068	102	0.2	20.4	730.37963	0.139653	0.11172272	0.105508328	0.150973478
Feeder Bituminous High Traffic Poor Condition	72.833	3.64165	0.039296968	102	0.2	20.4	519.12402	0.196485	0.15718787	0.150973478	0.150973478
Feeder Bituminous Low Traffic Fair Condition	2.857	0.14285	0.002990997	102	0.2	20.4	6820.469	0.014955	0.01196399	0.005749594	0.150973478
Feeder Bituminous Low Traffic Good Condition	3.319	0.16595	0.002841123	102	0.2	20.4	7180.2591	0.014206	0.01136449	0.0051501	0.150973478
Feeder Bituminous Low Traffic Poor Condition	2.871	0.14355	0.003872404	102	0.2	20.4	5268.046	0.019362	0.01548961	0.009275221	0.150973478
Feeder Bituminous Medium Traffic Fair Condition	42.866	2.1433	0.026925879	102	0.2	20.4	757.63542	0.134629	0.10770352	0.101489125	0.150973478
Feeder Bituminous Medium Traffic Good Condition	51.756	2.5878	0.022153925	102	0.2	20.4	920.83005	0.11077	0.0886157	0.082401308	0.150973478
Feeder Bituminous Medium Traffic Poor Condition	34.884	1.7442	0.031370504	102	0.2	20.4	650.2924	0.156853	0.12548201	0.119267622	0.150973478
Feeder Earth High Traffic Fair Condition	10.631	0.53155	0.021093254	102	0.2	20.4	967.13385	0.105466	0.08437302	0.078158623	0.150973478
Feeder Earth High Traffic Good Condition	5.513	0.27565	0.020663418	102	0.2	20.4	987.25195	0.103317	0.08265367	0.07643928	0.150973478
Feeder Earth High Traffic Poor Condition	61.16	3.058	0.021565585	102	0.2	20.4	945.9516	0.107828	0.08626234	0.080047949	0.150973478
Feeder Earth Low Traffic Fair Condition	11.378	0.5689	0.00166779	102	0.2	20.4	12231.753	0.008339	0.00667116	0.000456769	0.150973478
Feeder Earth Low Traffic Good Condition	2.487	0.12435	0.001553598	102	0.2	20.4	13130.808	0.007768	0.00621439	0	0.150973478
Feeder Earth Low Traffic Poor Condition	23.798	1.1899	0.001678516	102	0.2	20.4	12153.593	0.008393	0.00671406	0.000499671	0.150973478
Feeder Earth Medium Traffic Fair Condition	18.377	0.91885	0.003292307	102	0.2	20.4	6196.2627	0.016462	0.01316923	0.006954836	0.150973478
Feeder Earth Medium Traffic Good Condition	2.576	0.1288	0.003218391	102	0.2	20.4	6338.5714	0.016092	0.01287356	0.00665917	0.150973478
Feeder Earth Medium Traffic Poor	38.442	1.9221	0.003389	102	0.2	20.4	6018.8544	0.016947	0.0135574	0.007343004	0.150973478

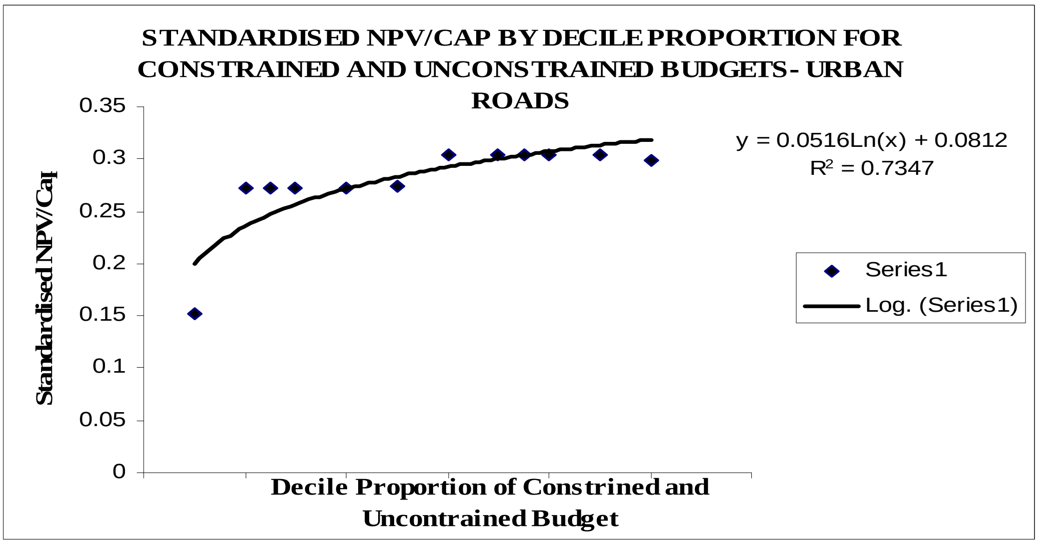
Condition			349								
Feeder Gravel High Traffic Fair Condition	1119.457	55.97285	0.02638362	102	0.2	20.4	773.20701	0.131918	0.10553448	0.099320088	0.150973478
Feeder Gravel High Traffic Good Condition	2083.636	104.1818	0.026215853	102	0.2	20.4	778.15511	0.131079	0.10486341	0.098649019	0.150973478
Feeder Gravel High Traffic Poor Condition	214.026	10.7013	0.026573876	102	0.2	20.4	767.67122	0.132869	0.10629551	0.100081113	0.150973478
Feeder Gravel Low Traffic Fair Condition	41.494	2.0747	0.001953578	102	0.2	20.4	10442.377	0.009768	0.00781431	0.00159992	0.150973478
Feeder Gravel Low Traffic Good Condition	104.328	5.2164	0.001875054	102	0.2	20.4	10879.687	0.009375	0.00750022	0.001285823	0.150973478
Feeder Gravel Low Traffic Poor Condition	20.951	1.04755	0.001950963	102	0.2	20.4	10456.375	0.009755	0.00780385	0.001589459	0.150973478
Feeder Gravel Medium Traffic Fair Condition	328.734	16.4367	0.007747679	102	0.2	20.4	2633.0468	0.038738	0.03099071	0.024776321	0.150973478
Feeder Gravel Medium Traffic Good Condition	486.638	24.3319	0.007653948	102	0.2	20.4	2665.2912	0.03827	0.03061579	0.024401398	0.150973478
Feeder Gravel Medium Traffic Poor Condition	63.213	3.16065	0.007848647	102	0.2	20.4	2599.1742	0.039243	0.03139459	0.025180194	0.150973478
All Sections	Sum								1.50835235	1.340563748	4.07628391
	Average		0.013966225				4608.2719	0.069831	0.0558649	0.049650509	0.150973478
											0.328869
							u_{mj}				0.328869

APPENDIX 6:12 SUMMARY OF UTILITY INDICIES FOR URBAN ROADS

SUMMARY OF UTILITY INDICES FOR NPV/CAP URBAN ROADS

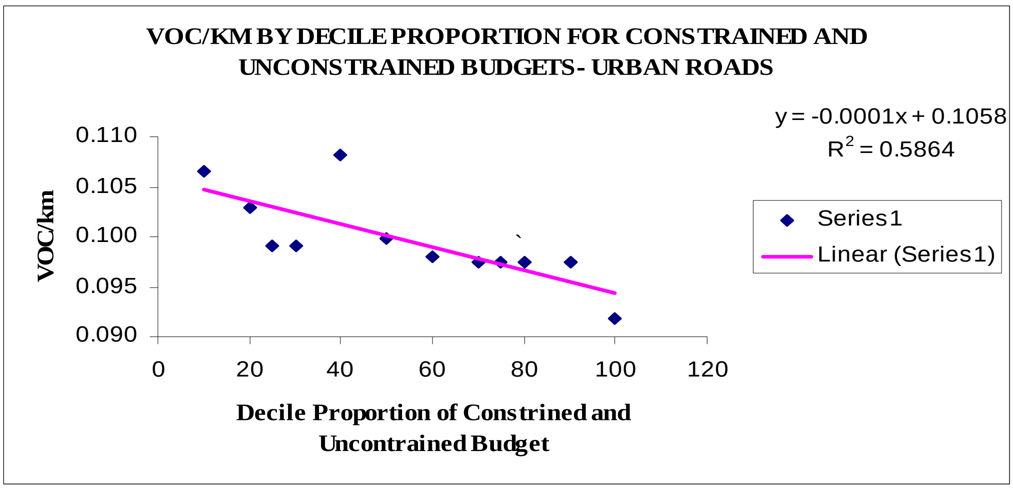
Item	Proportion of Constrained Budget in Percentage	Total NPV/Cap	Summary of Utility Indices for NPV/cap
1	10	38.74	0.15176852
2	20	69.5	0.27226027
3	25	69.5	0.27226027
4	30	69.5	0.27226027
5	40	69.5	0.27226027
6	50	69.91	0.27385803
7	60	77.39	0.30316965
8	70	77.39	0.30316965
9	75	77.39	0.30316965
10	80	77.39	0.30316965
11	90	77.39	0.30316965
12	100	78.5	0.29943474

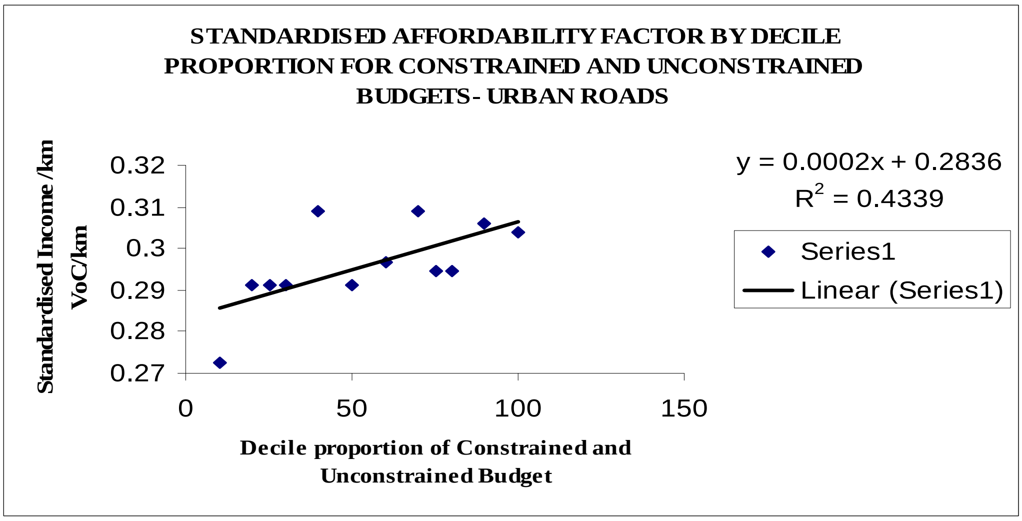




SUMMARY OF UTILITY INDICES FOR ADJUSTED VOC/KM –URBAN ROADS

Item	Proportion of Constrained Budget in Percentage	Income /Capita-VOC/km	Summary of Utility Indices for Income Capita-VOC/km
10	0.106	179.8935	0.303948
20	0.103	179.8971	0.305841
25	0.099	179.9008	0.294719
30	0.099	179.9008	0.294719
40	0.108	179.8919	0.308777
50	0.100	179.9002	0.296613
60	0.098	179.9021	0.291068
70	0.097	179.9021	0.291068
75	0.097	179.9021	0.291068
80	0.097	179.9021	0.291068
90	0.097	179.9021	0.291068
100	0.092	179.9082	0.27268

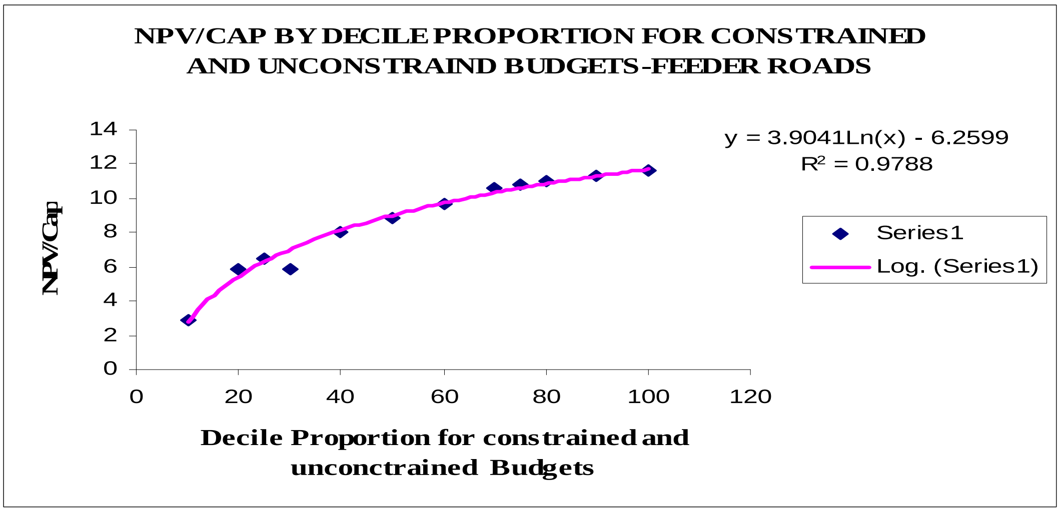


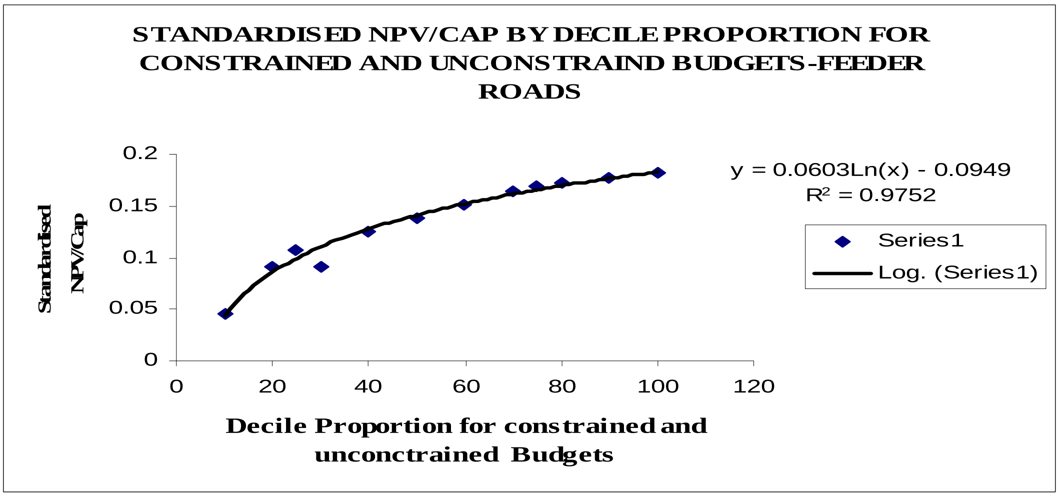

STANDARDISED AFFORDABILITY FACTOR BY DECILE PROPORTION FOR CONSTRAINED AND UNCONSTRAINED BUDGETS - URBAN ROADS
Standardised Income /km VoC/km
0.32
0.31
0.3
0.29
0.28
0.27
0
50
100
150
Decile proportion of Constrained and Unconstrained Budget
y = 0.0002x + 0.2836
R2 = 0.4339
Series1
Linear (Series1)

APPENDIX 6:13: SUMMARY OF UTILITY INDICIES FOR FEEDER ROADS

SUMMARY OF UTILITY INDICES FOR NPV/CAP-FEEDER ROADS

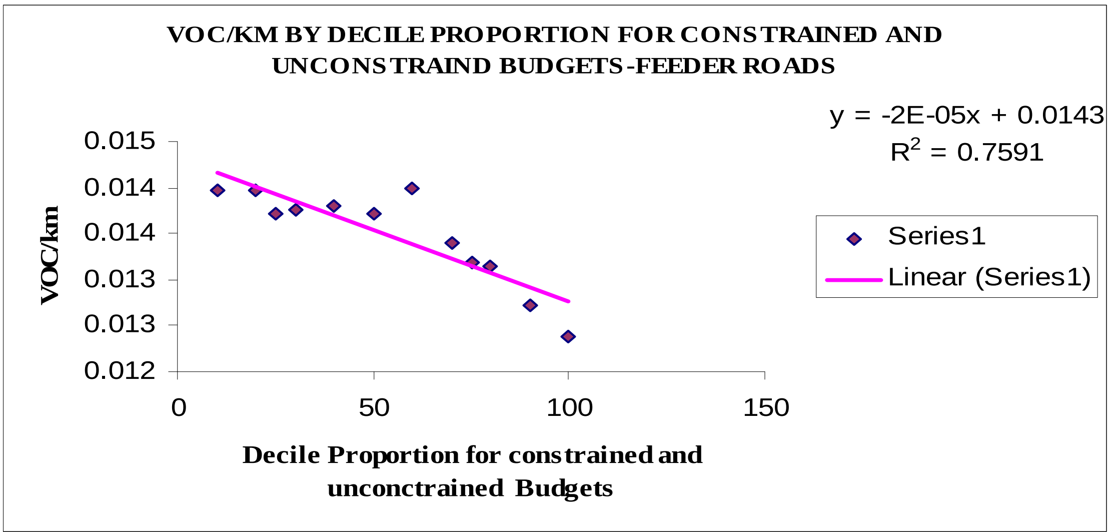
Item	Proportion of Constrained Budget in Percentage	Total NPV/Cap	Summary of Utility Indices for NPV/cap
1	10	2.92	0.0456
2	20	5.87	0.091665
3	25	6.52	0.1074917
4	30	5.87	0.09166559
5	40	8	0.12495522
6	50	8.89	0.13878621
7	60	9.65	0.1506776
8	70	10.56	0.16496492
9	75	10.84	0.16925629
10	80	11.05	0.17253486
11	90	11.37	0.17741342
12	100	11.63	0.18154677

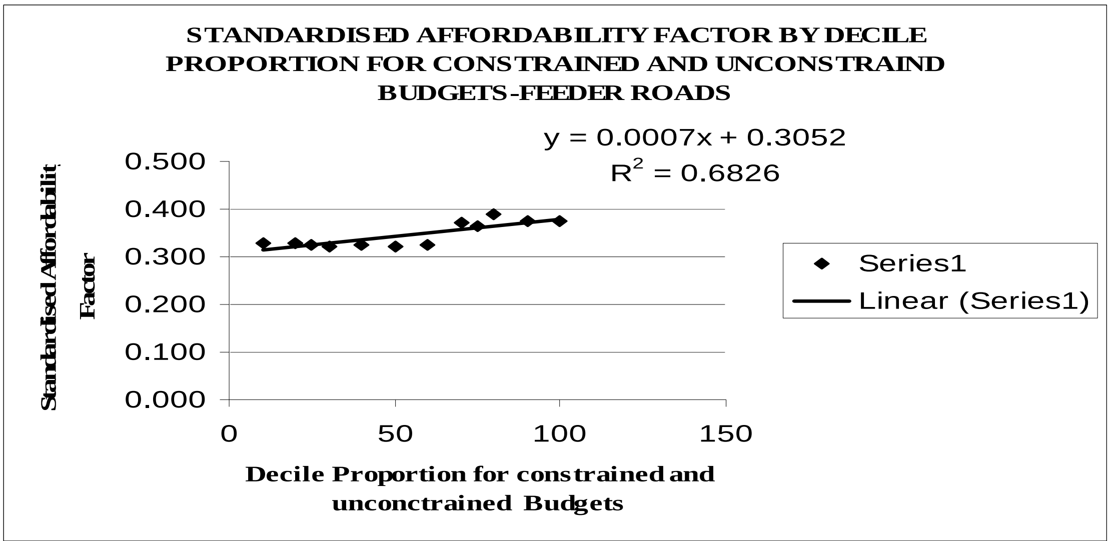




SUMMARY OF UTILITY INDICES FOR AFFORDABILITY FACTOR-FEEDER ROADS

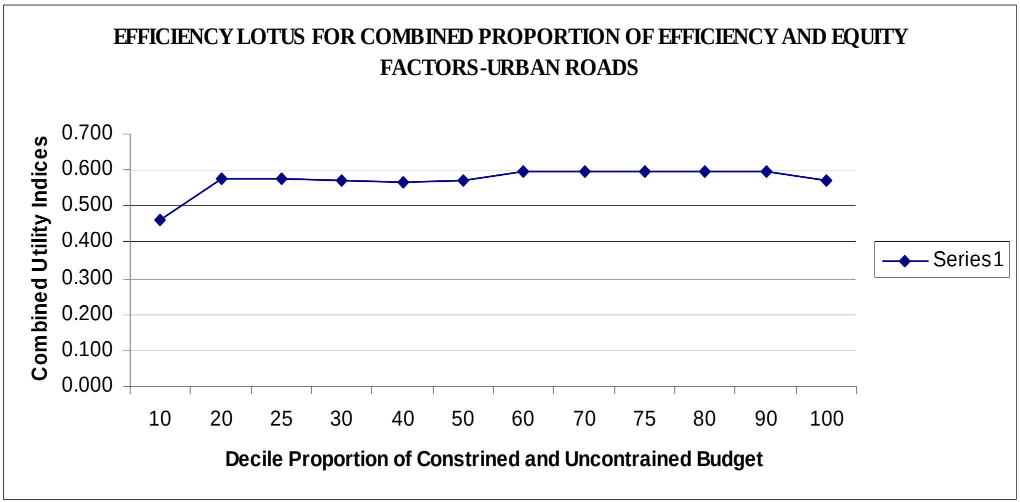
Item	Proportion of Constrained Budget in Percentage	Income /km-VOC/km	Summary of Utility Indices for Income Capita-VOC/km
10	0.014	0.056	0.329
20	0.014	0.056	0.329
25	0.014	0.055	0.324
30	0.014	0.055	0.321
40	0.014	0.055	0.324
50	0.014	0.057	0.321
60	0.014	0.055	0.324
70	0.013	0.054	0.372
75	0.013	0.053	0.366
80	0.013	0.053	0.389
90	0.013	0.051	0.376
100	0.012	0.051	0.375





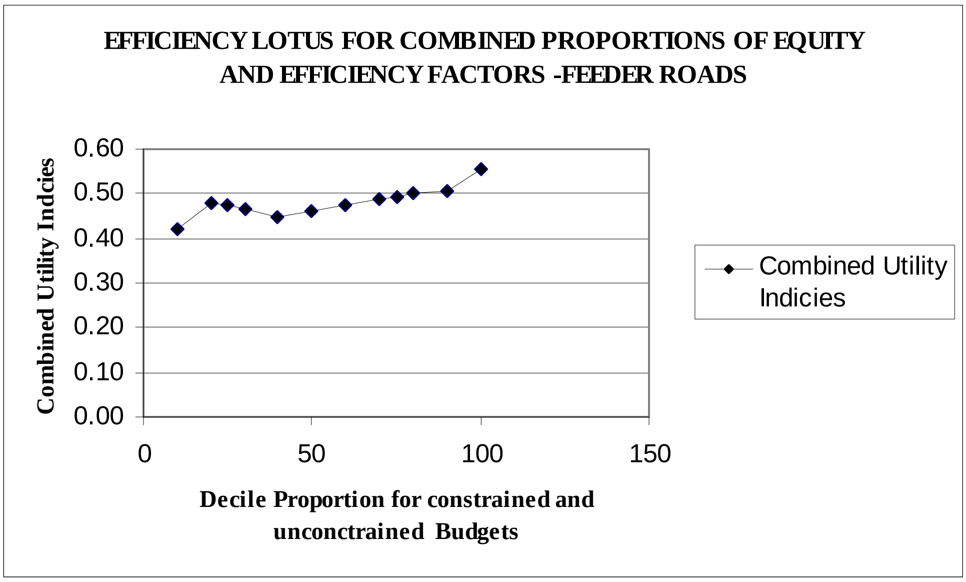
APPENDIX 6.14: SUMMARY OF COMBINED UTILITY INDICES FOR URBAN ROADS

Proportion of Constrained Budget	UI's for NPV/ cap	Inverse of Proportion of Constrained Budget	Inverse of Combine UI's for Ω-VOC/km	Combined Utility Indices	Rank
10	0.152	90	0.309	0.461	12
20	0.272	80	0.306	0.578	6
25	0.272	75	0.304	0.576	7
30	0.272	70	0.297	0.569	9
40	0.272	60	0.295	0.567	11
50	0.274	50	0.295	0.569	10
60	0.303	40	0.291	0.594	1
70	0.303	30	0.291	0.594	1
75	0.303	25	0.291	0.594	1
80	0.303	20	0.291	0.594	1
90	0.303	10	0.291	0.594	1
100	0.299	100	0.273	0.572	8



APPENDIX 6.15: SUMMARY OF COMBINED UTILITY INDICES FOR FEEDER ROADS

Proportion of Constrained Budget	UI's for NPV / cap	Inverse of Proportion of Constrained Budget	Inverse of UI's for Ω-VOC/km	Combined Utility Indices	Rank
10	0.05	90	0.38	0.42	12
20	0.09	80	0.39	0.48	10
25	0.11	75	0.37	0.47	8
30	0.09	70	0.37	0.46	11
40	0.12	60	0.32	0.45	6
50	0.14	50	0.32	0.46	9
60	0.15	40	0.32	0.48	7
70	0.16	30	0.32	0.49	5
75	0.17	25	0.32	0.49	4
80	0.17	20	0.33	0.50	3
90	0.18	10	0.33	0.51	2
100	0.18	100	0.37	0.56	1



APPENDIX 6.16 OUTPUTS OF CASE STUDY

Case Study -ROC

Attributes	Alternatives						
	(a_1) $\frac{1}{v_i(x_i)}$	(a_2) $\frac{1}{v_i(x_i)}$	(a_3) $\frac{1}{v_i(x_i)}$	$\sum\frac{1}{v_i(x_i)}$	$\frac{1}{n}$	$(k_i^{'})$ $\frac{1}{n}\sum\frac{1}{v_1(x_i)}$	(k_i) $\frac{k_i^{'}}{\sum k_i^{'}}$
c_1	3.45	3.57	10.64	17.66	0.25	4.41	0.47
c_2	3.03	3.85	2.63	9.15	0.25	2.38	0.26
c_3	1.85	2.22	2.17	6.25	0.25	1.56	0.17
c_4	1.25	1.45	1.09	3.79	0.25	0.95	0.10
Total						0.95	

Weighted Need Score -ROC Method (Case Study)

Weighted Value Function by Alternative	Alternative		
	(a_1)	(a_2)	(a_3)
$k_1v_1(x_1)$	0.47(0.29)	0.47(0.28)	0.47(0.094)
$k_2v_2(x_2)$	0.26 (0.33)	0.26(0.26)	0.26(0.38)
$k_3v_3(x_3)$	0.17(0.54)	0.17(0.45)	0.17(0.46)
$k_4v_4(x_4)$	0.10(0.80)	0.10(0.69)	0.10(0.92)

Case Study – Weighting by Equivalent Probability Method

Attributes	b	w	Probability (p)	P x b	1-p	(P x b)+(1-P)	Weight ((k_i) (ii) x (vi)
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(viii)
c_1	0.29	0.094	0.5	0.15	0.5	0.65	0.06
c_2	0.38	0.15	0.5	0.19	0.5	0.69	0.10
c_3	0.54	0.45	0.5	0.27	0.5	0.77	0.35
c_4	0.92	0.69	0.5	0.46	0.5	0.96	0.668

Weighted Need Score –Equivalent Probability Method (Case Study)

Weighted Value Function by Alternative	Alternative		
	(a_1)	(a_2)	(a_3)
$k_1v_1(x_1)$	0.06(0.29)	0.06 (0.28)	0.06(0.094)
$k_2v_2(x_2)$	0.10(0.33)	0.10(0.26)	0.10(0.38)
$k_3v_3(x_3)$	0.35(0.54)	0.35(0.45)	0.35(0.46)
$k_4v_4(x_4)$	0.66 (0.80)	0.66(0.69)	0.66(0.92)

Proportion of Funds

	US $M
Available Budget	121.1
Total Budget Estimates by HDM-4 Analysis for (20years)	4472.1
Budget Estimates by HDM-4 per Annum	223.61
Percentage of Funds available funds (%)	54
Proportion of HDM-4 Budget Estimates Available (20 years)	2421.95

APPENDIX 7.1: PRIORITY SETTING AT CRITERIA LEVEL 1 ON ECONOMIC AND SOCIAL BENEFITS AT COMMUNITY LEVEL.-GOOD ROADS

TRUNK ROADS:

Economic benefit	4	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Economic	Social
Economic	1	(4)/1
Social	1/(4)	1

Step 2
Calculate the Sum of each Column

	Economic	Social
Economic	1	4
Social	0.25	1
Total	1.25	5

Step 3
Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.8	0.8
Social	0.2	0.2

Step 4
Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.8	0.8	1.6	2	0.8
Social	0.2	0.2	0.4	2	0.2

URBAN ROADS: PRIORITY

Economic benefit	8	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Economic	Social
Economic	1	8/1
Social	1/8	1

Step 2
Calculate the Sum of each Column

	Economic	Social
Economic	1	8
Social	0.125	1
Total	1.125	9

Step 3
Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.888889	0.888889
Social	0.111111	0.111111

Step 4
Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.888889	0.888889	1.777778	2	0.888889
Social	0.111111	0.111111	0.222222	2	0.111111

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

Social benefits	6		Social costs
Social benefit		1	6/1
Social Costs	1/ 6		1

Step 2
Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	6
Social Costs	0.167	1
Total	1.167	7

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.857	0.857
Social Costs	0.143	0.143

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.857	0.857	1.714	2.000	0.857
Social Costs	0.143	0.143	0.286	2.000	0.143

APPENDIX 7.2: PRIORITY SETTING AT CRITERIA LEVEL 1 ON ECONOMIC AND SOCIAL BENEFITS COMMUNITY LEVEL –BAD ROADS

TRUNK ROADS:

Economic benefit	Social Benefit	3

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Economic	Social
Economic	1	(1)/3
Social	(3)/1	1

Step 2
Calculate the Sum of each Column

	Economic	Social
Economic	1	0.333333
Social	3	1
Total	4	1.333333

Step 3
Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.25	0.25
Social	0.75	0.75

Step 4
Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.25	0.25	0.5	2	0.25
Social	0.75	0.75	1.5	2	0.75

URBAN ROADS:

Economic benefit	3	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Economic	Social
Economic	1	(1)/3
Social	1	1

Step 2
Calculate the Sum of each Column

	Economic	Social	
Economic	1	3	
Social	0.333333	1	
Total	1.333333	4	
			3

Step 3
Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.75	0.75
Social	0.25	0.25

Step 4
Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.75	0.75	1.5	2	0.75
Social	0.25	0.25	0.5	2	0.25

FEEDER ROADS:

Economic benefit	Social Benefit	9

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Economic	Social
Economic	1	1/(9x2)
Social	1/(1/9x2)	1

Step 2
Calculate the Sum of each Column

	Economic	Social

Economic	1	0.055556
Social	18	1
Total	19	1.055556

Step 3
Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.052632	0.052632
Social	0.947368	0.947368

Step 4
Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.052632	0.052632	0.105263	2	0.052632
Social	0.947368	0.947368	1.894737	2	0.947368

APPENDIX 7.3 PRIORITY SETTING AT CRITERIA LEVEL 1 ON ECONOMIC AND SOCIAL BENEFITS (DISTRICT LEVEL)

TRUNK ROADS:

Economic benefit		5	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Economic	Social
Economic	1	(5/1)
Social	1/(5)	1

Step 2 Calculate the Sum of each Column

	Economic	Social
Economic	1	5
Social	0.2	1
Total	1.2	6

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.833333	0.833333
Social	0.166667	0.166667

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.833333	0.833333	1.666667	2	0.833333
Social	0.166667	0.166667	0.333333	2	0.166667

URBAN ROADS:

Economic benefit		3	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Economic	Social
Economic	1	(3/1
Social	1/(3)	1

Step 2 Calculate the Sum of each Column

	Economic	Social
Economic	1	3
Social	0.333333	1
Total	1.333333	4

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.75	0.75
Social	0.25	0.25

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.75	0.75	1.5	2	0.75
Social	0.25	0.25	0.5	2	0.25

FEEDER ROADS:

Economic benefit	Social Benefit		4

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Economic	Social
Economic	1	1/(4)
Social	1/(1/4)	1

Step 2 Calculate the Sum of each Column

	Economic	Social

Economic	1	0.25
Social	4	1
Total	5	1.25

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.2	0.2
Social	0.8	0.8

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.2	0.2	0.4	2	0.2
Social	0.8	0.8	1.6	2	0.8

APPENDIX 7.4: PRIORITY SETTING AT CRITERIA LEVEL 1 ON ECONOMIC AND SOCIAL BENEFITS (NATIONAL LEVEL)

TRUNK ROADS:

1 Comparison of Economic and Social benefits for Trunk Roads

Economic benefit	7	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Economic	Social
Economic	1	(7/1)
Social	1/(7)	1

Step 2 Calculate the Sum of each Column

	Economic	Social
Economic	1	7
Social	0.142857	1
Total	1.142857	8

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.875	0.875
Social	0.125	0.125

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.875	0.875	1.75	2	0.875
Social	0.125	0.125	0.25	2	0.125

URBAN ROADS:

Economic benefit	5	Social Benefit

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Economic	Social
Economic	1	(5/1
Social	1/(5)	1

Step 2 Calculate the Sum of each Column

	Economic	Social
Economic	1	5
Social	0.2	1
Total	1.2	6

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.833333	0.833333
Social	0.166667	0.166667

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.833333	0.833333	1.666667	2	0.833333
Social	0.166667	0.166667	0.333333	2	0.166667

FEEDER ROADS:

1 Comparison of Economic and Social benefits for Feeder Roads

Economic benefit	Social Benefit	7

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Economic	Social
Economic	1	1/(8)
Social	1/(1/7x2)	1

Step 2 Calculate the Sum of each Column

	Economic	Social
Economic	1	0.125
Social	8	1
Total	9	1.125

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Economic	Social
Economic	0.111111	0.111111
Social	0.888889	0.888889

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Economic	Social	Total	No. of Elements	Weights
Economic	0.111111	0.111111	0.222222	2	0.111111
Social	0.888889	0.888889	1.777778	2	0.888889

APPENDIX 7.5: PRIORITY RANKING OF COMBINED SCORES FOR CRITERIA LEVEL I ON ECONOMIC BENEFITS BY ROAD TYPE

ECONOMIC CRITERION (LEVEL 1)

Step 1 Construct the Hierarchy Matrix Based Economic Criterion

	Econ Criterion		Trunk	Urban	Feeder
Trunk	0.74	Trunk	0.74/0.74	0.74/0.8	0.74/0.13
Urban	0.8	Urban	0.8/0.74	0.8/0.8	0.8/0.13
Feeder	0.13	Feeder	0.13/0.74	0.13/0.8	0.13/0.13

Step 2 Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1	0.925	5.692308
Urban	1.081081	1	6.153846
Feeder	0.175676	0.1625	1
Total	2.256757	2.0875	12.84615

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.443114	0.443114	0.443114
Urban	0.479042	0.479042	0.479042
Feeder	0.077844	0.077844	0.077844

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.443114	0.443114	0.443114	1.329341	3	0.44
Urban	0.479042	0.479042	0.479042	1.437126	3	0.48
Feeder	0.077844	0.077844	0.077844	0.233533	3	0.08

APPENDIX 7.6: PRIORITY RANKING OF COMBINED SCORES FOR CRITERIA Level 1 ON SOCIAL BENEFITS BY ROAD TYPE

SOCIAL CRITERION (LEVEL !)

Step 1 Construct the Hierarchy Matrix Based Social Criterion

	Social Criterion		Trunk	Urban	Feeder
Trunk	0.26	Trunk	0.26/.26	0.26/0.2	0.26/0.87
Urban	0.2	Urban	0.2/0.26	0.2/0.2	0.2/0.87
Feeder	0.87	Feeder	0.87/0.26	0.87/0.2	0.87/0.87

Step 2 Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1	1.3	0.298851
Urban	0.769231	1	0.229885
Feeder	3.346154	4.35	1
Total	5.115385	6.65	1.528736

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.195489	0.195489	0.195489
Urban	0.150376	0.150376	0.150376
Feeder	0.654135	0.654135	0.654135

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.195489	0.195489	0.195489	0.586466	3	0.20
Urban	0.150376	0.150376	0.150376	0.451128	3	0.15
Feeder	0.654135	0.654135	0.654135	1.962406	3	0.65

APPENDIX 7.7: PRIORITY RANKING OF COMBINED SCORES FOR CRITERIA Level 2 ON ECONOMIC BENEFITS Based ON NPV/CAP BY ROAD TYPE

Step 1 Construct the Hierarchy Matrix Based NPV

	NPV		Trunk	Urban	Feeder
Trunk	4.02	Trunk	4.02/4.02	4.02/2.9	4.02/0.431
Urban	2.9	Urban	2.9/4.02	2.9/2.9	2.9/0.431
Feeder	0.431	Feeder	0.431/4.02	0.431/2.9	0.431/0.431

Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1.0	1.4	9.3
Urban	0.7	1.0	6.7
Feeder	0.1	0.1	1.0
Total	1.8	2.5	17.1

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.55	0.55	0.55
Urban	0.39	0.39	0.39
Feeder	0.06	0.06	0.06

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.55	0.55	0.55	1.6	3	0.55
Urban	0.39	0.39	0.39	1.2	3	0.39
Feeder	0.06	0.06	0.06	0.2	3	0.06

APPENDIX 7.8: PRIORITY RANKING OF COMBINED SCORES FOR CRITERIA LEVEL 2 ON ECONOMIC COSTS BY HDM-4 ANALYSIS BY ROAD TYPE

Step 1 Construct the Hierarchy Matrix Based Economic Costs

	Social Criterion		Trunk	Urban	Feeder
Trunk	1539.9	Trunk	4.02/4.02	4.02/2.9	4.02/0.431
Urban	2143.2	Urban	2.9/4.02	2.9/2.9	2.9/0.431
Feeder	391	Feeder	0.431/4.02	0.431/2.9	0.431/0.431

Step 2 Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1	0.718505	3.938363
Urban	1.391779	1	5.48133
Feeder	0.253913	0.182437	1
Total	2.645691	1.900943	10.41969

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.377973	0.377973	0.377973
Urban	0.526055	0.526055	0.526055
Feeder	0.095972	0.095972	0.095972

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.377973	0.377973	0.377973	1.133919	3	0.38
Urban	0.526055	0.526055	0.526055	1.578165	3	0.53
Feeder	0.095972	0.095972	0.095972	0.287916	3	0.10

APPENDIX 7.9: PRIORITY SETTING AT CRITERIA LEVEL 2 ON SOCIAL BENEFITS AND COSTS- COMMUNITY LEVEL (GOOD ROADS)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

Social benefits	6		Social costs
Social benefit		1	6/1
Social Costs	1/ 6		1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	6
Social Costs	0.167	1
Total	1.167	7

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.857	0.857
Social Costs	0.143	0.143

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.857	0.857	1.714	2.000	0.857
Social Costs	0.143	0.143	0.286	2.000	0.143

URBAN ROADS:

Social benefit	8	Social Cost

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Social benefits	Social costs
Social benefit	1	8 / 1
Social Costs	1/ 8	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	8
Social Costs	0.125	1
Total	1.125	9

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.889	0.889
Social Costs	0.111	0.111

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.889	0.889	1.778	2.000	0.889
Social Costs	0.111	0.111	0.222	2.000	0.111

FEEDER ROADS

Social benefit	Social Cost	6

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	6/1
Social Costs	1/6	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	6
Social Costs	0.167	1

	Total	1.167	7

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.857	0.857
Social Costs	0.143	0.143

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.857	0.857	1.714	2.000	0.857
Social Costs	0.143	0.143	0.286	2.000	0.143

APPENDIX 7.10 PRIORITY SETTING AT CRITERIA LEVEL 2 ON SOCIAL BENEFITS AND COSTS COMMUNITY LEVEL (BAD ROADS)

TRUNK ROADS:

Social benefit	8	Social Cost

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Social benefits	Social costs
Social benefit	1	(8)/1
Social Costs	(1)/8	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	8
Social Costs	0.125	1
Total	1.125	9

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.889	0.889
Social Costs	0.111	0.111

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.889	0.889	1.778	2.000	0.889
Social Costs	0.111	0.111	0.222	2.000	0.111

URBAN ROADS:

Social benefit	8	Social Cost

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Social benefits	Social costs
Social benefit	1	8 div by 1
Social Costs	1 did by 8	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	8
Social Costs	0.125	1
Total	1.125	9

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.889	0.889
Social Costs	0.111	0.111

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.889	0.889	1.778	2.000	0.889
Social Costs	0.111	0.111	0.222	2.000	0.111

FFEDER ROADS:

Social benefit		Social Cost	6

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Social benefits	Social costs
Social benefit	1	6/1
Social Costs	1/ 6	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	6
Social Costs	0.167	1
Total	1.167	7

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs

Social benefit	0.857	0.857
Social Costs	0.143	0.143

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.857	0.857	1.714	2.000	0.857
Social Costs	0.143	0.143	0.286	2.000	0.143

APPENDIX 7.11 APPENDIX 7.5: PRIORITY SETTING AT CRITERIA LEVEL 2 ON SOCIAL BENEFITS AND COSTS (DISTRICTLEVEL)

TRUNK ROADS:

Social benefit	5	Social Cost	

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(5)/ 1
Social Costs	(1)/5	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	5
Social Costs	0.200	1
Total	1.200	6

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.833	0.833
Social Costs	0.167	0.167

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.833	0.833	1.667	2.000	0.833
Social Costs	0.167	0.167	0.333	2.000	0.167

URBAN ROADS:

Social benefit	3	Social Cost	

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(3)/1
Social Costs	(1)/ 3	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	3
Social Costs	0.333333	1
Total	1.333333	4

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.750	0.750
Social Costs	0.250	0.250

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.750	0.750	1.500	2.000	0.750
Social Costs	0.250	0.250	0.500	2.000	0.250

FEEDER ROADS:

Social benefit		Social Cost	4

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(4)/1
Social Costs	(1)/4	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	4
Social Costs	0.250	1
Total	1.250	5

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.800	0.800
Social Costs	0.200	0.200

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.800	0.800	1.600	2.000	0.800
Social Costs	0.200	0.200	0.400	2.000	0.200

APPENDIX 7.12: PRIORITY SETTING AT CRITERIA LEVEL 2 ON SOCIAL BENEFITS AND COSTS (NATIONAL LEVEL)

TRUNK ROADS:

Social benefit	7	Social Cost

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(7)/ 1
Social Costs	(1)/7	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	7
Social Costs	0.143	1
Total	1.143	8

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.875	0.875
Social Costs	0.125	0.125

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.875	0.875	1.750	2.000	0.875
Social Costs	0.125	0.125	0.250	2.000	0.125

URBAN ROADS:

Social benefit	7	Social Cost

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(7)/1
Social Costs	(1)/7	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	7
Social Costs	0.142857	1
Total	1.142857	8

Step 3 Normalize Each Element in Each Column by Dividing by the Column Sum

	Social benefits	Social costs
Social benefit	0.875	0.875
Social Costs	0.125	0.125

Step 4 Divide the Row in Step 3 by the Number of elements that are being compared

	Social benefits	Social costs	Total	No. of Elements	Weights
Social benefit	0.875	0.875	1.750	2.000	0.875
Social Costs	0.125	0.125	0.250	2.000	0.125

FEEDER ROADS:

Social benefit	Social Cost	9

Step 1 Construct the Hierarchy Matrix Based on the Response for Road Maintenance

	Social benefits	Social costs
Social benefit	1	(9)/1
Social Costs	(1)/9	1

Step 2 Calculate the Sum of each Column

	Social benefits	Social costs
Social benefit	1	9
Social Costs	0.111	1

	Total	1.111	10			
Step 3	Normalize Each Element in Each Column by Dividing by the Column Sum					
		Social benefits	Social costs			
	Social benefit	0.900	0.900			
	Social Costs	0.100	0.100			
Step 4	Divide the Row in Step 3 by the Number of elements that are being compared					
		Social benefits	Social costs	Total	No. of Elements	Weights
	Social benefit	0.900	0.900	1.800	2.000	0.900
	Social Costs	0.100	0.100	0.200	2.000	0.100

APPENDIX 7.13: PRIORITY RANKING FOR COMBINED SCORES FOR CRITERIA Level 2 ON SOCIAL BENEFITS BY ROAD TYPE

Social Benefits

Step 1 Construct the Hierarchy Matrix Based Social Benefits

	Social Criterion		Trunk	Urban	Feeder
Trunk	0.86	Trunk	0.86/0.86	0.86/0.84	0.86/0.84
Urban	0.84	Urban	0.84/0.86	0.84/0.84	0.84/0.85
Feeder	0.85	Feeder	0.85/0.86	0.85/0.84	0.85/0.85

Step 2 Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1	1.02381	1.011765
Urban	0.976744	1	0.988235
Feeder	0.988372	1.011905	1
Total	2.965116	3.035714	3

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.337255	0.337255	0.337255
Urban	0.329412	0.329412	0.329412
Feeder	0.333333	0.333333	0.333333

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.337255	0.337255	0.337255	1.011765	3	0.34
Urban	0.329412	0.329412	0.329412	0.988235	3	0.33
Feeder	0.333333	0.333333	0.333333	1	3	0.33

APPENDIX 7.14: PRIORITY RANKING FOR COMBINED SCORES FOR CRITERIA LEVEL 2 ON SOCIAL COSTS BY ALTERNATIVE (LEVEL 2)

Step 1 Construct the Hierarchy Matrix Based Social Costs

	Social Criterion		Trunk	Urban	Feeder
Trunk	0.14	Trunk	0.14/0.14	0.14/0.16	0.14/0.15
Urban	0.16	Urban	0.16/0.14	0.16/0.16	0.16/0.15
Feeder	0.15	Feeder	0.15/0.14	0.15/0.16	0.15/0.15

Step 2 Calculate the Sum of Each Column

	Trunk	Urban	Feeder
Trunk	1	0.875	0.933333
Urban	1.142857	1	1.066667
Feeder	1.071429	0.9375	1
Total	3.214286	2.8125	3

Step 3 Normalize Each Element by Dividing by Column Sum

	Trunk	Urban	Feeder
Trunk	0.311111	0.311111	0.311111
Urban	0.355556	0.355556	0.355556
Feeder	0.333333	0.333333	0.333333

Step 4 Calculate the Sum of Each Column

	Trunk	Urban	Feeder	Total	No of elements	Weights
Trunk	0.311111	0.311111	0.311111	0.933333	3	0.31
Urban	0.355556	0.355556	0.355556	1.066667	3	0.36
Feeder	0.333333	0.333333	0.333333	1	3	0.33

APPENDIX 7.15: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL BENEFITS COMMUNITY LEVEL (GOOD ROADS)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance (Benefits)

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(4)/1	(4)/1	(7)/1
Benefit 2	(1)/4	1	1	(3)/1
Benefit 3	(1)/4	1	1	(3)/1
Benefit 4	(1/7)	(1)/3	(1)/3	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	4	4	7
Benefit 2	0.25	1	1	3
Benefit 3	0.25	1	1	3
Benefit 4	0.142857	0.333333	0.333333	1
Total	1.642857	6.333333	6.333333	14

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.608696	0.631579	0.631579	0.5
Benefit 2	0.152174	0.157895	0.157895	0.214286
Benefit 3	0.152174	0.157895	0.157895	0.214286
Benefit 4	0.086957	0.052632	0.052632	0.071429

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.608696	0.631579	0.631579	0.5	2.371854	4	0.592963
Benefit 2	0.152174	0.157895	0.157895	0.214286	0.682249	4	0.170562
Benefit 3	0.152174	0.157895	0.157895	0.214286	0.682249	4	0.170562
Benefit 4	0.086957	0.052632	0.052632	0.071429	0.263648	4	0.065912
Eigen value						4	
n						4	
n-1						3	
CI						0	
RI (4)						0.9	
CR						0	

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(4)/1	(3)/1	(8)/1
Benefit 2	(1)/4	1	(2)/1	(7)/1
Benefit 3	(1)/3	(1)/2	1	(7)/1
Benefit 4	(1)/8	(1)/7	(1)/7	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	4	3	8
Benefit 2	0.25	1	2	7
Benefit 3	0.333333	0.5	1	7
Benefit 4	0.125	0.142857	0.142857	1

Total	1.708333	5.642857	6.142857	23

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.585366	0.708861	0.488372	0.347826
Benefit 2	0.146341	0.177215	0.325581	0.304348
Benefit 3	0.195122	0.088608	0.162791	0.304348
Benefit 4	0.073171	0.025316	0.023256	0.043478

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.585366	0.708861	0.488372	0.347826	2.130425	4	0.532606
Benefit 2	0.146341	0.177215	0.325581	0.304348	0.953486	4	0.238371
Benefit 3	0.195122	0.088608	0.162791	0.304348	0.750868	4	0.187717
Benefit 4	0.073171	0.025316	0.023256	0.043478	0.165221	4	0.041305

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(4)/1	(5)/1	(5)/1
Benefit 2	(1)/4	1	(4)/1	(4)/1
Benefit 3	(1)/5	(1)/4	1	(1)/4
Benefit 4	(1)/5	(1)/4	(4)/1	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	4	5	5
Benefit 2	0.25	1	4	4
Benefit 3	0.2	0.25	1	0.25
Benefit 4	0.2	0.25	4	1
Total	1.65	5.5	14	10.25

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.606061	0.727273	0.357143	0.487805
Benefit 2	0.151515	0.181818	0.285714	0.390244
Benefit 3	0.121212	0.045455	0.071429	0.02439
Benefit 4	0.121212	0.045455	0.285714	0.097561

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.606061	0.727273	0.357143	0.487805	2.178281	4	0.54457
Benefit 2	0.151515	0.181818	0.285714	0.390244	1.009292	4	0.252323
Benefit 3	0.121212	0.045455	0.071429	0.02439	0.262485	4	0.065621
Benefit 4	0.121212	0.045455	0.285714	0.097561	0.549942	4	0.137485

APPENDIX 7.16: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL COSTS COMMUNITY LEVEL (GOOD ROADS)

TRUNK ROADS:

Step 1

Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(5)/1	(4)/1	(4)/1
Cost 2	(1)/4	1	(1)/4	(3)/1
Cost 3	(1)/4	(4)/1	1	(6)/1
Cost 4	(1)/4	(1)/3	(1)/6)	1

Step 2

Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	5	4	4
Cost 2	0.2	1	0.25	3
Cost 3	0.25	4	1	6
Cost 4	0.25	0.333333	0.166667	1
Total	1.7	10.33333	5.416667	14

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.588235	0.483871	0.738462	0.285714
Cost 2	0.117647	0.096774	0.046154	0.214286
Cost 3	0.147059	0.387097	0.184615	0.428571
Cost 4	0.147059	0.032258	0.030769	0.071429

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.588235	0.483871	0.738462	0.285714	2.096282	4	0.524071
Cost 2	0.117647	0.096774	0.046154	0.214286	0.474861	4	0.118715
Cost 3	0.147059	0.387097	0.184615	0.428571	1.147342	4	0.286836
Cost 4	0.147059	0.032258	0.030769	0.071429	0.281515	4	0.070379

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(8)/1	(2)/1	(3)/1
Cost 2	(1)/8	1	(1)/7	(1)/6
Cost 3	(1)/2	(7)/1	1	(5)/1
Cost 4	(1)/3	(6)/1	(1)/5	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	8	2	3
Cost 2	0.125	1	0.142857	0.166667
Cost 3	0.5	7	1	5
Cost 4	0.333333	6	0.2	1
Total	1.958333	22	3.342857	9.166667

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.510638	0.363636	0.598291	0.327273
Cost 2	0.06383	0.045455	0.042735	0.018182

Cost 3	0.255319	0.318182	0.299145	0.545455
Cost 4	0.170213	0.272727	0.059829	0.109091

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.510638	0.363636	0.598291	0.327273	1.799838	4	0.449959
Cost 2	0.06383	0.045455	0.042735	0.018182	0.170201	4	0.04255
Cost 3	0.255319	0.318182	0.299145	0.545455	1.418101	4	0.354525
Cost 4	0.170213	0.272727	0.059829	0.109091	0.61186	4	0.152965

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(6)/1	(5)/1	(4)/1
Cost 2	(1)/6	1	1	(1)/6
Cost 3	(1)/ 5	1	1	(1)/ 2
Cost 4	(1)/4	(3)/ 1	(2)/ 1	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	6	5	4
Cost 2	0.166667	1	1	0.333333
Cost 3	0.2	1	1	0.5
Cost 4	0.25	3	2	1
Total	1.616667	11	9	5.833333

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.618557	0.545455	0.555556	0.685714
Cost 2	0.103093	0.090909	0.111111	0.057143
Cost 3	0.123711	0.090909	0.111111	0.085714
Cost 4	0.154639	0.272727	0.222222	0.171429

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.618557	0.545455	0.555556	0.685714	2.405281	4	0.60132
Cost 2	0.103093	0.090909	0.111111	0.057143	0.362256	4	0.090564
Cost 3	0.123711	0.090909	0.111111	0.085714	0.411446	4	0.102861
Cost 4	0.154639	0.272727	0.222222	0.171429	0.821017	4	0.205254

APPENDIX 7.17 PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL BENEFITS COMMUNITY LEVEL (BAD ROADS)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(6)/1	(2)/1	(2)/1
Benefit 2	(1)/6	1	(2)/1	(5)/1
Benefit 3	(1)/2	(1)/2	1	(4)/1
Benefit 4	(1)/2	(1)/5	(1)/5	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	6	2	2
Benefit 2	0.166667	1	2	5
Benefit 3	0.5	0.5	1	4
Benefit 4	0.5	0.2	0.2	1
Total	2.166667	7.7	5.2	12

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.461538	0.779221	0.384615	0.166667
Benefit 2	0.076923	0.12987	0.384615	0.416667
Benefit 3	0.230769	0.064935	0.192308	0.333333
Benefit 4	0.230769	0.025974	0.038462	0.083333

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.461538	0.779221	0.384615	0.166667	1.792041	4	0.44801
Benefit 2	0.076923	0.12987	0.384615	0.416667	1.008075	4	0.252019
Benefit 3	0.230769	0.064935	0.192308	0.333333	0.821345	4	0.205336
Benefit 4	0.230769	0.025974	0.038462	0.083333	0.378538	4	0.094635

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(7)/1	(5)/1	(7)/1
Benefit 2	(1)/7	1	(3)/1	(2)/1
Benefit 3	(1)/5	(1)/3	1	(5)/1
Benefit 4	(1)/7	(1)/2	(1)/5	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	7	5	7
Benefit 2	0.142857	1	3	2
Benefit 3	0.2	0.333333	1	5
Benefit 4	0.142857	0.5	0.2	1
Total	1.485714	8.833333	9.2	15

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.673077	0.792453	0.543478	0.466667
Benefit 2	0.096154	0.113208	0.326087	0.133333
Benefit 3	0.134615	0.037736	0.108696	0.333333
Benefit 4	0.096154	0.056604	0.021739	0.066667

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.673077	0.792453	0.543478	0.466667	2.475675	4	0.618919
Benefit 2	0.096154	0.113208	0.326087	0.133333	0.668782	4	0.167195
Benefit 3	0.134615	0.037736	0.108696	0.333333	0.61438	4	0.153595
Benefit 4	0.096154	0.056604	0.021739	0.066667	0.241163	4	0.060291

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	1	(3)/1	(4)/1
Benefit 2	1	1	(5)/1	(4)/1
Benefit 3	(1)/3	(1)/5	1	(1)/2
Benefit 4	(1)/4	(1)/4	(2)/1	1

Step 2
Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	1	3	4
Benefit 2	1	1	5	4
Benefit 3	0.333333	0.2	1	0.5
Benefit 4	0.2	0.25	4	1
Total	2.533333	2.45	13	9.5

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.394737	0.408163	0.230769	0.421053
Benefit 2	0.394737	0.408163	0.384615	0.421053
Benefit 3	0.131579	0.081633	0.076923	0.052632
Benefit 4	0.078947	0.102041	0.307692	0.105263

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.394737	0.408163	0.230769	0.421053	1.454722	4	0.36368
Benefit 2	0.394737	0.408163	0.384615	0.421053	1.608568	4	0.402142
Benefit 3	0.131579	0.081633	0.076923	0.052632	0.342766	4	0.085692
Benefit 4	0.078947	0.102041	0.307692	0.105263	0.593944	4	0.148486

APPENDIX 7.18: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL COSTS COMMUNITY LEVEL (BAD ROADS)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(7)/1	(5)/1	(6)/1
Cost 2	(1)/7	1	(1)/2	1
Cost 3	(1)/5	(2)/1	1	(2)/1
Cost 4	(1)/6	1	(1)/2	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	7	5	6
Cost 2	0.142857	1	0.5	1
Cost 3	0.2	2	1	2
Cost 4	0.166667	1	0.5	1
Total	1.509524	11	7	10

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.662461	0.636364	0.714286	0.6
Cost 2	0.094637	0.090909	0.071429	0.1
Cost 3	0.132492	0.181818	0.142857	0.2
Cost 4	0.11041	0.090909	0.071429	0.1

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.662461	0.636364	0.714286	0.6	2.61311	4	0.653277
Cost 2	0.094637	0.090909	0.071429	0.1	0.356975	4	0.089244
Cost 3	0.132492	0.181818	0.142857	0.2	0.657167	4	0.164292
Cost 4	0.11041	0.090909	0.071429	0.1	0.372748	4	0.093187

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(7)/1	(6)/1	(2)/1
Cost 2	(1)/7	1	(1)/7	1
Cost 3	(1)/6	(7)/1	1	1
Cost 4	(1)/2	1	1	1

Step 2
Calculate the Sum of Each Column

Cost 1	1	7	6	2
Cost 2	0.142857	1	0.142857	1
Cost 3	0.166667	7	1	1
Cost 4	0.5	1	1	1
Total	1.809524	16	8.142857	5

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.552632	0.4375	0.736842	0.4
Cost 2	0.078947	0.0625	0.017544	0.2
Cost 3	0.092105	0.4375	0.122807	0.2
Cost 4	0.276316	0.0625	0.122807	0.2

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.552632	0.4375	0.736842	0.4	2.126974	4	0.531743
Cost 2	0.078947	0.0625	0.017544	0.2	0.358991	4	0.089748
Cost 3	0.092105	0.4375	0.122807	0.2	0.852412	4	0.213103
Cost 4	0.276316	0.0625	0.122807	0.2	0.661623	4	0.165406

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(3)/1	(1)/6	2)/1
Cost 2	(1)/3	1	(1)/5	1
Cost 3	(6)/1	(5)/1	1	(3)/ 1
Cost 4	(1)/2	1	(1)/3	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	3	0.166667	2
Cost 2	0.333333	1	0.2	1
Cost 3	6	5	1	3
Cost 4	0.5	1	0.333333	1
Total	7.833333	10	1.7	7

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.12766	0.3	0.098039	0.285714
Cost 2	0.042553	0.1	0.117647	0.142857
Cost 3	0.765957	0.5	0.588235	0.428571
Cost 4	0.06383	0.1	0.196078	0.142857

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.12766	0.3	0.098039	0.285714	0.811413	4	0.202853
Cost 2	0.042553	0.1	0.117647	0.142857	0.403057	4	0.100764
Cost 3	0.765957	0.5	0.588235	0.428571	2.282764	4	0.570691
Cost 4	0.06383	0.1	0.196078	0.142857	0.502765	4	0.125691

APPENDIX 7.19 PRIORITY SETTING AT SUB CRITERIA LEVEL ON SOCIAL BENEFITS (DISTRICT LEVEL)

TRUNK ROADS

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(7)/ 1	(6)/1	(7)/1
Benefit 2	(1)/7	1	(1)/5	(5)/1
Benefit 3	(1)/6	(5)/1	1	(2)/1
Benefit 4	(1)/7	(1)/5	(1)/2	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	7	6	7
Benefit 2	0.142857	1	0.2	5
Benefit 3	0.166667	5	1	2
Benefit 4	0.142857	0.2	0.5	1
Total	1.452381	13.2	7.7	15

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.688525	0.530303	0.779221	0.466667
Benefit 2	0.098361	0.075758	0.025974	0.333333
Benefit 3	0.114754	0.378788	0.12987	0.133333
Benefit 4	0.098361	0.015152	0.064935	0.066667

Calculate the Sum of Each Column

Step 4	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.688525	0.530303	0.779221	0.466667	2.464715	4	0.616179
Benefit 2	0.098361	0.075758	0.025974	0.333333	0.533426	4	0.133356
Benefit 3	0.114754	0.378788	0.12987	0.133333	0.756745	4	0.189186
Benefit 4	0.098361	0.015152	0.064935	0.066667	0.245114	4	0.061278

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(7)/1	(5)/1	1
Benefit 2	(1/7)	1	(2)/1	(6)/1
Benefit 3	(1/5)	(1)/2	1	(4)/1
Benefit 4	1	(1)/6	(1)/4	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	7	5	1
Benefit 2	0.142857	1	2	6
Benefit 3	0.2	0.5	1	4
Benefit 4	1	0.166667	0.25	1
Total	2.342857	8.666667	8.25	12

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4

Benefit 1	0.426829	0.807692	0.606061	0.083333
Benefit 2	0.060976	0.115385	0.242424	0.5
Benefit 3	0.085366	0.057692	0.121212	0.333333
Benefit 4	0.426829	0.019231	0.030303	0.083333

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.426829	0.807692	0.606061	0.083333	1.923916	4	0.480979
Benefit 2	0.060976	0.115385	0.242424	0.5	0.918784	4	0.229696
Benefit 3	0.085366	0.057692	0.121212	0.333333	0.597604	4	0.149401
Benefit 4	0.426829	0.019231	0.030303	0.083333	0.559696	4	0.139924

FEEDER ROADS:

Step 1

Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(2)/1		(1)/3
Benefit 2	(1)/2	1		(6)/1
Benefit 3				
Benefit 4	(3)/1	(1)/6	(1)/4	1

Step 2

Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	2		0.333333
Benefit 2	0.5	1		6
Benefit 3				
Benefit 4	3	0.166667	0.25	1
Total	4.5	3.166667	0.25	7.333333

Step 3

Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.222222	0.631579	0	0.045455
Benefit 2	0.111111	0.315789	0	0.818182
Benefit 3	0	0	0	0
Benefit 4	0.666667	0.052632	1	0.136364

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.222222	0.631579	0	0.045455	0.899256	4	0.224814
Benefit 2	0.111111	0.315789	0	0.818182	1.245082	4	0.311271
Benefit 3	0	0	0	0	0	4	0
Benefit 4	0.666667	0.052632	1	0.136364	1.855662	4	0.463915

APPENDIX 7.20: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL COSTS (DISTRICT LEVEL)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(8/)1	(7)/1	(6)/1
Cost 2	(1)/8	1	(1)/2	(4)/1
Cost 3	(1)/7	(2)/1	1	1
Cost 4	(1)/6	(1)/4	1	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	8	7	6
Cost 2	0.125	1	0.5	4
Cost 3	0.142857	2	1	1
Cost 4	0.166667	0.25	1	1
Total	1.434524	11.25	9.5	12

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.697095	0.711111	0.736842	0.5
Cost 2	0.087137	0.088889	0.052632	0.333333
Cost 3	0.099585	0.177778	0.105263	0.083333
Cost 4	0.116183	0.022222	0.105263	0.083333

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.697095	0.711111	0.736842	0.5	2.645049	4	0.661262
Cost 2	0.087137	0.088889	0.052632	0.333333	0.561991	4	0.140498
Cost 3	0.099585	0.177778	0.105263	0.083333	0.465959	4	0.11649
Cost 4	0.116183	0.022222	0.105263	0.083333	0.327001	4	0.08175

URBAN ROADS:

Step 1

Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	(6)/1	(4)/1
Cost 2	1	1	(4)/1	(4)/1
Cost 3	(1)/6	(1)/4	1	(1)/5
Cost 4	(1)/4	(1)/4	(5)/1	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	6	4
Cost 2	1	1	4	4
Cost 3	0.166667	0.25	1	0.2
Cost 4	0.25	0.25	5	1

Total	2.416667	2.5	16	9.2

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.413793	0.4	0.375	0.434783
Cost 2	0.413793	0.4	0.25	0.434783
Cost 3	0.068966	0.1	0.0625	0.021739
Cost 4	0.103448	0.1	0.3125	0.108696

Step 4
Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.413793	0.4	0.375	0.434783	1.623576	4	0.405894
Cost 2	0.413793	0.4	0.25	0.434783	1.498576	4	0.374644
Cost 3	0.068966	0.1	0.0625	0.021739	0.253205	4	0.063301
Cost 4	0.103448	0.1	0.3125	0.108696	0.624644	4	0.156161

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	0	(5)/1
Cost 2	1	1	0	(4)/1
Cost 3	0	0	0	0
Cost 4	(1)/5	(1)/4	0	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	0	5
Cost 2	1	1	0	4
Cost 3	0	0	0	0
Cost 4	0.2	0.25	0	1
Total	2.2	2.25	0	10

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.454545	0.444444	0	0.5
Cost 2	0.454545	0.444444	0	0.4
Cost 3	0	0	0	0
Cost 4	0.090909	0.111111	0	0.1

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.454545	0.444444	0	0.5	1.39899	4	0.349747
Cost 2	0.454545	0.444444	0	0.4	1.29899	4	0.324747
Cost 3	0	0	0	0	0	4	0
Cost 4	0.090909	0.111111	0	0.1	0.30202	4	0.075505

APPENDIX 7.21: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL BENEFITS (NATIONAL LEVEL)

TRUNK ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(4)/1	(2)/1	(2)/1
Benefit 2	(1)/4	1	1	(3)/1
Benefit 3	(1)/2	1	1	1
Benefit 4	(1)/2	(1)/3	1	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	4	2	2
Benefit 2	0.25	1	1	3
Benefit 3	0.5	1	1	1
Benefit 4	0.5	0.333333	1	1
Total	2.25	6.333333	5	7

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.444444	0.631579	0.4	0.285714
Benefit 2	0.111111	0.157895	0.2	0.428571
Benefit 3	0.222222	0.157895	0.2	0.142857
Benefit 4	0.222222	0.052632	0.2	0.142857

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.444444	0.631579	0.4	0.285714	1.761738	4	0.440434
Benefit 2	0.111111	0.157895	0.2	0.428571	0.897577	4	0.224394
Benefit 3	0.222222	0.157895	0.2	0.142857	0.722974	4	0.180744
Benefit 4	0.222222	0.052632	0.2	0.142857	0.617711	4	0.154428

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	1	(4)/1	(7)/1
Benefit 2	1	1	(3)/1	(3)/1
Benefit 3	(1/4)	(1)/3	1	(4)/1
Benefit 4	(1)/7	(1)/3	(1)/4	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	1	4	7
Benefit 2	1	1	3	3
Benefit 3	0.25	0.333333	1	4
Benefit 4	0.142857	0.333333	0.25	1
Total	2.392857	2.666667	8.25	15

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4

Benefit 1	0.41791	0.375	0.484848	0.466667
Benefit 2	0.41791	0.375	0.363636	0.2
Benefit 3	0.104478	0.125	0.121212	0.266667
Benefit 4	0.059701	0.125	0.030303	0.066667

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.41791	0.375	0.484848	0.466667	1.744426	4	0.436106
Benefit 2	0.41791	0.375	0.363636	0.2	1.356547	4	0.339137
Benefit 3	0.104478	0.125	0.121212	0.266667	0.617356	4	0.154339
Benefit 4	0.059701	0.125	0.030303	0.066667	0.281671	4	0.070418

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	(1)/7	(1)/4	(3)/1
Benefit 2	(7)/1	1	(4)/1	(4)/1
Benefit 3	(4)/1	(1)/4	1	(2)/1
Benefit 4	(1)/3	(1)/4	(1)/2	1

Step 2 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	1	0.142857	0.25	3
Benefit 2	7	1	4	4
Benefit 3	4	0.25	1	2
Benefit 4	0.333333	0.25	0.5	1
Total	12.33333	1.642857	5.75	10

Step 3 Normalize Each Element by Dividing by Column Sum

	Benefit 1	Benefit 2	Benefit 3	Benefit 4
Benefit 1	0.081081	0.086957	0.043478	0.3
Benefit 2	0.567568	0.608696	0.695652	0.4
Benefit 3	0.324324	0.152174	0.173913	0.2
Benefit 4	0.027027	0.152174	0.086957	0.1

Step 4 Calculate the Sum of Each Column

	Benefit 1	Benefit 2	Benefit 3	Benefit 4	Total	No of elements	Weights
Benefit 1	0.081081	0.086957	0.043478	0.3	0.511516	4	0.127879
Benefit 2	0.567568	0.608696	0.695652	0.4	2.271915	4	0.567979
Benefit 3	0.324324	0.152174	0.173913	0.2	0.850411	4	0.212603
Benefit 4	0.027027	0.152174	0.086957	0.1	0.366157	4	0.091539

APPENDIX 7.22: PRIORITY SETTING AT SUB CRITERIA LEVEL 3 ON SOCIAL COSTS (NATIONAL LEVEL)

TRUNK ROADS

Step 1 Construct the Hierarchy Matrix Based on the Response for Trunk Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(5/)1	(5)/1	(6)/1
Cost 2	(1)/5	1	(1)/5	(1)/2
Cost 3	(1)/5	(5)/1	1	(2)/1
Cost 4	(1)/6	(2)/1	(1)/2	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	5	5	6
Cost 2	0.2	1	0.2	0.5
Cost 3	0.2	5	1	2
Cost 4	0.166667	2	0.5	1
Total	1.566667	13	6.7	9.5

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.638298	0.384615	0.746269	0.631579
Cost 2	0.12766	0.076923	0.029851	0.052632
Cost 3	0.12766	0.384615	0.149254	0.210526
Cost 4	0.106383	0.153846	0.074627	0.105263

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.638298	0.384615	0.746269	0.631579	2.400761	4	0.60019
Cost 2	0.12766	0.076923	0.029851	0.052632	0.287065	4	0.071766
Cost 3	0.12766	0.384615	0.149254	0.210526	0.872055	4	0.218014
Cost 4	0.106383	0.153846	0.074627	0.105263	0.440119	4	0.11003

URBAN ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Urban Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	(8)/1	(6)/1	(5)/1
Cost 2	(1)/8	1	(1)/6	1
Cost 3	(1)/6	(6)/1	1	(5)/1
Cost 4	(1)/5	1	(1)/5	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	8	6	5
Cost 2	0.125	1	0.166667	1
Cost 3	0.166667	6	1	5
Cost 4	0.2	1	0.2	1
Total	1.491667	16	7.366667	12

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.670391	0.5	0.81448	0.416667
Cost 2	0.083799	0.0625	0.022624	0.083333
Cost 3	0.111732	0.375	0.135747	0.416667

Cost 4	0.134078	0.0625	0.027149	0.083333

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.670391	0.5	0.81448	0.416667	2.401537	4	0.600384
Cost 2	0.083799	0.0625	0.022624	0.083333	0.252257	4	0.063064
Cost 3	0.111732	0.375	0.135747	0.416667	1.039145	4	0.259786
Cost 4	0.134078	0.0625	0.027149	0.083333	0.307061	4	0.076765

FEEDER ROADS:

Step 1 Construct the Hierarchy Matrix Based on the Response for Feeder Road Maintenance

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	(6)/1	(7)/1
Cost 2	1	1	(5)/1	(5)/1
Cost 3	(1)/6	(1)/5	1	(6)/1
Cost 4	(1)/7	(1)/5	(1)/6	1

Step 2 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	1	1	6	7
Cost 2	1	1	5	5
Cost 3	0.166667	0.2	1	6
Cost 4	0.142857	0.2	0.166667	1
Total	2.309524	2.4	12.16667	19

Step 3 Normalize Each Element by Dividing by Column Sum

	Cost 1	Cost 2	Cost 3	Cost 4
Cost 1	0.43299	0.416667	0.493151	0.368421
Cost 2	0.43299	0.416667	0.410959	0.263158
Cost 3	0.072165	0.083333	0.082192	0.315789
Cost 4	0.061856	0.083333	0.013699	0.052632

Step 4 Calculate the Sum of Each Column

	Cost 1	Cost 2	Cost 3	Cost 4	Total	No of elements	Weights
Cost 1	0.43299	0.416667	0.493151	0.368421	1.711228	4	0.427807
Cost 2	0.43299	0.416667	0.410959	0.263158	1.523773	4	0.380943
Cost 3	0.072165	0.083333	0.082192	0.315789	0.55348	4	0.13837
Cost 4	0.061856	0.083333	0.013699	0.052632	0.211519	4	0.05288

APPENDIX 7.23: SUMMARY OF COMBINED WEIGHTS BY ROAD SECTOR AND ASSIGNED PREFERENCE SCALE

Alternative	Benefit 1		Benefit 2		Benefit 3		Benefit 4	
	Combined Score	Preference Scale	Combined Score	Preference Scale	Combined Score	Preference Scale	Combined Score	Preference Scale
Trunk	0.53	1	0.21	0.75	0.17	0.5	0.13	0.25
Urban	0.50	1	0.26	0.75	0.16	0.5	0.09	0.25
Feeder	0.27	0.75	0.40	1	0.10	0.25	0.23	0.25
	Cost 1		Cost 2		Cost 3		Cost 4	
Trunk	0.62	1	0.10	0.75	0.20	0.5	0.32	0.75
Urban	0.50	1	0.17	0.75	0.20	0.75	0.13	0.25
Feeder	0.45	1	0.25	0.25	0.17	0.5	0.14	0.25

APPENDIX 7.24: SUMMARY OF COMBINED WEIGHTED SCORES ON SUB CRITERIA LEVEL 3 FOR SOCIAL BENEFITS BY ROAD TYPE

Benefit

	Community	District	National	Average
Trunk				
Benefit 1	0.52	0.62	0.44	0.53
Benefit 2	0.21	0.19	0.22	0.21
Benefit 3	0.19	0.13	0.18	0.17
Benefit4	0.08	0.15	0.15	0.13
Urban				
	Community	District	National	Average
Benefit 1	0.58	0.48	0.44	0.50
Benefit 2	0.2	0.23	0.34	0.26
Benefit 3	0.18	0.15	0.15	0.16
Benefit4	0.05	0.15	0.07	0.09
Feeder				
	Community	District	National	Average
Benefit 1	0.45	0.23	0.13	0.27
Benefit 2	0.33	0.31	0.57	0.40
Benefit 3	0.08	0	0.21	0.10
Benefit4	0.14	0.46	0.09	0.23

APPENDIX 7.25: SUMMARY OF ADJUSTED COMBINED WEIGHTED SCORES ON SUB CRITERIA LEVEL 3 FOR SOCIAL BENEFITS BY ROAD TYPE

		Benefit					
	Trunk						
		Community	District	National	Average	Rank	Score
Benefit 1		0.52	0.62	0.44	0.53	4.00	1.00
Benefit 2		0.21	0.19	0.22	0.21	3.00	0.75
Benefit 3		0.19	0.13	0.18	0.17	2.00	0.50
Benefit4		0.08	0.15	0.15	0.13	1.00	0.25
	Urban						
		Community	District	National	Average	Rank	Score
Benefit 1		0.58	0.48	0.44	0.50	4.00	1.00
Benefit 2		0.2	0.23	0.34	0.26	3.00	0.75
Benefit 3		0.18	0.15	0.15	0.16	2.00	0.50
Benefit4		0.05	0.15	0.07	0.09	1.00	0.25
	Feeder						
	Community	District	National	Average	Rank	Score	Average
Benefit 1	0.45	0.23	0.13	0.27	3	0.75	0.41
Benefit 2	0.33	0.31	0.57	0.40	4	1	0.32
Benefit 3	0.08	0	0.21	0.10	1	0.25	0.14
Benefit4	0.14	0.46	0.09	0.23	2	0.5	0.14

APPENDIX 7.26: SUMMARY OF COMBINED WEIGHTED SCORES ON SUB CRITERIA LEVEL 3 FOR SOCIAL COSTS BY ROAD TYPE

	Costs			
	Trunk			
	Community	District	National	Average
Cost 1	0.59	0.66	0.6	0.62
Cost 2	0.1	0.14	0.07	0.10
Cost 3	0.23	0.12	0.26	0.20
Cost 4	0.08	0.08	0.8	0.32
	Urban			
	Community	District	National	Average
Cost 1	0.49	0.41	0.6	0.50
Cost 2	0.07	0.38	0.06	0.17
Cost 3	0.28	0.06	0.26	0.20
Cost 4	0.16	0.16	0.08	0.13
	Feeder			
	Community	District	National	Average
Cost 1	0.4	0.5		0.45
Cost 2	0.1	0.4		0.25
Cost 3	0.34	0		0.17
Cost 4	0.17	0.1		0.14

APPENDIX 7.27: SUMMARY OF ADJUSTED COMBINED WEIGHTED SCORES ON SUB CRITERIA 3 FOR SOCIAL COSTS BY ROAD TYPE

Costs

	Trunk					
	Community	District	National	Average	Rank	Score
Cost 1	0.59	0.66	0.6	0.62	4.00	1.00
Cost 2	0.1	0.14	0.07	0.10	1.00	0.25
Cost 3	0.23	0.12	0.26	0.20	2.00	0.50
Cost 4	0.08	0.08	0.8	0.32	3.00	0.75
	Urban					
	Community	District	National	Average	Rank	Score
Cost 1	0.49	0.41	0.6	0.50	4.00	1.00
Cost 2	0.07	0.38	0.06	0.17	2.00	0.50
Cost 3	0.28	0.06	0.26	0.20	3.00	0.75
Cost 4	0.16	0.16	0.08	0.13	1.00	0.25
	Feeder					
	Community	District	National	Average	Rank	Score
Cost 1	0.4	0.5		0.45	4	1
Cost 2	0.1	0.4		0.25	3	0.75
Cost 3	0.34	0		0.17	2	0.5
Cost 4	0.17	0.1		0.14	1	0.25

APPENDIX 8.1: DM- ROAD CONDITION RATING FOR TRUNK ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
373.11	3.6	Good		
297.79	3.9	Good		
306.08	4.0	Good		
62.36	4.1	Good		
157.80	4.2	Good		
544.55	4.5	Good		
108.40	4.5	Good		
106.84	5.0	Good		
168.41	5.2	Good		
132.83	5.4	Good		
43.63	5.5	Good		
100.83	5.5	Good		
222.11	5.6	Good		
302.84	5.7	Good		
143.46	5.8	Good		
346.11	5.9	Good		
350.86	6.0	Good		
110.47	6.0	Good	3,878.48	0.30
503.38	6.8	Fair		
336.23	7.9	Fair		
266.98	8.2	Fair		
135.97	8.4	Fair		
238.60	8.6	Fair		
436.45	8.9	Fair		
106.40	9.0	Fair		
151.48	9.0	Fair	2,285.96	0.18
157.25	9.2	Poor		
175.87	9.8	Poor		
182.47	14.1	Poor		
102.49	14.2	Poor		
145.52	14.4	Poor		
731.43	16.7	Poor		
114.53	16.8	Poor		
240.05	16.8	Poor		
260.31	16.9	Poor		
627.51	17.0	Poor		
646.28	17.2	Poor		
529.65	17.2	Poor		
145.05	17.2	Poor		
310.05	18.3	Poor		
186.32	18.3	Poor		
275.20	18.4	Poor		
238.77	18.4	Poor		
111.91	18.6	Poor		
355.64	18.8	Poor		
190.76	19.3	Poor		
281.03	19.3	Poor		
217.49	19.4	Poor		
105.48	19.6	Poor		
245.66	19.6	Poor		
75.42	19.6	Poor		
150.41	20.0	Poor	6,802.6	0.52
40%		Poor	12966.99	1.00

APPENDIX 8.2: DM- ROAD CONDITION RATING FOR URBAN ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
19.00	3.6	Good		
4.11	3.7	Good		
378.53	4.1	Good		
405.89	4.2	Good		
348.34	4.2	Good		
40.43	4.5	Good		
79.45	5.1	Good		
92.44	5.1	Good		
4.04	5.2	Good		
1.41	5.4	Good		
42.64	5.6	Good		
48.86	5.7	Good	1,465.14	0.15
1.80	7.9	Fair		
6.00	8.3	Fair	7.80	0.00
11.50	9.3	Poor		
0.78	11	Poor		
487.53	11.7	Poor		
307.75	12.1	Poor		
368.53	12.3	Poor		
145.80	13	Poor		
105.92	13.3	Poor		
322.88	13.5	Poor		
5,499.73	13.6	Poor		
265.95	15.1	Poor		
310.21	16.6	Poor		
247.55	18.1	Poor	8,074.13	0.85
			9,547.07	1.00

APPENDIX 8.3: DM- ROAD CONDITION RATING FOR FEEDER ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
20.19	0.5	Good		
38.14	0.5	Good		
59.56	0.5	Good		
119.93	0.5	Good		
415.38	0.5	Good		
214.59	0.6	Good		
511.10	0.6	Good		
844.03	0.6	Good		
1,062.17	0.6	Good		
102.84	5.0	Good		
212.01	5.1	Good		
127.49	6.2	Good		
453.71	6.4	Good		
52.48	7.9	Good	4,233.62	0.14
64.18	9.1	Fair		
86.88	10.3	Fair		
3,210.54	11.0	Fair		
6,013.99	11.0	Fair		
609.42	11.1	Fair	9,985.01	0.34
4,168.36	12.2	Poor		
804.52	12.4	Poor		
1,591.23	12.4	Poor		
4,763.20	12.6	Poor		
3,178.71	12.7	Poor		
603.38	12.8	Poor		
60.68	13.7	Poor		
40.73	14.7	Poor	15,210.8	0.52
			29,429.44	

APPENDIX 8.4: SPM- ROAD CONDITION RATING FOR TRUNK ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
373.11	3.6	Good		
222.11	3.7	Good		
297.79	3.9	Good		
306.08	4.0	Good		
62.36	4.1	Good		
157.80	4.2	Good		
544.55	4.4	Good		
108.40	4.5	Good		
302.84	4.8	Good		
106.84	5.0	Good		
168.41	5.0	Good		
132.83	5.2	Good		
43.63	5.2	Good		
100.83	5.4	Good		
143.46	5.5	Good		
346.11	5.6	Good		
350.86	5.7	Good		
110.47	5.8	Good		
503.38	5.9	Good	4,381.86	0.34
336.23	6.5	Fair		
266.98	6.8	Fair		
135.97	7.9	Fair		
238.60	8.2	Fair		
436.45	8.4	Fair		
106.40	8.6	Fair		
151.48	8.9	Fair		
157.25	9.0	Fair	1,829.36	0.14
175.87	9.2	Poor		
230.77	13.5	Poor		
182.47	14.1	Poor		
102.49	14.2	Poor		
145.52	14.4	Poor		
731.43	16.7	Poor		
114.53	16.8	Poor		
310.05	16.8	Poor		
240.05	16.8	Poor		
260.31	16.9	Poor		
627.51	17.0	Poor		
646.28	17.2	Poor		
529.65	17.2	Poor		
145.05	17.2	Poor		
245.66	18.0	Poor		
75.42	18.1	Poor		
186.32	18.3	Poor		
150.41	18.4	Poor		
275.20	18.4	Poor		
111.91	18.6	Poor		
355.64	18.8	Poor		
190.76	19.3	Poor		
281.03	19.3	Poor		
217.49	19.4	Poor		
105.48	19.6	Poor	6,645.30	0.52
			12856.52	1

APPENDIX 8.5: SPM- ROAD CONDITION RATING FOR URBAN ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
19.00	3.6	Good		
4.11	3.7	Good		
378.53	4.1	Good		
405.89	4.2	Good		
348.34	4.2	Good		
40.43	4.2	Good		
79.45	5.1	Good		
92.44	4.2	Good		
4.04	5.2	Good		
1.41	5.4	Good		
42.64	5.6	Good		
48.86	5.7	Good		
1.80	5.9	Good		
6.00	5.4	Good		
11.50	5.4	Good		
0.78	4.0	Good	1,485.22	0.16
487.53	8.7	Fair		
307.75	8.2	Fair		
368.53	8.3	Fair		
145.80	7.3	Fair	1,738.41	0.18
105.92	8.5	Fair		
322.88	8.5	poor		
5,499.73	13.6	poor		
265.95	12.6	poor		
310.21	16.6	poor		
247.55	18.1	poor	6,323.44	0.66
			9,547.07	1.00

APPENDIX 8.6: SPM- ROAD CONDITION RATING FOR FEEDER ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
20.19	0.5	Good		
38.14	0.5	Good		
59.56	0.5	Good		
119.93	0.5	Good		
415.38	0.5	Good		
214.59	0.6	Good		
511.10	0.6	Good		
844.03	0.6	Good		
1,062.17	0.6	Good		
60.68	4.5	Good		
102.84	5	Good		
212.01	5.1	Good		
127.49	6.2	Good		
453.71	6.4	Good		
52.48	7.2	Good	4,294.30	0.15
64.18	9.1	Fair		
86.88	10.3	Fair		
3,210.54	11	Fair		
603.38	11.1	Fair		
609.42	11.1	Fair	4,574.40	0.16
4,168.36	12.2	Poor		
804.52	12.4	Poor		
1,591.23	12.4	Poor		
4,763.20	12.6	Poor		
3,178.71	12.7	Poor		
6,013.99	13.1	Poor		
40.73	14.7	Poor	20,560.74	0.70
			29,429.44	

APPENDIX 8.7: BC- ROAD CONDITION RATING FOR TRUNK ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
373.11	3.6	Good		
306.08	4.0	Good		
168.41	4.1	Good		
157.80	4.2	Good		
43.63	4.3	Good		
108.40	4.5	Good		
106.84	5.0	Good		
302.84	5.5	Good		
143.46	5.5	Good		
346.11	5.6	Good		
350.86	5.7	Good		
110.47	5.8	Good		
503.38	5.9	Good	3,021.39	0.24
544.55	6.2	Fair		
266.98	6.8	Fair		
135.97	7.9	Fair		
238.60	8.2	Fair		
436.45	8.4	Fair		
106.40	8.6	Fair		
100.83	8.9	Fair		
151.48	8.9	Fair	1,981.26	0.15
222.11	9.0	Poor		
157.25	9.0	Poor		
175.87	9.2	Poor		
132.83	10.2	Poor		
297.79	11.7	Poor		
62.36	12.2	Poor		
182.47	14.1	Poor		
102.49	14.2	Poor		
336.23	14.3	Poor		
145.52	14.4	Poor		
731.43	16.7	Poor		
114.53	16.8	Poor		
240.05	16.8	Poor		
260.31	16.9	Poor		
627.51	17.0	Poor		
646.28	17.2	Poor		
529.65		17.2		
145.05	17.2	Poor		
310.05	18.3	Poor		
186.32	18.3	Poor		
275.20	18.4	Poor		
238.77	18.4	Poor		
111.91	18.6	Poor		
355.64	18.8	Poor		
190.76	19.3	Poor		
281.03	19.3	Poor		
217.49	19.4	Poor		
105.48	19.6	Poor		
245.66	19.6	Poor		
75.42	19.6	Poor		
150.41	20.0	Poor	7,853.87	0.61
			12,856.52	

APPENDIX 8.8: BC- ROAD CONDITION RATING FOR URBAN ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
378.53	3.6	Good		
4.04	3.7	Good		
368.53	4.1	Good		
4.11	4.2	Good		
145.80	4.2	Good		
92.44	4.2	Good		
310.21	4.2	Good		
247.55	4.4	Good		
19.00	5.1	Good	1,570.21	0.16
348.34	6.2	Fair		
322.88	6.4	Fair		
79.45	8.4	Fair		
265.95	8.6	Fair		
405.89	8.8	Fair		
40.43	8.0	Fair		
1.41	8.1	Fair	1,464.35	0.15
487.53	7.2	Fair		
0.78	8.1	Fair		
307.75	6.7	Fair		
1.80	13.0	Poor		
6.00	13.3	Poor		
5,499.73	17.7	Poor		
11.50	13.5	Poor		
105.92	13.6	Poor		
48.86	16.6	Poor		
42.64	18.1	Poor	6,512.51	0.68
			9,547.07	

APPENDIX 8.9: BC- ROAD CONDITION RATING FOR FEEDER ROAD BUDGET AT 100 PERCENT

Length	IRI	Condition	Total	Percentage
20.19	0.5	Good		
38.14	0.5	Good		
59.56	0.5	Good		
119.93	0.5	Good		
415.38	0.5	Good		
214.59	0.6	Good		
511.10	0.6	Good		
844.03	0.6	Good		
1,062.17	0.6	Good		
60.68	4.5	Good		
102.84	5	Good		
212.01	5.1	Good		
127.49	6.2	Good		
453.71	6.4	Good		
52.48	7.2	Good	4,294.30	0.15
64.18	9.1	Fair		
86.88	10.3	Fair		
3,210.54	11	Fair		
603.38	11.1	Fair		
609.42	11.1	Fair	4,574.40	0.16
4,168.36	12.2	Poor		
804.52	12.4	Poor		
1,591.23	12.4	Poor		
4,763.20	12.6	Poor		
3,178.71	12.7	Poor		
6,013.99	13.1	Poor		
40.73	14.7	Poor	20,560.74	0.70
			29,429.44	